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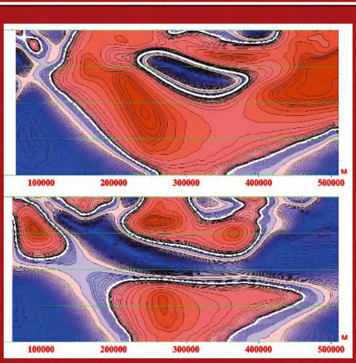

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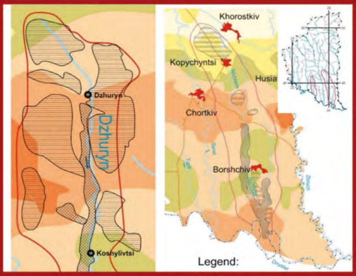

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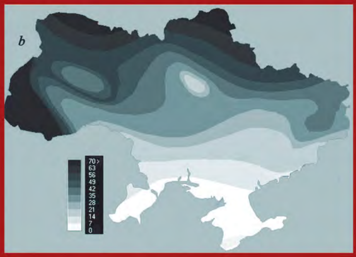

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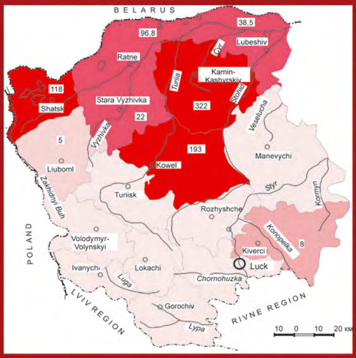

Burned peatlands

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Urban complex of geotourist sites of the city of Lviv (Western Ukraine)

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Abstract. Lviv is a city with a centuries-old history that is easy to adapt to introduce a new direction in tourism for Ukraine - urban geotourism. Urban geotourism is an innovative form of tourism, the basis of which is the use of objects of modern cities for the promotion of geology, educational activities and tourism business needs. Lviv is a city with high geotourist potential due to its unique geomorphological, geological position, well-developed tourist infrastructure, good information support and a large concentration of unique easily accessible diverse geo-tourist objects. The study of urban geosites for the needs of geotourism, the study of potential objects illuminating the interconnection of geology and architecture in the development of the historical urban landscape in Lviv have only just begun. Currently, there is a summarized short characteristic of the urbanistic complex of Lviv's geotourist sites and their classification was developed. They are divided into two supergroups (natural, anthropogenic), four groups (natural formations, natural processes, geotourism trails, natural-cultural, mining), two subgroups (polytypic, monotypic), 11 types and 19 categories. The geotourist sites of Lviv have scientific, cognitive, cultural-aesthetic value, are easily accessible, important for the educational process and in the case of their popularization will become attractive geo-tourist attractions. They are an important link for restoring Earth's history, exhibiting the geological structure of Lviv's territory, demonstrating new approaches to geotourism that combine nature, history and culture. Their study will allow the geomorphological and geological features of the city to be shown , allow us to get acquainted with the history of geological development, and help draw attention to the stone material used in the organization of urban space. Combining stone monuments with the cultural and tourist aspect is a great approach for disseminating geological knowledge.

Keywords: geotourism, urban geotourism, geotourism sites, natural and anthropogenic sites, Lviv

Урбаністичний комплекс геотуристичних об'єктів міста Львова (Західна Україна)

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Анотація. Львів місто з давньою історією, яке легко пристосувати для запровадження нового для України напряму – міського геотуризму, або урбангеотуризму. Міський геотуризм – це інноваційна форма туризму, основою якого є використання об'єктів сучасних міст для популяризації геології, просвітницької діяльності і потреб туристичного бізнесу. Львів – місто з високим геотуристичним потенціалом завдяки унікальній геоморфологічній, геологічній позиції, добре розвиненій туристичній інфраструктурі, хорошому інформаційному забезпеченню і значній концентрації унікальних легкодоступних різноманітних геотуристичних об'єктів. Вивчення урбаністичних сайтів для потреб геотуризму, дослідження потенційних об›єктів, що висвітлюють взаємозв›язок геології та архітектури у розвитку історичного міського ландшафту у Львові лише започатковане. Наразі наведена узагальнена стисла характеристика урбаністичного комплексу геотуристичних об'єктів Львова і розроблено їхню класифікацію. Вони поділені на дві надгрупи (природні, антропогенні), чотири групи (природні утворення, природні процеси, геотуристичні траси, природно-культурні, гірничопромислові), дві підгрупи (політипні, монотипні), 11 типів і 19 категорій. Геотуристичні об'єкти Львова мають наукову, пізнавальну, культурно-естетичну цінність, легкодоступні, важливі для навчального процесу і в разі їх популяризації стануть привабливими геотуристичними атракціями. Вони є важливою ланкою для відновлення історії Землі, експонування геологічної будови львівської території, демонструють нові підходи до геотуризму, що поєднують природу, історію та культуру. Їхнє вивчення дозволить показати геоморфологічні та геологічні особливості міста, ознайомитися з історією геологічного розвитку, привернути увагу до кам'яного матеріалу, що використовували при організації міського простору. Сполучення кам'яних пам'яток з культурно-туристичним аспектом є відмінним підходом для поширення геологічних знань.

Ключові слова: геотуризм, міський геотуризм, геотуристичні об'єкти, природні та антропогенні сайти, Львів

Introduction. Geological tourism (geotourism) is a new direction for tourist activity. The definition: «geotourism is the provision of such services and educational support, so that, in addition to aesthetic impressions, tourists have the opportunity to gain knowledge about the features of the geological structure of the territory» was first cited by British scientist Thomas Jose in 1995. (Slomka, Kicińska-Świederska, 2004), and in 2004 the term «geotourism» was officially approved by the National Geographic Union. In the early twenty-first century geotourism has received international publicity (Migoń, 2012; Ross, Dowling, Newsome, 2006; Wimbledon, SmithMeyer, Erikstad, Brilha, van den Ancker, 2013 and others) and gained popularity in Ukraine (Denysyk, Strashevskaya, Korinnyj, 2014; Khomenko, Isakov, Manyuk, 2018; Manyuk, 2015; Malska, Zin'ko, Shevchuk, 2014 etc.). The main purpose of geotourism is to promote and introduce into the tourism industry geotourism objects (or geotourism attractions) - geological objects and phenomena that are of interest to tourists. The objects of geotourism are diverse (Denysyk, Strashevskaya, Korinnyj, 2014; Grytsenko, Korniyets, Rusko, Yarozshuk, 2001 and others). These are geologic landmarks that are protected and are in the list of a geological heritage; geoparks nature conservation areas with a high concentration of interesting abiotic formations; geosites without protection, but which are important for demonstrating features of the geological structure of local areas of the Earth; objects that have arisen as a result of human activity (man-made landforms, works of material culture, museums and other exhibitions), etc.

For the successful implementation of geotourism activities, it is important, first of all, that there are territories with high geotourism potential with numerous and varied geological features (which are attractive, have scientific, cognitive value, capable of forming world-view principles and aesthetically pleasing); second, appropriate management and, third, infrastructure. All these requirements are met by the urbanized territories of large cities, in which it is easy to introduce new types of tourism for Ukraine - urban geotourism. Urban geotourism is an innovative form of geotourism, the basis of which is to use the objects of modern cities to promote geology, educational activities and tourism business needs. This area of geotourism in the world has only just begun to evolve. Among the main tasks of urban tourism is to identify, study and characterize interesting geoattractions in cities and develop geotrails. Such research is currently only being undertaken in some major cities: London, Lisbon (Rodrigues, Machado, Freire, 2011), Rome (Del Monte, Fredi, Pica, Vergari, 2013); and small towns (Górska-Zabielska, Zabielski, 2017) in Europe; Sao Paulo (Brazil) (Del Lama, Bacci, Martins, Garcia, Dehira, 2015), Mexico City (Mexico) (Palacio-Prieto, 2015) etc.

Lviv is a city with an ancient history and rich architectural heritage, known primarily for its historical and cultural values. The historical architectural and urban development complex of Lviv (central part of Lviv with the ensemble of St. George's Cathedral and mountain Vysokiy Zamok) with an area of about 120 hectares and a buffer zone (2441 hectares) has been on the UNESCO World Heritage List since 1998 (www.unesco.org). Characteristics of the territory of the ensemble, interactive maps, coordinates of historical sites, etc. are listed on the website of the Lviv City Council (www.lviv.travel).

But only a few people know that there are numerous and varied urban geosites within Lviv, reflecting its natural and natural-cultural heritage, showing the connection between geology, geomorphology and urban development, and which are interesting geo-tourist objects. These are landscapes with a great variety of natural conditions, contrast, with differentiated relief, caused by the peculiarities of the geological structure, numerous expositions of different geological periods layering sediments, springs, paleontological objects, etc.

The natural heritage of Lviv is unique, due to its specific tectonic and geomorphological position. It is located at the conjunction of two big geomorphological regions: Podilskyi and Volyn-Malopoliskyi. Within the limits of Lviv, the Podilskyi geomorphological region is represented by structural-denudation of residual heights with absolute markings of 330- 390 m of Roztochchya, Lviv Opillya and the Davidovsky horseback of Rozotsko Obil subregion. The hypsometrically low (absolute marks 220-270 m) accumulation-denudation height of the Pasmovy (Gryadove) Pobuzhzhya of Small Polissia is the part of the Volyn-Małopolska region (Matolych, Kovalchuk, Ivanov, 2009). Through the highest points of Roztochchya, Lviv Opillya and the Davidovsky horseback, Lviv crosses the Great European watershed, dividing the river basins, some of which flow into the Baltic and the other into the Black Sea.

Intectonically, these geomorphological units correspond to the following tectonic blocks: the Buskomitted block (the Pasmovy (Gryadove) Pobuzhzhya) of the Eastern European Platform and two raised Roztochchya and Lviv (probably the Western European Platform) blocks (Derzhavna geologichna karta Ukrainy, 2004): The raised blocks are separated from the lowered by a steep erosion-tectonic ledge 120- 135 m high; differing geological structure, stratigraphic completeness, the thickness, age, the composition of rocks and fossils.

The geological structure of Lviv was studied by A. Alt, M. Lomnitsky (Lomnicki, 1884), O. Vyalov, I. Venglinsky, V. Horetsky (Venglinskyi, Goretskyi, 1979), L. Kudrin (Kudrin, 1966), I. Kruglov, O. Kruglov (handwriting), P. Voloshin and others. The term «urban geotourism» was introduced recently, but interesting geological sites and the first trails for getting acquainted with the geology of Lviv were described in the 1960s. (Vyalov, Goretskyj, Kudrin, Pasternak, 1954; Babynec, Burov, Vyalov et al., 1958). On the territory of Lviv, there are rocks of different age: Cretaceous (Maastrichtian), Neogene and Quaternary. In the Busk block, the Maastrichtian deposits of the Cretaceous are with disconformities covered by Quaternary sediments. In the raised tectonic blocks, the sequence is generally more complete, heavier, composed by Cretaceous carbonate rocks, Neogene terrigenous-carbonate deposits of Langhian and, possibly, Serravallian (a common thickness of 60- 114 m) with (bottom-up) Baraniv, Znesen, Naraiv, Ratyn, Ternopil, Bugle layers (Andreeva-Grigorovich, Gruzman, Kulchytsky, Ivanina et al., 1997; Hozhyk, Semenenko, Polietaiev et al. in., 2012) and Quaternary sediments with thickness of 0.5- 9.0 m.

The modern natural-landscape of Lviv is caused not only by the peculiarities of the deep structural-tectonic and geological structure but also by the management of people. Due to economic activity, natural landscapes have seriously changed. Throughout the territory, there are mining sites. They are the former stone quarries formed during the open cast extraction of sand, sandstone, gypsum, marls, limestone .

All this indicates that Lviv, the tourist mecca of Ukraine, is also a geo-tourist cluster, a city with significant natural potential, with many interesting geo-attractions on its territory. But at present, the study of the territory of Lviv for the needs of geotourism and the formation of an information-analytical and empirical database has only just begun.

The main tasks of this stage of research are:

• identification, study, preparation and selection of interesting geo-attractions;

• systematization and creation of the classification of geo-tourist objects of Lviv;

• a brief description of the geo-tourism potential of Lviv.

Materials and methods of investigations. The varied and numerous natural formations (geological or geomorphological objects that were naturally formed and which are the subject of tourists' interest) and anthropogenic geotouristic attractions (landforms that are the result of an engineering-geological activity, works of material culture, museum exhibitions, etc.) of Lviv city provide the main research material.

An overview of the techniques and sequence of operations for the detection, study, evaluation of geo-tourist sites is presented in Wimbledon, Smith Meyer, Erikstad, Brilha, van den Ancker, 2013; Denysyk, Strashevskaya, Korinnyj, 2014; Ivanina, Hotsanyuk, Spilnyk, Pidlisna, 2018 etc. For now, let's just highlight the main elements. The algorithm for estimating the geotourism potential of the territories is generally recognized and includes: geological study, conservation assessment, identification of major natural and anthropogenic attractions and their passport description, the definition of classifiers and creation of classification systems of geotourism objects, assessment of geo-diversity, development of routes of geo-tourist excursions, determination of tourist and socio-economic factors, creation of infrastructure, assessment of the profitability of geotourism and more.

The definition of geoattractions and assessment of their geotourist attractiveness were performed in stages. In the first stage, the study and detection of objects used a traditional set of methods: observation, description, photographic documentation and all existing geological methods: stratigraphic, geochronological, paleontological, paleoecological, sedimentological, lithological, geomorphological, structural mapping and so on. In the second stage during the evaluation and selection of representative objects the method of the systematic review and comparative evaluation of geo-tourist sites (Wimbledon, Smith Meyer, Erikstad, Brilha, van den Ancker, 2013; Ivanina, Hotsanyuk, Spilnyk, Pidlisna, 2018)) was the main one.

The first attempts to assess the geo-tourism potential of Lviv in general and its individual parts (the Regional Landscape Park Znesinnia) were made in 2017 (Voloshyn, Slyvko, Knysh, Kremin, Bubniak, 2017; Ivanina, Pidlisna, 2017) and 2018 (Ivanina, Hotsanyuk, Spilnyk, Pidlisna, Pidlisna, Pidlisna 2018; Ivanina, Bornyak, 2018). These works are the basis for identifying and characterizing primarily geosites. But unlike natural areas (geoparks, national parks, etc.), the list of geo-tourist sites of cities is much wider. It includes anthropogenic geo-attractions, the vast majority of which exist only within urban areas.

Results. One of the most complex and least developed methodological issues is the systematization of urban geotourism objects, their division into groups, categories and the creation of an effective classifica-

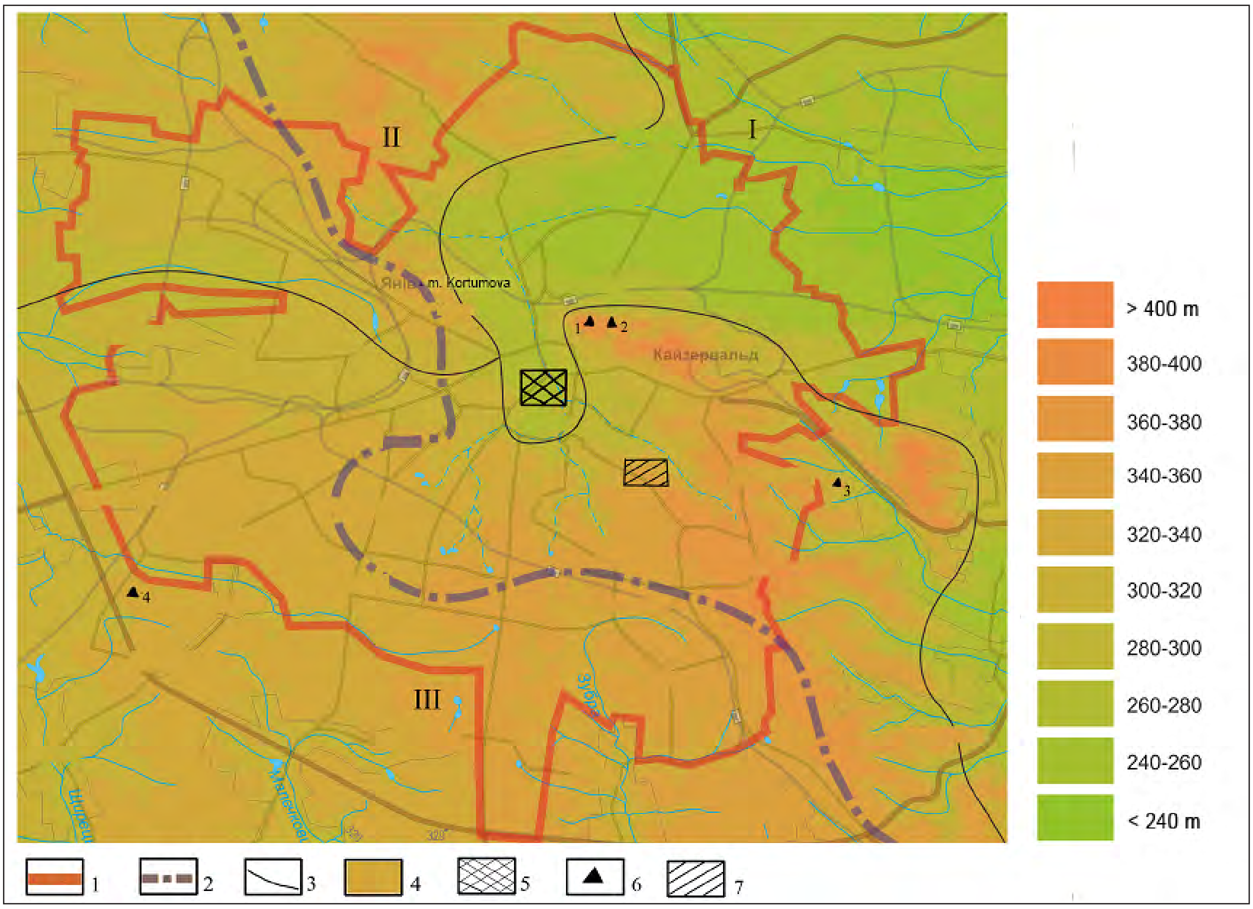

Fig. 1. Schematic geomorphological scheme of Lviv, by https: //uk.wikipedia with changes. IIII geomorphological elements: I Pasmovy (Gryadove) Pobuzhzhya; II Roztochchya; III –Lviv Opillya. 1 the borders of Lviv, 2 the line of the Great European watershed; 3 boundaries of geomorphological elements; 4 absolute height; 5 the central part of Lviv with a significant concentration of geotourist sites; 6 geosites with legal status (1 Gora Vysokiy Zamok; 2 Gora Leva; 3 Medova ('Honey') Cave; 4 Kortumova Gora); 7 Lychakiv Cemetery.

tion system, which would be based on several classification features and, most fully, reflect the variety of geo-attractions. The process of systematization of Lviv city tourism geoattractions has only just begun. There are currently some classification systems that are geared to streamline our knowledge about natural geological objects only. They are based on different approaches to understanding the subject of research and apply different systems of classifiers. According to the authors, the most objective classifications, are characterized in Gritsenko et al., 1995, 2001; Bezvinnyj, et al., 2006; Wimbledon, Gerasimenko, and Ishchenko, 1999, which were taken as the basis for the development of the first urban geotourism sites classification system by A. V. Ivanina for the Park Znesinnia (Ivanina, Hotsanyuk, Spilnyk, Pidlisna, 2018). But the diversity of Lviv's geo-attractions turned out to be much larger. Therefore, we propose an updated, improved and modernized classification system of urban geotourist sites of Lviv with the allocation of supergroups, groups, subgroups, types and categories (Table 1).

It is built on a hierarchical basis, composed of smaller units subordinate to larger ones. All objects by origin are grouped into two large supergroups: natural (natural geologic objects of inanimate nature) and anthropogenic geotourist attractions created by human activity. There are groups defined in subgroups: natural objects and natural processes are highlighted among natural geo-objects. Among the anthropogenic attractions are two groups: natural-cultural and mining objects. The subgroups that are subordinate to the groups are defined by the degree of validity. These are polytypic, or complex (landmarks that combine features of two or more types of geological attractions) and monotypic, defined by one feature. Subgroups on a subject basis are divided into types. In the subgroups of natural sites are distinguished the following types: stratigraphic (typical, or standard, sections exhibit a sequence of layers and characterize the

Table 1. Classification of geotourist sites in Lviv

Supergroup	Group	Subgroup	Type	Category	Number of objects
Natural	Natural formations	Polytypic	Geomorphological, stratigraphic	Typical sections, erosion remnants	Two
			Geomorphological, stratigraphic, speleological	Supporting section, erosion remnants, cave	One
		Monotypic	Stratigraphic	Typical sections	Three
				Supporting section	One
			Paleontological	Location of fossils	One
			Geomorphological	Erosion remnants	One
			Hydrogeological	Springs	Many
	Natural processes				At the detection stage
Anthropogenic	Natural-cultural		Stone for building needs	Stonewalls of sacred and residential buildings	Many
				Monument stone	Many
				Capstone	Many
				Finishing stone	Many
				Brooke	Many
			Urban Fossils	Fossils in wall and pavement stone	At the detection stage
			Museum exhibitions	Specialized geological museums	Four
				Museum exhibits made of natural stone	At the detection stage
			Historic and architectural sites	Buildings associated with well-known geologists or geological events	At the detection stage
	Mining			Sand quarry	Many

history of the geological development of a certain section of the crust; supporting sequences of the stratigraphic units of the local stratigraphic scale, which determine the station's volume, age and structure; paleontological (unique sites of fossils); hydrogeological (springs), geomorphological (erosional remnants), speleological (caves of natural karst origin). Within the group of natural-cultural objects are identified the following types: stone for building purposes (wall stone of sacral and residential buildings, stone of monuments and tombstones, facing and finishing stone, paving stone). In the mining group, there are categories: former quarries (artificially created object for the industrial development of the territory and open pit mining of sand, gypsum or marl) and quarry - mining facilities for open pit mining of rock-solid rocks and rocks sandstone.

Geotourist sites were evaluated by criteria that determine the object's rating. For the general characterization of Lviv's geotourist sites, the following classifiers are used: legal status (international, national, regional, local landmarks or no legal status), conservation (critical, recommended for improving geological study), level of protection (especially strict security mode, limited security mode with no recommendation for mass tourism, limited security mode with a recommendation for mass tourism, no need for protection), significance (global, supra-regional, regional, local); type of use (scientific reference, scientific and educational reference, scientific and tourist (importance for geotourism only), tourist (importance for tourism in general), priority (best, unique, first, model,standard), attraction (high, medium, low), geotourism value (high, medium, low), etc.

Below is a brief summary of the characteristics of Lviv's geo-tourist sites.

There are numerous geological formations in Lviv. These are outcrops of rocks of different ages springs, erosion remnants hills. Among the geotourist sites that are classified as natural supergroups, the most valuable and attractive for the tourism are 10 geosites, four of which are (Gora Vysokiy Zamok, Gora Leva, Kortumova Gora, Gora Ratyn with

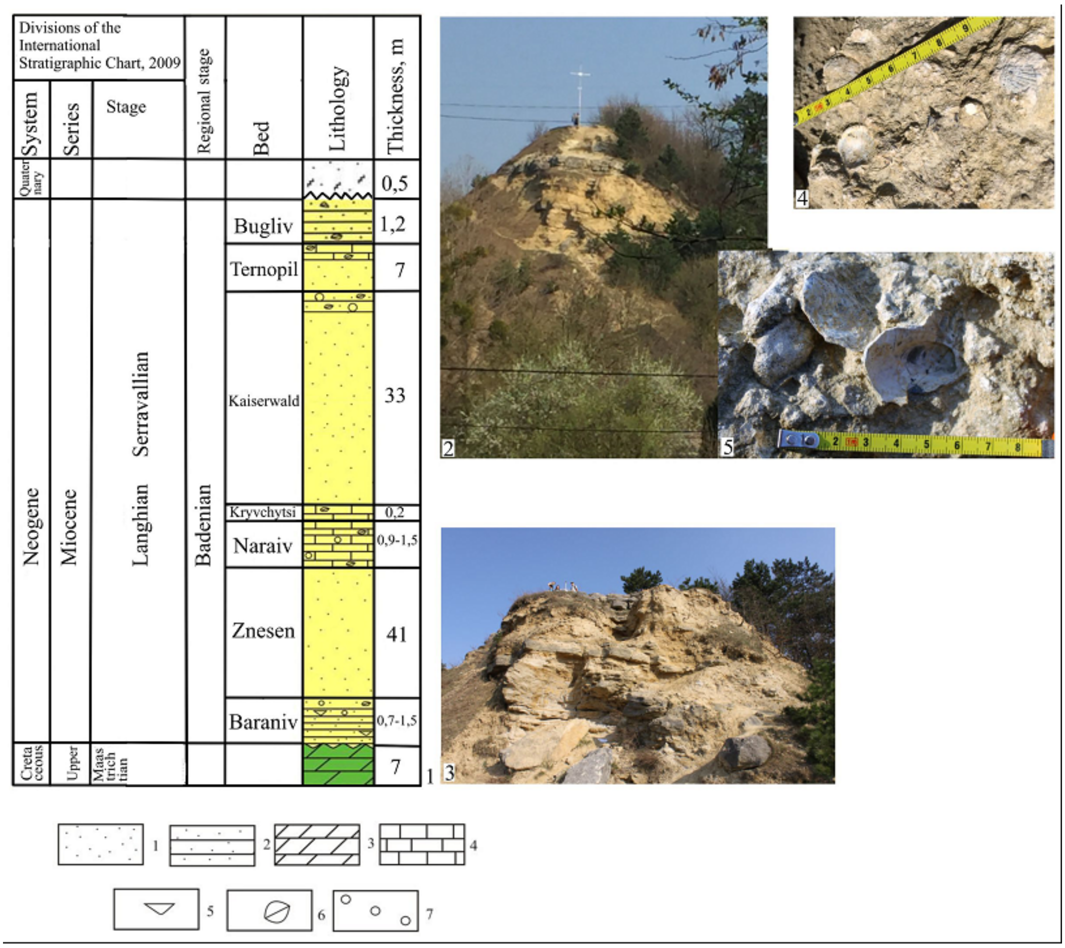

Fig. 2. Geological landmark Gora Leva: 1 – schematic stratigraphic column; 2 – general view of the mountain; 3 – outcrops of sandstone at the top of the sequence; 4, 5 – bivalve molluscs fossils. At the stratigraphic column: 14 – rocks: 1 – sand; 2 – sandstones; 3 – marls; 4 – limestone; fossils: 5 – litotamnium algae; 6 – bivalves; 7 – brachiopods.

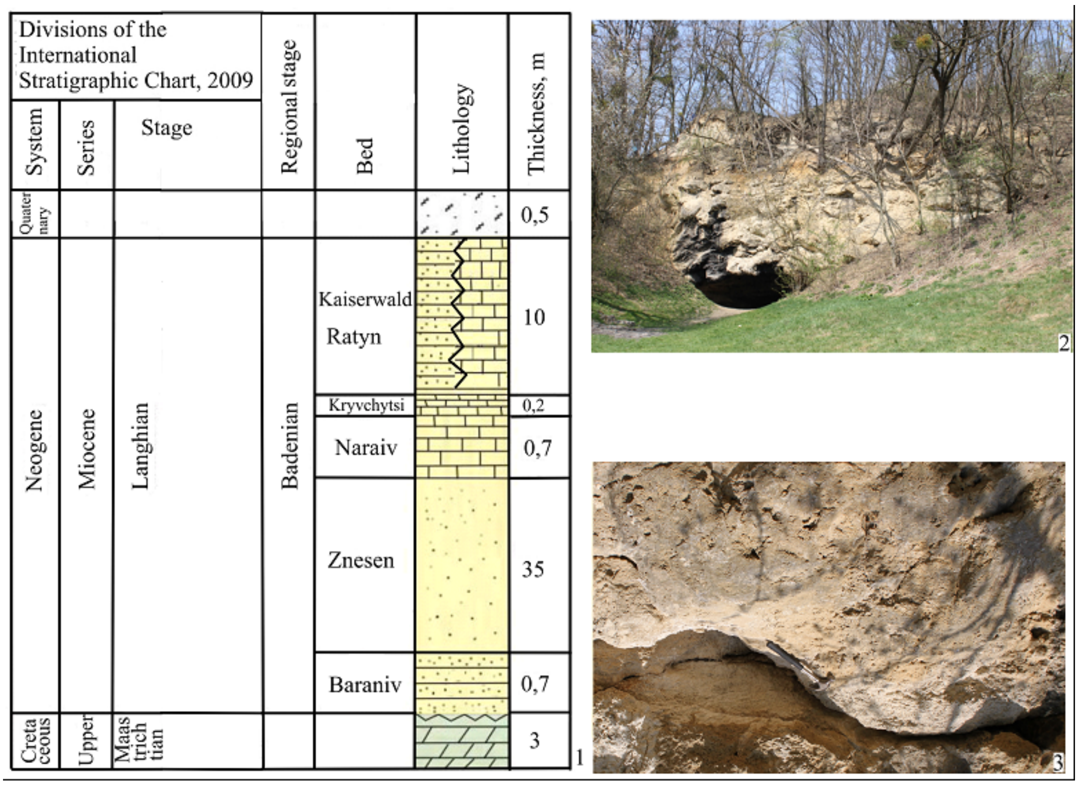

Fig. 3. Geological landmark Medova ('Honey') cave: 1 – schematic stratigraphic column; 2 – general view of the cave; 3 – Ratyn limestones. Symbols to the stratigraphic column in fig. 2.

Medova ('Honey') cave (Fig. 3) have legal status. They are local landmarks declared as geological sites, that require a regime of limited protection with a recommendation for mass tourism. They are scientific-educational and scientific-tourist sites with a high degree of attraction and important for the noesis of geological development history.

Gora Leva is a polytypic geological landmark because it belongs to the geomorphological and stratigraphic categories of geosites. The mountain is an erosion remnant, on the slopes of which the reference sections of the Kaiserwald and Ternopil layers of the Neogene are described (Bezvinnyj, et al., 2006; Ivanina, Hotsanyuk, Spilnyk, Pidlisna, 2018; Ivanina, Bornyak, 2018).

Mount Ratyn is a polytypic stratigraphic, geomorphological and speleological site. It is an erosional remnant and a supporting sequence (only in Western Ukraine) of the Ratyn layers of Neogene, composed of limestone. The mountain is known primarily for the horizontal cave (Honey Cave) of karst origin, which is located in limestones. The cave was entered in the State Register of Protected Areas in 1970 and partially described in the Geological Landmarks of Ukraine (Bezvinnyj et al., 2006).

Kortumova Gora is a geological landmark of Ukraine since 1970, a polytypic geo-tourist object since it is an erosion remnant (geomorphological category) and a reference sequence of the Neogene of Roztochchya (stratigraphic category); briefly described in Geological Landmarks of Ukraine (Bezvinnyj et al., 2006).

Gora Vysokiy Zamok is listed in the Register of Geological landmarks of Ukraine in 1970 (Bezvinnyj et al., 2006), is a monotypic object of the geomorphological category. It is an erosion remnant with the outcrop of the Kaiserwald layers of the Neogene and is a favourite vacation spot of Lviv residents and city visitors.

The other five geosites located in the territory of the Regional Landscape Park Znesinnia are monotypic stratigraphic (typical sequence of the Pasmovy (Gryadove) Pobuzhzhya; a typical section of the Cretaceous and Neogene boundary deposits the only section within Lviv; a typical section of the Narayev layers and borders); reference sequence of the Kaiserwald beds of the Neogene) and paleontological (unique paleontological site without official status, described in detail in Ivanina et al., 2016, 2018) categories. All geosites are important geotouritic objects with a high degree of geotourist attraction, with considerable scientific, educational and cognitive aesthetic, cultural value, and are the object of geological excursions and practice sessions, described in scientific (Ivanina et al., 2016, 2018 and others) and popular science literature.

Hydrogeologically, the territory of Lviv is located within the Volyn-Podilskyi artesian basin, where the main aquifers are confined to Quaternary, Neogene, and Upper Cretaceous deposits. The most common is the aquifer in the sandy deposits of the Neogene Baraniv beds with Maastricht marls serving as the water resistance. The water associated with it is low pressure, fresh, mainly calcium carbonate, with satisfactory physical properties. It is unloaded in the form of numerous springs along the slopes of Roztochchya, Lviv Opillya and the Davidovsky horseback and forms the sources of streams and the River Poltva. Springs with different flow rates are located in the picturesque green corners and are a natural decoration of Lviv. Most of them are interesting geotourist sites of hydrogeological type. In particular, at the foot of the northeast slope of the Gora Vysokiy Zamok, the Neogene aquifer is unloaded in the form of a highly debit spring, which is mentioned in historical documents from 1510 and is known as the Royal Source or St. Mary's Source (Fig. 5).

History of the formation and functioning of Lviv, like most other cities, is related to the geomorphological features of the territory and its geological structure. After all, the erection of any historic city depends mainly on the availability and types of natural stone building materials (natural geological resources) and defence capability (defensive geomorphological conditions). Natural stone material has been widely used throughout the world due to its durability, and its facilities allow us to see the historical and economic evolution of cities, to trace the architectural style of each era, to evaluate the suitability of each type for various processing for construction use, sculpture, interior or exterior. The natural stone of the walls of the buildings is an interesting object of urban tourism and attracts the attention of both tourists and scientists (De WEver, Baudin, Pereira et al., 2017; Górska-Zabielska, Zabielski, 2019).

The geotouristic objects of the anthropogenic supergroup in Lviv are numerous and diverse. Their discovery, research, systematization, cataloguing and mapping have only just begun. They are divided into two groups: natural-cultural (stone for building needs, urban fossils, museum exhibitions, historical and cultural sites related to geology or well-known geologists) and mining (former quarries) (Fig. 6).

The historical buildings in the construction of which natural stone material was used (for walls, decoration, facing), pavement, road stone determined

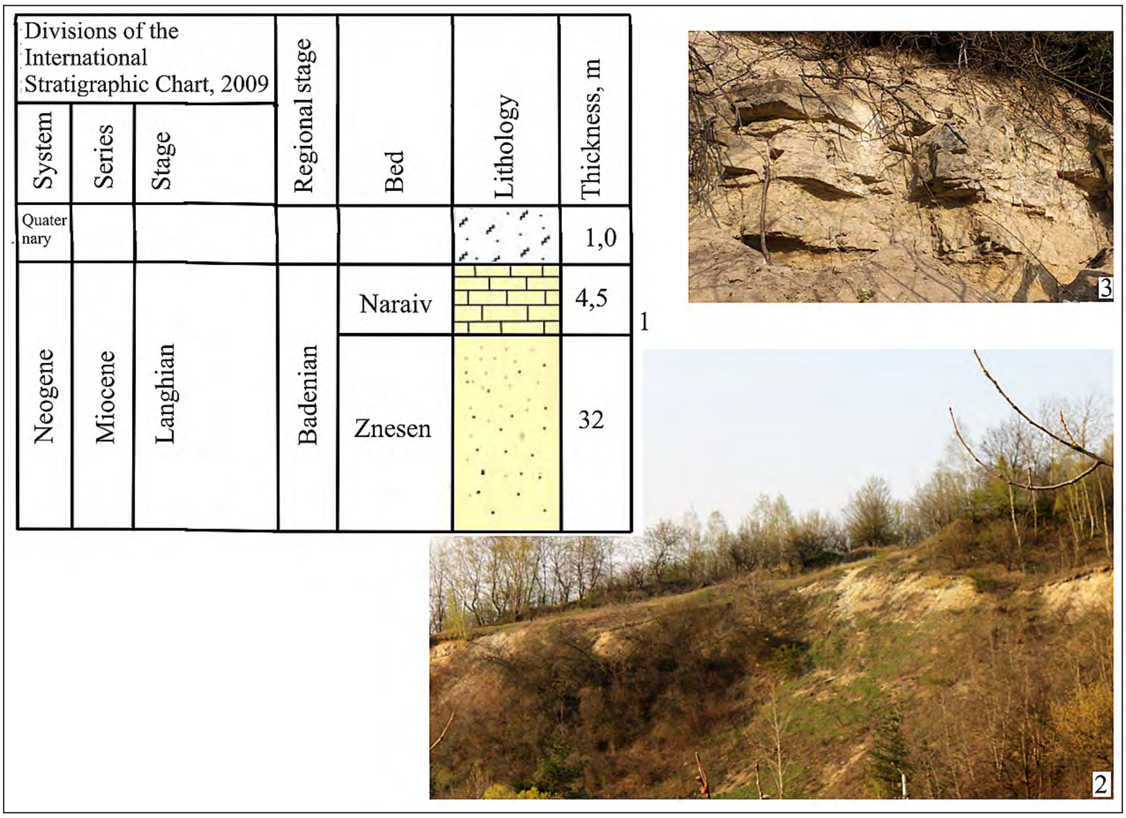

Fig. 4. Geological Landmark Kortumova Gora: 1 – schematic stratigraphic column; 2 – general view; 3 – Naraiv limestones. Symbols to the stratigraphic section in Fig. 2.

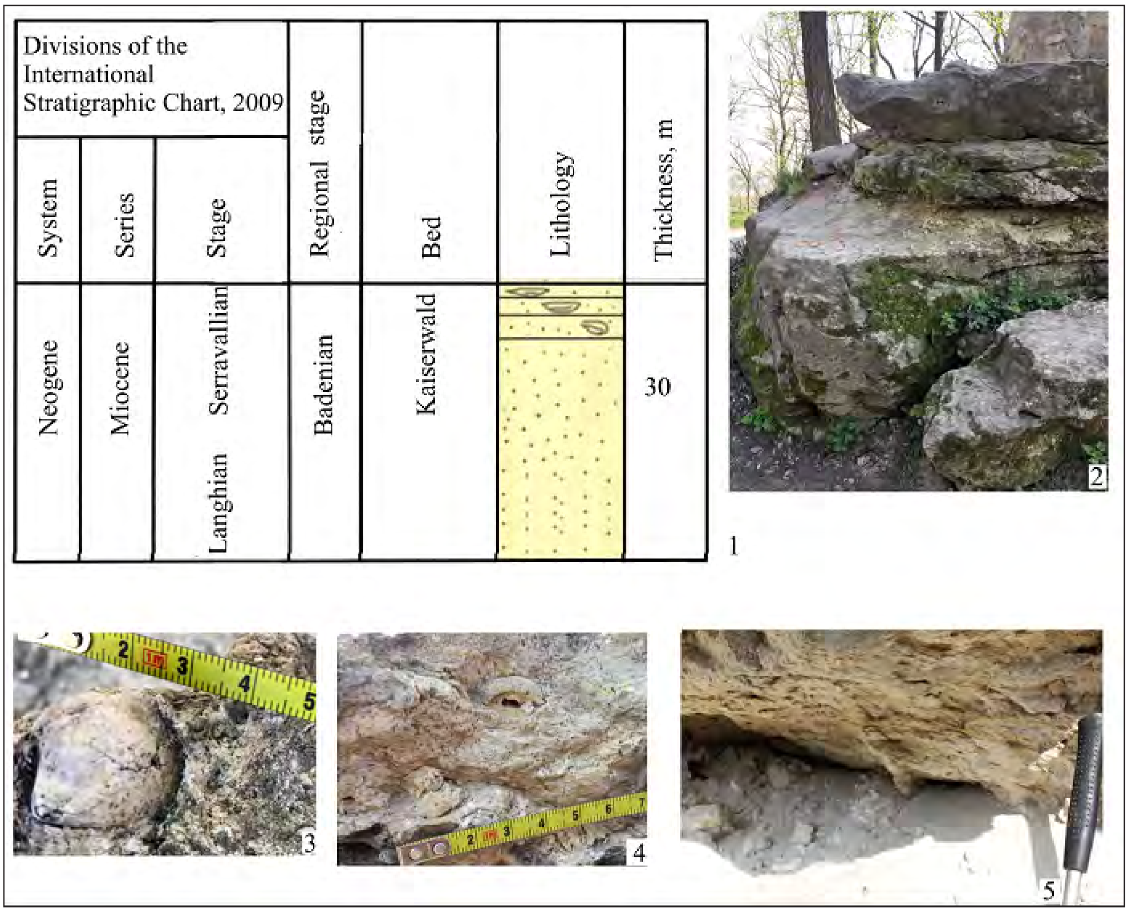

Fig. 5. Geological Landmark GoraVysokiy Zamok: 1 – schematic stratigraphic column; 2 – an outcrop of the Kaiserwald sandstones; 3, 4 – molluscs fossils; 5 – sediments of the Kaiserwald layerssand and sandstone. Symbols to the stratigraphic column in Fig. 2.

Fig. 6. Types of geotourist objects of Lviv: 1 hydrogeological type of group of natural formations "Royal" spring at the foot of the northeast slope of the Gora VysokiyZamok; 26 anthropogenic geotourism sites: 2 mining group: a former quarry of limestone mining on Mount Ratyn; a group of natural-cultural objects: 3, 4 – wall stone (sandstone) of Lviv defensive structures (3 broken stone; 4 general view of the wall); 5 stone (limestone) sculptures of the Cathedral; 6 wall stone (limestone) of historical buildings (Boim's chapel).

the architectural identity of Lviv. The buildings of the central part of Lviv, built at different times, show the trends of stone material usage during certain historical periods. First used was local stone, which did not cost much to extract and transport. Mostly it was limestone, which in the form of broken stone and hewn blocks we see in the remains of the defensive walls of Lviv (Fig. 6). The hewn blocks of various lithogenotypes of limestone are the main building material of the central part of the city. Here we see sacral and residential buildings that are built solely from it or in combination with other material, including bricks. Sandstone was somewhat less used. During a walk through the city centre, we have the opportunity to see the main types of limestones and sandstones mined in Lviv and its surroundings, their structural and textural features, fossils, areas of destruction and characteristic forms of weathering, mineral growths on them. The objects are all structures of the historical part of Lviv, in which the stone is not closed to inspection (Fig. 6).

The interior decoration of these buildings is much richer, although dominantly there is the alabaster of different colours (Fig. 7), Devonian black limestone known as 'dębnik', red-coloured Devonian sandstones and marble. The use of igneous rocks has become a hallmark of modern alterations and decorations. Granite and labradorite are dominant among them. Other objects where you can see this material are modern monuments and memorial plaques.

The Lviv cobblestone pavement deserves particular attention (Fig. 7). The tradition of laying street cobblestone was introduced in Lviv at the same time as the start of stone construction (Pihurko, U. 2000). For this purpose, broken stone of various sizes, paving stones, hewn blocks, face pavers, bar and mosaic from paving stones were used. Besides, natural stone paving was used on sidewalks and squares. The material which was used for the covering is very diverse. Certainly, the first one used was sandstone, which was mined in quarries near Lviv. If you look at the roads in the central part of Lviv today, it seems that they are mostly made of basalt. However , outside the central streets we see under our feet a diverse composition of shapes and colours.

A special place where a unique collection of different rocks is assembled in a small restricted area is the cemeteries (Del Lama, E.A., 2018). There are several historic cemeteries in Lviv, among which the

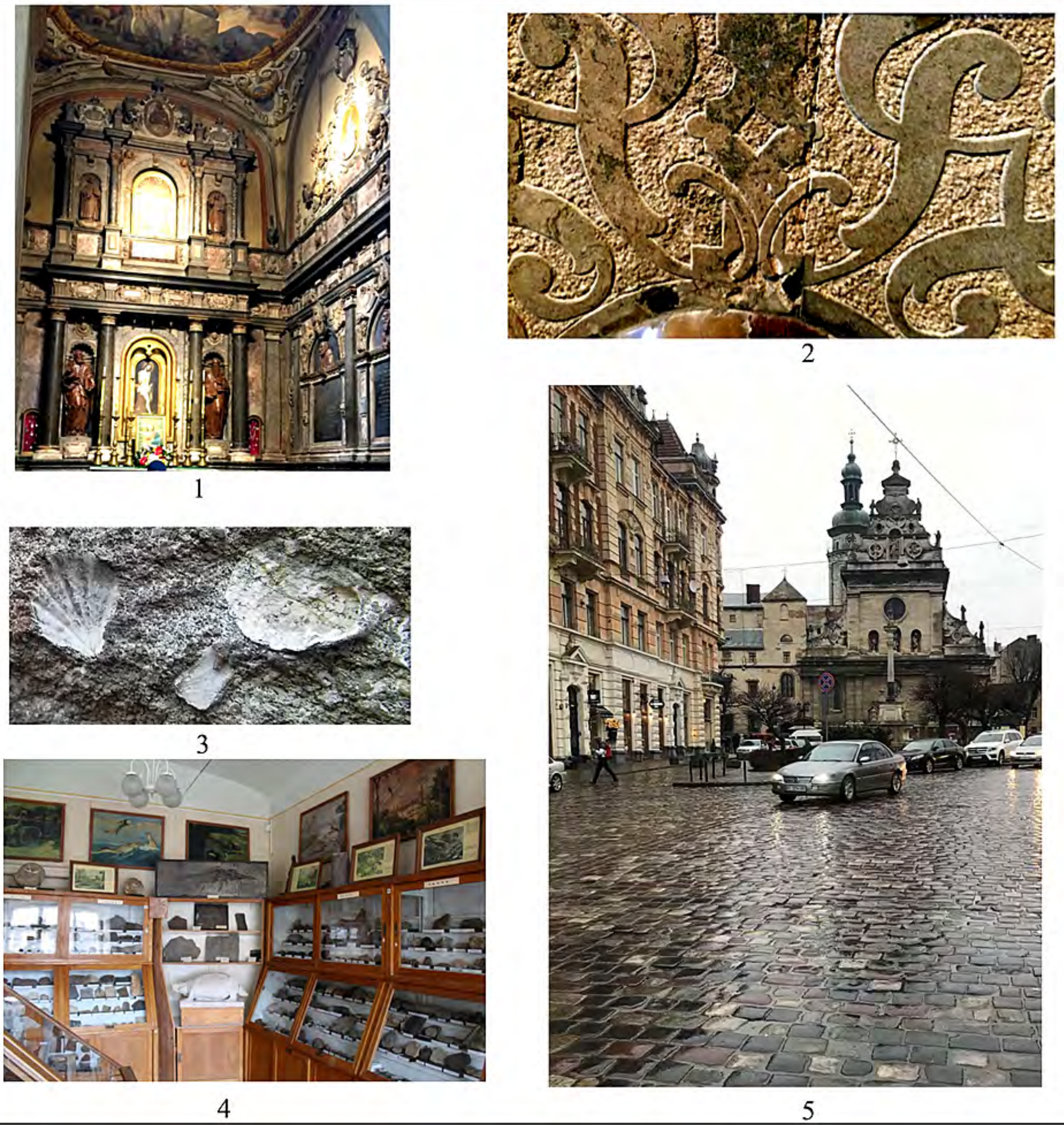

Fig. 7. Some anthropogenic natural-cultural geotourist sites of Lviv: 1, 2 – the natural decoration stone of the walls of the Chapel of the Campians of Latin Cathedral (1 – general view of the chapel, 2 – a fragment of the decoration of the wall with alabaster, or «Rusyn marble»); 3 – urban fossils (prints of the Bivalvia molluscs shell in the wall stone of the City Arsenal); 4 – exposition of the Paleontological Museum of the Geological Faculty of LNU I. Franko; 5 – pavement of Halytska Square

main attraction for tourists is the memorial cemetery "Lychakivsky Necropolis" one of the oldest existing communal cemeteries in Europe (Fig. 1). On the graves of the cemetery there are about 500 sculptures, mostly made of natural stone. Here you can trace the tendency to use one or another material depending on the preferences and capabilities of the customer, to assess the stability of natural stone in the conditions of 'open-air', to trace the main causes and directions of the destruction of various materials. This is a source of historical information, as well as a unique, very specific gallery of works of art, both of famous artists and unknown masters, which makes it an extremely attractive tourist destination.

In natural wall and road stone of sedimentary origin, fossil remains of animal and vegetable origin occur– urban fossils. It is an interesting and specific object of geotourism and paleontological research, the study of which requires a special technique, based mainly on visual observations in conditions of limited access to the fossils. The urban fossils of Lviv are numerous in the wall stone of ancient buildings, built in the XIV - beginning of the XX century. At this time the construction used the limestone of the Neogene, which contain fossils of algae, bivalves, gastropods, sea urchins (Fig. 7), etc.

For scientific-tourist purposes and educational activities, museum exhibits of specialized geological museums are important components of natural-cultural geotourist sites. There are four museums of geological profile in Lviv: Paleontological Museum (Fig. 7), Mineralogical Museum, Ore Formation Museum of the Geological Faculty of I. Franko Lviv National University. and paleontological exposition of the Natural History Museum of NAS of Ukraine. Their characteristics are in the public domain, including on their sites.

Different minerals have been mined around Lviv since ancient times. Anthropogenic influence on the territory of Lviv is traditionally manifested in the exploitation of rocks for construction purposes. These were quarries of sandstone, limestone, marls, gypsum and later (most intense in the second half of the XX century) the open-cast exploitation of sand deposits . Because of the intensive development of deposits

landscapes of Lviv were transformed, anthropogenic forms of relief were created, and on the site of former mining, there are bowls of inactive quarries that were not reclaimed at one time.

Steep upper and gentle contours, working walls, soles of quarries that characterize geometry, size of quarries and their depth have well preserved (fig. 2). They are classified as monotypic geo-industrial geosites with valuable geological features.

Conclusion. Lviv is a city with high geotourism potential due to the large concentration of unique easily accessible geotourist sites in the area, well-developed tourist infrastructure and good information support. The geotourist sites of Lviv are carriers of historical and cultural information, an element of the urban ecosystem. They are a particularly valuable asset to be preserved in the first place. Most of Lviv's urban geoobjects have just started to be explored. They are divided into two supergroups (natural, anthropogenic), four groups (natural formations, natural processes, geotourism trails, natural-cultural, mining), two subgroups (polytypic, monotypic), 11 types and 19 categories. The main groups of geosites and promising directions of development of geotourism in Lviv are briefly characterized. That will allow geomorphological and geological features of the city to be shown , allow us to get acquainted with the history of geological development, help to draw attention to the stone material used in the organization of urban space. Lviv as an urban complex of geotouristic objects has scientific, cognitive, cultural and aesthetic value. All geosites are easily accessible, useful for the educational process, are an important link for reconstructing the Earth's history, exposing the geological structure of Lviv territory. They demonstrate new approaches to geotourism that combine nature, history and culture. Combining stone memorials with a cultural and tourist aspect is a great approach for disseminating geological knowledge.

Future tasks related to urban geo-tourism in Lviv include cataloguing objects by geological attractiveness and informative nature, laying out routes that emphasize the relationship between the main stages of urban planning and geological features of the territory, and further exploration of anthropogenic geotourism objects.

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Philosophical geography: establishment, development, formation of scientific foundations

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Abstract. Science, at all stages of its development has always been in close connection with philosophical thought. Such synthesis is characteristic for any branch of science, including geography. This is related to the spatial content of geographical science, since the category of space itself is philosophical. At the boundary of geography and philosophy there are different scientific disciplines, each of which has its own specificity (geosophy, geophilosophy, etc.). This article deals with philosophical geography in general as the most neutral interpretation of the sphere of knowledge and thought about the deep essence of the terrestrial space and its landscapes.The purpose of the article is to substantiate the stage of development of philosophical ideas in geography. The works of ancient and medieval authors on natural philosophy, geographical and cosmographic works demonstrate attempts to comprehend the essence of the terrestrial space, to find its rational justification, either in the context of generalization and systematization of known factual material (e.g., Eratosthenes' sphragides), or for the purpose of filling in knowedge gaps, Crates globe), or when trying to explore the sacral space, which was favoured over Earth, which was treated as a secondary object (e.g., cosmographic study by Al-Khwarizmi).The 17th - 19th centuries include the New European stage in the evolution of philosophical ideas in geography. It was then that Oecumene spread to almost all the land of the Earth. By this time, the classical geographic works by B.Varenius, A. von Humboldt and C. Ritter were appearing, whose philosophical content is related either to the conceptual and terminological aspect (as in A. von Humboldt concerning the concept of "landscape"), or with the reliance on a philosophical system (in particular, dialectical idealism) on the basis of geographical research (as by C.Ritter). The concept of geographical determinism of Charles Louis de Montesquieu was also philosophical as was the Genetic Approach in Ethnography by Johann Gottfried Herder. An important prerequisite for the further development of philosophical geography was the emergence of methodological trends of geographical studies in the second half of the 19th century, such as anthropogeography of C. Ritter, F. Ratzel, E. Reclus and chorogeography, perfected by A. Hettner on the basis of the philosophical ideas of I. Kant. Anthropogeographic search indicated the possibility for combining the natural and human in one research object, and the holographic concept acquired the character of a paradigm because of its coverage of the entire set of objects on the Earth's surface which are amenable to spatial analysis. In the second half of the 19th century, geography experienced a methodological crisis related to the differentiation of science and, as a consequence, the threat of its loss of research object. Along with anthropogeography, a synthetic trend arose, which in the first half of the 20th century enabled this methodological crisis to be overcome , the emergence of V. Dokuchaev's doctrines about the nature zones, L. Berg - about the landscape, A. Grigoriev - about the "physical and geographical" shell, P. Teilhard de Chardin, and V. Vernadsky - about the noosphere.The main feature of the modern stage of the development of philosophical geography is the most harmonious combination of concrete scientific and philosophical foundations, which objectively reflects the dialectical nature of the relation between science and philosophy. Organic continuation of philosophical and geographical exploration is exemplified by modern research in geo-psychohistory, geography of culture, geosophy and a number of other scientific disciplines.

Key words: philosophical geography, philosophic ideas, phasing, earth surface, terrestrial space, Oecumene, landscape.

Філософська географія: становлення, розвиток, формування наукових засад

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Анотація. Пограниччя географічного знання та філософського пізнання віддавна є благодатним середовищем для наукового синтезу. Незалежно від форм, яких він набував, і назви відповідної дисципліни (геософія, геофілософія тощо), інтеграція географії та філософії виявилася цілком логічною й закономірною. Ми вважаємо, що причиною тому є просторовість як іманентна риса географічної науки, адже категорія простору сама по собі є філософською. Філософська географія є найбільш нейтральної інтерпретацією сфери знань і думки про глибинну суть земного простору та існуючих у ньому ландшафтів. На відміну від геософії, яка тісно пов'язана з проблемами державно-політичної організації людських спільнот, філософська географія зосереджує свою увагу на осмисленні простору, населеного, пізнаваного та в різний спосіб осмислюваного людиною. Історичний розвиток філософської географії мав свої особливості впродовж кожної епохи світової суспільної історії – Античності, Середньовіччя, Нового часу тощо. Перший етап філософсько-географічних пошуків охоплює весь час до середини XVII ст., головним змістом якого були спроби осмислити сутність земного простору, знайти її раціональне обґрунтування. Другий етап розвитку філософських ідей у географії відноситься до другої половини XVII – XIX ст., коли Ойкумена поширилася майже на весь суходіл Землі. На цей час припав вихід класичних географічних праць Б. Вареніуса, а згодом – О. фон Гумбольдта й К. Ріттера. Філософський зміст властивий також концепції географічного детермінізму Ш.-Л. Монтеск'є та генетичному підходові в етногеографії Й.-Ґ. Гердера. Третій етап еволюції філософських ідей у географії пов'язаний із подоланням географічною наукою методологічної кризи кінця XIX ст. завдяки розвиткові антропогеографії, з одного боку, та комплексної природничої географії, з іншого. Важливе значення мала також інтеграція до географічної науки вчення про ноосферу. Четвертий етап розвитку філософської думки в географії розпочався наприкінці XX ст., і його головною особливістю є найбільш гармонійне поєднання конкретно-наукових і філософських засад в еволюції філософської географії. Таке поєднання об'єктивно відображає діалектичний характер співвідношення науки та філософії. Органічним продовженням цього етапу є сучасні дослідження із суспільної географії, геопсихоісторії, географії культури, геософії та деяких інших географічних і суміжних із ними наукових дисциплін.

Ключові слова: філософська географія, філософські ідеї, етапність, земна поверхня, земний простір, Ойкумена, ландшафт

Introduction. The development of scientific knowledge over the centuries has confirmed its close relationship with philosophical thought. Despite multiple changes of the pattern of interaction between science and philosophy, the principle of unification of these two spheres remained non-alternative. If during early classical antiquity, conditioned by the lack of factual material, science was based mostly on abstract philosophical ideas and inferences, later due to increase in the amounts of scientific information, the role of philosophy became first of all the determining the strategic directions and landmarks for science, working on methodological fundamentals of research, deep understanding of essence of some intricate – usually complex and interdisciplinary – scientific problems.

The abovementioned importance of philosophy in the development of modern and recent science is attributed to practically every sphere of knowledge. For example, at the border of history and philosophy, a comparatively new discipline has formed - philosophy of history. Similar synthesis is characterictic for the geographical-philosophical border (and is actually at least of the same age). Regardless of the forms it was obtaining, as well as name of the corresponding discipline (geosophy (Banse, 1924; Savitskii, 1997), geophilosophy (Deleuze, Guattari, 1998), etc, the integration of geography and philosophy was completely natural and logical. We think that the reason for it is geographical science`s intrinsic spatial character, because the category of space is philosophical itself. In the same way, the category of time underlay the close relationship between philosophy and history as a chronological science. At the same time, in the authors` opinion, the scientific disciplines mentioned above, which emerged at the conjunction of geography and philosophy, have their own specificities expressed in special emphasization characteristic only of geosophy or geophilosophy. Particularly, geosophy, according to one of the authors of the present article (Kyselov, 2011a) is the theoretical basis for geopolitics (apart from its other essences and functions performed), and geophilosophy is not a geographical, but philosophical discipline which studies the most general features of organization of terrestrial space, and particularly, the Earth`s surface.

Therefore, this article concerns philosophical geography as the most neutral interpretation of the sphere of knowledge and the ideas about the deep essence of the terrestrial space and landscape existing in it. Unlike geosophy closely related to the problems of state-political organization of human communities, philosophical geography focuses on understanding space, populated, studied and in different ways understood by humans.

Important for any scientific discipline, is the study of its history. The pre-conditions of emerging, the process of formation and development to a large extent underlie the establishment of modern fundamentals of one or the other science. This is especially relevant for sciences of social-humanities and philosophical cycles, which, unlike the exact sciences (mostly physical-mathematical, biological and technical), in their geneses depend not only on the processes taking place inside the science itself, as well as continuously increasing needs in practical activities of people, but on the complex combination of social-humanities, socio-economic, ethno-national and other factors related to the activities of human communities and social institutions, as well as the content of philosophical ideas characteristic of one or the other period. Therefore, the development of philosophical geography had it own peculiarities during every epoch of global social history - classical antiquity, the Middle Ages, modern history, etc. Within these particular time sections we shall characterize the stages of establishment of this scientific discipline.

The problems of history of development of philosophical thought in geography have been described in many works only in the recent decades. Among them, we should note fundamental studies by N. Mukitanov (Mukitanov, 1985) who conducted an analysis of philosophical ideas in geographic research beginning from Ancient Greece; R. Johnson and J. Sidaway (Johnston, Sidaway, 2004), J. Martin (Martin, 2005), who in-detail revealed the course of the development of separate directions of geographical sciences; V. Pashchenko (Pashchenko, 1999) , who designated the historical periods in the development of geography in the context of formation of its methodological approaches; O. Shabliy (Shabliy, 2001) who emphasized the problems of relation of geography and philosophy, which became the basis for the genesis of geosophical studies; one of the authors of the present article who described separate aspects of the formation of philosophical thought in geography and substantiated the patterns of establishment of geosophy as orientation of philosophical-geographical searches (Kyselov, 2007, 2009, 2011b, etc).

The objective of this article was substantiation of periodization of the development of philosophical ideas in geography.

The goals of the article were as follows:

- To determine the origins of philosophical-geographic thought;
- To analyze the process of comprehending terrestrial space by the scientific community in different historical epochs;
- To characterize the effect of philosophical systems and development of geography and reveal the role of some methodological approaches in achieving unity;

Philosophical geography during classical antiquity and the Middle Ages. The perception of terrestrial space is associated with the implicit understanding by different peoples of the landscape as “ours” and “others``” goes way back in time. According to the corresponding position of dialectics that development has a spiral course, we note that both particular scientific knowledge and philosophical thought in the past achieved certain similar points in their evolutions (unfolding) and subsequent involution (folding). This to a certain degree is relevant for geography, the philosophical constituent of which was present in classical antiquity and even pre-antiquity natural philosophy.

Particularly, the Ancient Chinese, by philosophically understanding the coordinal directions, attributed symbolic meanings to them in the aspects of human fate and human activity. Every coordinal direction was associated with one or the other season, colour, force of nature and animals according to traditional Chinese philosophy (Piskozub, 1994). As Yi-Fu Tuan notes, similar views are seen in the Maya and Pueblo Indians (Yi-Fu Tuan, 1977).

Antique philosophical thought, particularly related to the understanding of space, reached the highest point of its development in Ancient Greece. Accordingly, Herodotus, who objectively distinguished history from natural philosophy (integrated non-divided scientific knowledge closely associated with philosophical thought), doubtfully did this consciously; it is just that in his Histories in nine books he collected all information on peoples and countries they settled in and the time when the events he described took place. The works of Herodotus are characteristic of both spatiality and temporality. The philosophical character of his spatial ideas is clearly noticeable in, particularly, descriptions of natural conditions and population of Scythia-Proto-Ukraine. The text by Herodotus clearly suggests that the country is foreign to the Greek (particularly, this is seen in emotional statement that “winter [there] is so harsh that unbearable frosts last for eight months…” (Herodotus, 2006, p. 240). Scythia as a land foreign to the Greek is indicated also in the stories about some of the peoples neighbouring the Scythians, especially the remotest of them inhabiting the North (Androphagi, Melanchlaeni, etc).

The elements of philosophical geography are characteristic also of the works by Eratosthenes. That is he distinguished “sphragides” – strip-like fragments of Oecumene at the time, which are to a certain degree the prototypes of today’s geographic zones. However, the sphragides of Eratosthenes are different from the belts of the Modern Age not only by their distribution in a limited part of the terrestrial space, but also the criteria of distinguishing them. In particular, an important role was played by sacred factors which significantly corrected the natural features. By introducing the notion “sphragides”, Eratosthenes enriched the geography with terminology, because, by obtaining another meaning, in the late of the XX century it has come into the scientific usage again (Reteyum, 1988).

One of the peculiarities of Ancient Greek geographical thought is inferential second-guessing of content of the terrestrial space which lay outside the Oecumene of that time. Then, Crates of Mallus (II century A. D.), having (similarly to other Ancient scientists) no information about countries in the other hemisphere, imagined the fragment of the terrestrial space which actually corresponds to the North America as a territory inhabited by "Perioeci" (that is those who supposed to live near "oikos" – "house" – Oecumene inhabited by "Sinoeci"). The fragment of the terrestrial space south from Eurasia (in the southern hemisphere), according to the researcher mentioned above, had to be inhabited by "Antioeci" (those living opposite the Oecumene). Finally, hypothetical inhabitants of the fragment of the terrestrial space which actually corresponds to the North America, Crates called "Antipodes" and depicted them in the south from the equator upside down. Particularly the territory "inhabited" by "Antipodes" he imagined as the mirror reflection of the Oecumene and indicated as the contours of separate islands, peninsulas, fragments of the coasts of Eurasia and North Africa in the world`s first globe , which he invented (Piskozub, 1994; Kyselov, 2011b). Therefore, Crates , who lived after Eratosthenes and was convinced of the global shape of the Earth, saw its surface as symmetrical (which in general correlated with the Ancient Greeks' aesthetic image of beauty and perfection); every object of the Oecumene had to have an equivalent on the other side of the planet.

During the Middle Ages, philosophical geographic thought was represented in particular by the spatial views of Ibn Khaldun, who proposed the concept of 'umrân – Oecumene transformed by humans, some sort of antithesis to primordial nature (Ignatenko, 1980).

Philosophical thought was characteristic to the geographical views of the Ancient Rus-Ukrainians of the Knjazhy period. It is distinctly expressed in the Ancient Kyiv written sources, particularly "Tale of Bygone Years" (Povist..., 2008). As emphasized by O. Shabliy, its author`s views were close to trinity in space, which was expressed for example in the borrowing the Biblical story of the division of the then Oecumene between Noah`s three sons, declaration of the trinity structure of the Slavic world, the mention of three rivers flowing out of the Okovsky Forest, etc (Shabliy, 2001). The chronicler Nestor also raised the question of point zero of count of the "beginning" of the world, which, in his opinion, over time migrated from Jerusalem to the Middle Danube and from there to Kyiv (Kyselov, 2011a).

Among the European philosophers of the Renaissance, we should note Nicolaus Cusanus, whose works were first published during his lifetime in the mid-XV century, contained a number of philosophical-geographical ideas. Particularly, in the work "About similarity and differences between people", this philosopher tried to compare separate characteristics of human psychology (domination of mind/feelings, manhood/femininity, etc) with cardinal directions (north, according to Nicolaus Cusanus, corresponds to "emotional" peoples; the middle zone is inhabited by people of rational thinking; the south is characteristic of "more free" way of thinking (Cusanus, 1979, v. I). Despite the discussability of the theses formulated by Cusanus, the most important aspect, in the authors` opinion, is the fact of the understanding of the phenomenon of humans in the context of terrestrial space. One can state that philosophical-geographical views of Nicolaus Cusanus were three centuries ahead of the ideas of geographical determinism, the essence of which shall be described below.

Modern European philosophical-geographical thought. In the Early Modern age, philosophical thought was expressed in the work of the founder of Modern European theoretical geography B. Varenius. Particularly, we should note his concept of the Earth`s surface as a "earth-water circle", described in his work Geographia Generalis (Mukitanov, 1985; Shabliy, 2001). Therefore, this author, taking into account the information and facts obtained during the Renaissance, redefined the antique idea of the "River Ocean" that contours the land. It is worth noting the polarity between dry land and water which is inherent in the formulation of the term "earth-water circle" , which gives reasons to see dialectic combination of the forces of nature in the Earth`s surface as a whole.

Philosophical-geographical ideas characteristic of also the prominent French philosopher Baron de La Brède et de Montesquieu, who for the first time formulated the concept of geographical determinism. He gave a special attention to the role of climate in the formation of the ways of life, customs and mentality of peoples, emphasized in the work "The Spirit of the Laws" (Montesquieu, 1758).

Still relevant are the philosophical-geographic views of J. G. Herder. Particularly, noteworthy is his view of the Earth`s land as "a mountain range above the surface of sea" (Herder, 1977). Interesting is also his thought that "The southern hemisphere was made the grand reservoir of water for our Globe, that the northern might enjoy a better climate" (Herder, 1977). In the abovementioned statement we can see this scientist comprehending the morphological asymmetry of the terrestrial surface manifested in the presence of continental and oceanic hemispheres. But the greatest philosophical-geographical value belongs to the ideas of the philosopher about proportion of impact of climatic and genetic factors in the formation of spirit and fate of peoples. Despite that the fact that J. G. Herder dialectically compared them, however, according to the authors, they act synergically, that is in the context of significance of the natural factors, particularly the factor of relation of the ethnicity and its native climate is determining for its subsequent fate.

By the end of the XVIII century, in general the development of land appropriate for human inhabitation in the terrestrial space had been completed. The boundaries of the Oecumene expanded almost to the planetary boundaries. Therefore, naturally, already in the late XVIII-early XIX century (1799-1804), the expedition by Alexander von Humboldt and Aimé Bonpland to the New World and the subsequent generalizing analysis of its materials created a precedent of deep scientific geographical research at the macro-regional level. The main result of that expedition was accumulation of facts of the previous epochs, and the analysis of the observed geographic phenomena, scientific conclusions and formulation of theoretical provisions. The analytic component of the research by A. von Humboldt and A. Bonpland, which was used for thirty years, became the first theoretical geographical work in one and a half centuries – after B. Varenius` tractate Geographia Generalis.

The first "purely" theorist geographer was Carl Ritter. It is his achievements that finally drove geographical knowledge out of the sphere of description to the level of explanation. The scientific views of C. Ritter and their place in the formation of the main theoretical-methodological provisions of geography of the Modern Age were sufficiently substantiated in the works of the late XX-early XXI centuries (Mukitanov, 1985; Sukhova, 1990; Shabliy, 2001 and others).

The establishment of the comparative research approach and general Earth science orientation is not the only innovation of C. Ritter in geography. This scientist also stood close to the origins of anthropogeography (which we will characterize below), and, moreover, was a conductor of the ideas of teleologism, which is the science about the purpose of existence of Everything in geographic science. In his recognition of the goal of development of geographic objects he showed himself as a follower of the philosophy of G. W. F. Hegel with his view on history as development of "absolute thought". In our opinion, C. Ritter transferred the views of G. W. F. Hegel on the problem of time (as well as the main principles of Hegel`s philosophy in general) to the spatial dimension. Therefore, he was a Hegelian philosopher in the sphere of geography.

According to J. Martin, the teleological views of C. Ritter originated in the philosophy of J. G. Herder. In particular , it is the abovementioned Hegelian view on the northern hemisphere as specifically Oikos on which C. Ritter`s idea of "continental hemisphere" is based , in which the researcher saw the manifestation of divine providence (Martin, 2005).

We should note that the views of C. Ritter on the essence of geographical science were exposed to acute criticism by the founder of the Ukrainian scientific geography S. Rudnytskyi (Rudnytskyi, 2007). In our opinion, the reasons for this were the peculiarities of the condition of geographic knowledge in Europe at the beginning of the XX century, when rapid development of anthropogeography was accompanied by insufficient attention to natural-geographic studies, and also contradictions in the philosophical beliefs between the Hegelian C. Ritter and the positivist S. Rudnytskyi.

The rapid development of anthropogeography which marked the second half of the XIX century, due to the works of C. Ritter`s followers – O. Peschel, F. Ratzel, É. Reclus, P. Vidal de *la Blache* and others – raised humans to the leading place in geographical research, which meant the reconsideration of the content of geographical science in its entirety. If practically all geographic works written until the mid XIX century could be divided into physical- and economic-geographic ("statistical" as then they were mostly called), then the representatives of the anthropogeographic school, perhaps for the first time in the Modern Age, made significant attempts to give geographic studies a complex character. In the authors` opinion, the appearance of such works is related first of all to the fact that geography, being a spatial science, began studying particularly the aspects of understanding of the terrestrial space by human communities. Secondly, the renewed view on the object and subject matter of geography required conceptualization of the essence of objects on the Earth`s surface, besides fulfilling the traditional fact-based researches.

The anthropogeographic orientation became a favourable field for the integration of social-geographical objects to the object of natural-geographical studies. At the same time, approaches of scientists to the unification of the spheres of interests of the two main sections of geography were different. While, for example, if F. Ratzel, adhered to the principles of geographical determinism, focused on the studying the state as a living organism, the body of which is the earth (the so-called organic theory of state, which is not included in the object of our study), P. Vidal de la Blache gave the leading role to the life of people and their communities in relation to the natural conditions and resources of the countries they live in. In particular, he greatly valued the material aspects of life activities (for example, studied the climatic-caused differences in the materials for constructing houses). At the same time, P. Vidal de la Blache, who stood on the principles of geographical possibilism, did not consider the influence of natural-geographic factors on humans and peoples as determining (in his opinion, the determining role belonged to humans themselves, while climate and landscape only create certain preconditions).

As mentioned by one of the authors of the present article, the main result of the activity of anthropogeographers was the closest approach at the time of studies of human sciences to natural-geographic research (Kyselov, 2007).

Almost at the same time with anthropogeography, another direction of philosophical-geographical research began to develop, founded back in the XVIII century by I. Kant – i.e. the researches of the terrestrial space ("choros") with everything filling it, but without explanation of the physical essence of geographical phenomena. The origins of the chorological concept could be traced back to antique times (particularly the works of C. Ptolemy), and was completed in the works by A. Hettner. If C. Ritter was a Hegelian geographer, A. Hettner was a Kantian geographer.

The greatest achievement of the Hettner`s geography (chorogeography), in the authors` opinion, is its covering of the volume of objects on the Earth`s surface which contributed to the driving of geographical science to one of the central places in human knowledge of the world. Thus, ideas of A. Hettner were half a century ahead of the "integral geography" of the Modern Age, which also enlarged the number of research objects while strongly adhering to the natural-scientific basis.

At first glance, geography based on the chorological conception, is a direct opposite to anthropology which to a large extent is related to the ideas of geographical determinism. If in the work of anthropogeographers and geodeterminists the influence of the irrational factor (Ch.-L. Montesquieu`s "The Spirit of the Laws") is seen, the geography of A. Hettner is imbued with formal-logical structures based on rational thinking. Formalistic understanding of geography by this researcher became a field for criticism of him by the founder of the Ukrainian National Scientific Geography, S. Rudnytsky – a representative of positivism (Rudnytskyi, 2007).

Despite the seemingly contradiction between anthropogeographic and chorological concepts, they, in the authors` opinion, could be quite productively dialectically combined in the recent synthetic theoretical-geographic structures. One of the lines of such convergence we consider to be the involvement of the two mentioned concepts in the sphere of "integral geography", which noticeably opposes the directions of Soviet science based on the methods of dialectical materialism – "unpeopled" physical geography and the spheres of economic geography, which focused on the studies of spatial aspects of production, while the phenomenon of humans remained for a long time outside the sphere of its interests.

To the orientations of the development of geography developing in the late XIX century, having strong a philosophical basis, apart from the abovementioned anthropogeography, we should identify the new physical geography which was formed due to the works by V. Dokuchaev (Dokuchaev, 1953). The main features of the new physical geography formed the complex approach to the studies of the natural environment, the establishment of the genetic principle in natural science and the final transition from establishment of geographical facts to their explanation and formulation of patterns, The indicated tendencies were expressed in the formation of the idea of natural zonality by V. Dokuchaev and his followers – sciences of landscape and geographical "shell".

A noticeable "step" in the development of the methodological bases of geography in the late XIX century was F. von Richthofen`s formulation of its four tasks related to study of morphological, structural, dynamic and genetic aspects of existence of geographical objects (Richthofen, 1883). At the same time, the task of study of the origins of the objects has the highest methodological level, because solving them to the highest degree reveals their deepest nature. Therefore, the genetic approach was formed and became broadly-distributed, becoming one of the greatest achievements of geography of the XIX century.

Philosophical thought in geography of XX century. Scientific work of the anthropogeographic school, the followers of which were also the most prominent Ukrainian geographers (particularly, S. Rudnytskyi), to some extent was ahead of its time. In the authors` opinion, it was precisely through the ahead-of-its-time character of its own development that anthropogeography with its ideas after a while enabled to a large degree the geographical sciences as a whole to successfully overcome the significant methodological crisis it underwent in the late XIX century.

That crisis was related to the design of the component geographical disciplines (geomorphology, oceanography, climatology, etc) and by obtaining scientific status, they threatened geography with the loss of its object of study. It became more diluted, less definite, and ultimately broke into the objects of the component sciences. Instead, anthropogeography did not become another component discipline which would deal with humans in the terrestrial space outside the characteristics of the space itself. Instead, particularly due to human and human communities, the enlargement of which is associated with certain regions, it was most rational and natural to focus on components of the environment in their unity and mutuality. This caused the necessity of new fundamental generalizations in this direction. Particularly due to such generalizations, it became possible to take geography to a qualitatively new level of its development. Scientific thought, depending on methodological benchmarks, was developing in different ways seeking the new object of geography. Such object gradually became distinct due to the more expressive view of the unity of components of geoma, pedobiota and humans in geospace.

Anthropogenic surveys were developing not only in the West, but in the Russian Empire as well. Particularly, V. Semenov-Tyan-Shanskyi based the division of the territory on the "structure of "surface formations" due to the relief, climate and vegetation, which gave the ground for the entire cultural view of the area, at the same time its anthropogenic peculiarities should be given serious attention (Semenov-Tyan-Shanskyi, 1915).

Apart from the development of anthropogeography, another way for geography to overcome the methodological crisis was development of the geocomplex approach. The pre-condition of its emergence was appearance of the study of zones of nature formulated by V. Dokuchaev based on the rich factual material he collected during empirical soil and soil-geographic surveys (Dokuchaev, 1953).

The theory of geographic zoning became over time the basis for formulation of the landscape-research concept of L. Berg – study of "the physical-geographical coat" of A. Grigoriev and biogeocenose of V. Sukachov.

A significant contribution to the development of philosophical geography was made by the German geographer E. Banse and the Russian scientist and philosopher of Ukrainian descent P. Savitskii. In the original concept of ratio of landscape and ethnicity which he developed, the central category is "local development" defined as "transcendental geohistorical, geopolitical, geocultural, geoethnographical… geoeconomical unity" of space (Bassin, 2005). This space, according to P. Savitskii, contains "symphonic personality" (including "culture and cultural-historical world which maintain traditional essence" (Savitskii, 1997), the research on which, moving beyond the limits of traditional discipline (geographic, historical, etc), is indeed the content of philosophic geography.

Development of philosophical ideas in geography to a large extent was slowed by the Second World War. In the authors` opinion, the reason for this was strictly subjective circumstances of political character. Because some developments of philosophy of the terrestrial space were used in purposes of others, including German geopoliticians (K. Haushofer, F. Hesse, E. Obst and others), and Germany lost the war, not only geopolitics, but some directions of philosophical geography (particularly geosophy interpreted by E. Banse) became attributed to national-socialism (despite the fact that K. Haushofer and his sons were twice arrested by Gestapo, and one of his sons was killed by SS. Therefore, we consider that the negative attitude of certain segments of scientific community towards the implications of philosophy of space at the beginning of the second half of the XX century is completely subjective and biased.

The certain decline in philosophical thought in geography which occurred in the second half of the XX century could not avoid being reflected in the condition of the entire geographical science. On one hand, natural sciences geographers of that time focused on non-classic methodological approaches – such as landscape, geocomplex, geosystemic approaches. Their application contributed to the one-sided character of subject-object relations in the system "human-environment", which gave no opportunity for geography to adequately respond to the challenges of the recent period, related, particularly, to the emergence and expending of ecological crisis, development of informational technologies, processes in the sacred sphere, and other factors. On the other hand, economic geography, which for a long time practically studied only the problems of territorial organization of the economy, was also unable to react to modern day challenges until it developed into "economic and social", and then – in social geography. Only since the 1990s has an important component of its methodological basis developed into the post-neoclassic research approach.

At the end of the XX century, geography has focused and begun to more and more actively use the knowledge developed by É. Le Roy, P. Teilhard de Chardin and - independently of them – V. Vernadsky about the noosphere, which had a notably philosophical character. It should be noted that the concept of noosphere by P. Teilhard de Chardin is clearly based on idealistic philosophical grounds (its author was a priest), whereas V. Vernadsky`s view of the noosphere was mentioned in the Soviet literature in various ways – from apologetic to critical. Particularly, the idealistic content in the notion "noosphere" was found by V. Anuchin, therefore, while maintaining a materialistic position and being a critic of idealism, he suggested replacing it with the notion "geographical environment" (Anuchin, 1982).

Contemporary geography, especially natural geography, broadly employs also synergic and evolutional approaches (as indicated by V. Pashchenko (Pashchenko, 1999), particularly "ecoevolutionness" is a notion commonly expressed by the term "sustainable" development).

In the 1980s, in the former USSR, a number of geographical works of then non-traditional, philosophical content were published , in particular, monographs by V. Anuchin – "Geographical factor in the development of community" (Anuchin, 1982) – and O. Reteyum – "Terrestrial worlds" (Reteyum, 1988).

The most important peculiarity of the abovementioned study by V. Anuchin, in the authors` opinion, was the raising and consideration of the problem of the influence of the natural environment on the life and activities of man in different historical epochs as one of the fundamentals in the context of relationship between nature and society. By this fact, the abovementioned author partly distanced himself from the dominating "Marxist-Leninist" scientific methodological doctrine of economic determinism; by contrast, the analyzed work contains elements of geographical determinism (which in the conditions back then were obviously unprecedented). Moreover, V. Anuchin in his monograph in fact affirmed the integrity of geography, which Soviet science viewed critically.

The problems which are geographical in nature are to a great extent described in the abovementioned monograph by O. Reteyum. First of all, this work is synthetic in character, combining the data of geology, natural and social geography, history, demography and other sciences, integrated into one integral body by philosophical thought. Secondly, philosophical content is present in some scientific notions applied in the study, particularly the notion "chorion" which the author developed (to mark the complex geospatial objects which have "that particular concentric plan of structure, similar to architectonics of our planet" (Reteyum, 1988) and his usage of the notion "sphragides" introduced by Eratosthenes, indicating decentralized chorions. Thirdly, the study presented spatial comprehension of some natural objects (particularly, botanical object – pines), for the purpose of which the abovementioned author broadly applied fragments of fiction (that is using narrative methods). Finally, in the analyzed work by O. Reteyum, a noticeable discord with most of the studies by Soviet geographers is the mention of "ideally-material" formations (Reteyum, 1988), suggesting that the author applied a dualistic (instead of the materialistic-monistic method dominant in the science of the former USSR) philosophical-methodological approach.

In the authors` opinion, works by V. Anuchin and O. Reteyum are among the few exceptions in the total number of geographical works by Soviet researchers who – intentionally or not – continuously followed the dogmas of dialectic materialism of "Marxist-Leninist" science.

Contemporary philosophical geography. The renaissance of philosophical-georgaphical ideas in Central Europe in the late XX century is associated with the studies by A. Piskozub (Piskozub, 1994). This author focused strongly on the problems of relationship of space and time, uniting them in "timespace". In the authors` opinion, such synthesis is based on the V. Vernadsky`s study on time as a specific fourth dimension of space. The combining factor uniting space and time was movement, since matter moves both in time and space. The emphasized ontological integrity of space and time the author projects also onto the sphere of consciousness, underlining the existence of close gnoseological relations between philosophical ideas in history and geography.

An important place in the research of A. Piskozub belongs to the development of global historiosophical thought. Such analysis gives the author reasons to see a significant effect of historiosophy on the development of philosophical geography (particularly geosophy). At the same time, A. Piskozub tries to be objective in the assessments of theory, concepts and other theoretic-methodological developments of his predecessors in the sphere of philosophical geography.

One of the most important achievements of A. Piskozub is the suggested view of history of perceptions of the World`s peoples on the terrestrial space in the context of natural conditions of their life and means of transport characteristic for them. He distinguishes three generations of agricultural cultures (which later, according to views of O. Spengler, became civilizations), each of about 1500 years – the oldest (2700 – 1200 years B.C.), antiquity (1200 B.C. – 300 A.D.) and pre-industrial European civilization (300 – 1800 A.D.). In turn, each of the distinguished generations is divided into three phases of development each of 500 years . The first five hundred years was the period of formation of classic features of one or the other cultures, the second five hundred years was the period of most complete manifestation, the third five hundred years (clearly seen “civilization”, according to O. Spengler) – was the time of gradual dying out of the established way of life and occurrence of the latent phase of development of processes, causing formation of new cultures. A. Piskozub emphasizes that pre-ancient cultures (Ancient Egyptian, Babylonian, Indus Valley, Ancient Chinese, etc) were “hydraulic”, i.e. spatially confined to valleys of major rivers, and the entire life of people was closely related to rivers. Cultures of Antiquity (Phoenician, Carthaginian, Ancient Greek and Roman) – marine cultures, because the peoples of the Ancient world lived around the Mediterranean Sea, and their life was inextricably linked to it. The European communities in the Middle Ages, in their evolution, increasingly obtained features of oceanicity; the role of the Atlantic Ocean in their life was constantly growing until the late XV century when the Europeans begun to overcome this water barrier. From around 1800 European civilization (including in direct connection to it the newly founded USA) became transoceanic completely. At the same time, the role of agriculture in economically developed countries in the last two centuries significantly decreased; the civilization became industrial, and recently began to obtain post-industrial features, including those related to the formation of informational community.

A. Piskozub`s suggested (from geographical positions) “triple” periodization of history is not a fundamental innovation: back in the Middle Ages, three conditions or eras of global development were distinguished (based on the sacred understanding of history) by the writer on mystical and spiritual science abbot Joachim of Fiore – the era of the physical (“secundum carnem”), the intermediate one between the physical and the spiritual (“i quo vivitur inter utrumque, hoc est carnem et spiritum”) and the spiritual life of people (“secundum spiritum”). Joachim – practically in the same way as A. Piskozub – within each era he distinguished its formal origin and “impregnation”, marking the near approach of the new era (Smirin, 1946, p. 293). To the “threeness” of the stages of development of mankind could be attributed also the work of L. Mechnikov “Civilization and great historic rivers”.

A. Piskozub not only philosophically conceives the experience of mankind in its relations with the terrestrial space, but outlines his vision of the further course of these relations, which he designates as probable future epochs. In such way, the author at the same time emphasizes the perspectives of these studies in the sphere of philosophical geography and underlines the orientation for the future. The correctness of such ideas of A. Piskozub is confirmed by the subsequent development of philosophical-geographical (including geosophic) ideas, particularly, the emergence in the early XXI century of regional geosophy as a special approach to geographic regionalistics (Kyselov, 2005). Around the same time, the fundamental works of social geography came out, replacing the traditional “economic” geography (Shabliy, 2001; Topchiyev, 2009), geohistory (Borysova, 2005), geography of culture (Rovenchak, 2008) and other allied branches. The scientific problems actualized in these publications are in one way or the other philosophical-geographic.

Conclusions. The history of development of philosophical ideas in geography demonstrates presence of several successive stages. The first (Antiquity-Middle Ages) stage lasted until the mid XVII century. The nature-philosophical, geographical and cosmographic works of authors of Antiquity and the Middle Ages contain attempts to comprehend the essence of the terrestrial space, find and rationally substantiate or generalize the systematizations of known factual material in the context (Eratosthenes` sphragides, for example), or with the aim of filling in the gaps in the knowledge of geographic facts (Crates` globe is a bright example) or attempts to study the sacred space which was given priority over terrestrial space, which was treated as a sort of secondary object, (cosmographical studies of al-Khwarizmi and others).

The second (New European) stage of the evolution of philosophical ideas in geography lasted until the second half of the XVII-XIX century, when the Oecumene spread to cover almost the entire land area of the Earth. Then it was the time when the classic geographical studies by B. Varenius, A. von Humboldt and were made, the philosophical content of which is related either to notion-terminological aspect (like A. von Humboldt regarding the notion “landscape”) or philosophically-based (particularly Hegel`s dialectical idealism) geographical studies (similarly to C. Ritter). The philosophical essence also is seen in the concept of geographical determinism formulated for the first time by Ch.-L. Montesquieu and genetic approach seen in J. G. Herder`s ethnography. In general, the works of the abovementioned researchers who objectively made significant efforts to develop philosophical geography belonged to various spheres of knowledge, but all have in common the involvement in re-considering the terrestrial space.

An important pre-condition of the further development of philosophical geography were the emergence in the second half of the XIX century of such methodological directions of geographical studios as anthropogeography (the basis for which was established by C. Ritter, and which underwent significant development in the works of F. Ratzel and É. Reclus) and chorogeography (perfected by A. Hettner based on the philosophical ideas of I. Kant). Anthropogeographical searches indicated the possibility of combining natural and human objects in one object of research, and the chorological concept became paradigmic due to its covering of all geographic facts subject to spatial analysis.

The third stage of evolution of philosophical ideas in geography is related to the overcoming by geographical science of the methodological crisis of the late XIX century due to the development of anthropogeography of F. Ratzel, É. Reclus, P. Vidal de la Blache, V. Semenov-Tyan-Shanskyi , on one hand, and complex natural geography of V. Dokuchaev, L. Berg, V. Sukachev, on the other hand. This stage also includes philosophical-geographical searches of E. Banse and P. Savitskii, where the objects and phenomena in the Earth`s surface were considered mainly in free thinking format rather than within the sphere of any particular science.

The first half of the XX century includes the appearance of studies on noosphere of P. Teilhard de Chardin and V. Vernadsky, which became the harbinger of post-neoclassics in geography and adjacent sciences. An important feature of these studies is the integration of humanity as a thinking substance to the natural phenomenon – biosphere, with which it forms an integral whole.

The fourth (contemporary) stage of the development of philosophical thought in geography began in the late XX century, and is associated first of all with the works by A. Anuchin, O. Reteyum, A. Piskozub. The main feature of this stage is the most harmonious combination of particular-scientific and philosophical tasks in the evolution of philosophical geography. Such combination objectively reflects the dialectical character of the relationship between science and philosophy. Contemporary studies in social geography, geohistory, geography of culture and geosophy are the organic continuation of this stage.

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On the issue of sustainable development of tourism in the Black Sea countries

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Abstract. The article observes the relevance and substantiates the need to raise the problem of tourism development in the countries of the Black Sea region (Turkey, Ukraine, the Russian Federation, Georgia, Romania and Bulgaria) on the basis of sustainability. Systematization of approaches to the definition of «sustainable development of tourism», «sustainable tourism» and «tourism constancy» has conditioned the elaboration of a sustainable tourism development model, the elements of which are the needs of tourists, tourism resources, tourism services, types of tourism, tourism activities, subjects - tourist, tourist enterprise, destinations and the state (management). It was determined that the achievement of sustainable tourism development in the country should be evaluated from the standpoint of meeting the needs of tourists and considering the factors such as security, sustainable tourism services, economic and environmental sustainability, socio-cultural sustainability, the country's basic sustainaility and political and regulatory constancy. During the study, the needs of the tourist were identified (cognition, recognition and his acceptance of the cultural, historical, national heritage of the destination, the development of spiritual potential and self-development), which act as a driving force for the growth of demand for sustainable types of tourism. It was found that satisfying the physiological needs of a tourist, his staying in a safe environment, confirming his social, professional, family status is associated with mass tourism, and does not fully contribute to the achievement of sustainable development goals. It is determined that the development of tourism in the Black Sea countries is characterized by a high loading on tourist facilities and irregular tourist flows, the irrational use of natural resources, and the continuous expansion of infrastructure that allows only fragmentary observance of the principles of sustainable development . To assess the sustainability of tourism in the countries of the region, we used the author's methodology for ranking the factors of the tourism sustainability index. Calculations demonstrated that the most important factors for tourists in the Black Sea region are the factor of safety, tourism services and the basic state of stability of the country, which is based on the level of food technology usage; the presence of harmful industries in the country; unemployment rate in the country; the importance of tradition in everyday life; international openness safety factors, tourist services and the basic condition of stability of the country. Environmental sustainability and a sociocultural strategy have a moderate impact. In the ranking of the countries of the Black Sea region according to the calculated tourism sustainability index, Georgia took the first place, and Ukraine received the lowest indicator. By the method of cluster analysis, the countries of the Black Sea region were combined into three clusters. The first cluster was formed by Turkey - a country that has a developed system of mass tourism and actively contributes to its reorientation continuously. The second cluster includes Bulgaria, Romania and Georgia, which combine the processes of active development of traditional and sustainable tourism. In the third cluster, which includes Russia and Ukraine, the development of tourism on the principles of sustainability practically does not occur.

Keywords: sustainable development of tourism,mass tourism, Black Sea region,index of tourism sustainability

До питання сталого розвитку туризму країн Причорномор'я

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Анотація. В статті розкрито актуальність й обгрунтовано необхідність підняття проблеми розвитку туризму в країнах Причорномор'я (Туреччини, України, Російської Федерації, Грузії, Румунії й Болгарії) на засадах сталості. Систематизація підходів до визначення понять «сталий розвиток туризму», «сталий туризм» та «сталість туризму» дозволила розробити модель сталого розвитку туризму, елементами якої виступають потреби туристів, туристичний ресурс, туристична послуга, види туризму, туристична діяльність, суб'єктами – турист, туристичне підприємство, дестинація та держава (управлінський орган). Визначено, що досягнення сталого розвитку туризму в країні має бути оцінено з позиції задоволення потреб туриста й враховувати такі чинники, як безпека, сталий туристичний сервіс, економічна й екологічна сталість, соціально-культурна сталість, базова сталість країни й політико-регуляторна сталість.В ході дослідження виокремлено сталі потреби туриста (пізнання, визнання та прийняття ним культурної, історичної, національної спадщини дестинації, розвиток духовного потенціалу та саморозвиток), які виступають рушійною силою зростання попиту на сталі види туризму. З'ясовано, що задоволення фізіологічних потреб туриста, перебування його в безпечному середовищі, підтвердження свого соціального-професійного, сімейного статусу пов'язано з масовим туризмом, і не повною мірою сприяє досягненню цілей сталого розвитку. Визначено, що розвиток туризму в країнах Причорномор'я характеризується високим навантаженням на туристичні об'єкти, нерівномірністю туристичних потоків, нераціональним використанням природних ресурсів, постійним розширенням інфраструктури, що дозволяє діяти на засадах сталого розвитку лише фрагментарно. Для оцінки сталості туризму країн регіону використано авторську методику ранжування чинників індексу сталості туризму. Розрахунки показали, що найважливішими для туристів в країнах Причорномор'я є чинники безпеки, туристичного сервісу та базового стану сталості країни, в основі якого лежить рівень використання складних технологій виготовлення харчових продуктів; наявність шкідливих виробництв на території держави; рівень безробіття в країні; значення традицій у повсякденному житті; міжнародна відкритість. Помірний вплив чинять екологічна сталість та соціокультурна стратегія. В рейтингу країн Причерномор'я за розрахованим індексом сталості туризму перше місце посіла Грузія, а найнижчий показник отримала Україна.Методом кластерного аналізу країни Причерномор'я було об'єднано в три кластери. Перший кластер сформувала Туреччина – країна, що має розвинену систему масового туризму і активно сприяє його переорієнтації в сталому напрямку. До другого кластеру увійшли Болгарія, Румунія та Грузія, які поєднують процеси активного розвитку традиційного і сталого туризму. В третьому кластері, в який увійшли Росія й Україна, розвиток туризму на принципах сталості практично не відбувається.

Ключові слова: сталий розвиток туризму, масовий туризм, регіон Причорномор'я, індекс сталого туризму

Introduction. For more than 10 consecutive years, Europe has remained the most visited region of the world. Thus, in 2017, the number of international tourist arrivals to European countries increased by 8 % compared with 2016, which brought international tourism receipts worth USD 519.2 billion and provided 37 million jobs (World Tourism Organization, 2018b).

A steady growth of statistical indicators for the development of tourism in the European tourist region is justified, first, by its natural geographic and cultural and historical attractiveness for tourists and, second, by the developed transport network that provides for the reachability of the region›s destinations. It is this attractiveness that defines the extensive and intensive advancement of tourism infrastructure in destinations, resulting in the increasing tourism revenues.

The highest growth rates of direct revenues from tourism and travel among all European countries in 2017 compared to 2016 were as follows: Georgia – 21.3%, Turkey – 17%; in terms of the number of tourist arrivals in Europe – Turkey, 28.6%, Romania, 26.8%, Georgia, 26.2% (WTTC, 2018, a).

Such indicators of countries located around the Black Sea, on the one hand, justify their already existing opportunities according to the usage of their own tourism potential, that finds support from state authorities, business organizations, investors, public initiatives. On the other hand, it attracts attention to countries across the entire Black Sea region as a promising center for the development of mass international tourism in Europe. Countries in the Black Sea region, in addition to those above specified – Georgia, Turkey, Romania,include Bulgaria, Ukraine, and Russian Federation.

At the beginning of 1990s, the region›s countries already had a relatively well-developed maritime infrastructure, which essentially has not changed since that time. However, there has been a great improvement in air traffic among the sea resorts of Turkey and Georgia, which has intensified tourist activities. Revitalizing the tourist destinations in Bulgaria and Romania was contributed to by their joining EU in 2007. However,over a decade, the countries in the region experienced political instability. Revolutions took place in Georgia in 2003, in Ukraine in 2004; Georgia was involved, and Ukraine has been involved since 2014 in a military-political conflict with Russian Federation. Turkey survived the failed military-political coup in 2016. The incident with the Russian plane in 2015 led to a fourfold decrease in tourist flows to Turkey from Russian Federation.

At present, there is a pressing need for a balanced, harmonious, uniform development of tourism in the region so that the economic development and the well-being of local residents, the development of culture, the environment, as well as meeting the needs of tourists,do not conflict with one another.

Analysis of recent research and publications. At the UN Conference on Sustainable Development "RIO + 20" in June 2012, the heads of countries noted the significant contribution of tourism, organized on the principle of permanence and aimed to create new jobs and the growth of international trade. Sustainable tourism, as one of the five components of the approved "The 10 Year Framework of Programs on Sustainable Consumption and Production Patterns" (High-level Political Forum on Sustainable Development, 2012), has been recognized as the leading tool for sustainable development of countries. It aims to reorient society and consumer behaviour towards sustainable development.

The recognition and adoption by the international community of Sustainable Development Goals (SDGs) as guidelines and milestones in countries' development in 2015 changes the environment of the tourist business. Tourism accounts for 30% of world exports of commercial services, or 7% of world exports. The tourism industry, which develops at a high rate, also stimulates the generation of revenues by 53 related industries, which is equivalent to 10% of global GDP. The tourism business has created every eleventh workplace, every seventh – in the related sectors of the economy (World Tourism Organization, 2018, a). Development of tourism is accompanied by construction and improvement of basic, financial, technological infrastructure, by the increasing affluence of territories and by a decrease in poverty of local population. The former UN Secretary-General Ban Ki-moon believed that tourism is the most important industry in achieving the goals of sustainable development (World Tourism Organization, 2015).The tourist industry has a very high potential to help countries achieve the goals of sustainable development (SDGs).

The issue of «ensuring the sustainable models of consumption and production» (SDG 12), specifically a change and sustainable models of consumer behaviour,was investigated by Hall (2013), Shove (2014), analysis of consumer behaviour from the standpoint of social marketing, technologies, institutions, modes of management and service provision – by Hall (2016), Williams (2013). Environmental issues in tourism in the context of struggle against climate change (SDG 13), protection of the marine and coastal environment (SDG 14), protection of ecosystems and reducing a biodiversity loss (SDG 15), were addressed in the works by Wall & Badke (1994), Scott (2011), Weaver (2011), Lowe, Phillipson & Wilkinson (2013), Leyshon (2014), Scott, Gössling, Hall & Peeters (2015), Scott, Hall & Gössling (2016).

The development of tourism contributes to accomplishing SDGs 8, 12, 14 (World Tourism Organization, 2015), indirectly – all SDGs. To raise the awareness of society about the role of sustainable tourism for SDGs, to introduce the principle of sustainability into the practice of travel companies and related entities, to form a «sustainable» behaviour of tourists, the World Tourism Organization (UNWTO) announced 2017 to be the year of sustainable tourism. SDGs balance the environmental, social and ecological aspects of societal development to 2030.

The concept of sustainable development has led to the formation in the field of tourism and travel of such concepts as: «sustainable development of tourism», «sustainable tourism», «sustainability in tourism». Defining the terminology is important to understanding and stating the issue on sustainable tourism and related policies (Bramwell, 2015), to forming views on «what matters and what does not, behind which lie ideas about how things work» (Harding & Blokland, 2014); the result of scientific discussions would include programs, as well as specific practical activities.

In 2004, UNWTO developed the concept of the sustainable development of tourism, which implies that the rules and practice of managing a sustainable development of tourism are universal for all types and directions, the principles of sustainability relate to the environmental, social and economic components of its development and must be balanced in order to guarantee the long-term development of tourism. The goals for sustainable development of tourism, formed by UNWTO, are to ensure economic feasibility, prosperity, employment, social justice, affordability of tourism, local control, welfare of the society, cultural richness, physical integrity, biological diversity, efficiency of use of tourist resources, environmental cleanliness of a host destination (United Nations Environment Programme. Division of Technology, 2005).

The start of a general debate on «sustainable tourism» is associated with B. Bramwell and B. Lane, who in 1993 proposed the interpretation ,established the difficulties, benefits, and risks in its development (Bramwell & Lane, 1993). One of the common approaches considers sustainable tourism to be a type of tourism that ensures a caring, rational use of resources in the environment, preservation of the socio-cultural features of host communities, efficiency and viability of long-term economic processes, while a share of money from tourism activities is aimed at restoring tourist resources, improvement of technologies for providing tourist services. Sustainable tourism demonstrates the development of such types as: ecological, green, country, eco-tourism, socially responsible, agritourism (Krasnikova, Krupskyi & Redko, 2019).

Thus, sustainable tourism should ensure the following (United Nations Environment Programme. Division of Technology, 2005: 11–12):

- optimal use of environmental resources to preserve the natural environment and biodiversity;

- respect for the social and cultural heritage and traditional values of host communities;

- the long-term contribution of tourism to the development of local industries, which provides for social and economic benefits for all stakeholders.

The aim of this study is to substantiate the determinants and ways for promoting the sustainable development of tourism in the countries of the Black Sea region. To achieve this, the model of the sustainable development of tourism that considers the needs of a tourist has been proposed, which systemized the elements, subjects, and metrics of tourism sustainability, aimed at accomplishing the sustainable development goals (SDGs) and developing the sustainable types of tourism.

Materials and methods. In the article we used methods of statistical analysis, mathematical methods for calculating the index of tourism sustainability in terms of meeting the needs of a tourist by our author's procedure.

To perform a study, we used 2 resources on Facebook: "Tourism business" was created in April 2014: by the time of the survey it had 1,745 subscribers (Tourism business, 2018); "Independent journeys around the world" was created in March 2013, it had 21,655 subscribers (Independent journeys around the world, 2018).

All the subscribers were sent a brief set of questions aimed at identifying people willing to take part in our research – it was of interest to 811 people, representing 3.3 % of the audience covered by these two resources. These people were sent a questionnaire. The participants were informed about the general purpose of the research, but the exact description was removed to reduce the social bias in responses. 697 responses were received (85 % of subscribers who received the questionnaire wishing to take part in the study). Next, we removed from the sample all incomplete answers and responses, which belonged to staff of enterprises of tourism and hospitality who could be termed "professionally shortsighted", so we were left with 426 responses (61.19 % of received questionnaires). These respondents, firstly, did not work at enterprises of tourism and hospitality, secondly, they expressed their opinions regarding the questions stated in the questionnaire, which, we assume, were the result of their personal experience related to travels.

After data cleaning, the sample contained 393 questionnaires – 56.38 % of the questionnaires returned (1.6 % – from subscribers to the resources). 69 % of the participants were women, 31 % – men. The average age was 37.21 years (SD=17.21).

In the questionnaire, participants of the survey had to estimate the level of 7 factors for 6 countries, based on our 10-point scale (1 – very low, 10 – very high). We included Turkey, Ukraine, Russian Federation, Bulgaria, Romania, and Georgia into the group of countries in the Black Sea region.

Results and discussion. Since the beginning of the 20th century, mass tourism "led to the over-utilization of historical and natural objects" (Sydorenko, 2019). According to I. Petrasov, the negative consequences of tourism development, in addition to the environmental, could include a negative/destructive influence on the culture of local inhabitants, a growth of population density in tourist regions, worsening socio-economic tension, the practice of employing minors. The author points out that international tourism can act as a catalyst for the transition from the traditional to the so-called "European" lifestyle, which could cause social conflicts and lead to the loss of cultural customs by local population (Petrasov, 2001).

Thus, on the one hand, the growing needs of tourists have spurred the development of the tourism industry, on the other hand, the limited tourist resources of a host destination did not meet these requirements in full. According to R. Sharpley (2003), the concept of sustainable development of tourism "originated with the aim of reducing the negative effects of tourism that has become almost routine as a desirable and politically expedient approach to the development of tourism". The purpose of sustainable tourism is to provide a balanced, harmonious, even development of tourism so that the economic development and well-being of local residents, the development of culture, the environment, as well as meeting the needs of tourists,are not opposed. We believe that any kind of tourism can become sustainable provided the rendered tourist services satisfy the economic, socio-cultural, aesthetic needs of tourists, preserve cultural heritage, support the recovery of the environment, biological diversity and life-supporting systems at a destination. The sustainable development of tourism would make it possible to recover, while sustainable tourism – to increase and qualitatively improve, the tourist resources in the future, without any social, environmental damage to future generations. The model of the sustainable development of tourism is shown in Fig. 1.

The sustainable development of tourism "constantly improves the experience of a tourist" (Hashemkhani Zolfani, Sedaghat, Maknoon & Zavadskas, 2015), changes his/her needs and requirements to travel services. In our opinion, the defining criterion of sustainable tourism is to meet the needs of a tourist – knowledge, recognition, and his/her acceptance of the cultural, historical, national heritage of a destination, the development of spiritual potential and the self-development of a tourist. In this context, there is a naturally growing demand for travel services involving active, interactive, creative, authentic, unique, in-

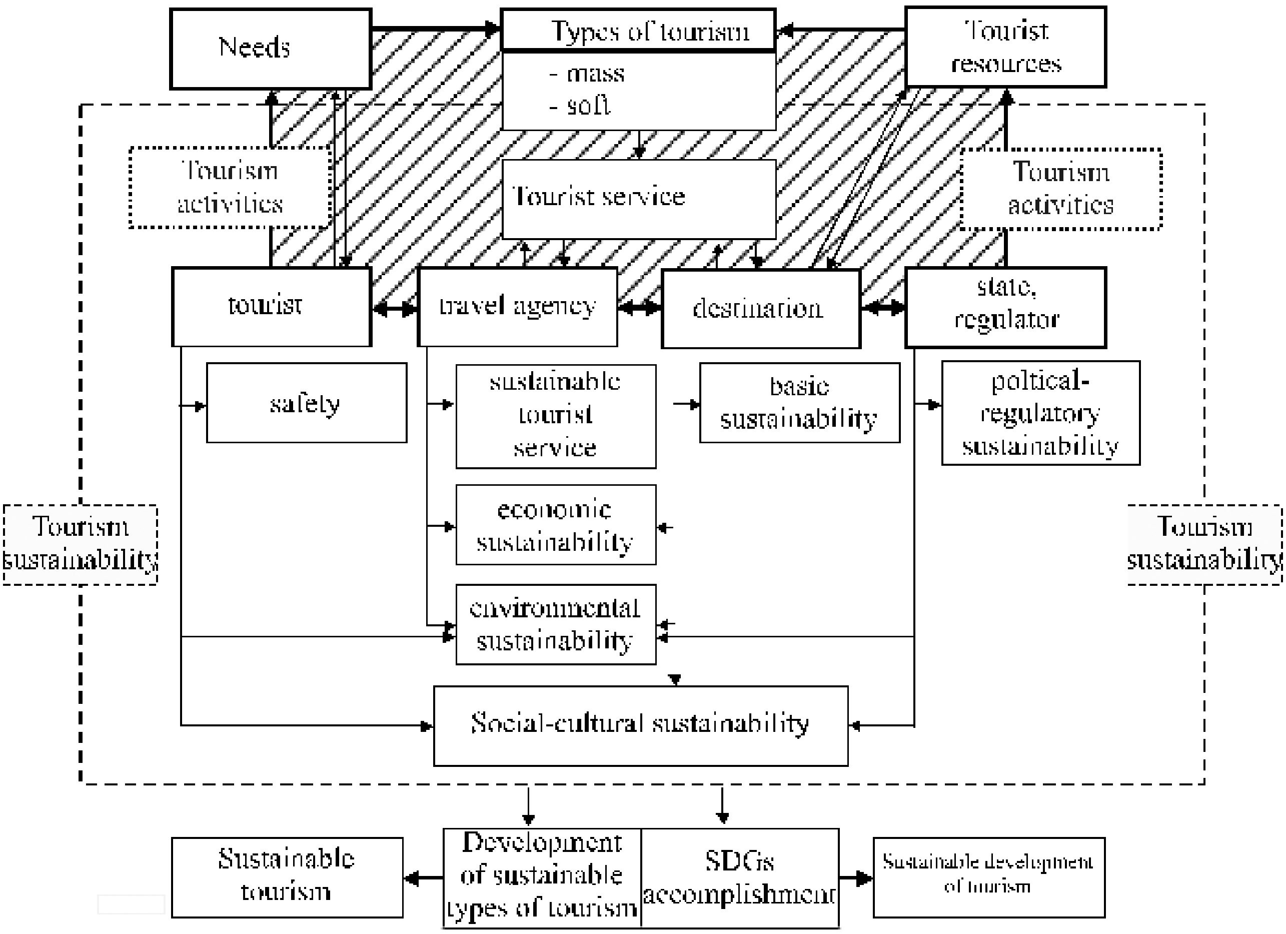

Fig. 1. Model of sustainable tourism development. *Prepared by authors*

teractive rest in harmony with nature. Using the pyramid Maslow et al. (1984) we identified the following needs for the conventional-technogenic tourist: physiological needs, being in a safe environment, confirmation of own social-professional, family status.

The concept of "sustainability in tourism" is associated with the overall positive balance of environmental, economic, and socio-cultural interactions among actors in the tourist business, mutual positive influence of tourists and locals on each other. The former Secretary General of UNWTO Taleb Pifai pointed to a possibility to promote the contribution of the tourism sector to the three "basics" of sustainability – economic, social, environmental. Kamphorst (2013) identified the fourth metric – cultural dimension of sustainability, Wray (2015) and Hartman (2016) supplemented the above with the fifth – management dimension. *Environmental sustainability* describes the preservation of the natural environment and biodiversity after providing tourist services. *Economic sustainability* is aimed at obtaining profits by implementing sustainable practices in the provision of tourist services. *Social sustainability* is associated with preservation of the social structure, the ways of life of local population, *cultural sustainability* is characterized by respect, by keeping traditions, ceremonies, and the cultural heritage of countries. The relatively new concept of *management* of tourist activities examines those systems,modes, technologies that affect the implementation of more sustainable practices in tourism. We propose considering the *safety* and *basic constancy* of a destination as well. The factor of personal safety is important given the increasing influence of adverse events at different levels on the desire to travel in general and the choice of a tourist destination. The basic constancy of a country is formed by considering the following criteria: the level of use of sophisticated technologies for the manufacture of food; the presence of harmful enterprises on the territory of a country; the unemployment rate in a country; the importance of traditions in everyday life.

Tourist activities are an important source of income for countries in the Black Sea region. In 2017, the share of tourism in Turkey's GDP amounted to 11.6%, in Bulgaria – 11.5%, in Georgia – 31%, in Ukraine – 5.7%, in Romania – 5.3%, and in Russian Federation – 4.8% (note the lowest indicator among all countries in the examined region). Thus, tourist arrivals in 2017 increased by 19.89%, 9.47%, 46.73%, 105.05%, 222.31%, respectively, in Turkey, the Russian Federation, Bulgaria, Romania, and Georgia as compared to 2010 (World Tourism Organization, 2018b). The only exception was Ukraine, tourist arrivals to which over the period of 2010–2017declined by 32.89% as a result of the political crisis in the country, carrying out anti-terrorist operation in the territory of Donetsk and Luhansk oblasts and the annexation of the Crimea. This testifies to the priority of safety as a factor in the sustainable development of tourism and in the formation of the tourist image of the country.

By analyzing the dynamics of revenues from international tourism over 2010–2017, it should be noted that Georgia increased revenues by 3.17 times in 2017 compared to 2010, while this indicator for Ukraine fell by 66.71% during this period, and in Turkey it decreased by 1%. Almost all other countries in the Black Sea region demonstrated the steady dynamics of a gradual growth in revenues from tourism activities (Fig. 2).

Federation, and the shortest is in Bulgaria. In the travel and tourism competitiveness ranking in 2017, based on an indicator of road and port infrastructure, the Russian Federation held 78th place among 136 countries, Bulgaria – 73, Ukraine – 81, Georgia – 63, Romania – 92, and Turkey – 54 (World Economic Forum, 2017:44), indicating that poor quality of transport routes within the region.

Our analysis of tourism development in the Black Sea region's countries has revealed that the tourist activities in these countries are characterized by positive developments, which manifest themselves in the increased tourist activity by people from different parts of the world in these countries, in the growth of revenues from tourism in the budgets of the countries, the emergence of new infrastructure objects and which show the extensive development of mass (traditional) tourism. This development is characterized by the maximum load and overload on tourist facilities, by the irrational utilization of natural resources, by constant expansion of the infrastructure and by a relatively low price for the tourist product, which predetermines an increase in tourist flow.

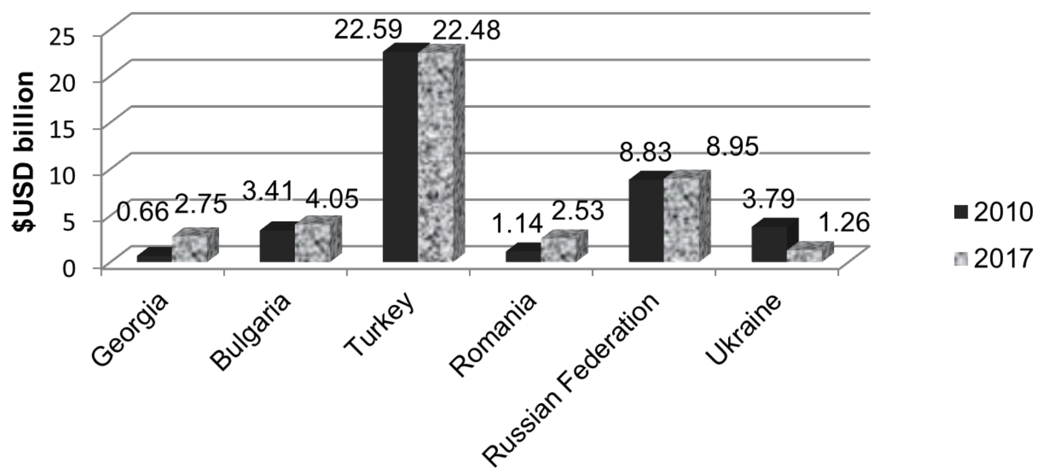

Fig. 2. The dynamics of revenues from tourism in the Black Sea region's countries between 2010 and 2017
Source: World Tourism Organization (2018 b)

Development of mass tourism predetermined the development of infrastructure in the countries. This is evidenced by the increase in the number of hotel facilities and their capacity. Georgia ranks first in terms of hotel accommodations in 2017 (18.22 places in hotels per 1,000 inhabitants in the country). The second place for this indicator is taken by Bulgaria (17.14), followed by the Russian Federation (7.76), Romania (5.74), Turkey (5.73), and Ukraine occupies the last place (3.12) (Table 1).

It is known that the indicator for stable development of the country's economy is the length of motorways. The motorways define the transport accessibility of a country and create conditions for domestic travel. Among the studied countries, the longest network of motorways is in the Russian

The methodology that we devised makes it possible to assess the sustainable development of tourism in terms of meeting a tourist's needs (Stukalo, Krasnikova, Krupskyi & Redko, 2018a). It enables us to rank a country based on expert assessments for the following 7 factors: economic, social, environmental sustainability, safety, sustainability of the political and regulatory environment, tourist service, and the basic state of the country›s sustainability. Advancing the study necessitated clarification of the title of the factor, originally denoted as a «tourist service», to designate it as «the sustainability of a tourist service».

Table 1. Indicators of tourism development in the Black Sea region's countries

Indicator	Georgia	Bulgaria	Turkey	Romania	Russian Federation	Ukraine
Number of country's objects ranked asUNESCO heritage sites, units: including	3	9	16	7	26	7
cultural	3	7	15	6	16	6
natural	-	2	1	1	10	1
Capacity of hotel accommodations in 2017, thousand beds	67.760	123.420	445.249	114.390	1137.000	133.4
Availability of hotel accommodations per 1,000 citizens in a country, places	18.22	17.14	5.73	5.74	7.76	3.12
Length of motorways, thousand km	19.1	19.5	385.8	84.2	1283.4	169.7
Share of tourism in the country's GDP in 2017, %	31.0	11.5	11.6	5.3	4.8	5.7
Share of state expenditures for tourism development in a country in 2017, %	3.4	3.3	0.5	1.8	2.7	5.1
Rate of growth (decline) in revenues from tourism over 2010–2017, %	222.31	46.73	19.89	105.05	9.47	-32.89
Rate of growth (decline) in revenues from international tourism over 2010–2017, %	317.45	18.73	-0.47	121.67	1.30	-66.71
Contribution of tourism to country's GDP, USD billion	4.682	6.58	98.4	11.185	76.1	5.452
Tourists expenditures, USD billion	2.98	4.502	31.3	2.87	14.4	1.618
Competitiveness index of travel and tourism in 2017	3.7	4.14	4.14	3.78	4.15	3.5
Place in the rating of competitiveness of travel and tourism in 2017	70	45	44	68	43	88

Source: CIA, 2018; Federal State Statistics Service, 2019; Galt & Taggart, 2018; SSC of Ukraine, 2019; Statista, 2018, a; Statista, 2018, b; World Tourism Organization, 2018, a; WTTC, 2018, b; WTTC, 2018, c; WTTC, 2018, d; WTTC, 2018, e; WTTC, 2018, f; WTTC, 2018, g.

Using such a title focuses attention directly on the importance of the sustainable development of tourism, rather than a simple increase in the number and coverage of countries engaged in tourist service.

Using the Saaty hierarchy method, the authors have ranked and arranged in descending order of importance 7 factors that affect the level of tourism sustainability(Saaty, 1984). Experts conducted a pairwise comparison of these factors in terms of importance based on a nine-point scale and compiled an appropriate matrix in which estimates imply the following: equal importance – 1; moderate superiority – 3; significant superiority – 5; strong superiority – 7; very strong superiority – 9; intermediate cases are graded by even number estimates: 2, 4, 6, 8. We compared the relative importance of left elements in the matrix with the elements at the top and, if a factor to the left is considered more important than the factor at the top, the cell records a positive integer, in the opposite case – fractional (Table 2). The relative importance of each factor in comparison with itself equals unity.

By applying a method of the geometric mean, we calculated the normalized estimate of the vector (Table 2). To determine the coherence of priorities (satisfactory results from expert survey), we computed the index of coherence (0.09656273), whose value is compared with a reference (1.32). In our case,0.09656273 is less than 0.1x 1.32=0.132, that is the result is satisfactory.

In the course of an earlier study it was found that tourists had almost disregarded the importance of indicators that were included in the group of factors such as economic sustainability and the sustainability of the political and regulatory environment. That is, the factors that form the country's tourism income and the country's legislative standards for its sustainability are not an incentive for choosing a country by a tourist for travel. Factor of safety and basic state of sustainability– form more than 90 % of the influence(Table 2).The basic state of sustainability is understood by the authors as the assessment of the country by tourists according to the following criteria:level of using sophisticated technologies for manufacturing food products; existence of harmful productions on the territory of a state; unemployment rate in a country; importance of traditions in everyday life; international openness (rating of passport power)

Table 2. Determining the importance level of factors for the sustainability of tourism

Factor	Safety	Tourist service sustainability	Sustainability basic state	Environmental sustainability	Socio-cultural strategy	Sustainability of political and regulatory environment	Economic sustainability	Matrix eigenvector	Normalized vector estimate (factor weight)
Safety	1	2	3	5	7	8	9	3.9543838	0.35000616
Tourist service sustainability	1/2	1	3	5	7	8	9	3.2439209	0.28712242
Sustainability basic state	1/3	1/3	1	3	5	7	9	1.9442017	0.17208308
Environmental sustainability	1/5	1/5	1/3	1	3	5	7	1.0492414	0.09286932
Socio-cultural strategy	1/7	1/7	1/5	1/3	1	3	5	0.5735131	0.05076218
Sustainability of political and regulatory environment	1/8	1/8	1/7	1/5	1/3	1	3	0.3321950	0.029i40288
Economic sustainability	1/9	1/9	1/9	1/7	1/5	1/3	1	0.2005846	0.01775392

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(Stukalo, Krasnikova, Krupskyi&Redko, 2018 b).

Based on the received questionnaires, we calculated the average value of an expert estimate for each of the 7 factors for all 6 countries. Next, the average values were adjusted according to the weight of the factor (Table 2) to derive the total magnitude for a country's tourism sustainability index (Table 3).

Based on the questionnaires received, the average value of the expert assessment was calculated for each of 7 factors for all 6 countries. After that, the average values were adjusted in accordance with the weight of the factor (Table 2) and the total value of the author's tourism sustainability index (Table 3).

Georgia ranked first with a value for the index of country's tourism sustainability of 7.38, which, according to the rating of competitiveness of travel and tourism, took 70th place only (Table 1). The lowest level of tourism sustainability was demonstrated by Ukraine (4.85), which, in our opinion, was predetermined by the unstable political situation and the military conflict that directly involved the main Black Sea recreation area of Ukraine, the Crimea.

Such a situation in Ukraine defined the reduced experts' estimates for all factors, especially, the factor of safety. The practice of development of tourist activities matches the mood of experts in assessing: as

Table 3. The tourism sustainability index of the studied countries

Factor	Factors' values for countries					
	Georgia	Bulgaria	Turkey	Romania	Russian Federation	Ukraine
1. Safety	2.583	2.583	1.883	2.333	2.033	1.600
2. Tourist service sustainability	2.237	2.209	2.540	1.809	1.768	1.440
3. Sustainability basic state	1.166	1.125	1.190	1.085	1.012	0.870
4. Environmental sustainability	0.626	0.660	0.639	0.596	0.506	0.450
5. Socio-cultural strategy	0.386	0.383	0.419	0.312	0.276	0.250
6. Sustainability of political and regulatory environment	0.236	0.236	0.249	0.204	0.170	0.140
7. Economic sustainability	0.147	0.152	0.172	0.131	0.112	0.090
Tourism sustainability index for country	7.380	7.349	7.093	6.470	5.877	4.850
Rank in rating	1	2	3	4	5	6

Calculated on the basis of the author's technique noted above, in contrast to other countries in the group, the main statistical indicators for tourism activities in Ukraine demonstrated a decline over the period of 2010–2017 (tourist arrivals – by one-third, revenues from tourism – by two-thirds).

Turkey, which ranks first in the region based on the statistical indicators for the development of tourism(tourist arrivals and revenues from tourism), was only the third among the countries for the index of tourism sustainability. In this case, the experts identified the highest level of sustainability of tourist service, as well as the sustainability basic state, socio-cultural strategy, economic sustainability, and the sustainability of political and regulatory environment, in Turkey among the region's countries. Only the safety level was ranked rather low, which led to the overall a third position in the ranking.

Bulgaria, a leader in terms of safety factor, was second in the ranking for the index of country's tourism sustainability. The country is outperformed by Turkey and Georgia by the level of sustainability of tourist service, but it is ahead of all the region's countries in terms of environmental sustainability. The Russian Federation, while being ahead of Turkey based on the rating of competitiveness of travel and tourism (Table 1), won the penultimate 5th place for the index of country's tourism sustainability. Note that the assessment of experts, based on the factor of a socio-economic strategy, is not correlated with statistics on the number of UNESCO heritage sites in a country.

By using a cluster analysis, given the estimates of experts for the sustainability of tourism in the examined countries, we established 3 clusters (Fig. 3). The first cluster includes Russian Federation and Ukraine. The common attitude of experts towards these two countries is determined by the identity of the perception of the vocation by consumers in these countries and perception of them as two sides of the military confrontation.In addition, these countries are the outsiders for the dynamics of changes in the statistical indicators for the development of tourism industry; they, therefore, do not give the proper amount of attention to the development of sustainable tourism and tourism in general.

Turkey forms a separate cluster, which is predetermined by the fact that the experts perceive this country as the main "Black Sea region Mecca" of

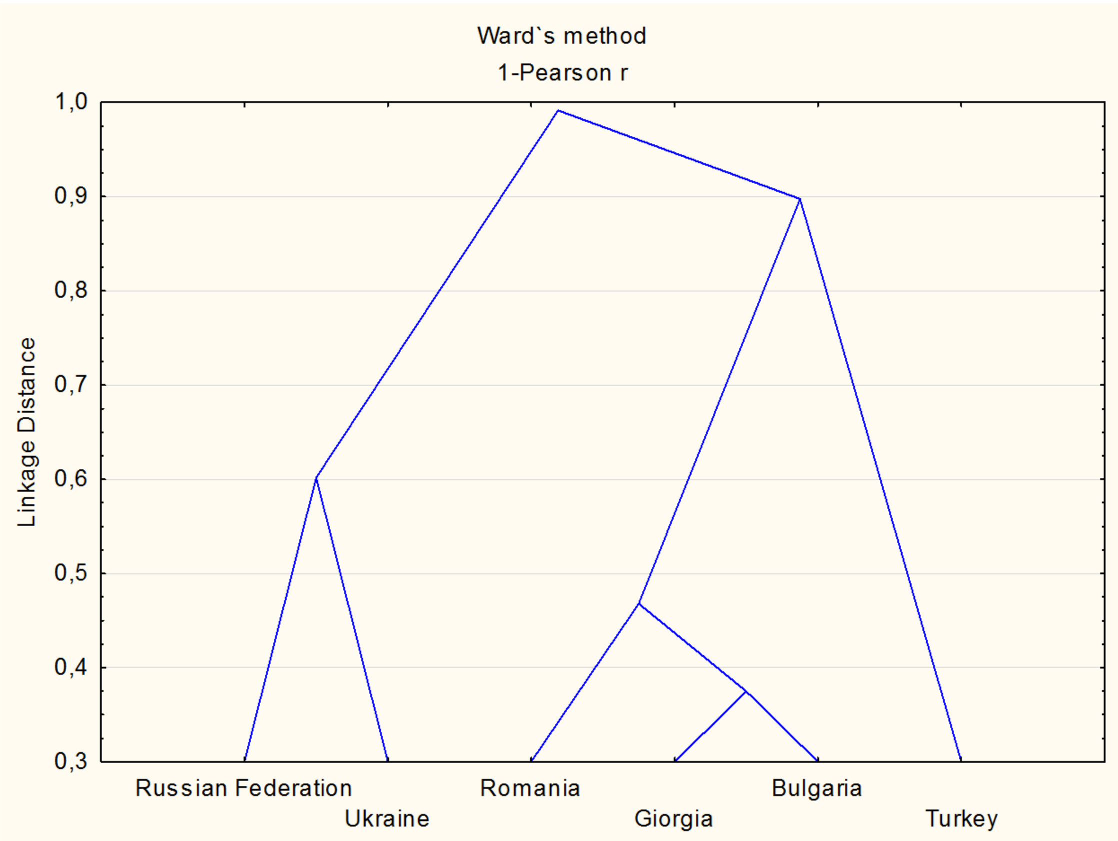

Fig. 3. Dendrogram of results from cluster analysis. *Prepared by authors*

Based on expert estimates
Cluster 1 – Russian Federation, Ukraine
Cluster 2 – Romania, Georgia, Bulgaria
Cluster 3 – Turkey + (Romania, Georgia, Bulgaria)

mass tourism where basic tourist needs are satisfied best. Romania, Bulgaria, and Georgia form the third cluster. These are the countries that actively develop their own tourism in a sustainable direction, and their positioning in the minds of tourists differs from the other two clusters, but is closer to the cluster of Turkey.

Conclusions. The results of testing the author's methodology for ranking the countries of the Black Sea Region according to the Tourism Sustainability Index from the standpoint of satisfying the needs of tourists indicate that tourists, while deciding on their travel destination, primarily pay attention to the safety of destination, the constancy of tourism services and the factor of basic stability of the country, that is, to the development factors of industrial tourism. Environmental sustainability and sociocultural strategy have a moderate impact on the tourism sustainability index in the studied countries, but do not affect the decision of the tourist to travel to this country.

The Black Sea countries are grouped into three clusters based on expert assessments of the tourism sustainability index in the studied countries. The first cluster is formed by Turkey, which focuses on international mass tourism and partially follows the principles of sustainable development to achieve its goals. The second cluster (Bulgaria-Romania-Georgia) has a high level of security and this directs its development towards sustainability, although it focuses mainly on the achievement of quantitative rather than qualitative indicators of tourism development. The third cluster was Russia-Ukraine, where the development of tourism on the principles of constancy practically does not occur, which requires improvement of tourism management mechanisms taking into account the impact of changes in the external and internal environment.

The trends formation of the tourism sustainability index in clusters 1 and 2 will go on taking into account their cultural authenticity, which is due to the growing role of active, interactive, creative, unique and harmonious types of recreation in these countries. For cluster 3, it is advisable not only to develop a strategy for the sustainable development of tourism, but also for its implementation at all levels of management and the transition to a service economy in this area of activity.

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Burned peatlands within the Volyn region: state, dynamics, threats, ways of further use

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Abstract. The consequences of peat fires are complete or partial loss of soil fertility over a considerable area of land, decrease in biodiversity, razing of unique landscapes, deterioration of the conditions for life and health of the population, disturbed carbon cycle, increase in the greenhouse gas emissions, intensification of climate change, etc. Climatic tendencies of recent years will further contribute to increase in peat fires and their negative aftermaths. Therefore, prevention of peat fires and recultivation of burned-out peatlands are extremely important nature-protective measures. The objectives of the article was evaluation of current condition of burned peatlands of Volyn Oblast, their territorial distribution, dynamics according to years, analysis of potential threats for ecological safety and development of recommendations for prevention of peat fires and overcoming the negative consequences. During the study we used: methods of collecting material, methods of statistical analysis of results, cartographic methods, methods of expert assessment. We determined that the problem of peat fires and burned peatlands is extremely relevant for Volyn Oblast, requiring development of a complex of measures to solve it. As of 2002, the area of burned peatlands in the Oblast accounted for 440 ha. For the period of 2002-14, a total of 803 ha of burned peatlands was recorded across Volyn Oblast. In 2015-19, their area increased by another 280 ha. The largest areas of burned peatlands were found in Kamin-Kashyrskyi (137.9 ha), Liubeshiv (26.72 ha), Manevychi (20.35 ha) districts. We determined the tendency towards increase in the number of fires and areas of burned peatlands starting from 2018. To prevent peat fires, two-sided (wetting and drying) regulation of water regime within reclamation systems, alkalinization of peat soils, increase in their fertility, sanding-up of dried peat soils are proposed. Also, important measures include monitoring of burned peatlands and prevention of wildfires. In order to further use, rehabilitate and recultivate burned peatlands, it is suggested to t inventorise burned peatlands, assess economic and ecological damages, develop a plan of further use of territories, determine priorities of development and propose corresponding economic and nature-protection measures.

Keywords: burned peatlands, peat fires, consequences of peat fires, dynamics of peat fires, measure to reduce negative effects of peat fires, recultivation of burned peatlands

Вигорілі торфовища в межах Волинської області: стан, динаміка, загрози, шляхи подальшого використання

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Анотація. Наслідками торфових пожеж є повна чи часткова втрата родючості значних площ земель, зниження біорізноманіття, знищення унікальних ландшафтів, погіршення умов життя та здоров'я населення, порушення циклу карбону, збільшення емісії парникових газів, посилення змін клімату тощо. Кліматичні тенденції останніх років сприятимуть і надалі збільшенню кількості торфових пожеж та їх негативних наслідків. Тому попередження торфових пожеж та зменшення їх негативних наслідків у майбутньому, а також подальше використання, відновлення та рекультивація вигорілих торфовищ є надзвичайно важливими природоохоронними заходами. Метою статті є оцінка сучасного стану вигорілих торфовищ Волинської області, їх територіального розподілу, динаміки за роками, аналіз потенційних загроз для екологічної безпеки та розробка рекомендацій для попередження виникнення торфових пожеж та подолання їх негативних наслідків. Під час дослідження застосовано: методи збору матеріалів, методи статистичної обробки результатів, картографічні методи, метод експертних оцінок. Встановлено, що проблема торфових пожеж та вигорілих торфовищ для Волинської області є дуже актуальною і вимагає розробки комплексу заходів для її вирішення. Станом на початок 2002 р. в області площа вигорілих торфовищ становила 440 га. За період 2002-14 р.р. у Волинській області зафіксовано 803 га вигорілих торфовищ. У 2015-19 р.р. їх площа збільшилась ще на 280 га. З'ясовано, що найбільші площі вигорілих торфовищ у Камінь-Каширському (137,9 га), Любешівському

(26,72 га), Маневицькому (20,35 га) районах. Виявлено тенденцію до збільшення кількості пожеж та площ вигорівших торфовищ починаючи з 2018 р. Для попередження торфових пожеж запропоновано здійснювати двостороннє регулювання водного режиму в межах меліоративних систем, залуження торфових ґрунтів, підвищення їх родючості, піскування осушених торфових ґрунтів. Також дуже важливими заходами є моніторинг вигорілих торфовищ та профілактика виникнення пожеж в природних системах. З метою подальшого використання, відновлення та рекультивації вигорілих торфовищ запропоновано своєчасно провести інвентаризацію вигорілих торфовищ, оцінити економічні та екологічні збитки, розробити план подальшого використання території, визначити пріоритети розвитку та запропонувати відповідні господарські та природоохоронні заходи.

Ключові слова: вигорілі торфовища, торфові пожежі, наслідки торфових пожеж, динаміка торфових пожеж, заходи зменшення негативних наслідків торфових пожеж, рекультивація вигорілих торфовищ

Introduction. Natural peat ecosystems are important components of the landscape of particular territories. They perform various ecological functions. For example, peatlands accumulate products of photosynthesis and the process of peat formation is going on continuously. Peat is a valuable raw material for many fields of the economy, and also local renewable energy. Also, bogs and peatlands play an important role in accumulation of compounds of atmospheric carbon (Diggelen, 2018). In natural conditions, bogs absorb more of it than they emit into the atmosphere. Peatlands are exceptionally important for the formation of the hydrological regime of territories and are a natural filter of water. Furthermore, deposits of peat are often located in lands covered with forests, are a part of the territories and objects of nature-reserve fund, wetlands of international significance, places which maintain biodiversity. Peatlands have also great botanical-geographical importance. Peat fires lead to burning-out of deep layer of peat, degradation of soils, razing of vegetation and organisms which inhabit the soil, sinking of the surface and change in relief, emission of large amounts of pollutants into the atmosphere, including greenhouse gases. From the perspective of ecology, burning of peatlands as a result of fires could be considered as a local ecological crisis.

Causes of peat fires are decrease in the levels of ground water in polder systems and separation of the capillary layer from peat deposits (Zajdelman, 2011). As a result of anthropogenic interference, peatlands, being especially valuable lands, have lost their natural resistance and became extremely vulnerable to natural and anthropogenic factors. Fires in soil massifs occur when groundwaters are located at the depth of 0.8-0.9 m and lower. Spread of fires is also driven by traditional annual burning of dry tree stands in pastures, stubble in tilled lands, domestic wastes in households of the local population. This degradational process continues to spread also due to inappropriate exploitation of the polder system and cessation of reconstruction of drying systems. The reasons for peat fires may also be tourists and local population due to carelessness in lighting fires. Recently, another factor which adds to the danger of fire danger has been actively increasing – climate change. Over the last several years (2015-19), many temperature records have been broken , there has been a decrease in the amount of precipitations, change in patterns of precipitations from steady downpour rainfall to heavy rains. This underlies the worsening of the territorial water balance, drying up of wells, etc. Decrease in the level of groundwater causes change in the base levels of erosion, significantly intensifying erosion of the lands (water and wind erosion). Lowland peatlands, due to decrease in moisture, generate large amounts of heat, causing ignition. Recently, problems of peat fires for some districts of Volyn Oblast have become catastrophic in extent.

At the same time, the Oblast has no effective regional program of measures against peat fires and overcoming their negative ecological consequences. No monitoring of the condition of burned peatlands is conducted. Obviously, the problem of peat fires and their ecological consequences should not be ignored. It is necessary to study the current condition of burned peatlands, analyze the dynamics of peat fires, their reasons and consequences, assess the threats to ecological safety of local communities, develop directions and measures for reducing negative effects of peat fires. This is what makes the article relevant.

Review of previous research. There are many scientific studies of peatland fires and burned peatlands. This problem is being actively described in the works of European scientists. The most thoroughly studied situation is the distribution and preservation of wetlands in Europe (Diggelen, 2018). Also, detailed studies were undertaken on peatland fires and their consequences in Ireland (Stracher et al., 2019), South-East Asia (Taylor, 2010), Africa (Barbosaetal., 1999), Central Kalimantan (Indonesia) (Hosciloet al., 2011), Klias Peninsula (Malaysia) (Phua et al., 2007).

Noteworthy are generalizing reviews of influence of fires on global ecosystemic patterns and processes, distribution and structure of vegetation, cycle of carbon and climate (Bowman et al., 2009). Scientists pay much attention to the peculiarities and patterns of carbon emission during peat and forest-fires. Among the researches in this direction, we should note the study on carbon emission as a result of fires in tropical and subtropical ecosystems (van der Werfet al., 2003), carbon balance in the North-American swamps (Bridgham et al., 2003), global assessments of pyrogenic emissions during various types of fires in natural ecosystems (Andreaeetal., 2001), assessments of impact of fires in forest and peat massifs on atmospheric pollution, condition of the environment and climate (Langmann etal., 2009). Interesting are also the researches where authors try to evaluate the potential vulnerability of peatlands to ignitions. Such studies were conducted for province of Alberta (Canada) and measured the differences in waterproof and hydrophysical capabilities of burned and unburned organic soils (Elmes et al., 2019). For Canada, an attempt was also made to quantitatively assess the changes in the main aspects of migration of nutrients in the system soil-plant-water during first years after fires (van Beest et al., 2019) and assess the sensitivity of peatlands to climate warming (Tarnocai, 2006). This researcher determined that around 60% of the total area of Canadian peatlands and 51% of mass of organic carbon in all Canadian peatlands, as expected, will be heavily or severely affected by climate change.

In Russia, scientists also pay great attention to the issues of pyrogenic degradation of peat soils and recultivation of burned peatlands (Zajdelman et al., 2002, 2006, 2011), and change in the chemical properties of dried peatlands under the influence of fire factor (Badmazhapova et al., 2014). Scientific researches in this field are being also conducted in Belarus (Tanovickaja et al., 2009).

In Ukraine, studies on the consequences of peat fires and pyrogenic peatlands are being conducted by scientists in the Institute for Soil Science and Agrochemistry Research named after O.N. Sokolovsky (Truskaveckij et al., 2010) within Polesia Minor – Ivan Franco National University of Lviv (Gaskevich et al., 2008). Among important results of the studies of burned peatlands, we should note also the assessment of dynamics of migrational capability of some heavy metals in soils of Kharkiv Region under the effect of the pyrogenic factor (Butsetal., 2019). This problem in Volyn Oblast was studied by specialists of Volyn Oblast State Projective-Technological Center of Protection of Fertility of Soils and Quality of Production (Zinchuk et al., 2007). Also, the Polesia Research Station of the Institute for Soil Science and Agrochemistry Research named after O.N. Sokolovsky developed recommendations for cultivation and agricultural use of peatlands damaged by fires (Shevchuk etal., 2006). A system of measures has been suggested for protection of peat soils against pyrogenic degradation (Polianskyi, 2006).

The purpose of the article. The objective of the article was assessing the current condition of burned peatlands of Volyn Oblast, their territorial division, dynamics according to years, analysis of potential threats to ecological safety and development of recommendations for prevention of ignition of peat fires and overcoming their negative effects.

Material and methods of research. For the article we used the materials of the Polesia Research Station of the Institute for Soil Science and Agrochemistry Research named after O.N. Sokolovsky, Volyn Oblast State Projective-Technological Center of Protection of Fertility of Soils and Quality of Production, Management of the State Emergency Service in Volyn Oblast, and also the materials of our own researches. During the studies we used a broad range of methods of scientific research: methods of colleting materials (work with fund materials, reconnaissance, expedition method), methods of statistical analyses of the results, cartographic methods (development of analytical maps, work with electronic cartographic services), method of expert assessments (to develop recommendations for prevention of peat fires).

Results and their analysis. According to the analysis of the extent of research made regarding pyrogenic degradation of landscapes in Volyn Oblast, 3 periods may be distinguished:

- until 2004. – soil surveys of the issue were undertaken, and a state program of monitoring of degraded (including pyrogenic) soils was made;
- 2005-2014 – absence of surveys, occasional scientific publications (Zinchuk et al., 2007);
- 2015-19 – absence of surveys, extents of pyrogenic degradation were assessed according to the materials of the Center of State Emergency Service in Volyn Oblast (statistics of recorded fires in peat massifs).

Over the period of 2002-14, in Volyn Oblast, over 803 ha of burned peatlands were recorded (Table 1, Fig. 1, 2). Until 2003, in the territory of the Oblast, there were already over 440 ha of such lands. The largest areas were in Kamin-Kashyrskyi district (200 ha), Kovelskyi (181 ha), Ratnivskyi (51.8 ha), Starovyzhivskyi (5 ha), Kivertsivskyi (3 ha). In 2003 the largest area of pyrogenic formations was observed in Ratnivskyi district (20 ha), and in 2004 – Shatskyi (102 ha), Liubeshivskyi (30.5 ha), Kamin-Kashyrskyi districts (12 ha).

In 2005-14 the area of pyrogenic formations continued to increase. According to expert assessments the increment accounted for 197 ha. Detailed

Table 1. The area of burned peatlands in the Volyn region in 2015-19.*

District /Years	2015		2016		2017		2018		2019 *		2015-19	
	Area, ha	Number of fires	Area, ha	Number of fires	Area, ha	Number of fires	Area, ha	Number of fires	Area, ha	Number of fires	Area, ha	Number of fires
Starovyzhivskyi	6.55	7	2.3	3	1	1	3.35	4	6.5	2	19.7	17
Manevytskyi	1.36	5	9.14	12			8.25	6	1.6	5	20.35	28
Kamin-Kashyrskyi	127.6	17	1.39	3	0.5	1	3.6	6	4.8	4	137.9	31
Liubeshivskyi	11.4	10	6.08	7			3.34	10	5.9	8	26.72	35
Liubomlskyi	3.88	6	0.61	3			1.7	3	0.55	3	6.74	15
Shatskyi	6.06	9	0.94	2			3.9	5	1	1	11.9	17
Ratnivskyi	1.64	7	0.5	1	0.4	2	1.22	5	6.95	3	10.71	18
Turiiskyi	1.1	4					1.25	3			2.35	7
Lokachynskyi	1	1	0.5	1			0.05	1			1.55	3
Horokhivskyi	0.06	1	0.5	1			0.35	1			0.91	3
Rozhyshchenskyi	5	2	9.5	4			1.72	4			16.22	10
Kivertsivskyi	0.5	1	1.4	3			1.3	3			3.2	7
Volodymyr-Volynskyi	2.6	4	1.62	4	2.5	2			2.95	4	9.67	14
Kovelskyi	5.5	2	4.55	6			2.5	2	0.92	2	12.47	12
Lutskyi	0.01	1									0.01	1
Ivanychivskyi			0.03	1							0.03	1
All over the Volyn region	174.3	77	39.06	51	4.4	6	32.53	53	31.17	32	280.4	219

* – *As of 1/12/19*

studies of pyrogenic soils at that time were not being conducted due to absence of financing. The greatest increment of the areas of burned peatlands occurred in Kamin-Kashyrskyi (110 ha), Ratnivskyi (25 ha), Starovyzhivskyi (17 ha), Shatskyi (16 га), Kovelskyi (12 ha), Liubeshivskyi (8 ha), Kivertsivskyi (5 ha), Liubomlskyi districts (4 ha). As for late 2014, the largest areas were characteristic (Fig. 1.) for Kamin-Kashyrskyi (322 ha), Kovelskyi (193 ha), Shatskyi (118 ha), Ratnivskyi (96.8 ha), Liubeshivskyi (38.5 ha) districts.

In 2015 (Fig. 3, 4), the largest areas of peat massifs affected by fires were recorded in Kamin-Kashyrskyi district (127.61 ha). Out of these areas, over 100 ha were burned out during one of the peat fires (19.08.2015) near villages Vyderta and Vorokomle. The second largest area of burned peatlands was in Liubeshivskyi district (11.4 ha), third and fourth – Starovyzhivskyi (6.55 ha) and Shatskyi (6.04 ha), fifth – Kovelskyi (5.5 ha). In other districts of the Oblast the areas accounted for less than 5 ha.

These numbers correlate with the quantity of fires recorded by the Center of State Emergency Service of Ukraine in Volyn Oblast, the correlation coefficient equaled 0.78. Therefore, in 2015, 17 fires were recorded in Kamin-Kashyrskyi district, 10 in Liubeshivskyi district, 9 in Shatskyi, and 7 in each Ratnivskyi and Starovyzhivskyi districts. In all other regions 1-5 fires were recorded. Only in Ivanychivskyi district were no fires recorded .

In 2016, largest areas of peat massifs affected by fire were recorded in Rozhyshchenskyi (9.5 ha) and Manevytskyi districts (9.14 ha), and also Liubeshivskyi districts (6.08 ha). In all other districts the areas of burned peatlands during the year increased less than by 5 ha. The highest number of fires was also recorded in Manevytskyi (12), Liubeshivskyi (7), Kovelskyi (6), Rozhyshchenskyi and Volodymyr-Volynskyi districts (4 in each). In other districts less than 3 fires occurred. In Lutskyi and Turiiskyi districts no fires were recorded. Correlation coefficient between the area of burned peatlands and the number of fires was 0.79.

Compared with the previous year the number of fires also decreased, equaling 51 compared with 77 and the area of burned peatlands was 39 ha compared with 174 ha (74 ha not taking into account the largest fire in the peat massif between villages Vyderta and Vorokomle of Kamin-Kashyrskyi district).

In 2017, the lowest number of fires for the recent years was recorded – only 6 and the area of burned peatlands was 4.4 ha. The main reasons are likely to be the climatic peculiarities of the year (regarding distribution of air temperature and amount of precipitations), but the issue requires further study. Two fires were recorded in Ratnivskyi (0.4 ha) and Volodymyr-Volynskyi (2.5 ha) districts, one in each

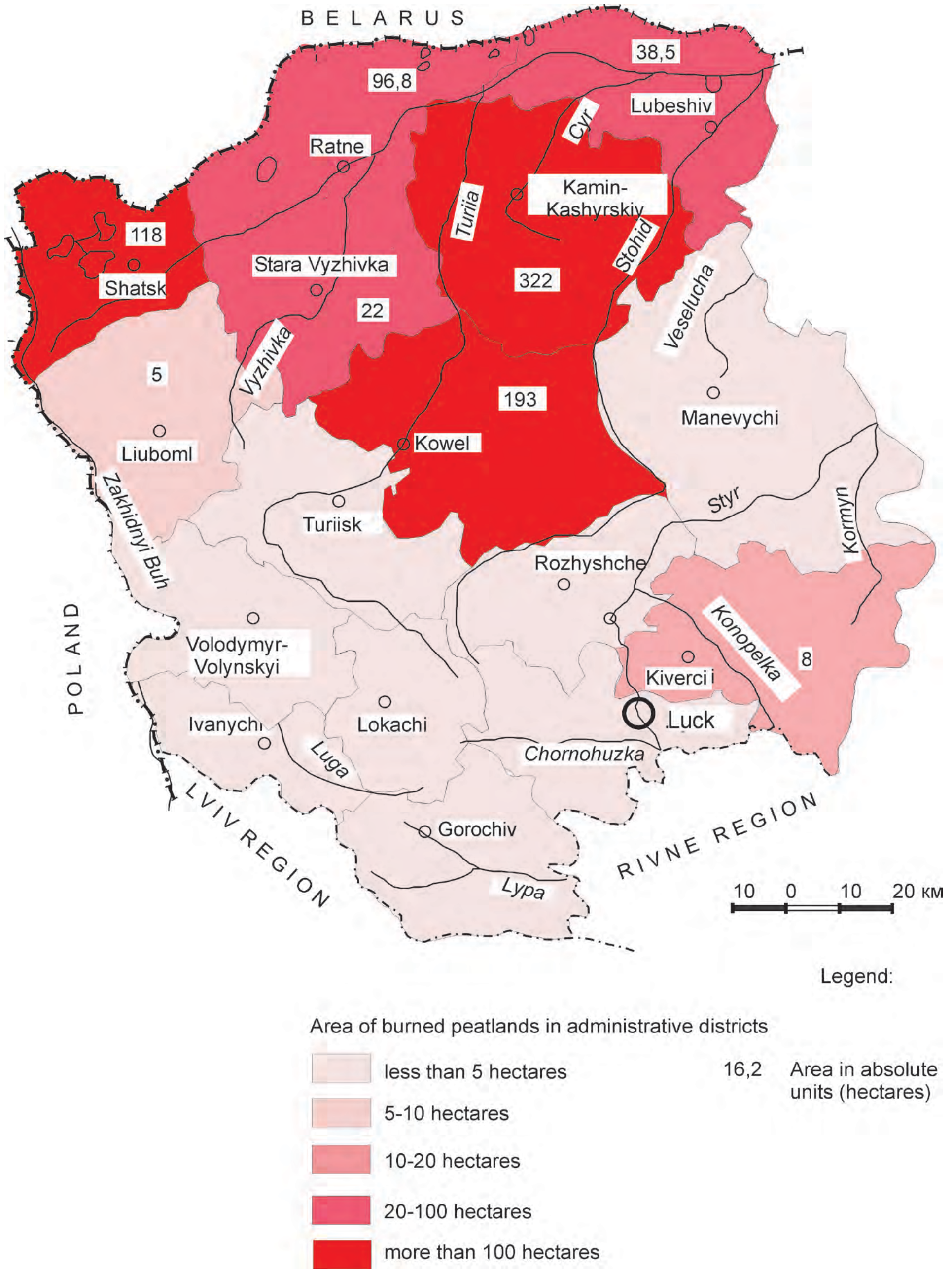

Fig. 1. Area of burned peatlands according to administrative districts of Volyn Oblast in 2002-14.

Starovyzhivskyi (1 ha) and Kamin-Kashyrskyi (0.5 ha). Correlation coefficient between the area of burned peatlands and the number of fires was also low – 0.42, which is atypical compared with other years.

In 2018 the situation with fires in peat massifs was exacerbated again compared with 2017, almost hitting the indicators of 2016. A total of 32.53 ha of peatlands burned out. Therefore, in particular, the largest areas of burned peatlands were in Manevytskyi (8.25 ha), Starovyzhivskyi (3.35 ha), Liubeshivskyi (3.34 ha), Kamin-Kashyrskyi (3.6 ha), Shatskyi (3.9 ha) districts. In other districts the parameter equaled less than 2 ha.

The total number of fires in peat massifs in 2018 in the territory of Volyn Oblast was 53 (almost the same as in 2016). Highest number of fires was recorded in Liubeshivskyi (10), Manevytskyi and Kamin-Kashyrskyi (6 in each), Shatskyi and Ratnivskyi districts (5 in each). In Lutskyi, Volodymyr-Volynskyi and Ivanychivskyi districts no fires were recorded. Correlation coefficient between the area of burned-out area of peatlands and amount of fires equaled 0.58.

In 2019, 32 fires were recorded, covering the area of 31.17 ha. In fact these indicators compared with 2016 and 2018 are much higher than in 2017. The most damaged were Liubeshivskyi (8 fires, 5.9 ha), Kamin-Kashyrskyi (4 fires, 4.8 ha), Starovyzhivskyi (2 fires, 6.5 ha), Ratnivskyi (3 fires, 6.95 ha), Volodymyr-Volynskyi (3 fires, 2.95 ha), Manevytskyi (5 fires, 1.6 ha) districts.

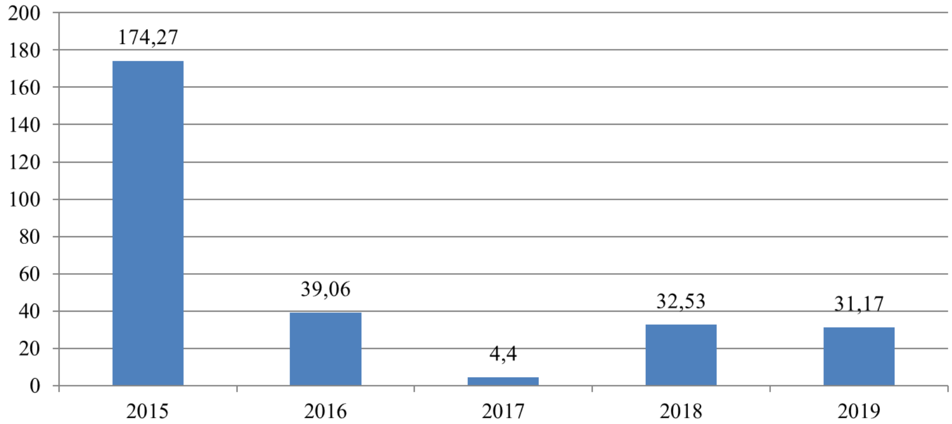

Fig. 2 Dynamics of area of burned peatlands in Volyn Oblast for 2015-19.

Summing up the consequences of fires in peat massifs, it should be noted that the processes of pyrogenesis cause destruction in the structure of soil column and properties in peat soils. Over 2015-19, the Center of State Emergency Service of Ukraine in Volyn Oblast recorded 219 cases of ignition in peat massifs. A total of 280.43 ha burned out. The largest areas of burned peatlands (Fig. 5) was seen in Kamin-Kashyrskyi, measuring 137.9 ha (49.17% of the indicator for the entire oblast), Liubeshivskyi – 26.72 ha (9.53%), Manevytskyi – 20.35 ha (7,26%), Rozhyshchenskyi – 16,22 ha (5.78%), Starovyzhivskyi – 19.7 ha (7%), Kovelskyi – 12.47 ha (4.45%), Shatskyi – 11.9 ha (4.24%), Volodymyr-Volynskyi – 9.67 ha (3.45%), Liubomlskyi – 6.74 ha (2.4%), Ratnivskyi districts – 10.71 ha (3.82%), in other districts – less than 1% (Fig. 5).

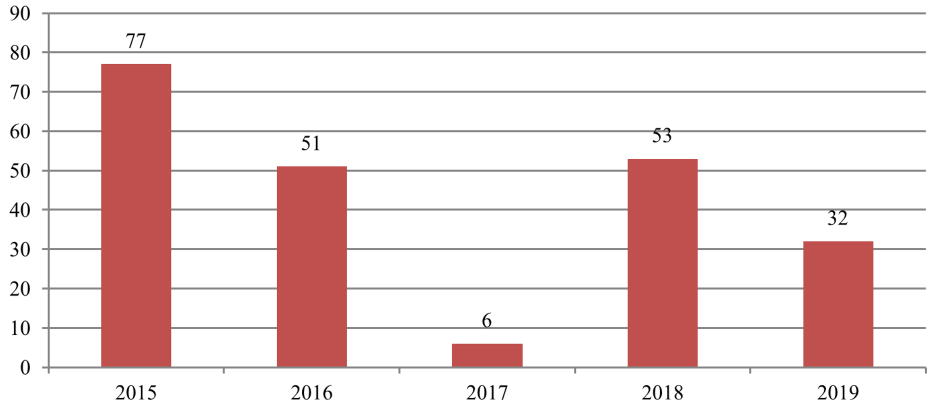

Fig. 3. Dynamics of number of peat fires recorded by the State Emergency Service in Volyn Oblast

A somewhat different statistical distribution of recorded fires for his period was found in the peatlands in Kamin-Kashyrskyi district, accounting for 16%, Liubeshivskyi – 14%, Manevytskyi – 13%, Starovyzhivskyi, Shatskyi, Ratnivskyi –8% for each, Liubomlskyi – 7%, Volodymyr-Volynskyi – 6%, Rozhyshchenskyi and Kovelskyi –5% for each. Three districts (Kamin-Kashyrskyi, Liubeshivskyi, Manevytskyi) comprise 43% of all the fires.

Interesting is the comparison of the situation with burned peatlands in 2014 and 2019 (Fig. 1, 4). The largest area of burned peatlands in 2019, similarly to 2014, was in Kamin-Kashyrskyi district. This was predicted. As of 2002, their area equaled 200 ha, increment for 2003-14 accounted for 122 ha, while for 2015-19 – 174.9 ha. The most problematic area is located between villages Vyderta and Vorokomle, where fires flare up regularly, and burned-out areas sometimes exceed 100 ha (Fig. 6). The category of districts with the largest areas of burned peats in 2014 also included Kovelskyi (193 ha) and Shatskyi (118 ha). As of 2019 the situation in these districts slightly improved. They were identified to the third group according to scales of pyrogenic degradation (within 10-20 ha). Therefore, during 2015-19, 12.47 ha of peat burned out in Kovelskyi district, and 11.9 in Shatskyi district.

The area of burned peatlands also decreased in that period in Ratnivskyi district (from 96.8 ha to 10.71 ha), Liubeshivskyi (38.5 ha to 26.72 ha), Starovyzhivskyi (22 ha to 19.7 ha), Kivertsivskyi (8 ha to 3.2 ha). Instead, the burned area increased in Liubomlskyi district (5 ha to 6.74 ha).

Moreover, in 2015-19, peatland fires were recorded in the districts where they had not occurred before, for example, in Manevytskyi district (20.35

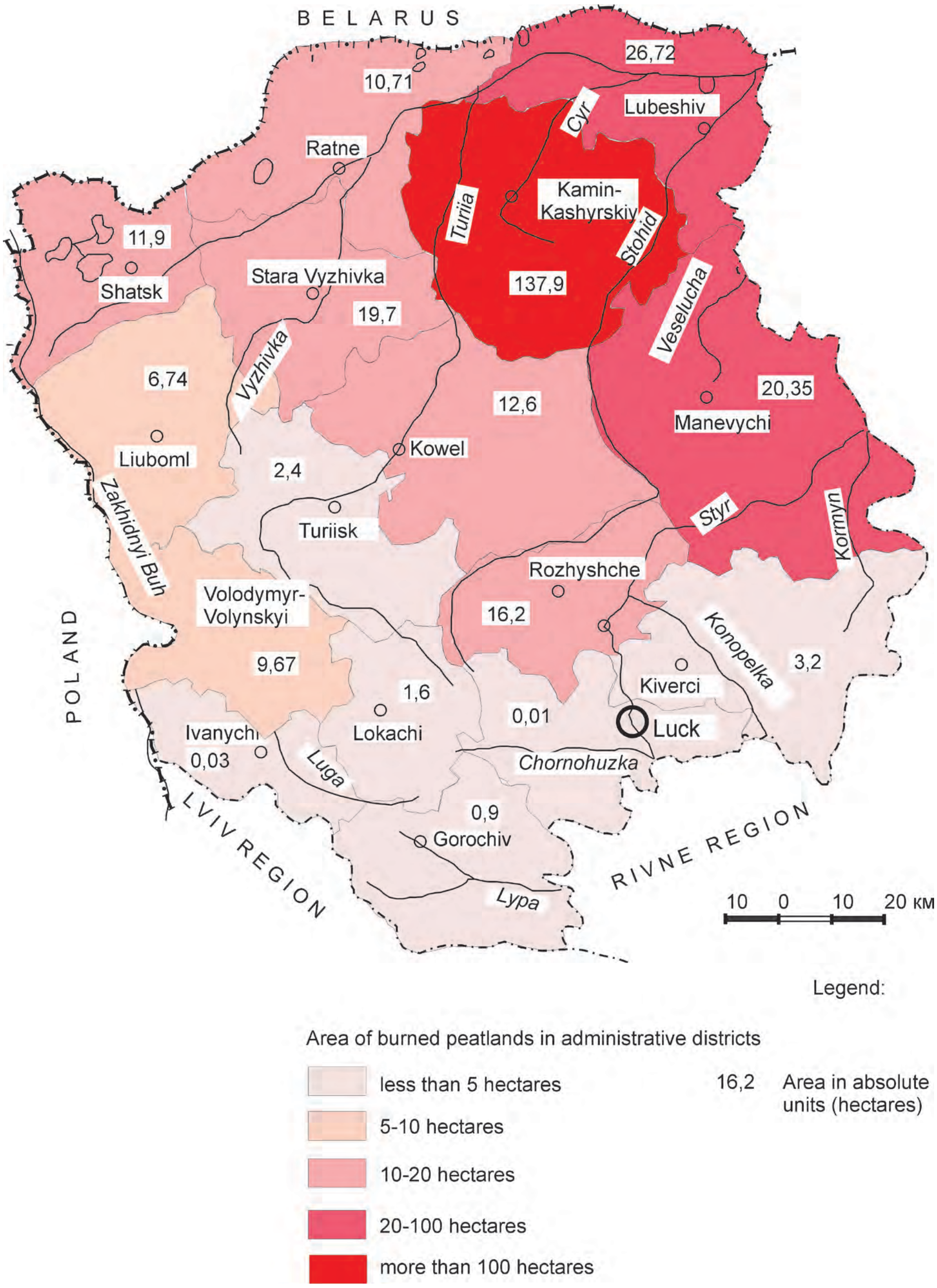

Fig. 4. Area of burned peatlands according to administrative districts of Volyn Oblast in 2015-19.

ha), Turiiskyi (2.35 ha), Lokachynskyi (1.55 ha), Rozhyshchenskyi (16.22 ha), Volodymyr-Volynskyi (9.67 ha). Therefore, currently, cases of burning-out of peatlands were recorded not only in the districts where they were usually recorded (so-called north-Polesia districts – Kamin-Kashyrskyi, Ratnivskyi, Liubeshivskyi, Shatskyi), but also increased in the so-called south-Poleisia districts (Turiiskyi, Lokachynskyi, Rozhyshchenskyi, Liubomlskyi, Volodymyr-Volynskyi, Manevytskyi, Kivertsivskyi) and were even recorded in administrative districts of the subzone of broad-leaved forests – Lutskyi (0.01 ha), Horokhivskyi (0.91 ha), Ivanychivskyi (0.03 ha).

Specialists of the Center of State Emergency Service of Ukraine and scientists assess the tendencies of the dynamics of peat fires pessimistically. The main reason of fires is burning of dry tree stands in pastures and of hayfields against the background of decrease in the level of groundwater and the dry climate of recent years. In mass media and social media, an active campaign for combating burning of dry grass and leaves has been started, but it has not proved sufficiently effective so far.

Therefore, we can ascertain the fact that burning peat massifs is becoming a significant ecological problem, jeopardizing not only the agroecological condition of soils, but also the safety of life of the

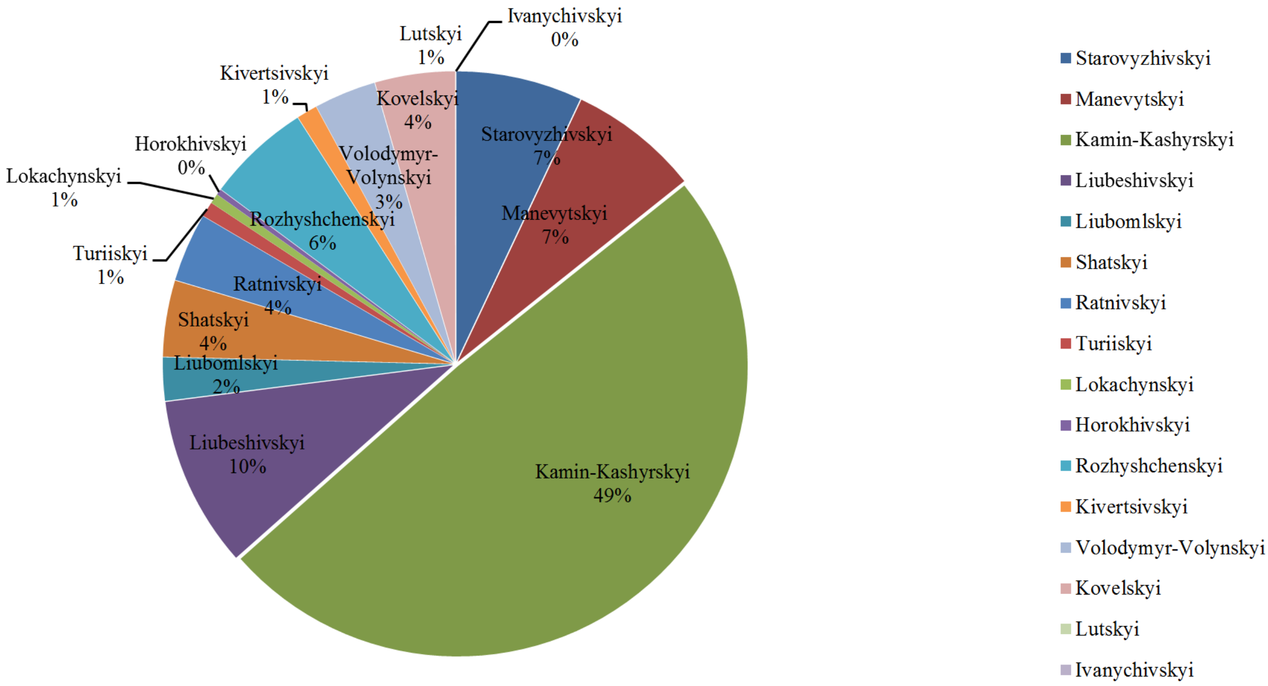

Fig. 5. Shares of the areas of burned peatlands according to administrative districts of Volyn Oblast (in %) for 2015-19.

population. Pyrogenic formations occupy large areas, adversely affect the conditions of agricultural activity, sometimes threatening the territories and objects of the nature reserve fund. The main threats posed by peat fires are:

- Decrease in fertility of soils and exclusion of land from agricultural use;
- Decrease in biodiversity and degradation of landscapes;
- Spread of soke over large territories, pollution of atmospheric air with poisonous substances

Decrease in the health of the population;

- Pollution of surface waters;
- Disturbance of the carbon cycle and increase in the emission of greenhouse gases.

Loss of soils as a result of peat fires in Volyn Oblast has already been evaluated above. It has to be noted that those soils are being destroyed which were used in agriculture. Soils are not only a necessary condition for agriculture for the local population, but a material resource of development and capabilities of local communities. This question becomes especially important due to decentralization.

The fall in biodiversity due to peat fires takes place specifically in these districts of Volyn Oblast which have highest nature reserve coefficients in the territories. Therefore, for example, Kamin-Kashyrskyi – 7%, Liubeshivskyi – 27.7%, Ratnivskyi – 7.9%, Shatskyi – 66.7%, Liubomlskyi – 4%, Manevytskyi – 6.4%, Starovyzhivskyi – 6%. Peat fires can spread also within the objects and territories of the nature-reserve fund. Moreover, the Polesia latitudinal ecological corridor of national importance with centers and nodes of an ecological network of international, national and regional importance is located in these territories. There are also wetlands of international significance from the list "Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat": Shatskyi Lakes, Floodplain of the Prypiat River, Floodplain of the River Stohid, Cheremsky Wetlands Complex in the territories of the Emerald Network, the number of which accounts for 13, most of them located in the northern Polesia districts of the Oblast.

We have not studied specifically the pollution of the atmospheric air with poisonous substances in the context of peatland fires. But as is known from the scientific publications (Gennadiev et al., 2013), during smoldering of peat in the conditions of insufficient oxygen, there accumulates benzo[a]pyrene – dangerous substance present in the associations of polycyclic aroma hydrocarbons, which has carcinogenic effect. According to the materials (Zajdelman, 2011), during the intense peat fires, in the central region of the Russian Federation in 2010, the mortality of the population increased by 1.5-2 times. That is, peat fires in the recent years have also become a significant factor of increase in ecological danger.

In the global balance of greenhouse gases, wetlands and peatlands are natural accumulators of carbon which reduce the content of carbon dioxide and emission of emission of greenhouse gases. In the swamped lands and peatlands dried for agricultural use or extraction of peat, the emission of greenhouse gases is much higher than in territories preserved in

Fig. 6. Burned peatland (Svydnyky village of Kovelskyi district) according to the materials (Zinchuk, 2019)

the natural condition or dried out and ferruginized (Crill et al., 2000). Thus, for example, wetlands and peatlands in natural condition absorb 856 kg/ha of CO_2 per year, dried out and salinised wetlands and peatlands – 515 kg/ha of CO_2 per year, and dried out wetlands and peatlands used in intense agricultural production by contrast produce 1,300-31,000 kg/ha of CO_2 per year. During the peat extraction, emission accounts for 10,600 kg/ha of CO_2 per year. Burned peatlands do not perform this important ecological function.

Therefore, the development of a complex of measures to prevent peat fires and overcoming their negative impacts is extremely important. These measures should ensure the execution of 2 important tasks:

- pevention of peat fires and reduction of negative effects in the future;
- further use, rehabilitation and recultivation of burned peatlands, re-naturalization of peatlands to natural wetland ecosystems.

Prevention of peat fires requires the following measures:

- two-sided (wetting and drying) regulation of water regime within reclamation systems;
- priority of using peatland soils for grasslands;
- increase in the fertility of dried-out soils by introduction of organic and mineral fertilizers, biopreparations;
- sanding-up of dried peat soils (Zajdelman, 2011);
- monitoring of burned peatlands;
- prevention of ignitions in natural ecosystems.

Two-sided (wetting and drying) regulation of water regime within reclamation systems not always is easily performed due to the fact that many of these systems were not projected for two-sided regulation. Some were developed considering only fall of excess of groundwaters. Currently, even systems of two-sided regulation are not always in good exploitation condition, therefore could not be effectively operated. Out of 346.7 thou ha of lands of reclamation fund of Volyn Oblast, the two-sided regulation of water regime is used only in 157.7 thou ha, while in 47.8 thou ha the polder systems are constructed. According to the data of inventory checking of reclamation systems of Volyn Oblast, there are 37 thou ha of lands in which the water regime is not regulated at all due to unsatisfactory technical condition of hydrotechnical constructions and pump stations (Lishchuk, 2014). Problem of regulation of water regime within separate non-working reclamation systems developed only considering that the one-sided water discharge could have been solved by waterlogging a part of the reclamation system which is not being used. This would allow increasing the level of groundwaters and biological productivity of phytocenoses, therefore reducing the level of danger of ignition.

The priority of using peat soils for grasslands is due to the fact that currently most of the dried peatlands are used in agriculture. They are intensively being exhausted, their surface is open to ignition and farming contributes to decomposition of organic mass of peat and emission of CO_2. Instead, using dried peatlands as grasslands and meadow-pasture lands, planting perennial plants on them would contribute to decrease in the tempi of decomposition of peat by 2-3 times, decrease in deflation, danger of ignition, and also would provide conditions necessary for the development of effective animal husbandry (Zajdelman, 2011).

Increase in fertility of dried soils by introduction of organic and mineral fertilizers, biopreparations, and in the acidic peat soils – also liming, would increase the resistance of soils to fires, contribute to structuring and reduce deflation.

Sanding-up of dried peat soils. Experience of developed European countries indicates that there the number of peat fires and their negative impacts on nature are much lower than in Ukraine. This is due to the high culture of farming, use of polder systems with two-sided regulation of water regime, restoration using perennial herbs, and also use of mixed, covering or mixed-layer-by-layer sanding-up. Such approach allows one to a great extent of completely exclude the possibility of surficial ignition of dried peatlands (Zajdelman, 2011).

Monitoring of burned peatlands and areas of high risk of possible peat fires is also an effective measure for prevention of peatland fires. As indicated by the analysis of materials of the State Emergency Service concerning the localization of peat fires during 2015-19, they are repeated practically every year in the same massifs. For example, within Vorokomliv and Vydert village councils, the largest peatland fire in Volyn Oblast occurred on 9.08.2015. Also ignitions of peat within or near this peatland were recorded on 25.03.2015, 10.05.2015, and 2.05.2019. Similar examples could be provided for other places of ignitions. Therefore, it is important to conduct inventory checking of burned peatlands, distinguish areas with high possibility of peatland fires and perform their constant agroecological and reclamation monitoring. Organizing of monitoring needs a developed and properly funded program of monitoring peatlands. Sources of financing should comprise regional and local funds of nature protection.

Prevention of fires includes constant informational work of subdepartments of the State Emergency Service with population, village councils and united territorial communities aimed at preventing ignitions in natural systems and following the rules of fire safety. Especially important is abandoning the practices of burning leaves in autumn and dry grass in meadows in spring. Also important is timely liquidation of non-sanctioned landfills, burning rubbish, which is often the cause of fires.

To perform the second important task – the following use, renewal and rehabilitation of already burned peatlands, realization of a complex of measures must be provided depending on the extent of pyrogenic degradation of peatlands and priority of the direction in the nature protection sphere. For example, most often two approaches are considered to solve this task (Zajdelman, 2011): extensive and intensive approaches. The first consists of use of the territories occupied by pyrogenic formations with close embedding of groundwaters for creating farms of breeding waterfowl, ponds for fishery, lands for recreational hunting or fishing, and also for plantations of energetic willows or other undemanding quickly growing energetic crops. The intensive approach is creating new mineral fertile soils in the places of pyrogenic formations. On pyrogenic formations, in the column of which the peat has completely burned out, deep recultivation should be performed. At the same time, recultivation of pyrogenic formations, formation of fertile horizons and return of such massifs into agrarian production is associated with such problems as absence of experience of such work; low fertility of formations; waterlogging of the territory (Shevchuk et al., 2005).

Choice of particular measures should include inventory checking of burned-out peatlands, assessment of economic and ecological damage, development of a plan of further use of the territories, determining priorities of development and measures for realization of determining priorities. Within Volyn Oblast, centers of burning out of peatland usually occupy not especially large areas (up to several ha). Therefore, fires were more or less quickly liquidated. Cases of complete burning out of peat down to parent rock are not frequent. It is expedient to exclude the burned-out peat lands from agricultural processing, separate areas allocated to the elements of the regional and local econetwork, buffer zone of nature-protected objects, perform restoration with grasses, water-supply development (if the condition of drying system allows it) Another effective way could be the use of pyrogenic formations for creating plantations for growing cranberries with prior artificial waterlogging of the territories, and also blueberries.

Conclusions. Therefore, problem of peat fires and burned out peatlands in Volyn Oblast is extremely relevant and requires a complex of measures to solve it. As of early 2002, the area of burned peatlands in the Oblast accounted for 440 ha. For the period of 2002-14, over 803 ha of burned peatlands were recorded across Volyn Oblast,. In 2015-19 their area increased by 280 ha more. The largest areas of burned peatlands were in Kamin-Kashyrskyi district – 137.9 ha, Liubeshivskyi – 26.72 ha, Manevytskyi – 20.35

ha, Rozhyshchenskyi – 16.22 ha, Starovyzhivskyi – 19.7 ha, Kovelskyi – 12.47 ha, Shatskyi – 11.9 ha, Ratnivskyi – 10.71 ha.

The climatic tendencies of the recent years indicate an increase in the number of peat fires and their negative effects, including: decrease in soil fertility, decrease in biodiversity, degradation of landscapes, deterioration of the health condition of the population, changes in the carbon cycle and increase in the emission of greenhouse gases. Therefore, it is necessary to prevent fires and decrease their negative consequences in the future, and also to ensure further use, restoration and recultivation of burned peatlands.

Prevention of peat fires requires a two-sided water regime within reclamation systems, restoration with grasses of peat soils, increasing their fertility, sanding-up of dried peat soils. Also, important measures include monitoring of burned peatlands and prevention of ignitions in natural systems.

To further use, restore and recultivate burned peatlands, it is important to perform in good time inventory checking of burned peatlands, assess economic and ecological damages, develop a plan of further use of the territory, determine priorities of development and propose corresponding economic and nature-protection measures.

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The relation of the northwestern shelf deep geological structure of the Black Sea with the phenomenon of gas seeps

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Abstract. Geophysical model inputs were the results of a survey on an anomalous magnetic field and a gravitational field of the Black Sea's north-western shelf. The geophysical profiles of the complex effective parameter (CEP) are calculated and graphed. Complex effective parameter characterizes the relationship between the effective densities and the magnetization by their spatial distribution. Effective parameters (magnetization, density, CEP) were calculated within the study area with their distribution on the optimum depth. The profiles are meridional and parallel to each other, direction of the profiles from south to north. The distance between the profiles is 50 kilometers. The generalized deep structure of the study area was elucidated using the graphed profiles. The distribution of CEP on vertical sections within the shelf zone of the western Black Sea basin emphasizes the position in the space of tectonic elements. That is gives an idea about the nature and structure of the region's lithosphere and their relationship with the spatial distribution of deposits and manifestations of hydrocarbons. Structural and geological interpretation of the CEP profile data was performed. According to the spatial consistency of the correlation by structures, the profiles are conditionally divided into two groups, the western and the eastern. Structural differences in profiles are explained by the presence of the Odesa-Sinop fault zone between the groups. According to the results of profiles interpretation and works of previous researchers, paleogeodynamic processes were established. That significantly complicated the geological structure of the Black Sea's north-western shelf. The interpretation of the CEP field distribution gives additional arguments in favour of the Earth crust evolution on the north-western shelf of the Black Sea in the conditions of a passive continental margin with short periods of reverse motions with obligatory subduction due to the activation of rifting, the nature of which is yet to be studied. According to the results of interpretation, the presence of the Earth's crust destruction zone was established. With the help of spatial analysis, the spatial regularities of the gas seeping manifestations with the zone of destruction of the Earth's crust of continental type and sites of rising of the mantle surface are established.

Keywords: gas seeping, geological structure, north-western shelf, Black Sea, depth structure, geophysical model

Зв'язок глибинної геологічної будови північно-західного шельфу Чорного моря з феноменом газових сипів

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Анотація. Вхідними даними геофізичного моделювання стали результати зйомки аномального магнітного поля та гравітаційного поля північно-західного шельфу Чорного моря. Побудовано геофізичні профілі КЕП – комплексного ефективного параметру, що характеризує взаємозв'язок ефективних густини і намагнічування за їх розподілом у просторі. Ефективні параметри (намагнічування, густина, КЕП) обчислювались у рамках території досліджень з розподілом на оптимальну глибину. Профілі є меридіональними, напрямок профілів з півдня на північ, та паралельними один одному. Відстань між профілями склала 50 кілометрів. За допомогою побудованих профілів з'ясовано узагальнену глибинну структурну будову району досліджень. Розподіл КЕП в вертикальних розрізах в межах шельфової зони західно-чорноморської западини підкреслює положення у просторі окремих тектонічних структур, дає уявлення про характер і будову літосфери регіону та їх взаємозв'язок з просторовим розподілом родовищ та проявів вуглеводнів. Проведено структурно-геологічну інтерпретацію даних профілів КЕП. За просторовою узгодженістю кореляції по структурам профілі умовно розділені на дві групи західну та східну. Структурні відмінності по профілям пояснюються наявністю між групами Одесько-Синопської розломної зони. За результатами інтерпретації профілів та роботами попередніх дослідників встановлено палеогеодинамічні процеси, що суттєво ускладнили структурно-геологічну будову Північно-західного шельфу Чорного моря. Інтерпретація розподілу полів КЕП дає додаткові аргументи на користь розвитку земної кори північно-західного шельфу Чорного моря в умовах пасивної континентальної окраїни з короткочасними періодами реверсних рухів з обов'язковою субдукцією завдяки активізації рифтогенезу, природу якого ще належить вивчати. За результатами інтерпретації встановлено наявність зони деструкції земної кори. За допомогою просторового аналізу встановлено просторові закономірності проявів глибинної дегазації із зоною деструкції кори континентального типу та ділянок підйому поверхні мантії.

Ключові слова: газові сипи, геологічна будова, північно-західний шельф, Чорне море, глибинна будова, геофізична модель

Introduction. The combination of properties of the Black Sea natural gas seepage phenomenon and its magnitude have aroused great interest among experts in Ukraine, Black Sea and Western European countries.Seep gases contain 80-99 percent of methane.The emissions of these gases can be very powerful; therefore, they can be considered as a hydrocarbon resource, for the production of which there is no need to drill wells.

Previous researchers have collected a large amount of information (Egorov, Artemov&Gulin, 2011; Shnyukov, Kobolev&Pasynkov, 2013), that allows gas emissions to be connected with the geological features of the Black Sea bottom and, as a consequence, connected with deep active faults, which gives grounds to link the nature of the origin of methane with deep faults, as with sources. This is also indicated by the restoration of reservoir pressure in already developed hydrocarbon deposits. Today there is no single viewpoint on this feature.Two hypotheses compete for explaining the methane origin in seeps: biological methane origin and the migratory methane origin.The magnitude of gas seeps and the lack of their confinement to the places of probable organic materials' accumulation cast doubt on the dominance of the methane genesis biological hypothesis. Analysis of the chemical and isotopic gas composition reinforces the notion that this methane gas is likely to have a predominantly deep origin.(Lukin, 2003)

Geological and geophysical studies of the Black Sea gas seeps' distribution zones, including the northwest shelf, are being carried out in Ukraine since the significance of such works is obvious.

Data and research methods.A long-term geophysical study of the geological structure for the territory of Ukraine and analysis of the data obtained in the course of the performed studies indicate its complex deep structure, which is reflected in geophysical fields.But numerous highly qualified researchers have studied the distribution of geological heterogeneities mainly on the research area (on the horizontal plane). Vertical geological heterogeneities were detected only by seismic and geoelectric studies. Such studies are performed on separate profiles, or in three-dimensional version on very local sites.Therefore, this study uses a different approach to the study of territory -a technique that was developed in 2001-2015 in the Department of Regional Geophysical Research of UkrSGRI. This technique is used to study the depth of the structure of a network of vertical sections along a regular network of profiles, as well as sections that are calculated along with regional seismic profiles and international arbitrary geo-traverse.The analysis covers not only sections of physical parameters by each of the geophysical methods but also their transformants.The most informative of them in the study of deep geological structure is CEP - a complex effective parameter.It characterizes the relationship between effective densities and the magnetization of their distribution in space.The distribution of CEP in vertical sections and horizontal sections characterizes the possible geological structure of the study area, that is, allows one to determine the probable geometrical parameters and positions in the space of individual structures and their relationship with adjacent structures both in the plane of the section or slice and at different hypsometric levels of the lithosphere.The initial data are anomalous magnetic and gravitational fields. The distribution of effective magnetization, density, and CEP are calculated with help the methods developed at KazVIRG (Koval, Priezzhev, 1983).

Effective parameters (magnetization, density, CEP) are calculated within the study area with distribution at optimum depth.The result of the calculations is cubes of parameter distribution, where each node of the cube in the coordinates X, Y, Z corresponds to a certain value of the parameter.The plane along an arbitrary direction, vertical horizontal or inclined, can cut each cube.Analysis of the CEP distribution on the horizontal plane of any depth of immersion, as well as the corresponding analysis of vertical sections, allows one to perform interpretation of the sections in conjunction with the data of other geophysical methods (for example: DSZ, MTZ) and geological data.The results of interpretation are the material that allows us to build a spatial (three-dimensional) geological-geophysical model of the study area (its first, initial version, which can be refined and adjusted in the future).

The authors calculated, constructed and analyzed vertical sections of a complex effective parameter of the meridional direction, the distance between which is 50 km (sec.625-650 Fig. 1, 2) and whose directions coincide with the grid of the Gauss-Kruger coordinate system-42 (6250000-6500000 respectively). The sections were analyzed by the researchers in conjunction with pre-built maps, which helped to fill the scheme of the deep geological structure for the region with some information.The profiles in blue (negative CEP value) correspond to the sub-oceanic lithosphere, red colour (positive CEP value) corresponds to the continental-type lithosphere, and the white line (zero CEP value) is the conditional boundary of earth crust types.

Key aspects of interpretation of CEP profiles. In connection with the discovery of hydrocarbon deposits, fixed displays numerous gas flares in the north - western shelf of the Black Sea, researchers have recently given increased attention to the study of the Earth's crust and upper mantle of this region

Within the framework of the scientific tasks, the researchers ofUkrSGRI constructed six meridional profiles of the complex effective parameter (CEP), calculated according to the gravitational and magnetic fields with the distance of 50 km between them and a step along the 5 km profiles (Figs. 1, 2). In the north, the profiles cover the southern part of the Ukrainian Shield, composed of Early Cambrian rocks, and continue through the Southern Ukrainian Monoclinic and ended in the northwestern shelf of the Black Sea within the economic zone of Ukraine.The western profile extends slightly to the east of the Danube Delta, the eastern one passes through the Tarkhankut Peninsula in the northwest of Crimea.

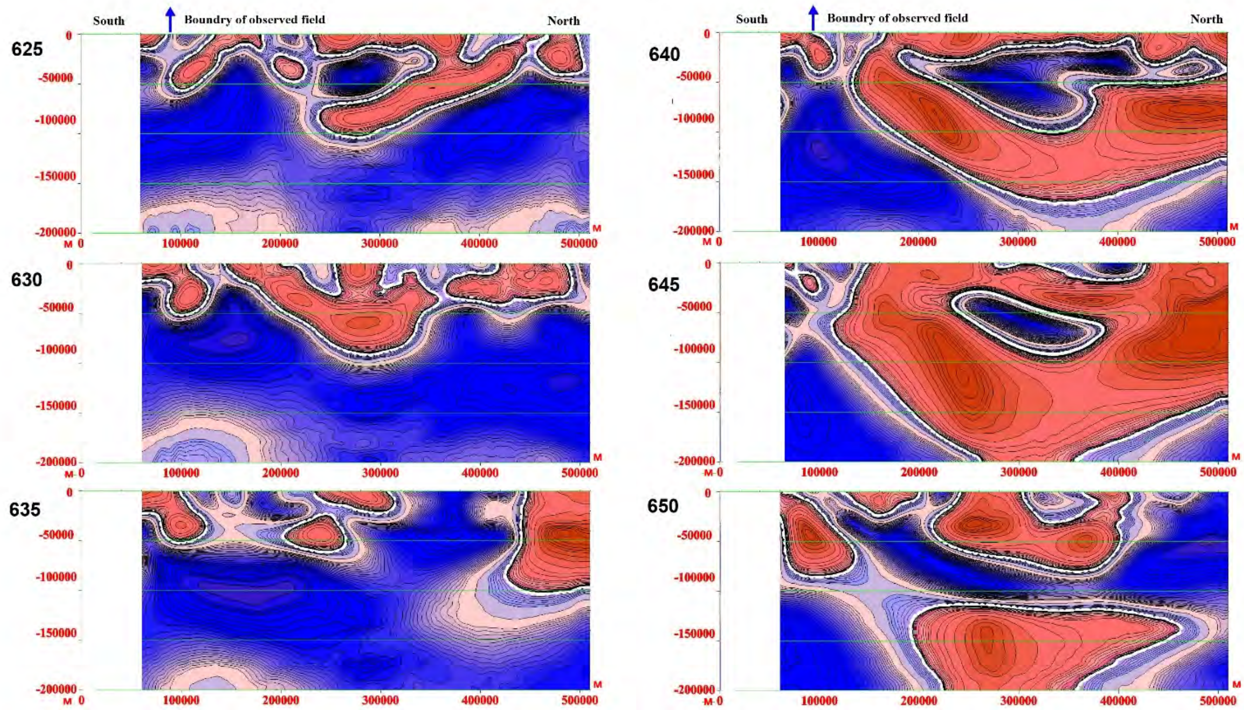
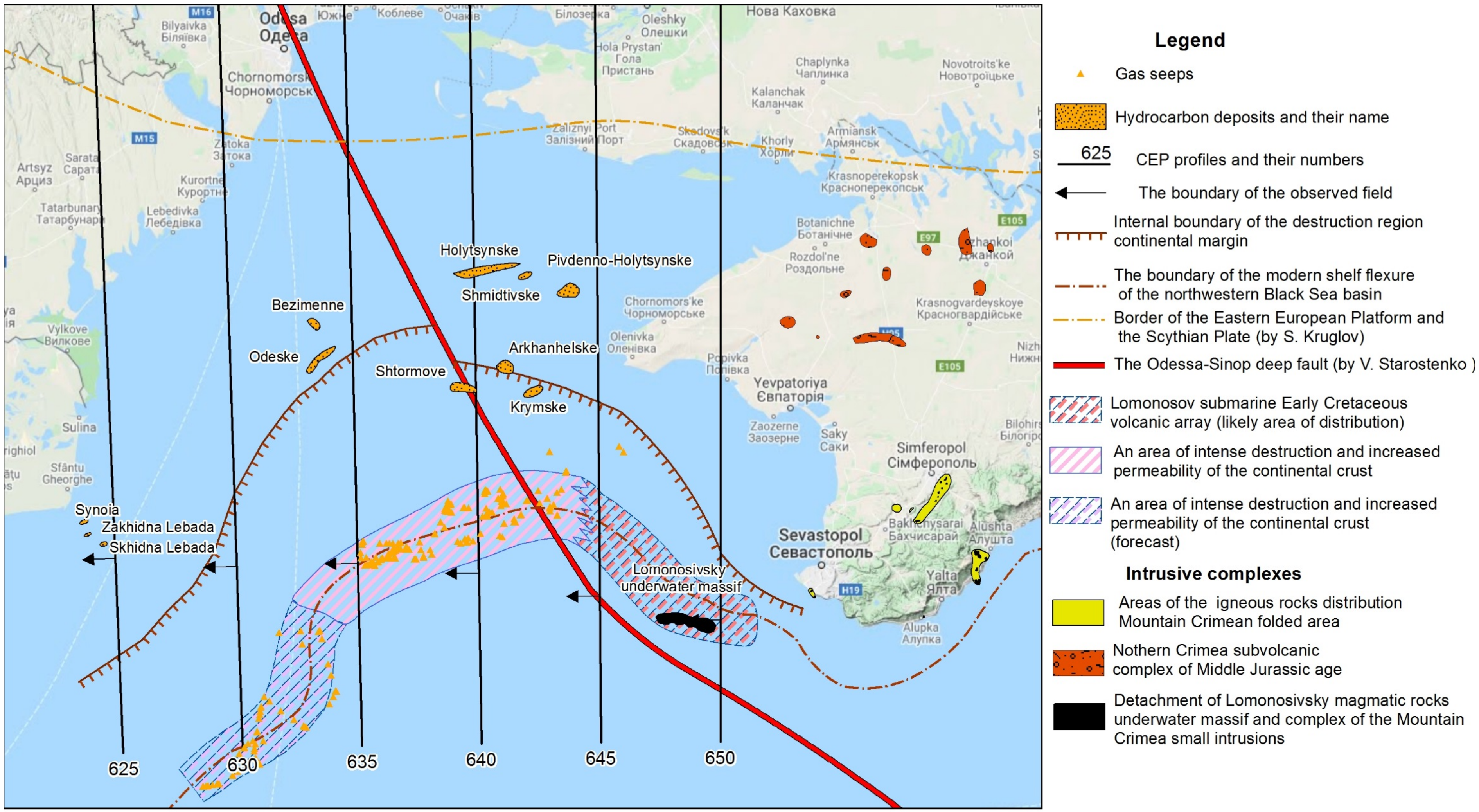


Fig. 1. The geophysical sections of the complex effective parameter (CEP) for the northwestern shelf of the Black Sea

The northern part of the territory through which the profiles pass is the ancient Eastern European Platform with the corresponding foundation.For the shelf zone of the northwestern depression of the Black Sea, according to the tectonic scheme of the deep structure(Gurskiy, Kruglov, 2007;Samsonov, Chumak, 2004), the foundation is the Epihercynian Scythian plate (SP) with the continental type of lithosphere. Late Paleozoic sediments with fragments of Baikalids were deformed in the Triassic, and since the Jurassic, the Scythian plate represented the area of sediment accumulation in the platform regime.There is some thought about the earlier age of the Scythian plate foundation, and it is regarded as an SEP marginal zone with an Early Cambrian foundation characterized by reduced continental crustal thickness.The dominant tectonic regime of the area in the Late Devonian-Late Jurassic was rifting, which was replaced by opposite movements, the main of which is the closure of the Taurian Basin of the Paleo- Tethys Ocean in the Late Triassic(Gintov, Egorova, Tsvetkova, Bugayenko, Murovskaya, 2014).

The Odessa-Sinop deep fault of the northwestern extension divides the Scythian plate in the study area into the western and eastern parts, which differ in the depth of the basement.To the west of the fault (sections 625-635), the pre-Jurassic formations are abandoned and even reach the bottom (Snake Island), while in the eastern part (ex. 640-650) the surface of the pre-Jurassic rocks is submerged.The analysis of CEP profiles confirms the fact that the eastern and western groups of profiles do not agree on each other at the level of the lithosphere.It is likely that the structure of the lithosphere on the study area may be affected



Scale 1: 3,000,000

Fig. 2. Map of the destruction zone distribution of the northwestern shelf continental margin

by the trans-regional tectonic seam of Kherson-Smolensk, which is displaced by the system of right-hand displacements of the Krasnoperekopskaya zone on the southern flank of the Eastern European platform.

The majority of researchers adhere to the point of view of the rifting nature of the Black Sea (Western and Eastern) depressions, which were formed as a result of the continental-type lithosphere expansion. However, for the present, scientists are discussing the causes of rifting. The most common idea is the rise of the mantle diapir (or plume) from the lower mantle proposed by Chekunov A.V. Due to the warming of the continental crust, reducing its viscosity, the formation of convective flows by mantle diapirs, the continental crust began to stretch and open with the formation of a rift, which enters magmatic rocks as mantle derivatives and a new type of oceanic crust was formed. Followers of the asenolithic (plume) concept of oceanic crust formation in the Western Black Sea depression (Kobolev, 2017) have proposed a three-vector form of rifting crustal elongation in the formation of a domed uplift over the mantle diapir. The rest of the geologists see the Black Sea as an arch-basin formed in the rear of the Pontic island arc as a result of rifting that began in the Cretaceous, and even in the Paleogene. Magmatic formations (Fig. 2) are an indicator of geodynamic conditions of the development on the studied territory. Shnyukova K.E. (Shnyukova, 2016) presents the results of petrographic, petrological, geochemical, mineralogical studies of the discovered magmatic rocks underwater exits, especially the Lomonosov submarine massif. Comparison of the above characteristics of the erupted rocks of the Lomonosov submarine massif with magmatic formations known in the Crimea, allowed the author to conclude about the different time of their rooting in different geodynamic conditions. The author argues that in the course of the geological evolution of the study area, several stages of subduction-related magmatism are distinguished, and are of repeated occurrence. The collected data indicates at least two stages of such magmatism: the end of the Middle Jurassic - early Cretaceous and late Cretaceous - Paleogene. Scientists who have studied this region share a common view that the modes of stretching of the crust changed over time in opposite movements, which was accompanied by tectonic dislocations of sedimentary rocks and processes of subduction.

The CEP sections ended in the continental slope within the economic zone of Ukraine and do not extend through the Black Sea depression. The absence of primary data on the gravitational and magnetic fields above the depression does not allow us to analyze the CEP field above the area, where, according to the assumptions of other researchers, the rifting zone is located. The subduction phenomenon that has occurred in the past indirectly indicates the nature of the CEP field in the eastern profiles, which, in our opinion, is related to the processes of continental crust destruction. In addition, the sections (sec. 640-650) exhibit an increased continental-type lithosphere with the keel-like shape, which is underlain by sub-oceanic crust .This phenomenon may be related to the continental-type cortical tightening due to the A-type paleo-subduction. It should be noted that in the CEP fields of the eastern group of profiles, an elongated negative anomaly is clearly distinguished among the positive field, which has a slight northward slope. This feature can be interpreted as a mega-outlier of the oceanic type crust, over which the gravitational anomaly of the Mountain Crimea and the continental slope adjacent to the west are fixed. The phenomenon of rooting of mantle melt in the weakened zones of the continental-type crust is the characteristic phenomenon during subduction processes. The presence of “mantle rejectors” may indicate paleo-subduction that occurred during the closure of the Tauride basin in the Jurassic under the conditions of an active continental margin (Gintov, Egorova, Tsvetkova, Bugayenko, Murovskaya, 2014; Gurskiy, Kruglov, 2007) with a simultaneous approaching of the Scythian plate sedimentary rock to the outskirts of Eastern European platform. At profile 650 above the projection of the «recluse», underwater deviations of intrusive rocks, which by petrological features are related to island-like, subduction-related complexes, have been detected (Shnyukova, 2016).According to drilling in the Karkinitsky deflection of lowland Crimea, “volcanic rocks (basaltic tuffs, breccia of lava, andesite-basalts, andesite, and their tuffs) and plutonic analogues of the South Crimean sub-volcanic complex of the Middle Jurassic were discovered above the “body of rocks of mantle origin” ,which by their petrological nature may be associated with the phenomenon of paleo-subduction. Also on the west-south-west shelf of the continued Karkinitsky trough and the northern slope of the Kalomitsky uplift gas-bearing structures in the Mesozoic-Cenozoic shelf deposits were discovered.

In the southern part of the 640-650 profiles, there is an area, which by the nature of the CEP field, is interpreted by authors, as a zone of the continental crust destruction, its extension, and reduction of thickness. The saturation with faults of the dropping type and increased permeability is characterized this geological situation. The zone of degassing of the lower mantle is probably associated with the same zone. On the sections 640-650 in the fields of the complex effective parameter is registered the rising of mantle matter to the depth near 18-20 km (sec. 640). The corresponding form of the CEP field negative anomaly has emphasized this conclusion. The magmatic solutions and deep fluids migrationchannel of is formedabove the apical part of the mantle vault. Numerous manifestations of gas seeps and igneous rocks of the Lomonosov massif (sec. 650) have spatially gravitated to the destruction zone (sec. 635, 640, 645).

For the marine part of the western profile group (625-635), a different character of the CEP field is observed, for which lateral positive and negative anomalies alternate. According to S.S. Krasovsky (Institute of Geophysics of NASU) for this segment of the crust is characterized by an increase in continental-type crust thickness with which the Khmelnytsky-Odessa orthocraton coincides, within which the formation of a granulite-basite layer of crust extends to the surface of the Precambrian section.In the area of the intersection with the sections of the Ukrainian shield crystalline basement rocks, granulite exiting the day surface in the Dniester-Buzshky mega-block correspond to the negative anomalies of the complex parameter (Kirilyuk, 2005).In the shelf zone, the positive and negative anomalies in the upper part of the sections are isometric and elongated, alternating on lateral. The structures (handfuls-grabens) of the underwater part of the Scythian Plate identified in this area according to geological and geophysical data are in good agreement with the anomalies of the CEC field. The uplifts and depressions of the Odesa Black Sea shelf conform to the boundaries of the Scythian plate, and their alternation is typical for shelf zones of the oceans. Numerous manifestations of gas fountains are confined to the outer boundary of the shelf zone, which is traced along the edge of the Northwestern Depression continental slope of the Black Sea. In the rear zone of the gas seeps distribution there are known hydrocarbon deposits (Fig. 2) and potentially promising local antiform formations. The absence of vultures in the eastern part of the Earth's crust destruction zone (sec. 650) near the Crimea is probably associated with volcanism over the subduction zone, which resulted in the formation of Lomonosov submarine massif igneous rocks (Fig. 2).According to the authors, such processes led to the "filling" of cracks in deep faults with igneous rocks and prevented the penetration of deep methane into the discharge zones.

Conclusions. The distribution of CEP in vertical sections within the shelf zone of the Western Black Sea depression emphasizes the spatial position of individual tectonic structures, gives an idea of the nature and structure of the lithosphere of the region and their relationship with the distribution of hydrocarbon manifestations. The interpretation of the CEP field distribution gives additional arguments for the option of the Black Sea northwestern shelf crust developing in the passive continental margin conditions with short periods of reverse motions with obligatory subduction due to activation of rifting genesis, the nature of which remains to be explored. The spatial relationship of deep degassing manifestations with the continental crust destruction zone and the mantle surface elevation areas is shown.

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Jewish cultural heritage of the Lviv Oblast as a tourism resource

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Abstract. The article describes the theoretical and methodical foundations of the study of the Jewish cultural heritage as a modern tourism resource. It turned out that in both foreign and domestic literature studies are not enough. The historical background of the formation of the cultural heritage of the Jewish ethnic group in the territory of the modern Lviv Oblast, which for many centuries has been the center of Jewish life, is considered. The dynamics of the ethnical composition of the population of the Lviv Oblast in 19312001 is studied and a significant reduction in the share of the Jewish community is found. The dynamics of the share of the Jewish population in urban settlements of the Lviv Oblast is studied, and it is found that it sharply decreased after the events of the World War II, primarily as a result of the Holocaust. A map of the share of the Jewish population in the urban settlements of the Oblast in 1939 is developed. The existing objects of Jewish cultural heritage (in particular, synagogues and cemeteries) in Lviv and other cities of the Lviv Oblast are characterized, and a map of these objects is developed. The main centers of Jewish cultural heritage of the Lviv Oblast are: Lviv, Brody, Busk, Zhovkva, Rava-Ruska, Uhniv, Velyki Mosty, Sokal, Belz, Stryi, Drohobych, Staryi Sambir, Turka. It found that the main problems of the Jewish cultural heritage of the Lviv Oblast are: neglected state of the objects, insufficient funding for the rehabilitation and restoration of these objects, the absence of tourist routes involving these objects, etc. The tourist route "By places of the Jewish sacred heritage of the Lviv Oblast" is developed and a map of this route is created. Measures for the restoration and popularization of Jewish cultural heritage of the Oblast are identified: allocation of budgetary funds, attraction of private investors, international organizations and Jewish communities; development of new tourist routes; determination of places by information stands; publication of information materials about objects; organization of international conferences, round tables, festivals; training of guides on the topic of Jewish cultural heritage, etc.

Key words: Jews, ethnos, cultural heritage, synagogue, tourism, Lviv Oblast

Єврейська культурна спадщина Львівської області як туристичний ресурс

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Анотація. У статті охарактеризовано теоретико-методичні основи дослідження об'єктів єврейської культурної спадщини як сучасного туристичного ресурсу. З'ясовано, що і в зарубіжній, і у вітчизняній літературі бракує таких досліджень. Розглянуто історичні передумови формування культурної спадщини єврейської етнічної групи на території сучасної Львівської області, яка впродовж багатьох століть була осередком єврейського життя. Вивчено динаміку етнічного складу населення Львівської області у 1931-2001 рр. і виявлено суттєве скорочення частки єврейської спільноти. Досліджено динаміку частки єврейської людності в міських поселеннях Львівської області та встановлено, що вона різко зменшилася після подій Другої світової війни, передусім, внаслідок Голокосту. Розроблено картосхему частки єврейської людності в міських поселеннях області за даними перепису населення 1939 р. Охарактеризовано існуючі об'єкти єврейської культурної спадщини (зокрема, синагоги і цвинтарі) у Львові та інших містах Львівської області, а також розроблено картосхему цих об'єктів. Головними центрами єврейської культурної спадщини Львівської області є: Львів, Броди, Буськ, Жовква, Рава-Руська, Угнів, Великі Мости, Сокаль, Белз, Стрий, Дрогобич, Старий Самбір, Турка. Вставлено, що основними проблемами єврейської культурної спадщини Львівщини є: занедбаний стан об'єктів, недостатність фінансування для відновлення та реставрації цих об'єктів, відсутність туристичних маршрутів із залученням цих об'єктів та ін. Розроблено туристичний маршрут «Місцями єврейської сакральної спадщини Львівщини» та створено картосхему цього маршруту. Визначено заходи відновлення і популяризації об'єктів єврейської культурної спадщини області: виділення бюджетних коштів, залучення приватних інвесторів, міжнародних організацій та єврейських спільнот; розроблення нових туристичних маршрутів; означення місць інформаційними стендами; видання інформаційних матеріалів про об'єкти; організація міжнародних конференцій, круглих столів, фестивалів; навчання екскурсоводів, гідів на тему єврейської культурної спадщини тощо.

Ключові слова: євреї, етнос, культурна спадщина, синагога, туризм, Львівська область

Introduction. Heritage can be considered as a modern use of the past according to the current cultural, social and economic realities (Ashworth, 2011), for social identity, legitimizing of political power or supporting tourism development. Heritage mainly seeks to exclude the past of minorities, preferring artifacts, places, and events of stronger groups, with a tendency to use it for power and cultural hegemony (Harvey, 2001). Promotion of heritage is, in essence, an act of power, reflects the vision of dominant groups that constantly decide what should be preserved, highlighted and brought to the future. Thus, the legacy is inevitably associated with the choice of which story should be discredited, which legacy should be forgotten (Corsale, Vuytsyk, 2015).

The most common reasons for visiting heritage objects are education and entertainment. However, it is worth adding another important reason, in particular, the desire of tourists to get acquainted with their own heritage (Poria, 2004). International tourists are often motivated by their desire to see and experience things that they don’t have in their familiar environment (Cohen, 2004). Thus, the cultural heritage is undoubtedly a significant tourism resource. A single tourism resource itself is a static category, and only if the resource is combined and organized with other necessary components, entrepreneurial initiative, human labor and investments involved, a static resource transforms into the dynamic category – tourism potential, the ability of a destination to form and implement tourism services, products that will be in demand and satisfy the needs of tourists and vacationers in certain volumes (Terebukh, 2016). The approach, based on broad participation in tourism development, a sense of community, a sense of responsibility and practical participation in tourism and inheritance management, has long been promoted by researchers and practitioners as a basis for tourism sustainability and is of a great importance of planners, managers and operators. The ultimate goal of participation in the development of cultural tourism is determined by expanding the capabilities of the destination community at four levels – economic, psychological, social and political – to achieve sustainable development (Corsale, Vuytsyk, 2015).

The purpose of this article is to analyze the features of the Jewish cultural heritage of the Lviv Oblast as a modern tourism resource. The tasks: 1) to characterize the theoretical and methodical foundations of the study of the Jewish cultural heritage objects as a tourism resource; 2) to describe the historical background of the formation of the cultural heritage of the Jewish ethnic group in the territory of the modern Lviv Oblast; 3) to analyze the dynamics of the ethnic composition of the population of the Lviv Oblast, the dynamics of the share of the Jewish population in urban settlements of the Oblast and to develop a map; 4) to characterize the existing objects of the Jewish cultural heritage (in particular, synagogues and cemeteries) in Lviv and other cities of the Lviv Oblast, as well as to develop a map; 5) to identify the problems of the Jewish cultural heritage of the Lviv Oblast and suggest the ways to solve them.

The article contributes to the discussion of heritage management and cultural tourism issues related to minorities, and gives an idea of the risk of cultural commodification, which may arise when the discourse is conducted by heritage selectors, appears in the former multiethnic context, thus leaving the heritage in mind as an ethnic group, has lost most of its influence, but still asks for participation and tries to have a voice in its management and development. The Holocaust of Jews and the mass executions of the Second World War in Kyiv Babyn Yar and throughout Ukraine claimed the lives of more than a half of Ukrainian Jewry. The full restoration of the community and the gradual restoration of synagogues, the number of which once were up to 800 in Ukraine, began already with the collapse of the Soviet Union (Ukrainer). The Lviv Oblast is not accidentally chosen as the object of study, because it is a historically multinational region, in which mainly Ukrainians, Poles and Jews lived. Despite the rather close communication of these ethnic groups in everyday life, the strategy of their social identification in one or another way is associated with the humiliation of other competitive communities in this territory, often resulting in increased interethnic tension, fencing one group from another, differentiation and polarization of society (Levyk, 2017). The cultural heritage of the Jews of the Lviv Oblast, in particular, Lviv, is the subject of research conducted by many scientists – historians, cultural scientists, ethnographers, religious scholars. The first scientific studies on the Jewish culture in Lviv took place in the second half of the XIX century. However, these works became systematic in the first third of the XX century. Mayer Balaban (Bałaban, 1906, 1909) was the leading researcher of the Jewish culture of Lviv, whose scientific heritage is an important source of modern scientific research. However, these studies are mainly devoted to only a certain narrow aspect of the formation and development of Jewish cultural heritage. Nevertheless, comprehensive studies of the Jewish cultural heritage objects of the Lviv Oblast as a modern tourism resource are almost not presented in modern domestic scientific literature.

Materials and methods of the study. The study is mainly based on a qualitative method and includes two main data sources: observation and analysis of secondary sources. The observations included visits to and descriptions of the main cultural monuments and areas related to the Jewish cultural heritage in the Lviv Oblast. Numerous works of domestic and foreign scholars on Jewish heritage, tourism, geography, management and marketing are analyzed. A number of secondary sources are also analyzed, in particular, statistics on the demographic situation in the Oblast (Main Department of Statistics in the Lviv Oblast, All-Ukrainian Population Censuses, Religious Information Service of Ukraine), materials directly or indirectly related to Jewish history and tourism (Center for Urban History of Central and Eastern Europe), brochures, maps and web-sites.

It is worth noting that the Jewish topic of tourism has taken a strong niche in the European tourism market. Numerous new guides, brochures, maps of Jewish heritage, posters and other materials were published, and new travel agencies specializing in Jewish tours were opened. In response to this growing interest, the old Jewish quarters are being developed as tourist destinations in Seville, Cordoba, Venice, Budapest, Prague, Krakiv, Lublin, Vilnius, and elsewhere. Jewish museums were opened in Berlin, Frankfurt, Warsaw, Moscow, Vienna, Paris, Munich, Copenhagen, Thessaloniki, Budapest, etc. (Gruber, 2007).

The following methods are used during the processing of the collected data, as well as to illustrate the results of the study: historical (to describe the historical preconditions for the formation of the cultural heritage of the Jewish ethnic group in the modern Lviv Oblast); graphic and cartographic (for the analysis of the dynamics of the share of the Jewish population in the urban settlements of the Oblast); analysis (to identify problems of the Jewish cultural heritage of the Lviv Oblast); "brainstorming" (during the development of a tourist route by sacred objects of the Jewish heritage of the Lviv Oblast).

Results of the study. *Historical preconditions for the formation of the cultural heritage of the Jewish ethnic group in the Lviv Oblast*

The study of the Jewish cultural heritage, as well as the cultural heritage of any other ethnic community is not possible without understanding the historical background of its formation and development.

The history of Galician Jews can be divided into historical periods: princely age (12401387); polish period (13871772); Austro-Hungarian period (17721918); interwar or second Polish period (19181939); pre-war period (19391941); Holocaust (19411944); soviet period (19441991); period of independent Ukraine (from 1991 to the present day) (Levyk, 2017).

The presence of the Jewish ethnic group in the territory of the modern Lviv Oblast is historically long, and its beginnings date back to the princely period of Ukrainian history. At that time, small Jewish communities could exist only in the largest centers of the Galicia-Volyn state, in particular, Zvenyhorod, and later in Lviv. Obviously, that after the capture of Kyiv by the Mongol-Tatars, a certain part of the Jewish community moved from the eastern cities of Rus to Lviv and other urban centers of Galicia.

From the XIV century a new period in the history of Jews begins in the modern Lviv Oblast, associated with the colonization of Galicia by Jews from Western Europe. The largest number of Jewish ethnic groups emigrated to Ukrainian lands in the XV century mainly from Germany, when King Maximilian I, for various economic and political reasons, deported Jews from this country.

Another wave of mass colonization of Ukraine by Jews began after the adoption of the Lublin Union in 1569. Then they were given many rights, in particular, in the field of trade, financial transactions, the possibility of renting magnate estates and crafts. Given this, during the XVII and XVIII centuries the Jewish ethnic group already belonged mainly to the ruling class.

Jewish colonization of Galicia played an important role in the processes of urbanization in the Lviv Oblast. That is, the processes of Jewish resettlement and the formation of cities and towns in the Lviv Oblast were closely linked, as the granting of Magdeburg right to settlements was accompanied by their settlement by Jewish groups, which gradually occupied a significant share in these settlements. In the same way, the centers of Jewish settlement were those cities that existed in the period of Kyiv Rus and the Galicia-Volyn state. (Dnistrianska, 2013).

The social and economic positions of the Jewish population in Galicia did not deteriorate after the entry of this Oblast in the late XVIII century to the Austrian Empire, and higher rates of natural increase compared to other ethnic groups even provided Jews with some increase in demographic weight. As a result, in the second half of the XIX century – at the beginning of the XX century in some cities and towns, Jews even constituted an absolute or relative majority. This applies, in particular, to such urban settlements as Belz, Boryslav, Brody, Drohobych, Dobromyl, Zhuravno, Peremyshliany, Rava-Ruska, Skole, Shchyrets. Jews had their own public self-government in most of the urban settlements in the Lviv Oblast, and an integral religious and cultural infrastructure was created, which provided all aspects of vital activity to of the Jewish community.

Between the First and the Second World Wars, when Galicia became the part of Poland, the share of Jews in some cities and towns in Galicia decreased (Fig. 1), but the bases of the vital activity of the Jewish population have not changed significantly. In general, the share of the Jewish population in the territory of the Lviv Oblast in terms of the counties of interwar Poland was significant (Fig. 2).

And only as a result of the Second World War, primarily due to the Holocaust, the demographic and social presence of Jews in urban settlements in the Lviv Oblast decreased significantly. At the beginning of the German occupation in July 1941, there were 870 000 Jews in Western Ukraine (in Eastern Galicia and Volyn). After the departure of Germany in 1944, only about 17 000 Jews survived, or 2% of the total prewar Jewish population. These figures speak for themselves and point to the tragic fate of the Jewish people in the region (Aster, 1990).

Regarding the current state of the population of the Lviv Oblast, it should be noted that the population is constantly decreasing. Thus, in 2000 it amounted to 2676.9 thousand people, in 2010 – 2549.6 thousands people, and in 2019 – 2522 thousand people (Sait Holovnoho upravlinnia statystyky u Lvivskii oblasti). The national composition of the population of the Lviv Oblast according to the results of all-Ukrainian censuses is presented in the Table 1.

In 1931 the share of Jews in the structure of the population living in the modern Lviv Oblast was quite high and amounted to 12%. It dropped to 1.4% in 1959 and to 0.1% in 2001 due to the extermination of Jews during World War II and migration during Ukraine's independence. In 2001 most Jews lived in Lviv (0.3% of the total population), as well as in the cities of Drohobych (0.1%), Stryi (0.1%), Truskavets (0.1%), and Mykolayiv (0.1%).

Regarding religious communities in the Lviv Oblast, the share of Jews is 0.3% (10 communities) (Sait Relihiino-informatsiinoi sluzhby Ukrainy).

Characteristics of the Jewish cultural heritage objects in the Lviv Oblast

The largest number of the Jewish cultural heritage objects is located in Lviv. The city was an important center of Jewish cultural, religious and political life until 1940. Jews made an important contribution to the development of education, culture, art, science, medicine, architecture of the pre-war Lviv Oblast.

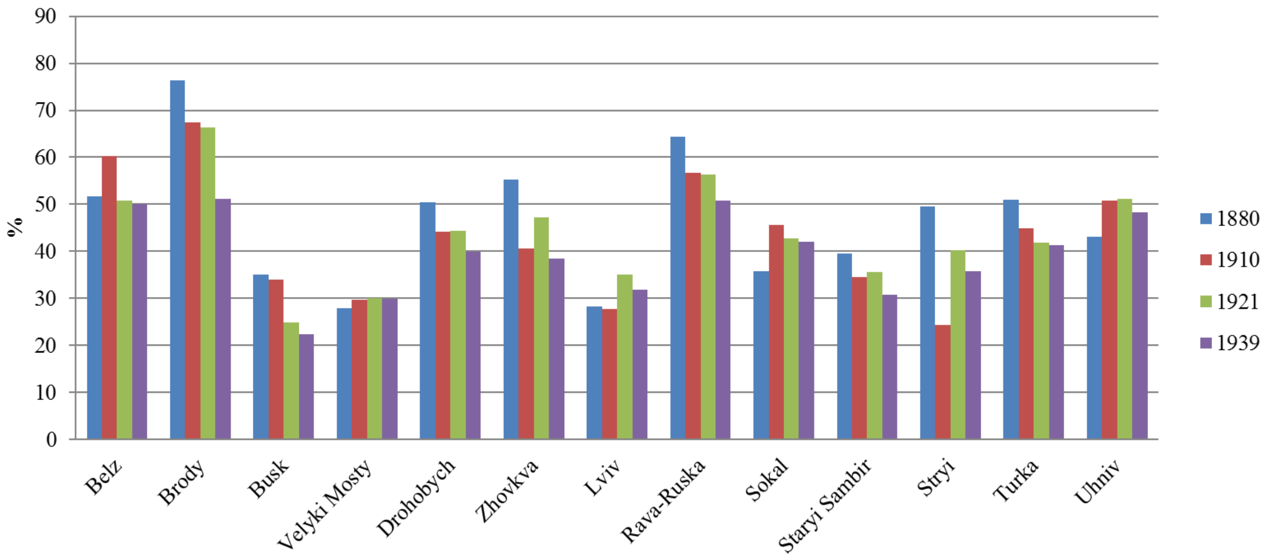

Fig. 1. The dynamics of the share of the Jewish population in some urban settlements in the territory of the modern Lviv Oblast in 1880, 1910, 1921, 1939 *(created on the basis of data Lozynskyi, 2005)*

Since the Jewish community in Lviv was large, there were many synagogues. There were more than 200 of them in Lviv before 1940 (40 large and 160 small) (Boiko, 2008). The total number of synagogues was about 350. It should be noted that synagogues in the Jewish community were divided into Hasidic (Cloise), large (Shul – in Yiddish or Hebrew – Beit Ha-Knesset ha-Gadol), small (Shilehl), and houses for science (beit midrash). Each synagogue had two names: one was common, the other in Hebrew and taken from the Scriptures (Sait yevreiskoi relihiinoi hromady "Turei Zahav di Hildene Roize").

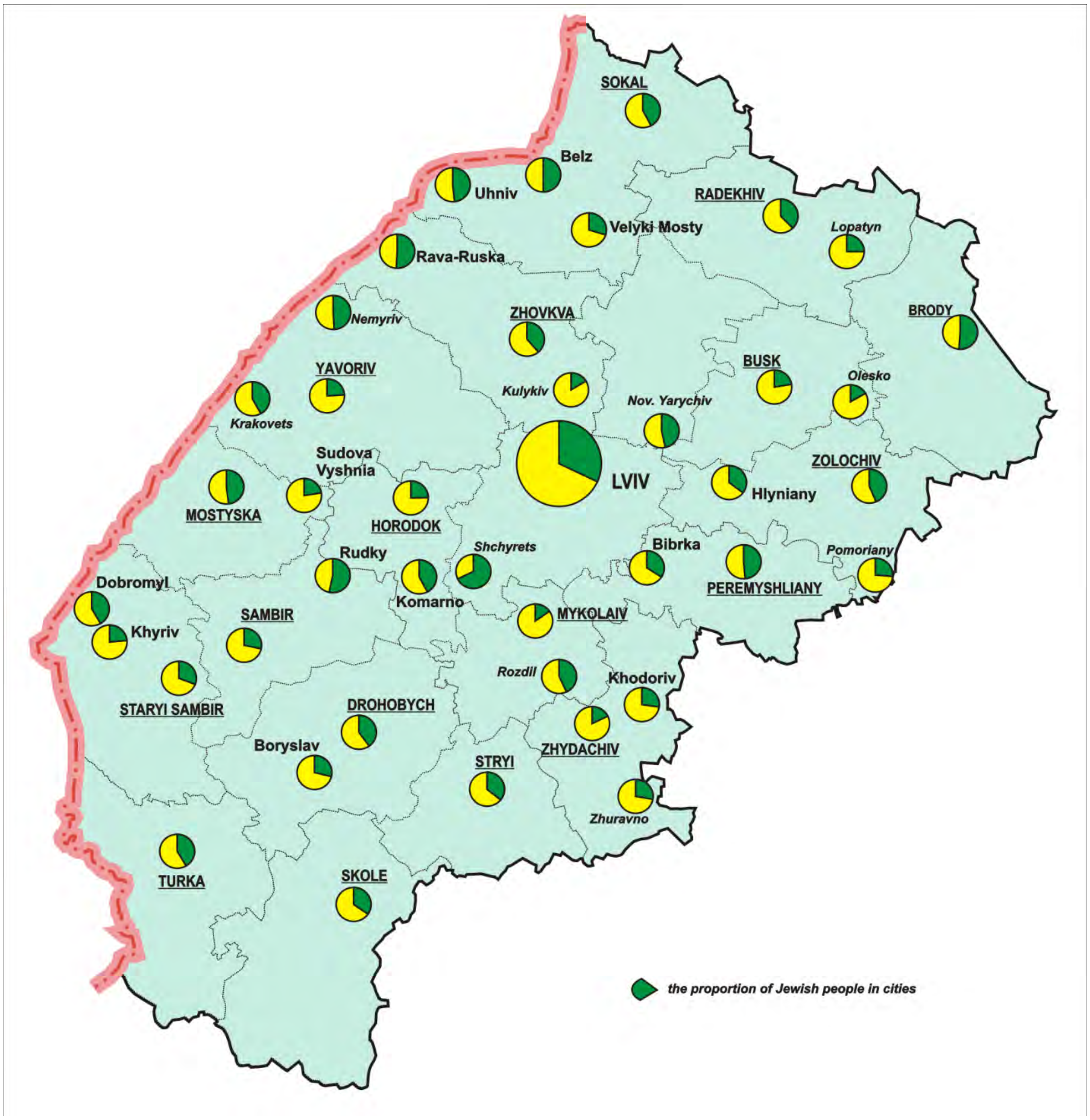

Fig.2. The share of the Jewish population in urban settlements in the Lviv Oblast (created on the basis of data Kubiiovych, 1983)

Currently, there is only one active synagogue in Lviv – Tsori Gilod, which is located on the Brativ Mikhnovskykh Street (Sait Tsentru miskoi istorii Tsentralno – Skhidnoi Yevropy). The building was constructed in 1897. It has a rich architecture, decorated with chandeliers, stained glass windows of the David's Star, polychrome paintings. The synagogue is quite large and can accommodate 384 men, there are galleries for women. It should be noted that the shrine was recently restored. It is also possible to see the ruins of the synagogue "Golden Rose" (another name – "Turei Zahav") in Lviv, which was built by a wealthy merchant Isaac Nakhmanovich in 1582 (Sait yevreiskoi relihiinoi hromady "Turei Zahav di Hildene Roize"). It belongs to one of the oldest Jewish shrines in Ukraine. The building is an architectural monument made in the Renaissance style. As it is known, from the XVI century to the 1801 the Golden Rose was the main religious place in the Jewish community, as well as the cultural and spiritual center of the townspeople. This synagogue is a UNESCO World Heritage Object and is an architectural monument of local significance. The building is a part of a program to revive historical and cultural objects around the world.

Well-known monuments of Jewish cultural heritage in Lviv should also include: 1. The Monument to prisoners of the Yaniv concentration camp. This is a memorial stone, which is located on the place of the Yaniv concentration camp, and reminds of the tragic events that took place with the Jewish and civilian population of the Lviv Oblast. The pedestal was erected on the initiative of prisoners and the Jewish community of Lviv. More than 150 000 Jews and civilians were tortured in the Yaniv concentration camp during the World War II. According to archival data, 6 000 people were murdered in May 1943 alone.

Table 1. Distribution of the population of the Lviv Oblast by nationality (Pro kilkist ta sklad naselennia Lvivskoi oblasti)

Nationality	1959		1970		1989		2001	
	Thousand people	%	Thousand people	%	Thousand people	%	Thousand people	%
Ukrainians	1818.3	86.3	2134.4	87.9	2464.7	90.4	2471.0	94.8
Russians	181.1	8.6	199.8	8.2	195.1	7.2	92.6	3.6
Poles	59.1	2.8	41.5	1.7	26.9	1.0	18.9	0.7
Jews	30.0	1.4	27.7	1.1	14.2	0.5	2.2	0.1
Belarusians	9.0	0.4	11.5	0.5	10.8	0.4	5.4	0.2

2. The Monument to the victims of the Lviv ghetto. This area is known as the "gate of death", was located in the heart of the Nazi ghetto and became one of the symbols of the Holocaust. 3. "Space of Synagogues" – located on the place of the Jewish synagogue and school destroyed during the war. It includes the remains of the Golden Rose Synagogue, the Beit Hamidrash Jewish School, and the Perpetuation Memorial (Sait Tsentru miskoi istorii Tsentralno-Skhidnoi Yevropy). Public discussions can be held in this area. "Space of Synagogues" also includes 39 steles, which contain expressions from memoirs, writers, residents of the city, books of rabbis. The purpose of this project is to honor the Jewish history in Lviv, a better understanding of the common history and heritage of Lviv residents and tourists. This project was implemented by the joint efforts of scientists, the Jewish community of Lviv, local authorities, international organizations, as well as received financial support from foreign sponsors, including Israel, Germany, the United States, and the United Kingdom.

There are a significant number of synagogues in the cities of the Lviv Oblast, because, as already mentioned, in the period before the Second World War, the share of the Jewish community was quite significant in this territory. However, almost all objects are in a blasted state now and need restoration. Only the Choral Synagogue in Drohobych was restored in 2018 and received a visualization that allows a virtual tour over it.

The main synagogues of the Lviv Oblast are presented in the Fig. 3:

Zhovkva Synagogue is a monument of history, architecture and culture, one of the largest in Europe. It is a defensive structure made in the Renaissance and Baroque style, was built in 1700. During this period and before the First World War, the number of the Jewish community of Zhovkva was more than 50%.

Choral Synagogue in Drohobych was built from 1842 to 1865. This was a period of the spread of the Jewish community in the city, when their share was 50% of the population.

Brody Synagogue is a stone building constructed in the XVIII century. It has the status of an architectural monument of national importance.

Synagogue in the city of Turka. It was a Jewish temple destroyed by the Soviet government, the first mention of which is dated to the XIX century.

Staryi Sambir Synagogue was built in the late XIX century.

Stryi Synagogue was built at the beginning of the XIX century.

Synagogue in Busk was built in 1842–1843 in the Baroque style. A part of the building is used as a residential building, and another part is restored.

Velyka Synagogue in the city of Velyki Mosty of Sokal Raion was built in the XX century.

Synagogue in Sokal was built in the XVII century.

Uhniv Synagogue was built in the style of historical Art Nouveau in the early XX century located in the town of Uhniv, Sokal Raion.

In addition to these synagogues, which have architectural expressiveness, grandeur, there are a number of smaller synagogues that are currently used for residential and household purposes. These is the Hasidic Synagogue in the city of Zhovkva (XVIII century), Velyka Synagogue (the town of Kulykiv in the Zhovkva Raion, XVII century), the Synagogue in the village of Pidkamin of Brody Raion (XX century).

In addition to synagogues, an important object of Jewish cultural heritage is a cemetery. The medieval Jewish cemetery is called a kirkut. The creation of a cemetery is important for the Jewish community. The largest Jewish cemeteries in the Western region of Ukraine are located in the cities: Belz, Kamianka-Buzka, Sambir, Brody, Zhovkva, Drohobych, Stryi, Zhydachiv, Boryslav, Velyki Mosty, Rava-Ruska, Turka, Staryi Sambir, Lviv (Fig. 3). There were two cemeteries in most cities in the region. The oldest tombstone of the Jewish Matzevah dates back to 1676.

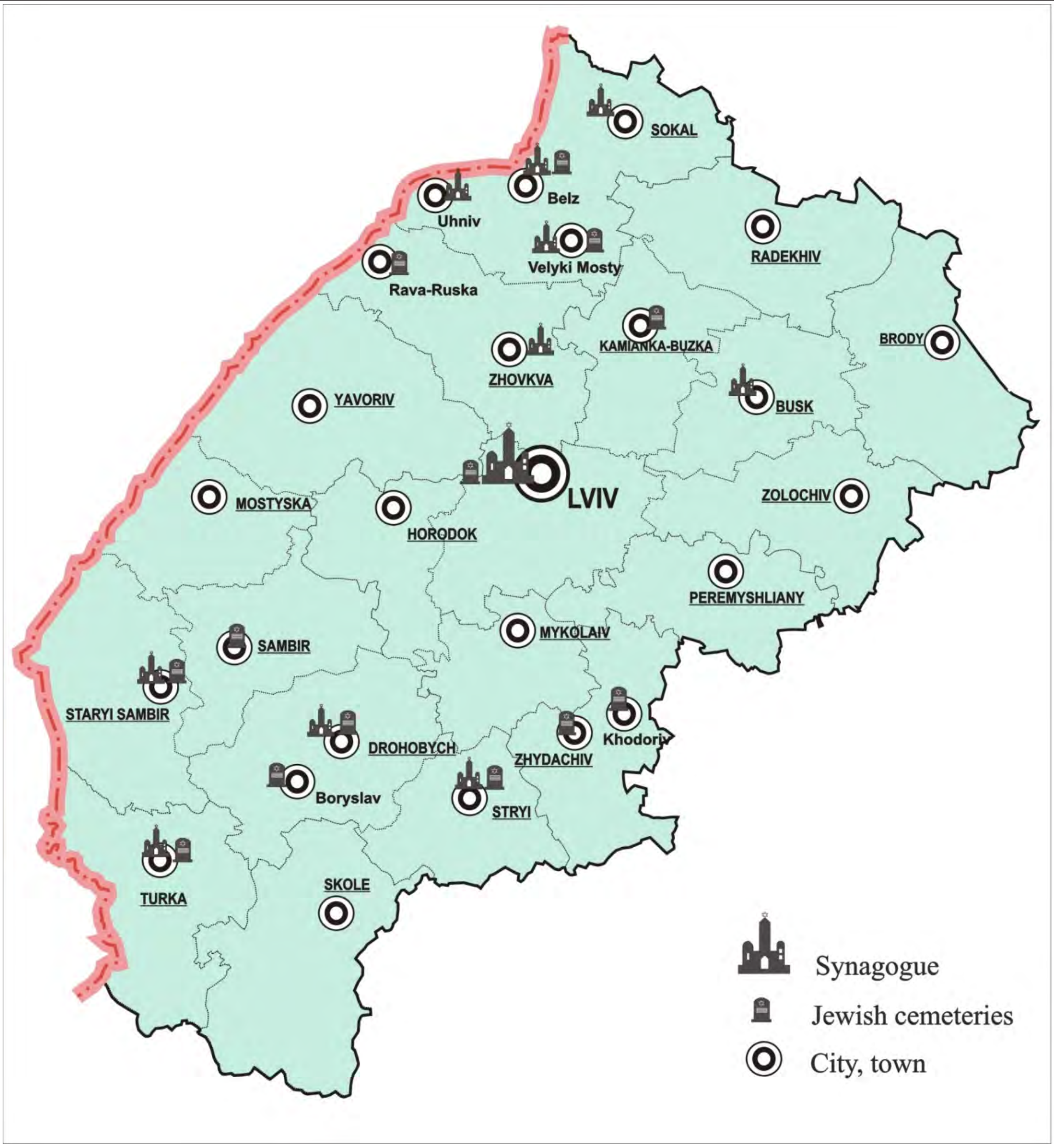

Fig. 3. Sacred objects of Jewish heritage in the cities of the Lviv Oblast (Developed by the authors)

This is evidence that in Ukraine the objects are not much inferior to the Jewish necropolis in Prague. According to religion, Jews cannot be depicted as people on tombstones, so they depict a profession, character, family tree, and have a symbolic meaning. In most Jewish cemeteries in both Eastern and Western Europe, the story is the same over the past 60 years – the destruction of steles during the war.

One of the oldest cemeteries in Ukraine is Brody Kirkut. There are approximately 8 000 burials in the cemetery, 5 477 of which are intact steles. Representatives of well-known Jewish families are buried in the cemetery – Babad (Rabynovych), Bentsion, Bershtein, Bik, Horowits, Kalir, Erter, Kahane, Shor, etc. In 1994, a monument to the victims of the Holocaust was opened at the cemetery. According to the order of the Ministry of Culture (2013), it was included in the state register of historical monuments and monumental art of local significance.

The Staryi Sambir Jewish Kirkut was founded in the middle of the XVI century. In 1998-2001, by a native of Staryi Sambir, it was restored at his own expense. There are about 1 000 tombstones (Matzevah). A monument was built at the entrance to the cemetery to commemorate the Jews of Staryi Sambir. Jewish tombstones (Matzevah) are interesting artistic stone carvings vicarious texts in Hebrew.

Drohobych Kirkut was founded in the middle of the XVII – beginning of the XVIII century. There is a mass grave of Jews in the new Jewish cemetery. In

2004, researchers conducted a census of surnames in the new Jewish cemetery, contributing to the preservation of the former city.

At the end of the XVI century a Jewish community was established in Belz. The miraculous Hasidic tzaddik Sholom Rokah moved to the city. He is buried in the local Jewish cemetery with his family. In the Belz Jewish necropolis there are burials of the leaders of the famous Belz tzaddik dynasty, Rabbi Shalom, Rabbi Yehoshua and Rabbi Izahar Dov Rokah. From 1859 to 1931, most of Belz population were Jews. In 1835-1845 a synagogue was built in Belz according to the design of Sholem Rokah. This synagogue is a sacred place for pilgrims. In the summer of 2007, the Belz Kirkut was surrounded by a brick fence. Numerous pilgrims come here to pray in the Jewish cemetery and in place of the ruined synagogue. In 2013, more than 1 000 Jewish pilgrims arrived from London, Budapest, Brussels, and Tel Aviv to honor the miraculous Tzaddik rabbis buried in the Belz Cemetery (Sait Naukovoho tsentru Iudaiky).

There were two Jewish communities in Lviv – suburban and urban. The Jewish section of princely Lviv lay on both rivers of Poltva, flowing along the current V. Chornovil Avenue. It covered B. Khmelnytskyi Street, district from Yaroslav Osmomysl Sq. to Staryi Rynok Sq. In the XIX century it occupied a significant part of the Krakiv suburbs. An ancient Jewish kirkut was located in the Krakiv suburbs (Melamed, 1994). One of the oldest in Europe is the Jewish cemetery in Lviv. According to experts, 25-30 thousand people are buried here. The old Jewish cemetery does not exist today.

In 1855 near Shevchenko Street a new Jewish cemetery in Lviv was opened, which was annexed to the Yanivskyi Cemetery. In 1856 a new cemetery synagogue was built on it. Many prominent figures of the Jewish community rest in the new Jewish cemetery. The memorial to the Jewish soldiers killed in the Polish-Ukrainian war and the victims of 1918 was built at their own expense by the Lviv Jewish community. A monument to the victims of the pogrom was built on the Kortumova Mount, next to it there is a memorial, and there are 375 burials. All graves in the new Jewish cemetery were destroyed during the World War II. The oldest monument that has survived to this day dates back to 1914. Today, Jewish burials are located along the main alley of the cemetery in the adjacent fields. In addition to these two main cemeteries, in the XIX century there were also other small Jewish cemeteries: in Znesinnia, opened in 1972 on Kulparkivska street and opened in 1884, a small cemetery on V. Yeroshenko street (Helston, 1998).

Therefore, most of the objects of the Jewish cultural heritage of the Lviv Oblast are destroyed and need restoration. Due to the fact that these objects are also little-known for ordinary tourists, tourist routes that include visits to these objects are not developed in the Oblast. Only routes within Lviv are known. In view of this, we have developed a tourist route "By places of the Jewish sacred heritage of the Lviv Oblast" (Fig. 4). The purpose of creation and implementation of this route is to attract public attention to the need to preserve and restore Jewish cultural heritage objects in the cities of the Lviv Oblast and to popularize the objects themselves with a tourism purpose.

The tourist route will be implemented in the form of a 3-day bus tour, which includes the following cities: Lviv, Busk, Brody, Zhovkva, Rava-Ruska, Uhniv, Velyki Mosty, Sokal, Belz, Stryi, Drohobych, Staryi Sambir, Turka. The approximate cost of the tour is 3 000 hryvnias (10 people).

Brief tour program:

Day 1: Lviv – Busk – Brody – Lviv.

It is recommended to visit: Tsori Gilod Synagogue, monuments of Jewish cultural heritage, Jewish Cemetery in Lviv, Busk Synagogue, Brody Synagogue and Cemetery.

Day 2: Lviv – Zhovkva – Rava-Ruska – Uhniv – Belz – Sokal – Velyki Mosty – Zhovkva – Lviv.

Sightseeing objects: Zhovkva Synagogue and Cemetery, Holocaust Memorial and Rava-Ruska Cemetery, Uhniv Synagogue, Velyka Synagogue and Jewish Cemetery in Velykyi Mosty, Sokal Synagogue, Belz Cemetery and Synagogue.

Day 3: Lviv – Staryi Sambir – Turka – Drohobych – Stryi – Lviv.

Sightseeing objects: Synagogue and Cemetery in Stryi, Choral Synagogue and Cemetery in Drohobych, Staryi Sambir Synagogue and Cemetery, Synagogue and Cemetery in Turka.

Thus, the implementation of this tourist route will contribute to the solution of the problems of Jewish cultural heritage in the Lviv Oblast. Other measures for the restoration and popularization of Jewish cultural heritage objects of the Oblast: allocation of budgetary funds, attraction of private investors, international organizations and Jewish communities; development of new tourist routes; determination of places by information stands; publication of information materials about objects; organization of international conferences, round tables, festivals; training of guides on the topic of Jewish cultural heritage, etc.

Conclusions. Lviv Oblast has a multinational cultural heritage, including the Jewish one. The main centers

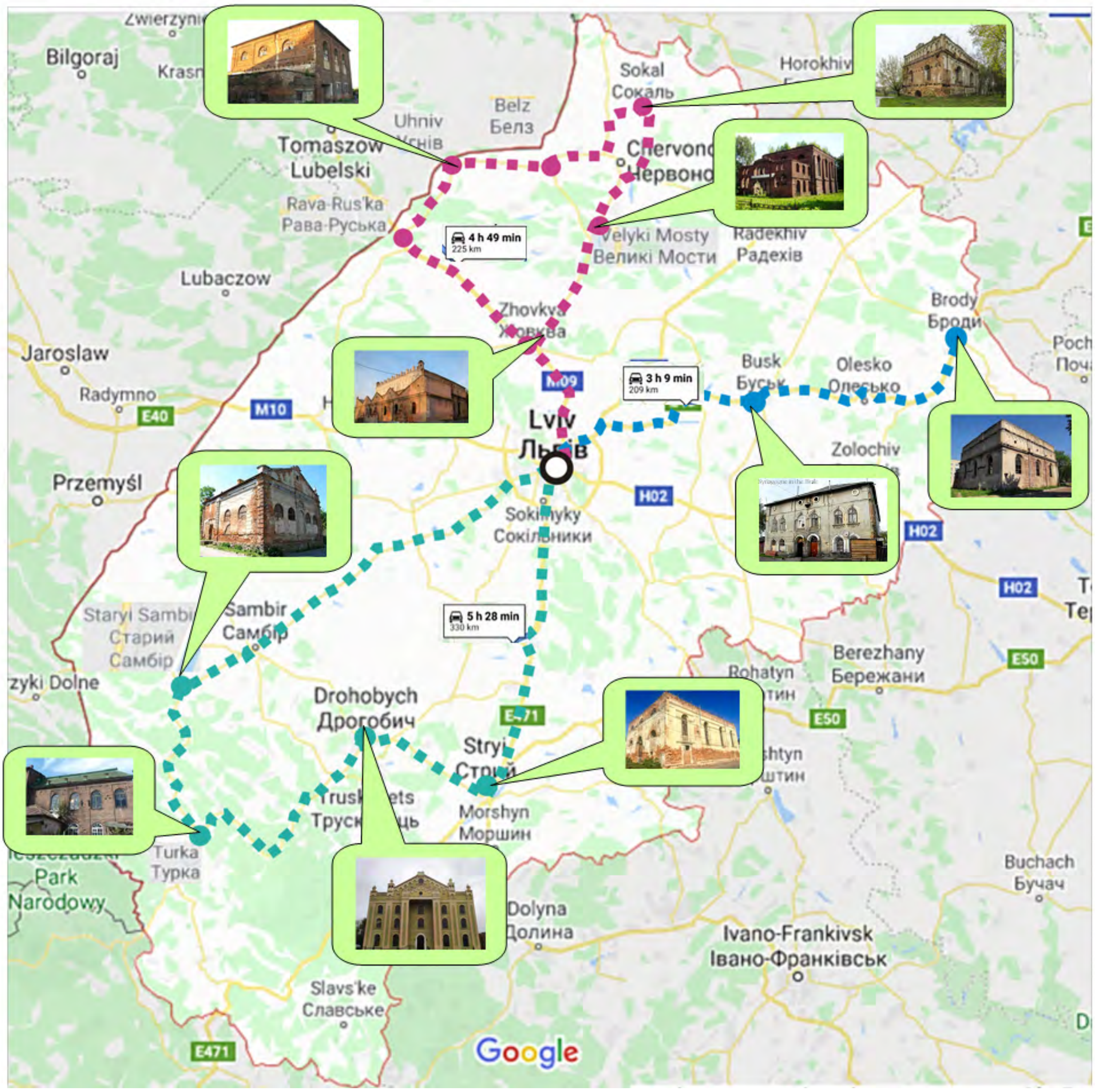

Fig. 4. Tourist route "By places of the Jewish sacred heritage of the Lviv Oblast" (Developed by the authors)

of the Jewish cultural heritage of the Oblast are the cities: Lviv, Zhovkva, Busk, Brody, Drohobych, Belz and others. Most Jewish cultural heritage objects (synagogues and cemeteries) are destroyed and need funds to restore them. The development and implementation of tourist routes will contribute to the solution of existing problems of Jewish heritage in the Lviv Oblast, the popularization of Jewish culture, and the establishment of intercultural exchange.

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Prospects for the development of transport network in Transcarpathia within cross-border territories with EU countries

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Abstract. The article is devoted to the study of the transport network development in Transcarpathia along the border with the EU neighboring countries. The historical stages of the Transcarpathian transport network formation are considered. The main criteria for evaluation and conformity of the transport network in Ukraine have been determined in accordance with European standards. A number of legislative, regulatory, strategic and programme documents covering the development of the national transport network and border infrastructure within the study area are analyzed. The main factors proving the foreign economic activity of the Transcarpathian region towards the EU market are considered and highlighted. The capacity of transit through Ukraine and Transcarpathia within the cross-border territories are revealed. The necessity of the transport network construction is considered due to the fact that the number of passengers and cargo flows on the state border is increasing. It is described, for example, the capacity of rail and road transport across the border of Ukraine and the borders of neighbouring countries , in particular: Poland, Slovakia, Hungary, Romania. It is statistically concluded that the most congested is the Ukrainian-Hungarian border area. The main obstacles to the effective implementation of transport and transit work in the study area are identified and possible solution is proposed involving reconstruction of old units and construction of new checkpoints on the border area of Transcarpathia and its neighbouring countries. The dimensional picture of the border areas is presented: Ukraine - Poland; Ukraine - Slovakia; Ukraine - Hungary; Ukraine - Romania. Within each part the natural resource potential, transport load, features of tourism development, necessity for development and the existing transport network modernization are characterized. Suggestions for construction the new checkpoints as well as their advantages and disadvantages are analyzed and discussed. The priorities of Ukrainian state policy, Transcarpathia as well as the priorities of neighbouring countries in the development of the national transport network within the cross-border territories have been determined.

Key words: national transport network, integration, foreign economic activity, passenger and cargo flows, checkpoints, cross-border territories

Перспективи розбудови транспортної мережі Закарпатської області в межах транскордонних територій з країнами ЄС

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Анотація. Стаття присвячена дослідженню питань розбудови транспортної мережі Закарпатської області вздовж кордону з країнами-сусідами ЄС. Розглянуто історичні етапи формування транспортної мережі Закарпатської області. Визначено основні критерії оцінки та відповідності транспортної мережі України європейським стандартам. Проаналізовано низку законодавчих, нормативно-правових, стратегічних та програмних документів, що регулюють розвиток національної транспортної мережі та прикордонної інфраструктури в межах території дослідження. Розглянуто та виокремлено основні чинники, які доводять, що зовнішньоекономічна діяльність Закарпатської області повністю зорієнтована на ринок ЄС. Розкрито суть та потенціал транзитності території України та Закарпатської області в межах транскордонних територій. Вказано на необхідність розбудови транспортної мережі, оскільки навантаження пасажиро- та вантажопотоків на ділянках державного кордону зростає. Наведено, як приклад, пропускну спроможність залізничного та автомобільного транспорту через кордон України та її сусідів, зокрема: Польщі, Словаччини, Угорщини, Румунії. Статистично доведено, що найбільш завантаженою є українсько-угорська ділянка кордону. Визначено основні проблеми, що перешкоджають ефективній реалізації транспортно-транзитних функцій території дослідження та запропоновано шляхи їх вирішення за рахунок реконструкції старих та побудови нових пунктів-пропуску на ділянці кордону Закарпатської області та її країн-сусідів. Подано просторову картину прикордонних територій: Україна – Польща; Україна – Словаччина; Україна – Угорщина; Україна – Румунія. В межах кожної території охарактеризовано природно-ресурсний потенціал, транспортне навантаження, особливості розвитку туризму, необхідність розбудови та модернізації наявної транспортної мережі. Подано пропозиції побудови нових пунктів-пропуску, виділено їхні слабкі та сильні сторони. Визначено пріоритети державної політики України, Закарпатської області та її країн-сусідів в розвитку національної транспортної мережі в межах транскордонних територій.

Ключові слова: національна транспортна мережа, інтеграція, зовнішньоекономічна діяльність, пасажиро- та вантажопотоки, пункти-пропуску, транскордонні території

Introduction. The transport network of any country, state or region plays a key role in the development of its economy. It is a significant source of the state budget replenishment; the transport network provides domestic and international transfer of goods and passengers. In fact, the transport network provides links between production and consumption, among different branches of the economy, among countries and regions.

Transcarpathia is a part of the Carpathian region of Ukraine, and makes so called «western gate» into the EU countries, as a result its transport network faces more and more congestion; besides it provides transport and economic links within the cross border territories. The integration of Ukraine and its regions into the European and world economy will be successful due to the existence of highly developed transport network. It must comply with international standards of legal, technical, economic and information base. The criteria for its characteristics are the intensity of traffic, amount of cargo and passenger transportation, safety, the quality of the transport network in compliance with European standards. It is this range of issues that prompts research into the development of the national transport network in Transcarpathia and its integration into EU transport networks.

There are many Ukrainian scientists who dealt with the issue of cross-border transport infrastructure and its role in accelerating Ukraine›s integration into the EU. For instance, the works by M.L. Tsyhaniuk, I.H. Smirnov (2015), V.V. Goblik (2013), I.G. Smirnova (2012), I.G. Smirnova, T.V. Kosareva (2008) and others are devoted to the formation of transport and logistics clusters (TLCs) as one of the main components of the transport and logistics system (TLS); the works by I.G. Smirnova (2007, 2004), A.M. Novikova (2003), O.B. Bordun (2003) and others – to the development of transport infrastructure of the border territories. So, in the dissertation «Western Border Transport Infrastructure: Economic and Geographic Survey» by A.B. Bordun (2003) the author presents the background for improving the geo-spatial organization of the Border Transport Infrastructure PMU in the context of regions and neighboring countries and Transcarpathia region is among them. Lately the researchers focus their attention on the role of the border transport infrastructure of the PMU in tourism development (Bordun and Kotik, 2010). Despite the amount of scientific publications in the Ukrainian scientific literature there is still no thorough assessment of the existing transboundary transport infrastructure of Transcarpathia region and its perspectives.

The research methods. The national legislation of Ukraine about the development of transport and border infrastructure, construction of checkpoint network was analyzed during the research; legislative support for the development of transport networks in the EU and the national strategies of the Thranscarpathian neighboring countries, in particular: Poland, Slovakia, Hungary and Romania regarding the spatial development of border areas.

The provisions on the development of the border and transport infrastructure in Ukraine, which are covered in the national transport strategy of Ukraine for the period up to 2030 are studied as well as two important programs, in particular: the Program on the development of the border infrastructure in Transcarpathia for 2018-2022 and the Regional program of the road development for 2019- 2022 years.

The following methodology was used in the study: method of analysis and synthesis, historical, statistical and comparative analysis.

Outcome and its analysis. Transcarpathia is a unique, western region of Ukraine bordering with four EU countries (Poland, Slovakia, Hungary and Romania) with a border length of 470 km. The cross-border location of the region creates additional opportunities to make effective use of the transit potential and its development for entering the European markets for goods and services through enhanced interaction and mechanisms of cross-border cooperation and adaptation of European legislation in the field of regional policy, etc (Promizhnyi zvit Instytutu rehionalnykh doslidzhen NAN Ukrainy, 2019).

The economy of Transcarpathia, in comparison with other regions, is small – in 2016-2017, the region's GRP made up about 1.4% of Ukraine's GDP.

The volume of GRPs per person in Transcarpathia in 2017 was up to UAH 34 202, which is more than 2 times less than on average in Ukraine. At the same time, the index of physical volume of GRP per capita in Transcarpathia during 2014-2017 (except 2016) exceeded the average indicator in Ukraine, that is a sign of the development potential of this region (Promizhnyi zvit Instytutu rehionalnykh doslidzhen NAN Ukrainy, 2019).

The favorable geographical location of the study area, favorable natural and climatic conditions, significant natural and recreational potential, as well as the mental characteristics of the population and their economic forms in total make the key feature of this region – high (with a tendency to further dynamic growth) foreign economic and transboundary orientation of its economy (Promizhnyi zvit Instytutu rehionalnykh doslidzhen NAN Ukrainy, 2019).

Transcarpathia has a strong transit potential, as there are two trans-European corridors approaching to its border, such as:

1) «The Mediterranean Corridor» is a railway branch that reaches the Záhony-Chop checkpoint and the car branch leads to the Beregshurany-Luzhanka checkpoint;

2) «The Rhine-Danube Corridor» with a railway branch passing through the border of Slovakia to Ukraine at the crossing Čierna nad Tisza – Chop (Strazh) and road – to the border Uzhhorod - Vyshne-Nemetskoye.

The study area is the leader in Ukraine in terms of export-import orientation in the economy. The share of export in the output of the region in 2018 was 56%, which is 2.9 times higher than on average in the regions, and the share of import in total consumption in 2018 was 52%, that is 20 times higher than in Volyn, which economy is also import-oriented (Statystychnyi shchorichnyk Zakarpattia, 2018). The foreign economic activity of this area is fully oriented towards the EU market. In 2018, EU countries accounted for 95.5% of the region's commodity exports, with an average of 42.6% in the regions of Ukraine (Statystychnyi shchorichnyk Zakarpattia, 2018). Therefore, the issue of border infrastructure development is relevant to Ukraine's national transport strategy and requires the creation of new transport networks. Thus, the Law of Ukraine «On the General Scheme of Territory Planning in Ukraine» sets out priorities and defines conceptual decisions on the planning and use of the territory of the country.

Special emphasis is focused on the development of industrial, social and engineering transport infrastructure. For instance, in order to meet the needs of the population and the economy of the country in passenger and cargo transportation, the Law includes the necessity of (Pro Heneralnu skhemu planuvannia terytorii Ukrainy. Zakon Ukrainy, 2012»):

1) effective use of the country's powerful transit potential with the integration of its transport complex into the European and world transport and communication system;

2) creation of a national network of international transport corridors, which will ensure the connection of the main scientific, industrial and socio-cultural centers of Ukraine with other countries and stimulate the development of the territories adjacent to these transport corridors;

3) intensive development of high-speed types of electric transport, organization of high-speed movement of passenger trains with integration of the railway network and highways of Ukraine to the European system of highways.

Historically, the transport network of Transcarpathia was formed in several stages:

Stage I – the Eneolithic Age, when first wheeled means of transport drawn by animals were used, it is still in use by the local rural population;

Stage II – the end of the XVII century, when the lands of Transcarpathia for six centuries were part of Hungary, and later – of the Austro-Hungarian Empire. There was a well-developed rail transport network and in the 80's of the XIX century the supply of forests from the Ukrainian Carpathians and minerals such as salt from Solotvyno were transported through Transcarpathia railways that was laid from Lviv via Stryi to Chop.

Stage III is related to the development of trade at the end of the XIX century – the beginning of the XX century, construction of suburban roads began in the largest cities of Transcarpathia – Uzhhorod, Khust, Mukachevo, and on the territory of neighboring countries – in Maramorosh, Sigeti.

Stage IV began in 1946, when the territory of Transcarpathia became a part of the Ukrainian SSR. It was characterized by a significant strengthening of the border crossings role due to its strategic function (mm. Chop, Uzhhorod, Batyovo).

Later road, aviation and pipeline transport began to be actively used in transportation (Istorychnyi narys ta chynnyky formuvannia transportnoi systemy Zakarpatskoi oblasti, 2019).

The modern transport network of Transcarpathia is being fully developed, improved at the expense of the state, local budgets and with the assistance of neighboring states.

The region's foreign economic activity is fully oriented towards the EU market, accounting for over 90% of exports and 60% of imports of the region's goods. The regime of autonomous trade preferences is the unilateral (by the EU) abolition of import duties, which accounted for 94.7% of the total volume of industrial goods and 83.4% of agricultural and food products imported from the EU from our country.

During 2015-2018, exports of goods and services grew by 53.4% and imports by 49.6% (Promizhnyi zvit Instytutu rehionalnykh doslidzhen NAN Ukrainy, 2019). Such dynamics require the development of border and transport infrastructure. It is stated that in February 2020 nineteen (19) operating checkpoints have been opened across the Transcarpathian state border and it is proposed to build 18 more.

According to the types of connections among the operating checkpoints are: 9 automobile; 5 rail; 2 pedestrians (Fig. 1).

The analysis of statistics for the period 2015-2019 showed that 48 million citizens and 111 million tons of cargo crossed these checkpoints. Positive growth dynamics are common for all types of traffic and means of transportation: 1) 28.5% – pedestrian; 2) 5% – cars; 3) 35.5% – trucks; 4) 6% – buses.

In fact, only the number of freight cars, crossing the border, has decreased, that is actually connected not only with the economic crisis but also with the military conflicts between Ukraine and Russia in the southeastern part of the country.

The analysis of the number of passenger and cargo flows through the existing border crossing points of Transcarpathia region and European neighboring countries in accordance with the Association Agreement between Ukraine and the EU showed that their redistribution and foreign trade volumes change every year. For example, in 2018, 42% of all rail transport and 60% of all road transport crossed the border with four EU Member States.

The parts of the railway crossing through the Polish, Slovak, Hungarian and Romanian sections of the state border of Ukraine are shown in Fig. 2. It shows that the Polish and Slovak border areas are the most intensive in terms of the number of rail crossings and their shares have increased steadily during 2010-2018.

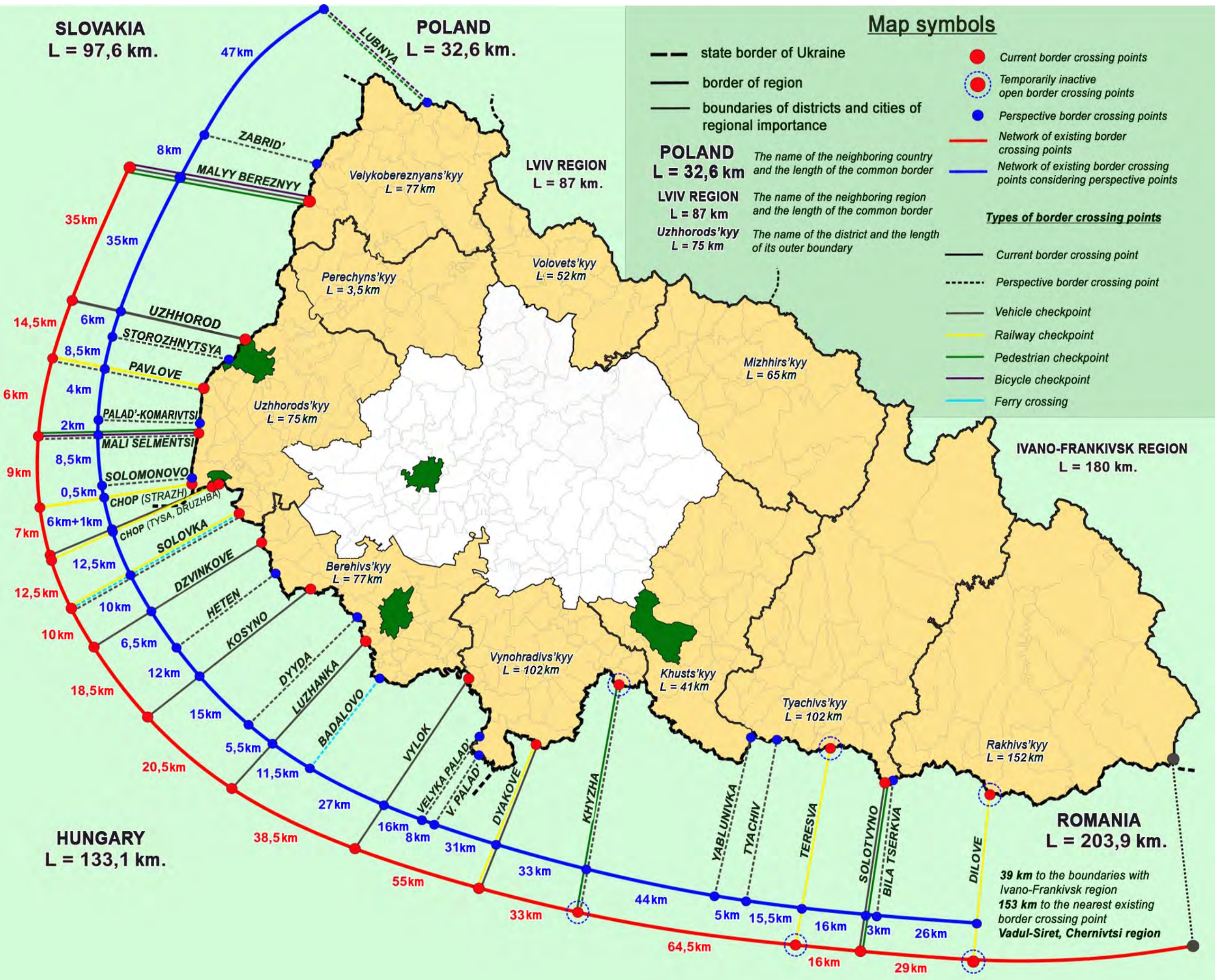

Fig. 1. Scheme of current and perspective border crossing points in Transcarpathia (based on Promizhnyi zvit Instytutu rehionalnykh doslidzhen NAN Ukrainy, 2019])

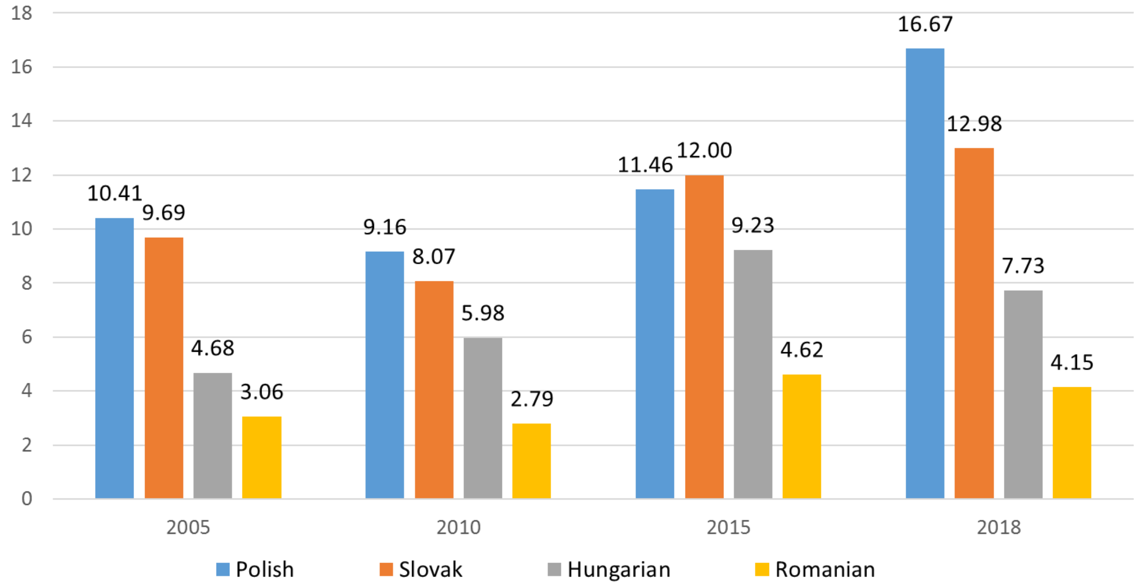

Fig. 2. Crossing of railway transport divided by sections of the state border (share of the certain section of the border in the total amount of the crossing),% (made according to the materials Transport i zviazok Ukrainy, 2018)

The share of road transport through the Polish, Slovak, Hungarian and Romanian sections of the state border of Ukraine is shown in Fig. 3. The most intense border crossings regarding road crossing are Polish and Hungarian (in 2018 – 34.28 and 13.22% consequently).

The border area between Ukraine and Poland within the Transcarpathia region is bordered with the Beszczadsky County of the Subcarpathian Voivodship with a population of 21.9 thousand people, mountain ranges of the Polish Beskyds and centers of ski tourism development, with three nature protected

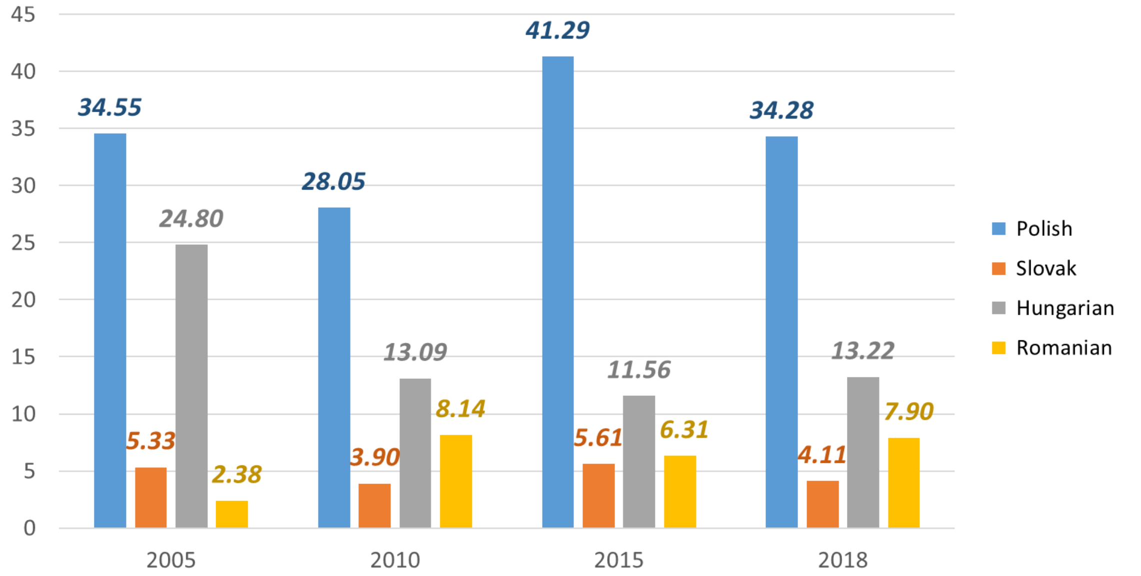

Fig. 3. Crossing of road transport on sections of the state border (share of the respective section of the border in the total volume of crossing), % (made according to the materials Transport i zviazok Ukrainy, 2018)

The indicator of the load on the state border in the context of Transcarpathia region shows its growth at the existing checkpoints, so most of them need reconstruction and in the future – the construction of new ones. The busiest is the Ukrainian-Hungarian border area, but unloading is required on both Ukrainian-Romanian and Ukrainian-Slovak (Zakarpatska oblasna administratsiia. Transportne perevezennia, 2019).

areas. Perspective on the state and regional level is the construction of the crossing point (hereinafter – PE) «Lubnya-Volosate», namely, pedestrian and bicycle. In the Carpathian Euroregion strategy (2020), its construction is outlined as a priority project and its implementation is expected for 2019-2024 (The Carpathian Euroregion Strategy 2020 Beyond. Carpathian Euroregion, 2015), which aims at cross-border mobility of territories and tourism development.

The border area Ukraine-Slovakia includes Prešov and Kosice self-governing countries, which have not only ecologically clean territories but also historical and cultural sites, four of them are considered to be UNESCO World Heritage Sites. There are several industrial parks in the outskirts of Kosice. On the other side of the Slovak border, there are three districts of the Transcarpathia region: Velyky Bereznyi, Perechyn and Uzhhorod. Within the given territory the Uzhansky national park has the environmental perspective, and therefore, in the future that is a perspective for the development of rural (green) tourism.

Only the Ukrainian-Slovak cross-border region has its own Development Strategy, which envisages the development and modernization of border infrastructure. Six new car crossing points are planned to be built, namely: «Zabrid-Ulich», «Storozhnytsa-Zagor», «Pavlove-Matyovce», «Palad-Komarivtsi - Ruska», «Mali Selmentsy - Velke Slemence» and «Solomonovo-Chierna».

Analyzing the legal acts on the opening of the checkpoints, identifying the pros and cons that determine the prospects and construction of these objects, we›d like first of all highlight the construction of «Pavlove-Matyovce» and «Solomonovo-Chierna».

During the period 2015-2018, the Ukraine-Hungary border area was characterized by the following indicators: first of all, 65% of citizens crossed the border here; secondly, the volume of border rail crossings by citizens was 90% in 2018, and the volume of cargo accordingly – 26.18%; thirdly, the share of total rail freight traffic increased from 15.14% in 2015 to 29.48% in 2018 (Statystychnyi shchorichnyk Zakarpattia, 2018).

It should be noted that the Ukrainian-Hungarian borderland has significant tourist potential, in particular, it is famous for its historical and cultural monuments, thermal springs (Lake Bath «Tofurdo», and Park Bath «Aquarius»), ethnographic open air museum – Shoshto, thirteen industrial parks and intermodal terminals.

The Ukrainian lands of Uzhhorod, Berehiv and Vynohradiv districts are relevant to the territory of Hungary. These are investment attractive tourist areas of Transcarpathia, in particular, Berehiv district with thermal waters (Kosyno), developed gastronomic tourism (Hungarian and Ukrainian cuisine, wine tasting) and rural green tourism (villages of Vary, Hecha, Bene). Mukachevo is famous for its sanatorium-resort complexes such as «Synyak», «Carpathians», «Vodohrai», «Belle Royalle», that operate on healing mineral waters. Therefore, it is obvious that the number of those who want to recreate will increase every year at this section of the border. Six checkpoints are considered to be promising, but after being examined on their technical features, to our mind, only three are about to be built in the coming years. These are «Dyida-Beregdarots», «Grand Palad – Little Palad (Kishpalad) and «Grand Palad – Nod-godosh».

As for the Ukraine-Romania border, it connects two counties – Satu Mare and Maramuresh on the Romanian side and Vynogradiv, Khust, Tyachiv and Rakhiv districts on the Ukrainian side. Despite the predominance of mountainous terrain, the northwestern part of Romania has significant tourism and recreational potential, like Maramuresh County, it is an authentic village with wooden churches, entrance carved gates, hand-made carpets and narrow rugs. Satu Mare County is a festival area, and the shepherd festival is of the highest demand among tourists. There are many temples, local architectural monuments and the ruins of the medieval Ardud Fortress as well, and in the village of Medieshu – Aurit there is a palace of the Renaissance time.

Some Transcarpathian districts (Vynogradiv, Khust, Tyachiv and Rakhiv) are interesting as well, as territories on the Ukrainian side (Sotsialno-ekonomichne stanovyshche Vynohradivskoho raionu, 2019). Vynogradiv district is promising as well due to the prospect of construction modern health resorts on the basis of mineral water deposits such as «Olegivske» and «Teplytsa». Such enterprises as «Genterm Ukraine LLC, PJSC «Grono-Tex» and «Sanders-Vynogradiv» LLC have significant export potential of industrial product (Sotsialno-ekonomichne stanovyshche Khustskoho raionu. Statystychnyi biuleten, 2019).

Direct investment in Khust district is made into industry (62.5% of total volume). Most of the export-import operations have taken place within countries such as Italy, Czech Republic and Hungary. The involved foreign capital provides a positive balance of foreign trade in the field of light industry and livestock in agriculture (Sotsialno-ekonomichne stanovyshche Khustskoho raionu, 2019). Tourism of the study area covers the Carpathian Nature Reserve «Narcissus Valley»; the famous mineral waters of Dragovo, Shayan, Vyshkovo with a spa-sanatorium network; a unique cheese factory in the village of Nyzhnye Selyshche; a deer farm; folk crafts – weaving in the village of Iza, pottery in Khust and Vyshkovo, etc. (Khustskoho, 2019).

In 2018, the largest amount of direct investments ($ 7.1 million, USA) of the Tyachiv district involved in industry (95.6%) come from Austria, Italy, the Netherlands, Germany (Publichnyi zvit holovy Tiachivskoi raionnoi derzhavnoi administratsii, 2018).

The tourism and recreation industry is developing and has 114 tourist infrastructure objects. The volume of services rendered to the subjects of tourism, recreation and hotel sphere amounted to 9910.7 thousand UAH (Zakarpattia onlain, 2020). Gastronomic tourism, including wine, is also in high demand in the study area; military tourism with elements of the defensive structures of the Arpad line from World War II; speleotourism in karst caves – Chur, Crest, Milk stone, Friendship (Karstovi pechery Zakarpattia, 2019).

The economic complex of Rakhiv district is poorly developed and based on the forest complex. At the same time, Rakhiv district has extremely favorable conditions for winter recreation and development of skiing. The core rehabilitation part of the Kvasiv spa complex is mineral water with arsenic content used for summer and winter recovery and here an extensive network of tourist sites of various fields operates as well. Among them are: Yasinya – Sports Base «Tysa»; Dragobrat; Dragobrat LLC; «Tysa» and «Trembita» wellness complexes. New facilities are being constructed, especially in the mountainous area, including private mini-hotels, recreation centers, health resorts, villas' estates, which welcome guests in accordance with the rural green tourism requirements. Pedestrian, ski, water, bicycle, horse and car tours are developed and are in demand.

The current situation in this part of the state border requires the building of modern checkpoints. In the future, the governments of two countries have identified four promising ones; most likely in the first five years the following checkpoint will be built and operate successfully: PE «Yablunivka-Remete (Guta)» as a motor vehicle and PE «Bila Tserkva – Sigetu – Marmatsiya» for automobile cargo and passenger service.

Conclusions. Therefore, the existing network of border checkpoints in Transcarpathia region is characterized by its outdated infrastructure, long waiting times for citizens to cross the border, and high levels of passenger and freight traffic load. Therefore, the opening of new checkpoints will ensure the redistribution of these flows, more uniform distribution along the state border. The most modern logistic transport network is able to provide:

1) inclusion of Ukraine, Transcarpathia in the transport system of Eastern Europe;

2) increase in transit of passengers and cargo through the territory of the study;

3) increase of capacities and quality indicators of the transport network;

4) optimization of passenger and cargo flows;

5) ensuring the growth of the investments volume in the fixed capital of the region;

6) development of the tourist and recreational branch in the study area.

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Geoecological approach to organization of naturalized anthropogenically-modified territory

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Abstract. The problem today is to ensure a harmonious relationship between anthropogenic activity and natural processes in order to preserve the dynamic integrity of the environment. The best specimen of the territorial compatibility of the natural and cultural component is a rather specific category in the list of objects of the nature reserve fund (PFP) - "parks and gardens". The article deals with the formation, operation and development of the Alexander Park, located in the Tomashpil district of Vinnytsia region. It, like the vast majority of areas of existing and designated nature reserves and sites of Vinnytsia region, has a complex origin, caused by long (about 150 years) and multi-stage human impact. The purpose of this study is to combine ecological and geographical approaches in determining the features of organization of the park and park territory at the present stage of their functioning. Alexander Park, which is of great environmental, historical and cultural importance for the whole Vinnytsia region, is characterized and symbolized by the indivisibility of natural and cultural heritage, and thus provides the fulfillment of several interrelated functions: environmental, recreational and economic. The use of both traditional and modern methods, such as geo-ecological analysis and synthesis, comparative-geographical, key areas, etc. made it possible to study the features of the territorial organization of nature management, relations and relationships between their most characteristic forms, the "cultural morphology" of the forest park type. The development of the Benetto-Alexander Surprises Nature Trail demonstrates the results of conservation and efficient use of biotic and landscape diversity, combined with the sustainable use of natural resources, which is one of the main tasks of modern environmental management and conservation. In addition, it is also a basic condition for balanced development of the region. The practical value of the proposed methodology is to use them, especially in Vinnytsia region, as a reference and scientific and practical basis in the assessment of cultivated landscapes in scientific and practical activities in the development and improvement of planning nature conservation and recreational and tourist activities of the region.

Key words: territorial organization, park, ecological trail, cultural landscape, nature management, biodiversity.

Геоекологічний підхід в організації природокористування антропогенно-модифікованої території

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Анотація. Проблемою сьогодення є забезпечення гармонійних взаємозв'язків між антропогенною діяльністю та природними процесами з метою збереження динамічної цілісності навколишнього середовища. Найкращим зразком територіальної сумісності природної й культурної компоненти слугує досить специфічна категорія в переліку об'єктів природно-заповідного фонду (ПЗФ) — «парки-пам'ятки садово-паркового мистецтва». У статті розглянуті питання формування, функціонування й розвитку Олександрівського парку, розташованого в Томашпільському районі Вінницької області. Він, як і переважна більшість площ сучасних і проектованих природно-заповідних територій та об'єктів Вінниччини, має складне походження, зумовлене тривалим (близько 150 років) і багатоетапним впливом людини. Метою цього дослідження є поєднання екологічного й географічного підходів у визначенні особливостей організації паркової й припаркової території на сучасному етапі їх функціонування. Олександрівський парк, відіграє велике природоохоронне та історико-культурне значення для усієї Вінницької області та символізує неподільність природної й культурної спадщини, а відтак забезпечує виконання декількох взаємопов'язаних функцій: природоохоронної, рекреаційної та господарської. Використання як традиційних, так і сучасних методів, зокрема геоекологічного аналізу і синтезу, порівняльно-географічного, ключових ділянок уможливило вивчення особливостей територіальної організації природокористування, відносин і зв'язків між їхніми найхарактернішими формами, «культурної морфології» лісопаркового типу.Упорядкована природо-пізнавальна екологічна стежка «Бенетто-Олександрівські сюрпризи» наочно демонструє результати збереження та ефективного використання біотичного й ландшафтного різноманіття у поєднанні з невиснажливим використанням природних ресурсів, що є одним з головних завдань сучасного природокористування, екобезпеки та охорони природи. Окрім того, – це є також основною умовою збалансованого розвитку регіону. Практична цінність пропонованої методики полягає у використанні їх, передусім у Вінницькій області, як довідкової й науково-практичної основи в оцінюванні окультурених ландшафтів у науково-практичній діяльності при розробці та удосконаленні планувальної природоохоронної й рекреаційно-туристичної діяльності регіону.

Ключові слова: територіальна організація, парк, екологічна стежина, культурний ландшафт, природокористування, біорізноманіття

Introduction. The UN has announced 2021-2030 the decade of ecosystem restoration. Moreover, for the first time in the half-a-century history of the Economic Forum in Davos, five greatest global risks were determined to be ecological. These risks are climatic catastrophes, losses of biodiversity and destruction of terrestrial and aquatic ecosystems (Diamond, Carvajal., 2020). In such conditions, the acute problem is determining scientifically-substantiated priorities and directions of nature use within cultural landscapes which, at the level with the natural landscapes, perform the role of ecological centers and corridors, supporting the integrity of the biosphere at the local and regional level. Among these landscapes, a special group comprises parks or cultural phytocenoses. The founder of theory of phytocultural landscapes Y. P. Byallovich (Byallovich, 1936) has determined culturephytocenosis as a certain complex characterized by certain relations of plants between each other, with the environment affected by the reactions of landscape and complexes of purposeful planting measures by humans. Such complex includes both shrub-tree (field-protecting windbreaks, plantations in recreation zones, sanitary zones of industrial enterprises, forest-parks, urban parks and gardens, boulevards and garden squares) and herbaceous plant groups (lawns, flower gardens, pastures, etc), which are formed, controlled and regulated by humans at all stages of their development.

Such landscapes, formed as a result of complex interaction of natural and socio-historical factors, are at the cutting-edge of European approaches, self-contained and significant territories or fragments of biotic- and landscape diversities. The best example of territorial compatibility of their natural and cultural components is a quite specific category, included in the list of the object of the nature-reserve fund (NRF) - "parks-monuments of garden design" (Dubrovskiy, 2008). They belong to the group of artificially created objects, subjected both to protection and use for esthetic, educational, scientific, nature-protection and health-improving purposes. It should be noted that particularly nature-protected territories of such type are given a special mission – formation of knowledge among the population about ecologically practical nature use, understanding the necessity of preservation of diversity of life forms, promotion of nature-protection and ecological cultures (Hudzevych, 2012). Thus, parks along with their immediate surroundings create favourable capabilities for organization-educational trails (ecological trail) and scientific-research and recreation activities of representatives of different layers of the local population.

The objective of this article was combining ecological and geographic approaches in determining the peculiarities of organization of park and pre-park territories at the current stage of their formation. The specific purpose of this article was to create the image of a park and its surroundings which would really reflect the valuable features of cultural landscape and thus attract the local population, guests and also interested structures to the need of preservation and rational use of park territories.

Material and methods of the research. Anthropogenic activity underlies the effect which causes disturbance or modification (or transformation) of the structure of the natural complex and causes formation of numerous classes of anthropogenic landscapes. The directions of territories` development or nature-use are determined taking into consideration the special differentiation of natural conditions and pattern of division of natural-resource potential. The practical aspect of contemporary concepts of nature-use is the organization of territories when a region of the planet in general functions as an integral stable system where the economic subsystem is correlated with natural one according to the principle of compatibility of the components of natural landscape, providing:

- rational (careful, economical) exploitation of natural resources and effective preservation and restoration of them taking into account potential interests of the development of economic activity of human;
- preservation of high-quality environment, health of the population and environment of recreational capability of the territorial economy (Hudzevych, 2012).

Overlapping (interference) of the elements of anthropogenic-cultural and natural environments, which determines and provides the structural integrity of parks-monuments of garden design, is the subject of discussions among specialists concerning this category in the system of the NRF. Their positions range from unconditionally or cautiously positive (Ena, 1989; Krasnitskiy, 1983; Stoiko, Hadach, Shymon, Mykhalyk, 1991) to sharply negative, including suggestions to exclude them from the NRF. At the same time, supporters of the most radical actions, understanding that without cultivation and care the old historical parks will become abandoned and degraded, do not reject the provision of a protective regime for parks (Dubrovskiy, 2008), nor do they reject active regulation.

At the same time, the issues of optimization of nature use taking into account the status of polyfunctional territories are being insufficiently studied from the perspectives of the geoecological approach. This leads to contradictions and conflicts between the nature users of different spheres and makes impossible the monopolized use of natural resources. Such situation requires development of a national, regional and local strategy of ecologically-balanced use of nature-resource potential, fulfillment of requirements of resource-ecological safety by all the subjects of economic activity and therefore creation of conditions for improvement of the environment on this basis.

Problems of projecting and organizing an ecological trail is described in a number of studies by domestic and foreign scientists, including methodological developments of the group of authors led by Y. P. Didukn (Didukh, Ermolenko, Kryzhanivska, Popovych, Serebriakov, 2000) and proposals on use of walking trails within nature-protection territories for educational purposes in the works by V. Strasdas, P. Chizhova, Y. Eylart, 1996 (Strasdas, 2002; Chizhova, Dobrov, Zahlebnyiy, 1989; Eylart, 1996), S. Trapp with co-authors (Trapp, Gross, Zimmerman, 1994) and others. Until recently, there have been solid theoretical developments regarding the problem of using ecological trails in tourism (Dmytruk Iu., Dmytruk, S., 2009). However, the issue of organizing ecotrails in Vinnytsia Oblast, taking into account the specifics of those trails and reasons for their existence, despite some practical steps (Hudzevych, 2014; Hudzevych, 2002), require more substantiated research.

The methodological basis of our research comprised both traditional and contemporary methods used in complex geoecological studies, including geoecological analysis and synthesis, the morphometric method, geoinformational cartography and modeling, the comparative-geographical, key-plots method, techniques and methods of ecological optimization of territorial structure of landscapes.

Results and their analysis. Geoecological analysis of nature use involves study on the correspondence of the structure of use of a territory to its natural capabilities. Among well-known directions of the structure of nature use in the sphere of nature-protection (strict preservation, regulated, compensational directions) the monuments of garden design are regulated localized territories. They have distinct borders, and their activity is determined by legislative acts. According to Articles 6 and 7 of the Law of Ukraine "On the Nnature-protection Fund of Ukraine" (Zakon Ukrainy, 1992), they are subjected to complex protection and belong to lands of nature-protection and historical-cultural purposes, because they have special ecological, scientific, esthetic, economic, and historical-cultural values. The recommended regime is temporary rejection of economic use, though recreational use with minimum effect on nature is allowed (Reymers, 1990).

The object of our studies was the territory of Oleksandrivsky Park. It is located on the south border of a small village Blahodatne, 5 km from Oleksandrivka village of Tomashpil district of Vinnytsia Oblast. Oleksandrivsky Park was founded in the late XIX century around the manor house of Gräfin Hanna Benett. As the records tell, in the territory of the park, there was built a palace and houses for servants. During the Revolutionary events of 1917, the palace was destroyed Two small houses which remained from that time were restored and designated as a hotel.

The park has been built in regular-landscape style (Hudzevych, 2002). This allowed maximum use of flat interfluves and erosion-valley elements of the relief. The water-divide surface contained decorative compositions of biogroups of trees and shrubs, isolated sculptures, wooden log-benches, flower gardens. Slope areas were covered chiefly by trees and shrubs typical of broad-leaved forests. The bed of the ravine was transformed into cascade of interrelated water bodies. All these parts of the park are connected by the Gräfin`s Alley of horse-chestnuts (*Aesculus hippocastanum*) and small-leaved limes (*Tilia cordata Mill.),* and also northern white-cedars (*Thuya occidentalis L.*), forming an integrated and harmonious composition (Fig. 1). Since the foundation, the Gräfin`s Park had 80 species of broad-leaved and coniferous species. During the USSR no one was interested in the fate of the Park. It was the property of the Sovkhoz and silrada. Then, according to the decision of the executive committee № 441 from 30.07.1969, this territory of 11.0 ha was included in the Nature-Reserve Fund of Vinnytsia Oblast as park monument of garden design (Hudzevych, 2002). The restoration works began only in 2009. The Park`s pond was restored (Fig. 1). New alleys were planted, particularly of *Thuya* genera. Since then, the nurseries at the place of old garden (Fig. 2, 3) have been in operation. An apiary and a well were also constructed.

Fig. 1. Gräfin`s Alleys of horse-chestnuts and the Park`s pond

Among the park biotopes, two groups of forest phytocenoses were distinguished according to current ecological condition of the tree stand (proportion of tree species, condition of growth gain and natural restoration, species diversity of herbaceous vegetation, anthropogenic impact): cultural or anthropogenic, actual culturephytocenosis (constantly taken care of by humans) and natural-anthropogenic (natural course of the development practically is not disturbed). The first group is a complex of biogroups, mostly of introduced species concentrated in the west side, the other group occupies the largest part of the park which is remote from the outbuildings and occupied mainly by local trees and shrubs.

Fig. 2. Husbandry of forest plants and the ravine in the outskirts of the park

The rationally organized part of the park territory is presented by scattered one- and multi-trunk trees and biogroups which reach various height (15-30 m) and diameter (27-52 cm), including European beech (*Fagus sylvatica L.*), Kentucky coffeetree (*Gymnocladus dioicus L.*), pin oak (*Quercus palustris Munchh.*), sweet chestnut (*Castanea sativa Mill.*), Japanese pagoda tree (*Sophora japonica L.*). Evergreen species are successfully supplemented by *Rhododendron*, European larch (*Larix decidua Mill.*) and Siberian larch (*L. sibirica L.*), black pine (*Pinus nigra Arn.*), Norway spruce (Picea abies *L.*) and blue spruce (*Picea pungens Engelm.*)), European silver fir (*Abies alba Mill.*), savin juniper (*Juniperus sabina L.*), common juniper (*J.Communis L.*) and Irish juniper (*J. Hibernica L.*).

Nearby, lianas are planted — Italian woodbine (*Lonicera× caprifolium L.*), dogwoods (*Cornus*) - Lukyanovsky dogwood (*Cornus mas* «*Lukyanovsky*») and Cornelian cherry dogwood (*Cornus mas `Elegant`*) and shrubs of Paeonia × suffruticosa (*Paeonia suffruticosa Andrews*). Twelve quite mature specimens of *Cornus mas* «*Lukyanovsky*» aged 112 years continue to bear fruit.

Among the old-timer plants of the phytocenosis which are distinctive by compact form and decora-

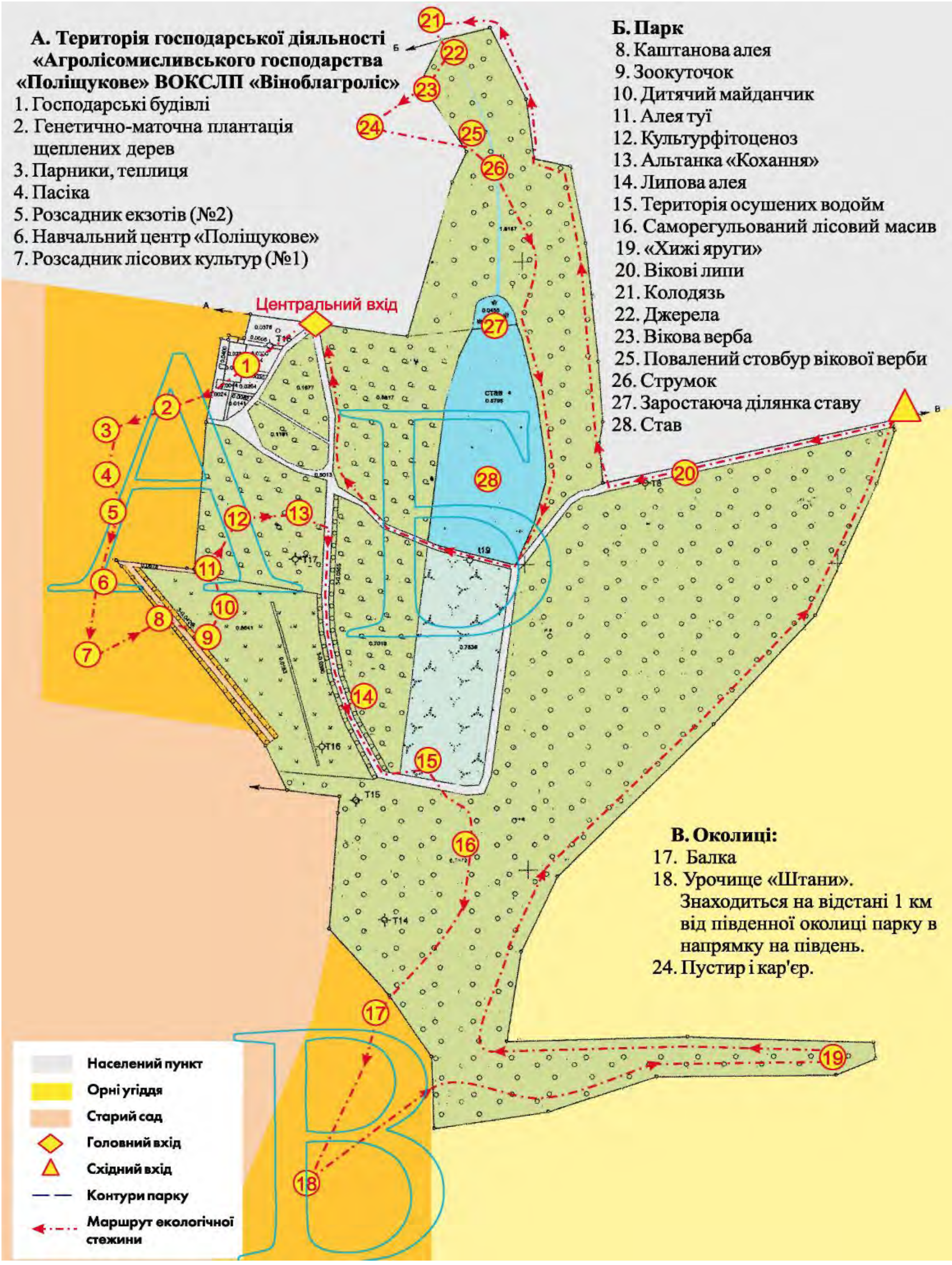

Fig. 3. Scheme of ecological trail Benetto-Alexander Surprises within the objects of the Oleksandrivsky Park and Polishchukove Agroforestry of Vinnytsia Oblast Municipal Specialized Forestry Vinoblahrolis

A. Territory of Polishchukove Agroforestry of Vinnytsia Oblast Municipal Specialized Forestry (AVOMSF) Vinoblahrolis
1. Outbuildings
2. Genetic-mother plantation of grafted trees
3. Cold frames and greenhouse
4. Apiary
5. Nursery of exotes
6. Polishchukove Educational Center
7. Nursery of forest species

B. Park
9. Maple alley
10. Zoo corner
11. Children's playground
12. Organized cultural phytocenosis
13. Love gazebo
14. Lime tree alley
15. Territory of dried water bodies
16. Self-regulating forest structure
19. Hyzhi Yaruhy Gullies
20. Centennial lime trees
21. Well
22. Springs
23. Centennial willow
24. Fallen trunk of centennial willow
26. Stream
27. Overgrowing area of the pond
28. Pond

C. Outskirts
17. Ravine
18. Shtany Tract (at the distance of 1 km from the south edge of the park)
24. Wasteground and quarry

tiveness, are the garden form of *Viburnum* – European cranberrybush (*Viburnum Roseum L.*) and weigela (*Weigela hortensis Thunb*).

In the past, the Park`s system of landscape views was composed of picturesque alleys with early-blossoming shrubs of lilac and winter jasmine (*Jasminum nudiflorum*). Among them, as fruit-bearing accompanying species, planted varieties of Persian walnut (*Juglans regia L*) are distinctive mainly for their ball-shaped and branchy crown.

Apart from the introduced species, the tree stand is to a high degree formed by local species of broad-leaved trees: common oak (*Quercus robur L.*), limes (common lime *Tilia europaea L.,* large-leaved - *T. Platyphyllos Scop* and small-leaved lime *T. cordata Mill.*), European ash (*Fraxinus excelsior L.*), maples (Norway maple *Acer platanoides L.*, field maple *A. campestre L.*, box elder *A. negundo L.*). The conditions of all of them are satisfactory. Growth gain occurs in scattered cases, represented chiefly by common lime *Tilia europaea L.*, common hornbeam (*Carpinus betulus L*) or common oak (*Quercus robur* L.), though ecotonically, that is at the border with the self-regulated part of the park. Projective cover of herbaceous plants is 60-80%. In different areas the dominants are asarabacca (*Asarum europaeum L.*), yellow archangel (*Lamium galeobdolon L.*) and ground elder (*Aegopodium podagraria L.*). One of the lawns is made into a children's playground. Undeveloped areas are provided with recreational zone comprising tables and benches, and the road-trail network was expanded. Sporadically, small architectural forms, gazebos, are constructed. They are scattered around the water body. In the center of the cultural-phytocosis, these structures are rather higher – gazebo with harmonious name Love Gazebo. It is the only one restored, standing in the place of a pre-Revolution small architectural form.

On the old park`s territory free of trees and shrubs, near the maple alley, aviaries with protective grids are constructed for ostriches (*Struthio camelusL.*) and emus (*Dromaius novaehollandiae L.*) exotic in our country. According to the workers of Vinoblahrolis AVOMSF, the park`s zoocorner will in the nearest future be supplemented by species from the of local ornihtofauna, and also interesting mammals (*Mammalia*). The zoocorner should become some sort of a window into the world of animals, enabling study on their behaviour and contributing to the complicated and extremely necessary work on preservation and breeding of rare species.

In general, the scattered trees and shrubs, the park`s zoocorner and children's playground are well fitted into the landscape, having a strong esthetic effect on the visitors.

Apart from the recreational, and currently managed part of the park, an important environment-forming function is performed by self-regulating forest area of the park. It is located on well-manifested slopes of north-east, east and south-east expositions.

The broad-leaved forest aged over 100 years is represented by quite dense (0.7-0.9) tree stand of 24-26 m and diameter of trees measuring 23–45 cm. In the first stratum there, the dominant species are common oak (*Quercus roburL.*), common hornbeam (*Carpinus betulus L.*) and common ash (*Fraxinus excelsior L.*)

The second stratum of the forest part of the park is composed of Norway maple (*Acer platanoides L.*) and box elder (*A. negundo L.),* wild cherry (*Cerasus avium L.*), small-leaved lime (*Tilia cordata Mill.*), and also common hornbeam (*Carpinus betulus L.*) and common ash (*Fraxinus excelsior L.*). Common in the understory of these park phytoconoses are common hazel (*Corylus avellana L.*), cornus (*Swida sanguinea L.*), black elder (*Sambucus nigra L.*), euonymus – european (*Euonymus europaea L.*) and verrucosus *(*E. *verrucosus Scop.*), and field maple (*Acer campestre L.*).

Apart from the indicated plants, there are scattered silver birch (*Betula pendula Roth.*), common aspen (*Populus tremula L.*), black poplar (*Populus nigra L.*), silver poplar (*Populus alba L.*). Under trees and shrubs, species of plants which are genetically related to broad-leaved forests are represented: asarabacca (*Asarum europaeum L.*), yellow archangel (*Galeobdolon luteum Hudls.*), unspotted lungwort (*Pulmonaria obscura Dum.*), ground elder (*Aegopodium podagraria L.*), greater stitchwort (*Stellaria holostea L.*).

Against the background of conditionally optimum life conditions for the tree stands, however a critical ecological situation is seen. It is manifested in a large amount of drying and weakened trees damaged by pests, diseases; inhibition of growth by taller specimens with better developed crowns. Thus, there are dry tree stands and coarse woody debris (recent and of past years). The decrease in the intensity of forestry measures for forming park`s plantation (thinning) in the previous decades has contributed to the concentration of these unhealthy signs. One of the main reasons of abandonment of sanitary cuttings in the park is the absence of the need of the local population in wood, first of all the trees in the age of the main-use felling. Natural intensity of self-thinning typical for wild forests has not been reached so far in these plantations. According to the types of growing conditions, the largest share of trees is seen in humid forest parts of the tract of the ravine`s bed.

The natural function of separation of the two different park areas is performed by the pond in the central part of the park. From pre-Revolutionary system of interrelated water bodies (cascade of ponds), only one is still remaining. The pond bed belongs to the valley-streambed type. The water level in the pond, compared with stream one, as at the beginning of its formation, remains 1.5-2 m higher. The banks are asymmetric in their structure: the right bank is low, while the left is steep. Current average depth of the pond is 0.80-1.20 m, whereas maximum depth is 1.8 m.

The deterioration of the sanitary condition of the water body is indicated by natural eutrophication of the pond through shoaling and overgrowing by aquatic vegetation. The latter factor reflects the specific terrestrial-aquatic stratification composed of plants of the shore part and the water body. The shore stratum is represented by water-whorl grass (*Catabrosaaguaticaᴸ.*), shortawn foxtail *(Alopecurus aequalis Sobol.),* floating sweet-grass (*Glyceria fluitans L.*) and great manna grass (*G. maxima* (*C.Hartm*) *Holmb.),* true sedges (*Carex cespitosa L*., *C.Hirta L.* and others.), purple loosestrife (*Lythrum salicaria L.*), jointleaf rush (*Juncus articulatus L.)*, arrowhead (*Sagittaria sagittifolia L.*), flowering rush (*Butomus umbellatus L.*), European water-plantain (*Alisma plantago-aguaticaL.*). Behind them there is a wall (up to 3-4 m) of wood clubrush (*Scirpus sylvaticus L.*), common reed (*Phragmites australis* Cav.), lesser bulrush (*Typha angustifolia L.*) and broadleaf cattail (*T. Latifolia L.*). Somewhat deeper, or right behind them, the free areas are occupied by aquatic plants with leaves that float on the water surface: longroot smartweed (*Persicaria amphibia L.*), common frogbit (*Hydrocharis morsus-ranae L.*), broad-leaved pondweed (*Potamogeton natans L.*), yellow water-lily (*Nuphar lutea L.*).

The park is home to a large diversity of ornithofauna. Nesting forest-park birds include great spotted woodpecker (*Dendrocopos major L.*), great tit (*Parus major*), Eurasian jay (*Garrulus glandarius L.*), common cuckoo (*Cuculus canorus L.*), thrushes (common blackbird – *Turdus merula L*., song thrush – *Turdus philomelos L.*), greenish warbler (*Phylloscopus trochiloides Sundevall*), European robin (*Erithacus rubecula L.*), nightingale (*Luscinia F.* – up to 20 individuals), common linnet (*Acanthis cannabina L.*), common starling (*Sturnus vulgaris L.*), European turtle dove (*Streptopelia turtur L.*), rock dove (Columba livia L.), rook (*Corvus frugilegus L.*), western jackdaw (*Corvus monedula L.*), woodlark (*Lullula arborea L.*), black kite (*Milvus migrans B.*), Eurasian wren (*Troglodytes troglodytes L.*), spotted flycatcher (*Muscicapa striata P.*), bluethroat (*Luscinia svecica* L.) and others. From the settlement (Blahodatne village), sparrows (house sparrow *Passer domesticus L*. and Eurasian tree sparrow *P. montanus L.*) and barn swallow (*Hirundo Rustica L.*) often fly into the park.

The territory of the park is surrounded by various agricultural lands. Not so long ago, large fields of the stepped ravine in the outskirts of Oleksandrivsky Park were used for grazing local cattle. Now, because the locals have massively abandoned maintaining of cattle, the ravine has lost its importance as pasture. The decision of the silrada gave the forbs meadow-steppe ravine the status of "land in reserve", and now it is developing according to the natural ecoevolutional laws in unison with latitudinal-caused peculiarities of self-development. We may say that the place restores naturally. At the same time, shrub vegetation tends to drive out herbaceous meadow-steppe species. As a result, rich forbs (marsh-mallow *Althaea officinalis L*., Valerian *Valeriano officinalis Kreuer*., meadowsweet *Filipendula ulmaria L. Maxim*., orchard grass *Dactylis glomerata L*., common comfrey *Symphytum officinale L*., meadow fescue *Festuca pratensis Huds*., common bent *Agrostis tenuis Sibth*., peppermint *Mentha piperita L*., common agrimony *Agrimonia eupatoria L*., white cinquefoil *Potentilla alba L*., couch grass *Elymus repens L.,* Timothy grass *Phleum pratense L*., Kentucky bluegrass *Poa pratensis L*., common chicory *Cichorium intybus L*., tufted hairgrass *Deschampsia cespitosa* and other) have been supplemented by dog rose (*Rosa canina L.),* hawthorn *Crataegus ucrainica Pojark*., forest (known commonly as "wild") pears – European pear (*Pyrus communis L.*) and European crab apple (*Malus sylvestris Mill.*), and silver birch (*Betula pendula Roth*).

Near the cultural part of the park there is the agroforestry Polishchukove of Vinoblahrolis AVOMSF. Based on this forestry of 1.8 ha and the territory of the park the forestry took control and care of the "foothold" of Vinoblahrolis AVOMSF was created with the area of 12.8 ha. Experienced foresters have created the selection breeding base. Cold frames with polyethylene covers have been built to grow grafter plants with closed root systems [root system of container-grown plants – *Translator`s note*]. On the area of 0.4 ha, Vinnytsia Oblast`s first mother plantation has been laid out, collecting the offspring of several dozens of plus trees. Out of propagules prepared in it, the genetic mother plantation of grafted trees has been created.

The work of agroforestry resulted in creating a collection of 15 thousand established species (shrubs, trees) using the cutting method. They include thujas (first of all northern white-cedar *Thuja occidentalis L.*), common box (*Buxus sempervirens L.*), terry-flowered varieties of lilac (*Syringa*–Bohdan Khmelnytsky, Iliver Deser, Taras Bulba) and mock-orange (*Philadélphus L.*). In the future, the collection will ensure that the park is in continuous bloom – from March to November. Most trees and shrubs are arranged in plantations of 3x3 m.

Agroforestry measures of the workers of Polishchukove are oriented towards protection and restoration of biodiversity in the nature-protected territories and outside them. Their actions demonstrate preservation and efficiency of use of biotic and landscape diversities combined with non-exhausting use of natural resources which is one of the main goals of contemporary nature-use, ecosafety and nature protection and the main condition of balanced development of the region.

In spite of relevance of the concept of formation of econetwork, it is important that the monument of garden design Oleksandrivsky Park plays the important role of natural center of regional importance and is included in the system of Halytsko-Slobozhansky latitudal eco-corridor. It is given a special place of border between three regional landscape parks of Vinnytsia Oblast which were established during the first decade of XXI century: Murafa (2008, area of 3452.7 ha), Serednie Pobuzhia (2009, area of 2618.2 ha), Dnister (2009, area of 5049.03 ha). At the same time, Oleksandrivsky Park is a component of the Buzko-Dnistrovsky water-divide regional eco-corridor which connects it with the Oblast`s only National Nature Park Karmeliukove Podillia.

The main tasks include improvement of effective use of the park. In the immediate future, it will be necessary to develop the territory, carry out inventory checking and reconstruction of the green plantations, first of all the self-regulated part (clearing thickets and removing self-seeding plants, planting new forms of shrubs around the pond and strengthening of the banks). In some places, the old tree stand of the phytocenosis needs new plants. Since they will develop in the conditions different from those in which they were growing during the creation of the park, they will require constant control measures for their protection by foresters responsible for the condition of the park monument.

Currently the dominating forms of nature-use within the park territory and its outskirts are: 1) recreational nature-protection ; 2) forest- and agro-park-economy; 3) water management system; 4) settlement (village) and transport or road forms. These , apart from the territorial structure, reflect the functional and organization capabilities of the territory (functional and organizational structure). Each of the types of nature-use has specific features and requires separate study approaches. In our opinion, in the contextual aspect, it is most important to, analyze as logically as possible, the territorial groups of certain types and forms of nature use using the educational ecological trail (ecotrail), the creation of which is due to its high scientific substantiality and objectivity which is combined with simplicity and practicability.

An ecological trail is defined as a path of travel, journey, recreational-health improving walks, ecological-educational excursions, etc which is geographically determined, associated with a certain locality and characteristic (specific) objects and is described with a certain amount of detail (Didukh, Ermolenko, Kryzhanivska, Popovych, Serebriakov, 2000). The advantages of nature protection and ecological education in ecopaths are: year-round use, high informativeness, involuntary learning of information and rules of behaviour directly in nature. In spite of the fact that such itineraries are developed first of all for school pupils and students, they are located near settlements or directly within their borders. Important roles in selecting the path are played by accessibility for visiting, attractiveness and esthetic expressiveness of the landscape, informational capacity of the itinerary (Hudzevych, 2012). According to purpose, ecological paths are divided into problem-educational, educational-touristic and educational-informative.

The itinerary we developed in the conditions of monument of garden design Oleksandrivsky Park of Blahodatne village has logically received its name, that is Benetto-Oleksandrivsky Surprises and may be used for any of the abovementioned purposes. Obviously it is developed to provide better perception of components, laws, phenomena and processes of the environment, help give a complex understanding of the results of impact of human communities on the environment, broaden world-view positions concerning nature use, rational organization of territory and its protection. According to the purpose, the path is poly-functional, but one of its most important tasks is to transform passive observers of naturein to conscious nature users. It is also important that it is organized within the specialized research forestry, where the guide may be an experienced specialist in forestry.

Depending on the goal of visit, various educational forms could be used: lessons, elective classes, lessons of study circles, and of course different-topic excursions. The total length of the itinerary is about 4 km. If necessary it could be shortened to 1-2 km.

To enable visitors to stay long (combining recreation and education) the park territory has all the necessary conditions. There is a functioning hotel and dining hall. As educational premises, the buildings of the Educational-Production Zone of Vinoblahrolis AVOMSF could be used. This allows the territory of the park and its surrounding to be used throughout the year.

Trekking, ski treks and sleigh rides, sport games would contribute to general health improvement and recreation of fans of places remote from settlements.

The viewing scheme of Oleksandrivky Park and its outskirts (Fig. 3) focuses on the main objects which may be used for observations and studies. Apart from the main scheme, the landmarks in the itinerary of the natural-educational trail are indicators and information boards with brief characteristics of the stopping place and view. It should be noted that most of the proposed objects are within the Park`s territory, i.e. the object of nature-reserve fund which requires the visitors to meet the nature-protection demands. The rules of behaviour in the itinerary are presented on the board near the main information stand. Moreover, they are set as separate signs along the entire educational route.

Finally, it should be noted that Oleksandrivsky Park has important nature-protection and historical-cultural significance for the entire Tomashpilsky district and is characterized by the following peculiarities: 1) it is located near the Southern Bug-Dnister water-divide and the interfluves of two rivers of the Transnistria – the Rusava and Murafa; 2) it is a territorial integrity of regional natural and historical-cultural peculiarities of park landscape; 3) is the place of the formation of the gene fund of the flora and fauna of forest-park habitat, first of all ornithofauna; 4) provides performance of several interrelated functions: nature-protection, recreational and economic; 5) belongs to a small number of parks living through their renaissance.

Conclusions. On the basis of the geoecological approach, we determined the peculiarities of organization of the nature-protection park, and adjacent territories at the current stage of functioning. Functional and organizational structures of nature use in the territory of the park reflect the most characteristic forms: a) anthropogenic nature-protection and recreational areas as the environment-forming: restoration of biodiversity with the elements of landscape design of the territory for more comfortable recreation of visitors of the park; oriented at creating and restoring the recreational potential of the park and infrastructure (organizing walking areas and recreation zones, further construction of hotels, etc); b) ecological: adaptiveness of park, and additional ecotone environments to the local nature conditions by self-sustaining processes in the context of multi-year succession changes; c) social: creating conditions for accommodation and rational nature-use; establishing the basics of new recreational and educational spaces using the ecotrail with increase in the capabilities for observation of wildlife and geoecological phenomena in the system of propagandistic-educational, excursion, research activities at different level of formal (pre-school, school, specialized secondary and higher education) and informal education of the population.

The environment of the territory of Oleksandrivsky Park (green and open areas, hydrographic network) and its surrounding require further scientific researches as an integral system according to the territorial level of planning and organization of regional econetwork. It is practical to combined the key territory with other territories which now belong to other administrative units, as a whole, including pastures, hayfields, artificial forests and other plantations, windbreaks, of the roadsides, agricultural lands, etc.

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Geotechnological Foundations of Mining Natural-Technogenic Deposits in Donbas

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Abstract. The purpose of this study is to substantiate theoretically and technologically both parameters, formation and recovery schemes to use natural-technogenic and capacity resources of the mined coal deposits with the help of a set of geo-modules providing their activation, extraction, and storage depending on seasonable irregularity of energy consumption. Methods. Complex approach has been applied to achieve the purpose. The approach involves collection, systematization, and analysis of actual data concerning filtration as well as physical and mechanical characteristics of enclosing rocks, and seam mining conditions effecting formation of natural and technogenic deposits in addition to analytical and numerical methods to solve hydrogasodynamic, heat and mass transfer equations. The models reflect thermodynamic processes of a geocirculating system performance providing both heating and conditioning of industrial facilities and civic buildings since it accumulates summer heat and winter cold within the disturbed aquifers. Numerical modeling has been applied to simulate formation dynamics and a pattern of heat resource within an aquifer located over the coal seam being burnt depending on its inclination angle, coal mining stage, and aquifuge thickness. Originality. Spatial nonstationary model of heat transfer, simulating filtration direction, velocity of underground water and its temperature while carrier pumping and extracting from an aquifer for heat and cold supply of buildings according to ambient temperature has been developed and tested. Heat transfer mechanism within the flooded rock massif in an abandoned mine, followed by periodical injection and extraction of mine water from different levels, and its heating with the help of natural geothermal heat as well as underground burning of residual coal reserves has been analyzed. Practical implications. Operation parameters of a geotechnological module for reuse of thermal resource of the flooded mine workings while extracting and injecting water from different levels for heat and cold supply of buildings have been substantiated. It has been proved (in terms of the "Novohrodivska 2" mine being during liquidation) that the thermal flow, which is formed while coal burning and heated water pumping, is quite sufficient to meet calorific requirements of a town with 15 thousand inhabitants.

Keywords: coal deposits, hydrothermal resources, thermal energy, geocirculating systems

Геотехнологічні основи розробки природно-техногенних родовищ Донбасу

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Анотація. Метою даної роботи є теоретичне і технологічне обґрунтування параметрів і схем формування та використання природно-техногенного теплового і ємнісного ресурсів відпрацьованих вугільних родовищ за допомогою комплексу геомодулів, що забезпечують їх активізацію, відбір і зберігання синхронно із сезонною нерівномірністю споживання енергоносіїв. Для досягнення поставленої мети застосований комплексний підхід, що включає збір, систематизацію та аналіз фактичних даних про фільтраційні і фізико-механічні властивості вміщуючих порід, і гірничотехнічні умови розробки пластів, що впливають на формування природно-техногенних родовищ, а також аналітичні та чисельні методи рішення рівнянь гідрогазодинаміки і тепломасопереносу. Оцінено динаміку формування і конфігурація обсягів теплового ресурсу в водоносному горизонті, що залягає над вугільним пластом, що спалюється, в залежності від кута його падіння, стадії розробки вугілля і потужності водотриву. Обгрунтовано геотехнологічний модуль, що забезпечує ефективне освоєння теплового ресурсу затопленої шахти за рахунок відбору та закачування вод різних горизонтів для тепло- і холодопостачання будівель відповідно до температури зовнішнього повітря, а також його періодичну активізацію шляхом підземного спалювання залишкових вугільних запасів. Розроблено і протестовано просторову нестаціонарну модель перенесення тепла, що відтворює напрямок фільтрації, швидкість і температуру підземних вод при нагнітанні і відборі теплоносіїв з водоносного горизонту для опалення та охолодження будинків з урахуванням температури зовнішнього повітря. Досліджено механізм теплопереносу в затопленому гірському масиві ліквідованої шахти, що супроводжується періодичним закачуванням і відбором шахтних вод різних горизонтів, а також їх нагріванням природним геотермічним теплом і підземним спалюванням залишкових запасів вугілля. Обгрунтовано параметри експлуатації геотехнологічного модуля для багатократного використання теплового ресурсу затоплених гірничих виробок шляхом відбору і закачування шахтних вод різних горизонтів для тепло- і холодопостачання будівель. На прикладі ліквідованої шахти «Новогродівська 2» доведено, що тепловий потік, який утворюється при спалюванні вугілля і відкачування нагрітих вод практично повністю покриває теплові потреби населеного пункту з 15 тисяч жителів.

Ключові слова: вугільні родовища, гідротермальні ресурси, теплова енергія, геоциркуляційні системи

Research problem statement. Significant technogenic reorganization of geological structures being mined as well as critical environmental situation is typical for old coal-mining regions. Taking into account the severe problem of energy carrier deficit, the situation signifies technological inferiority of the industry in terms of use of natural and technogenic resources concentrated within the worked-out areas (Ermakov, 2001; Gavrilenko, 2003; Falshtynskyi, 2017). Incoordination of different stages of exploration, extracting as well as scaling down of mining operations, especially in the context of coal deposits, are the main reasons of the current situation. Neither techno-economic nor geotechnical predictions of the efficient development of mine fields pay~~s~~ sufficient attention to the prerequisites concerning formation of associated commercial components and ~~a~~ collectors, the hydrothermal resource of which is considered negative at the stage of coal seam development; moreover, it is not taken into account at the stage of the mining termination.

Adequate quantitative assessment is required to determine formation conditions and a potential of technogenic hydrothermal deposits, as well as technological substantiation for integrated development of energy intensive resources of coalfields and mining enterprises during liquidation, which can satisfy current thermal requirements of the country. Thus, coordination of development stages of coal deposits on the unified theoretical foundation with characterization of geotechnological modules concerning the use of natural and technogenic energy resource and capacity properties of the worked-out rock massif and adjacent areas is both topical and strategically important theoretical and practical problem.

The paper presents theoretical and engineering substantiation of parameters as well as schemes to form and use natural-technogenic thermal and capacity resources of the worked-out coal deposits with the help of a system of geo-modules providing their activation, extraction, and storage depending on seasonable irregularity of energy consumption.

Substantiation of models for accumulation of heat carriers within aquifers. A system of underground heat accumulation is profitable if only its mining conditions and operating schedules avoid mutual effect of heat envelopes of wells; in this context, thermal losses should not be more than 25% (Dickinson, 2009; Sadovenko, 2015). Taking into consideration complex nature of physical processes and recommendations of the world theory and practice (Andersen, 1985; Inkin, 2018), the geotechnology application must be substantiated by numerical modeling of filtration and heat transfer within an aquifer used as a collector of heated and cold water.

The equation of filtration during injection and pumpout in water forced mode has the following form:

$$\frac{\partial}{\partial x}\left(Km\frac{\partial H}{\partial x}\right)+\frac{\partial}{\partial y}\left(Km\frac{\partial H}{\partial y}\right)+Q_\Sigma-\frac{K_1}{m_1}(H_1-H)-\frac{K_2}{m_2}(H-H_2)=S_s\frac{\partial H}{\partial t}, \quad (1)$$

where K and m are filtration coefficient and aquifer thickness respectively; K_1 and m_1, K_2 and m_2 are identical parameters of its roof and bottom respectively; H, H_1, and H_2 are pressures within an aquifer, in overlying and underlying aquifers, respectively; and Q_Σ is time-variant total intensity of water extraction and injection by means of wells

$$Q_\Sigma=\sum_{i=1}^{N}Q_i\delta(x-x_i,\,y-y_i),$$

where Q_i is i^{th} well capacity; x_i, and y_i are its coordinates; and S_s is compressibility of the seam.

Two-dimensional (in horizontal plane) heat migration within underground water is described by means of the equation:

$$\frac{\partial}{\partial x}\left(\lambda m\frac{\partial T}{\partial x}-\rho_w C_w v_x mT\right)-\frac{\partial}{\partial y}\left(\lambda m\frac{\partial T}{\partial y}-\rho_w C_w v_y mT\right)+$$
$$+mq_\Sigma-q_b-q_t=m[n\rho_w C_w+(1-n)\rho_{sk}C_{sk}]\frac{\partial T}{\partial t}, \quad (2)$$

where λ is heat transfer coefficient of aquifer rocks; ρ_w, ρ_{sk} are densities of water and rock matrix; T is underground water temperature; q_t and q_b are thermal flows from an aquifer to its roof and bottom; C_w, C_{sk} are specific densities of underground water and rock matrix; q_Σ is intensity of heat sources and heat sinks distributed within a seam

$$q_\Sigma = \sum_{i=1}^{N} q_i \delta(x - x_i, y - y_i),$$

where q_i is intensity of i^{th} heat source (heat sink) corresponding to a location of i^{th} well for water injection (extraction).

In the context of water injection and extraction through a well, thermal flow intensity is determined using the formula

$$q_i = C_w \rho_w Q_i \Delta T_i,$$

where $\Delta T_i = T_i - T_0$ is during water injection; $\Delta T_i = T(x_i, y_i, t) - T_0$ is during water extraction. In this context, T_i is the temperature of water being injected through i^{th} well; $T(x_i, y_i, t)$ is temperature of water being extracted from i^{th} well; and T_0 is current temperature of underground water.

Thermophysical properties of water are determined for the area of an aquifer near the well.

Thermal flows, passing through the seam roof and bottom, are determined using the formulae

$$q_t = -\frac{\lambda}{n}\frac{\partial T}{\partial z}\bigg|_{z=m}; \quad q_b = \frac{\lambda}{n}\frac{\partial T}{\partial z}\bigg|_{z=0}.$$

After dividing both parts of equation (2) by a product $nC_w\rho_w$ it is possible to proceed to the equation

$$\frac{\partial}{\partial x}\left(\frac{\lambda m}{C_w\rho_w n}\frac{\partial T}{\partial x} - \frac{v_x m}{n}T\right) - \frac{\partial}{\partial y}\left(\frac{\lambda m}{C_w\rho_w n}\frac{\partial T}{\partial y} - \frac{v_y m}{n}T\right) +$$

$$+\frac{mq_\Sigma - q_b - q_t}{C_w\rho_w n} = mR_T\frac{\partial T}{\partial t}, \quad (3)$$

where $R_T = 1 + \frac{1-n}{n}\cdot\frac{\rho_{sk}C_{sk}}{\rho_w C_w}$ is a coefficient being similar to so-called coefficient of delay in terms of mass transfer equation within underground water; and n is porosity.

Numerical model, based on equations (1) and (3) with nonstationary sources and sinks of water and heat, makes it possible to describe transient processes of heat transfer with random arrangement of several wells, various temperatures of water being injected and extracted, nonhomogeneous structure, and variable thickness of the aquifer. It is impossible to solve analytically such a boundary heat transfer problem.

Thermal balance evaluation within aquifer rocks over underground gas generator. Substantiation of rational parameters of heat energy extraction should involve the modeling of propagation of geothermal fields being formed within an aquifer in the process of coal burning.

Reasonable formulation of a boundary condition in terms of temperature at the aquifer bottom over reaction channel is of crucial importance. To determine underground water temperature, three-dimensional shallow-thickness module in a form of a parallelepiped is singled out within the share of the aquifer. The module is located directly over a heated separating seam (i.e. aquifuge) where thermal exchange is taking place (Fig. 1) (Sadovenko, 2015). Heat balance within the module is established on the basis of equality of heat amount (U_Σ) incoming the block or leaving it during time interval τ, and amount of heat consumed to warm up both underground water and rocks within the block (U_{heat}).

Changes in temperatures of water and rocks within the block can be determined with the help of a heat balance equation (Sadovenko, 2012)

$$U_\Sigma = (q_0 + q_1 - q_2 - q_3)\tau = U_{heat}T_1 - T_0) \cdot B; \quad (4)$$

and $$q_1 = AT_w; \; q_2 = A\cdot\frac{T_1 + T_0}{2}; \quad (5,6)$$

$$q_3 = D\cdot(\frac{T_1 + T_0}{2} - T_w); \quad D = \frac{\lambda\Delta x\Delta y}{\Delta z}, \quad (7, 8)$$

$$A = \Delta y\cdot\Delta z\cdot v\cdot C_w\rho_w; \quad (9)$$

$$B = \rho_w C_w V_w + \rho_{sk}C_{sk}V_{sk}; \quad (10)$$

where T_0, and T_1 are temperatures of water and rocks within a volumetric grid with $\Delta x\Delta y\Delta z$ dimensions at the beginning of time interval τ, and at its end respectively; v is filtration velocity; V_w, and V_{sk} are volumes of water and rocks within the block; q_0 is thermal flow from a reaction channel; q_1 and q_2 are convective thermal flows along the filtration flow direction; q_3 is conductive thermal flow from this block to the block located above; λ is thermal conductivity of the aquifer; ρ_w, C_w, and V_w are density, thermal capacity, and amount of water within the block; ρ_w, C_w, and V_w are density, thermal capacity, and amount of rocks within the block.

Substituting expressions (5) – (10) in (4), we obtain an equation for time temperature series

$$T_i = \grave{O}_{i-1} + \frac{q_0 - (A+D)\cdot(T_{i-1} - T_w)}{B + (A+D)\tau/2}\cdot\tau ,$$

where T_i is temperature within the volumetric grid during i^{th} averaging period.

tectonic disturbance is a fault with an amplitude of more than 9 m. Stratigraphic cross-section of coal rocks consists of several blocks (A, B, C, D), which are deposited from older to younger ones. Block D, which consists of silt shales, has a thickness from 5 to 30 m, and block C with a thickness of 30-45 m is mostly represented by sandstones, which alternate with aleurolite and clay sediments. Blocks A and B are the roof of the coal seam and are predominantly represented by aleurolite and sandstone inter layers.

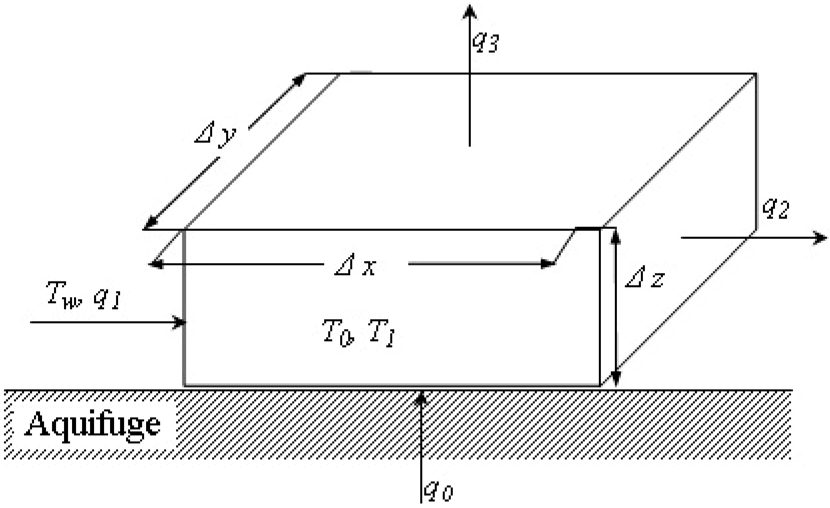

Fig. 1. Heat balance scheme within aquifer block over a reaction channel roof

Evaluating the model accuracy while epignosic problem solving. The developed parametrically modeled technique, aimed at the activation of water-saturated rock massif of the flooded mine, has been tested using the published actual data of a large-scale industrial experiment on underground coal gasification (Rocky Mountain area, the USA) (Berdan, 1993). In the context of the experiment, the effect we used was considered as a side problem.

According to recommendations, suggested in (Sadovenko, 1991, 2015; Rudakov, 2011), layout of the studied area Hanna – 1 (Berdan, 1993) with 500 x 500 m dimensions is approximated by means of a grid with 25 x 25 m pitch, and its 5-time decrease near burning modules making it possible to register accurately a pattern of thermo- and piezo-isohyps (Fig. 2).

According to the data of geological structure, filtration is considered as a multilayer stratum where average thickness of a coal seam is 10 m, average thickness of an aquifuge is 7 m, and average thickness of an aquifer is 15 m. Seam Hanna – 1was subjected to underground burning. The seam thickness is 10 m and depth of seam roof deposition is from 100 to 300 m. Coals of the seam don't heave, are bituminous, have large amounts of volatile components and coal interlayers with 40-75% ash content. Their only

An aquifer is located within the boundaries of blocks A and B, which is confined to coarse-grained sandstones, located between layers of aleurolites. Rocky Mountain, located within the area and extending from the south-east to the north-west, is a barrier for water movement; it is specified as impenetrable hydrodynamic boundary. Detailed information on feeding and discharging area of the aquifer is not available. Then, boundary conditions of the first type are defined for the remaining contour of Hanna – 1with water head values, which simulate actual hydraulic gradient of underground water (i.e. 0.006).

Burning cavities are internal boundaries of the model. The cavities are also displayed with the help of boundary conditions of the first type with a hydrodynamic head value being equal to absolute elevation of a coal seam floor. The placement of these boundaries is performed by tracing the contours of worked-out areas on the calculated layers. While modeling the operation of UCG (underground coal gasification) modules, internal boundary conditions were switched off after the blow stopped to be supplied.

Fig. 3 presents a comparison of full-scale data and simulated data concerning changes in underground water temperature in wells located near modules

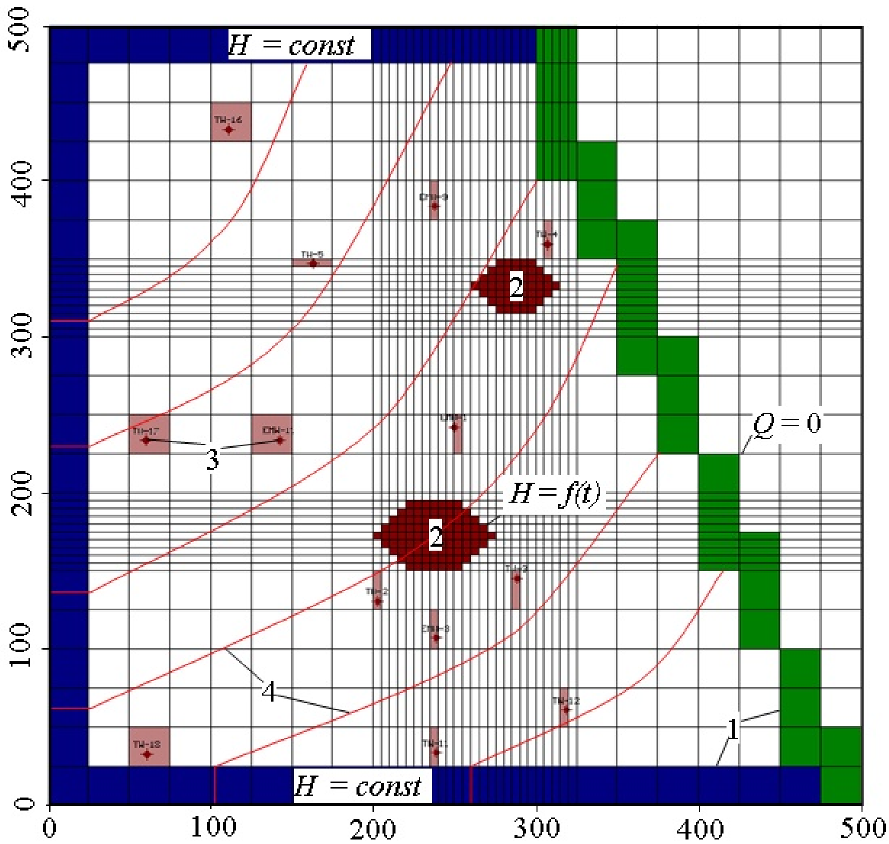

Fig. 2. Schematization of Hanna – 1 area model in terms of ModFlow software solution: 1 – hydrodynamic boundaries; 2 – IAF modules; 3 – wells; 4 – piezo-isohyps

for coal burning. Analysis of the graphs shows that maximum relative calculation error is not more than 5%, which confirms the results reliability. The data provide support for the heat transfer model adequacy, and possibility to apply it in the context of practical tasks concerning evaluation of thermal resource of aquifers in the process of underground coal seam burning.

Parameterizing the development, activation, and use of thermal potential in terms of the "Novohrodivska 2" mine being during liquidation. The mine field is geologically and structurally located within the southwestern wing of the Kalmius-Toretska hollow and is confined to the footwall of a large regional tectonic disturbance – Selidovsky thrust fault. Mid-Carboniferous sediments (C_2^6 and

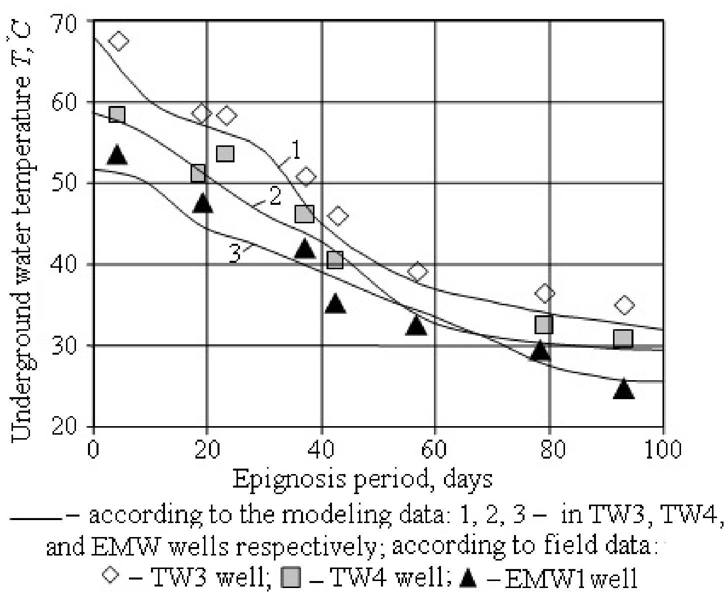

Fig. 3. Dynamics of changes in underground water temperatures within Hanna – 1 area

C_2^5), overlapped by Paleogene-Neogene sands and Quaternary loamy soils (Trigub, 1978, Sadovenko, 2019) are present in a structure of the area. Series C_2^5 contains a large amount of sandstones and a small amount of coal (Krasnopolsky, 2006) in the lower part. Coal seams and interbeds of variable thickness are concentrated in the middle part. "Novohrodivska 2" mine developed the coal seam k_8 out of the seams of series suitable for industrial development to the mark –370.3 m, with average water inflows into mine workings of 100 – 120 m^3/h and frequent water influxes from overlying sandstones and limestones. This character of groundwater inflow is caused by the presence of thick aquifers in the k_8 seam roof confined to carstified limestone L_1 and sandstones L_1sl_1 and l_1sl_3. From the side of soil, the seam was saturated from sandstones that are 5 – 10 m away from it.

Series C_2^6 within the field of the "Novohrodivska 2" mine is the most coal-saturated and contains seven coal seams and interbeds. Only the l_1 "Shestychetvertovy" seam out of these seven was industrially developed. It should be noted that water-saturated sandstone l_1sl_3, located directly in the seam l_1 caused significant water inflow (200 – 250 m^3/h) in mine workings. Balance reserves of coal are estimated at 17355 thousand tons, and industrial reserves – 12644 thousand tons, which corresponds to losses of 4711 thousand tons. Off-balance reserves of series C_2^6, mainly concentrated in seams l_4 and l_5 are estimated at 3215 thousand tons. Accounting the losses and off-balance reserves allows concluding that more than 8 million tons of coal are concentrated at the present time within the boundaries of the "Novohrodivska 2" mine during liquidation.

The low-amplitude discontinuous disturbance within the "Novohrodivska 2" mine is caused by the influence of mid-amplitude faults (Novohrodivska and Hrodivska) extending from the south-west to the south-east. A total of 15 low-amplitude discontinuities were found in k_8 and l_1 coal seams, which determined the disturbance coefficient (the ratio of a sum of products of amplitudes of discontinuities by their length to the studied area) of the mine field – 0.93 (Krasnopolsky, 2006, Trigub, 1978).

The hydrogeological conditions of the "Novohrodivska 2" mine field are closely connected to its geological structure (Trigub, 1978, Ruban, 2005). Thus, two aquifers can be pointed out to be located within deposits of Quaternary sediments that are first from the day surface. One of which is the horizon of Holocene alluvial sediments (*aH*), it is confined to modern alluvial formations and fills the valley of the Solona river and bottoms of ravines flowing into it. Its water-bearing rocks are represented by sandy silts, loamy soils, and clay sands with a thickness from the first meters to 10 m. The depth of groundwater levels varies from 0.5 to 3 – 4 m. The water content of the horizon is low, the values of filtration coefficients are usually hundredths or tenths m/day. The second aquifer horizon of Quaternary aeolian-deluvial loamy soils is developed on watershed areas and is confined to loamy soils with a thickness of 5 – 20 m, that are located on the top of an aquiclude of Pliocene–Lower Quaternary red-brown clays. This aquifer is developed almost everywhere in the northern part of the mine field. It is fed from atmospheric precipitation, and is discharged through the crossflow to the underlying Paleogene-Neogene sands and evaporation. The prevailing depth of the groundwater level varies from 10 to 20 m. Their mineralization varies from 2.5 to 6.0 g/dm^3, the hardness – 18 –50 mmol/dm^3 (Ruban, 2005, Sadovenko, 2019). The composition of water is often sulphatic, less often – chloride-hydrocarbonate-sulphatic and calcium-magnesium-sodium.

Aquifer of Paleogene-Neogene sands (P_3-N_1) is confined to fine-grained sands overlying on weathered Mid-Carboniferous sediments. Thickness of sands within the "Novohrodivska 2" mine reaches 40 m, decreasing to 0.5 – 2 m in its north-eastern part and wedging out in the south-eastern direction. In the area of basset under Cenozoic deposits of coal seams l_1 and k_8, Paleogene-Neogene sands are often completely drained. The water content of this horizon is low: well inflow rates are usually 1.5 – 2.0 m^3/h at descensions of 3 – 10 m, inflows to shafts – 5 – 6 m^3/h. The chemical composition of groundwater is often chloride-hydrocarbonate-sulfatic, less often – calcium-magnesium-sodium, their mineralization varies from 1.1 to 5.0 g/dm^3, the hardness – from 4 – 5 to 30 – 36 mmol/dm^3.

Mid-Carboniferous aquifer complex C_2 and its horizons are confined to sandstones and limestones, depositing among clay and carbonaceous shale (Krasnopolsky, 2006, Trigub, 1978). In the weathering zone, which is developed to a depth of 50 – 60 m below the surface of Carbon deposits, all lithological varieties of rocks are flooded to some degree. Sandstone thickness averages 10 – 20 m, in some cases reaching 40 – 50 m. Sandstones L_1sl_1 and l_1sl_3 are the most sustained in terms of thickness and seam strike in the considered territory. Their filtration coefficients vary widely; from $n\times10^{-4}$ to the first m/day and decrease regularly with depth. Porosity in the interval from ±0 to –400 m decreases from 20.6 to 14.5% respectively.

The chemical composition of underground water of coal deposits within depths reached by the mine is predominantly chloride or hydrocarbonate-sulphatic or calcium-sodium with mineralization from 1 to 3.5 –4.5 g/dm^3. Water is generally hard (total hardness of up to 34.4 mmol/dm^3), foaming with a large amount of solid boiler sediment when boiling. The aquifer complex is fed from the flow of groundwater from the overlying Paleogene-Neogene sands, and is less often associated with bassets of black coal rocks to the surface. In mine fields the leading role in feeding belongs to absorption of surface discharge.

Mine water of the "Novohrodivska 2" mine, as well as water of adjacent mines, was characterized by sulphatic magnesium-calcium-sodium composition and mineralization of 3.1 – 3.4 g/dm^3 during the operation period. In this case, the flooding of a significant volume of workings of k_8 and l_1 seams (around 4 million m^3) practically did not affect their chemical composition. At the present time, the mine water has mineralization of 3.3 – 3.7 g/dm^3 and contain the following basic microcomponents (mg/dm^3): lithium – 0.039 – 0.05; bromine – 0.01 – 0.022; lead – 0.017 – 0.05; manganese – 0.55 – 1.82. It should be noted that the content of almost all components does not exceed the MPC (maximum permissible concentration). After discharge to the surface and settling in the Maslovsky pond-clarifier, located in the upper reaches of the Solony stream, the mine water practically does not change its composition. However, at a distance of 100 m downstream, after the municipal wastewater from the Novohrodivka treatment plants

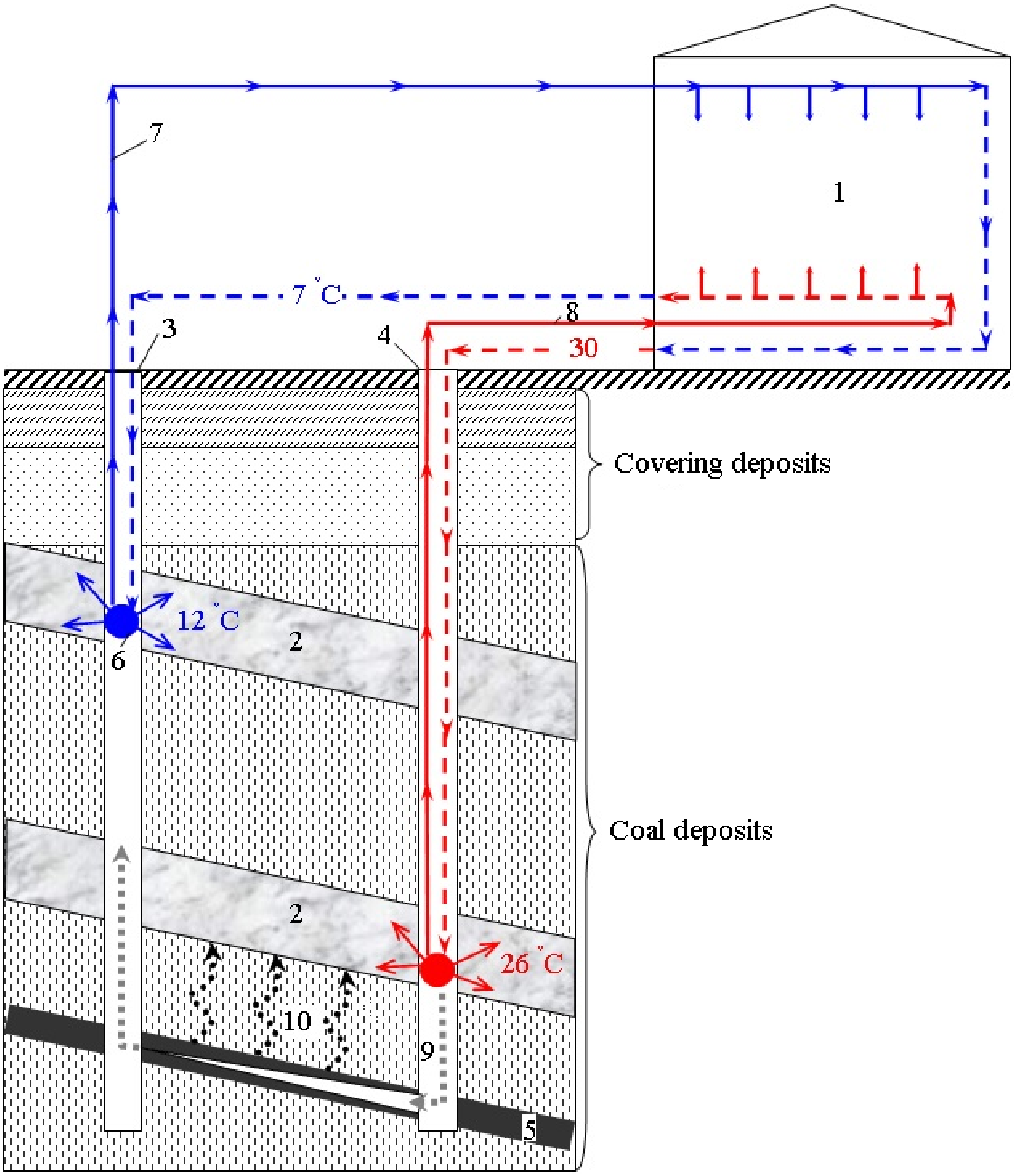

Fig. 4. Technological scheme of geomodule within the territory of "Novohrodivska 2" mine field: 1 - a building; 2 - productive stratum with the flooded mine workings; 3, and 4 – "cold well" and "warm well"; 5 - off-grade coal seam; 6 - packer; 7, and 8 - a path of mine water flow from "cold well" and "warm well"; 9, and 10 - the directions of blow (gas) flow and thermal flow while coal burning

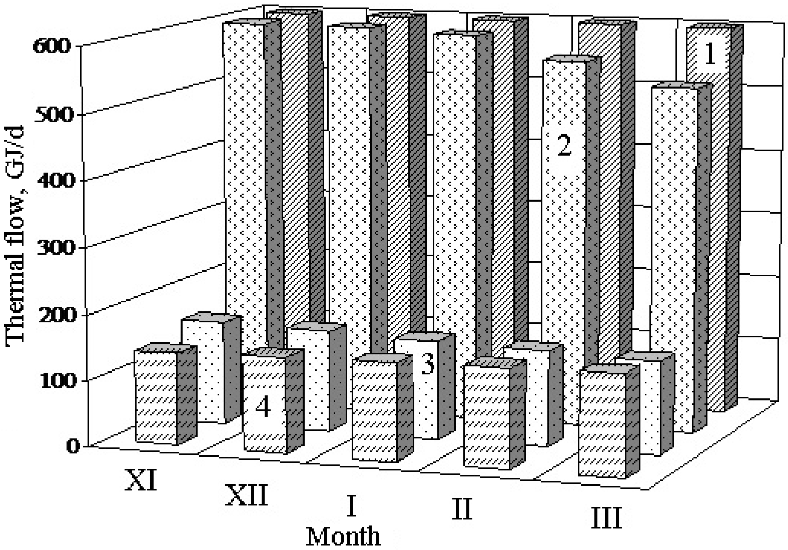

Fig. 5. Geomodule efficiency at the territory of the "Novohrodivska 2" mine: 1 – 3 - a thermal flow, required to heat up Novohrodivka town, generated by the geomodule according to the first and second technological schemes respectively; 4 - thermal capacity equivalent required by a pump to heat up buildings with the help of mine water (variant one) as a source of low-potential energy

enter the stream, water salinity and hardness in it decrease to 2.2 – 2.7 g/dm^3 and 15.0 –21.7 mmol/dm^3 respectively (Trigub, 1978, Ruban, 2005).

Preliminary calculations have helped to determine that the total amount of the thermal energy, accumulated by the water from the flooded workings of the "Novohrodivska 2" mine, is 1300 TJ (Sadovenko, 2014; Sotskov, 2017). Its use with the help of geomodule can be considered in terms of two technological variants (Fig. 4). One of them is connected with the development of natural thermal resource of a mine ("cold well"); another one is connected with its extra activation at the expense of underground burning of residual coal ("warm well") (Inkin, 2016; Falshtynskyi, 2017).

Analysis of the diagrams in the Fig. 5 explains that thermal resource, generated by the geomodule in terms of variant two, is quite sufficient to meet the thermal requirements of Novohrodivka town during its heating season. That gives a ground to consider the technological scheme as the most advanced one while using resources of the "Novohrodivska 2" mine being during liquidation. If the geomodule operates in terms of variant one, when mine water is used as low-potential energy in thermal pumps, the energy, consumed by them to heat up buildings, is 150 GJ/day. It is four times less than that of the required thermal flow. Efficiency of the first technological scheme may be improved through replacing expensive thermal pumps by such heating solutions as heat-insulated floor system.

Conclusions. Long-term coal mining as well as mine liquidation in Ukraine has resulted in the formation of natural and technogenic environment in the territories of coal-mining regions; the environment contains substantial reserves of energy resources in a form of residual coal and off-grade coal, warm mine water as well as warm underground water. The disturbed rock massif involves significant capacity resource capable of accumulating heat carriers in the amounts sufficient to smooth up seasonable irregularity of energy consumption.

The developed models of filtration and heat transfer within water-saturated rocks are the key tools of the research. The models reflect thermodynamic processes of geocirculating system performance providing both heating and conditioning of industrial facilities and civic buildings since it accumulates summer heat and winter cold within the disturbed aquifers.

Numerical modeling has been applied to simulate formation dynamics and a pattern of heat resource within an aquifer located over the coal seam being burnt depending on its inclination angle, coal mining stage, and aquifuge thickness. The model has been identified basing on epignosis simulation of industrial experiment concerning underground coal burning in the context of Rocky Mountain deposit (the USA). Relative calculation error does not exceed 5%.

Geo-technical module, providing the efficient development of a thermal resource of the flooded mine has been substantiated. It operates due to extraction and injection of water from different levels for heat and cold supply of buildings depending on ambient temperature with its periodical activation by means of underground burning of residual coal. It has been proved in terms of the Donbas "Novohrodivska 2" mine being under during liquidation that a thermal flow of 500-580 GJ/day formed while coal burning and heated water pumping out is quite sufficient to meet calorific requirements of a town with 15 thousand inhabitants.

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Positional-dynamic territorial structure of the urban landscape

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Abstract. The knowledge of landscapes' positional - dynamic structure enabled us to include it in the work on urban landscape and ecological planning, with its own specifics as environmental management objects. *The aim* is to create cartographic models of a positional-dynamic territorial structure of Kharkiv landscape to ensure a balanced use of nature in environmental management. *Methods:* a positional-dynamic structure of urban landscape was selected by compiling and analyzing cartographic works of landscape strips, tiers and districts. Territorial configuration of different types of landscape strips were identified and established based on the classical scheme of landscape locations typology by water-geochemical regime proposed by B. Polynov and supplemented by M. Glazovska, which includes 9 main types. Technically, synthesis of parameters combinations and determination of the territories affiliation to certain types of landscape strips was carried out using spatial analysis tools (in particular, reclassification and raster calculator) of initial data on morphometric relief parameters in ArcGIS. *Results*. A set of qualitative parameters is proposed, based on the characteristics of each type of landscape strips by which they can be identified.Composition and territorial configuration of positional-dynamic landscape strips of the urban landscape are established as a result of systematization and processing of geodata parametric features of the water-geochemical regime. Cartographic models of the positional-dynamic structure of Kharkiv landscapes have been developed, including 13 types of landscape strips with individual features united in 5 groups by types of lateral migration of substances due to the peculiarities of their positionality (common position in relation to frame lines of flow directions) and factors of relief morphology similarity, nature of income and intensity of substances transfer. The identified mode types and the nature of the spatial distribution of the corresponding landscape strips have been described in detail. *Conclusions.* Cartographic models of the positional-dynamic territorial structure of Kharkiv, developed during the inventory stage of landscape-ecological planning, make it possible to choose areas of balanced nature management of a particular area.

Keywords: positional-dynamic structure, landscape-ecological planning, nature management, environmental management, cartographic model, urban landscape

Позиційно-динамічна територіальна структура міського ландшафту

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Анотація. Використання знань позиційно-динамічного устрою ландшафтів в процесі їх територіального планування дало поштовх до їх включення до складу робіт із ландшафтно-екологічного планування територій міських ландшафтів, що мають власну специфіку як об'єкти інвайронментального менеджменту. Мета – створення картографічних моделей позиційно-динамічної територіальної структури ландшафту м. Харків для забезпечення збалансованого природокористування в інвайронментальному менеджменті. Виділення позиційно-динамічної структури міського ландшафту відбувалось шляхом укладання та аналізу картографічних творів ландшафтних смуг, ярусів та районів. Ідентифікація та встановлення територіальної конфігурації різних типів ландшафтних смуг спирались на класичну схему типології місцеположень ландшафту за водно-геохімічним режимом запропоновану Б. Полиновим та доповнену М. Глазовською, що включає 9 основних типів. Технічно операція синтезу комбінацій параметрів та визначення приналежності територій певним типам ландшафтних смуг здійснювалась за допомогою інструментів просторового аналізу (зокрема, рекласифікації та калькулятора растрів) вихідних даних щодо морфометричних параметрів рельєфу у середовищі ArcGIS. На основі характерних ознак кожного з типів ландшафтних смуг запропонована сукупність якісних параметрів, за якими вони можуть бути ідентифіковані. В результаті систематизації та обробки геоданих параметричних ознак водно-геохімічного режиму встановлено склад та територіальну конфігурацію позиційно-динамічних ландшафтних смуг міського ландшафту. Розроблено картографічні моделі позиційно-динамічної структури ландшафтів м. Харків, яка включає 13 видів ландшафтних смуг із індивідуальними рисами, що об'єднані у 5 груп за типами режиму латеральної міграції речовини зумовленими особливостями їх позиційності (спільного положення по відношенню до каркасних ліній зміни напрямків потоків) та факторами подібності морфології рельєфу, характеру надходження та інтенсивності переносу речовин. Зроблено детальну характеристику виявлених типів режимів та характеру просторового поширення відповідних ним різновидів ландшафтних смуг. Картографічні моделі позиційно-динамічної територіальної структури м. Харків, розроблені під час реалізації інвентаризаційного етапу ландшафтно-екологічного планування дають можливість обрати напрями збалансованого природокористування в інвайронментальному менеджменті конкретної території.

Ключові слова: позиційно-динамічна структура, ландшафтно-екологічне планування, природокористування, інвайронментальний менеджмент, картографічна модель, міський ландшафт

Introduction. Theoretical foundations of the positional-dynamic structure of the landscape were first formulated by a team of Ukrainian scientists for the needs of rational agriculture (Shvebs & Shyshchenko, 1990), (Hrodzynskyi & Shyshchenko, 1993). Subsequently, the main provisions generalized and involved in the study of territorial configurations of landscapes in the monograph (Hrodzynskyi, 2005), were found in the study of self-organization of fluvial relief in the monograph (Kostrikov & Chervanyov, 2010). Some fundamental provisions were included in the professional educational publications of the higher school of Ukraine (Hrodzynskyi, 2014). There is also experience in establishing regional aspects and local features of the positional-dynamic structure of landscapes in different regions of Ukraine, using GIS (Kostrikov & Maksymenko, 2010; Karpets, 2015; Vlasova, 2013; Udovychenko, 2016a; Udovychenko, 2016b).

In general, the knowledge of landscapes' positional-dynamic structure in the process of their spatial planning gave an impetus to their inclusion in the work on landscape and ecological planning of urban landscapes. The last ones have their own specifics as objects of environmental management (Maksymenko & Klieshch, 2017; Maksymenko 2018). During the inventory stage of landscape-ecological planning of city landscapes it is difficult to isolate natural or anthropogenic factors in territory formation. Quite often the existing appearance of the day surface of certain areas looks quite natural, but it is the result of long-term transformation (backfilling of gorges, ravines, hills leveling, cutting of slopes, etc.). At the same time, during the construction, reconstruction or redevelopment of the territory it is necessary to have reliable information about the positional and dynamic structure of the landscape. As we have noted earlier (Klieshch, Maksymenko, & Ponomarenko, 2017), there is a direct dependence on the conditions of territory formation and balance of natural and anthropogenic factors in the territorial structure of nature management in Kharkiv. Therefore, it is advisable to use cartographic and descriptive information about the positional and dynamic structure of urban landscapes for the needs of environmental management. This is what this work is dedicated to.

The aim of the study is to create cartographic models of the positional-dynamic territorial structure of Kharkiv's landscape to ensure a balanced use of nature in environmental management.

Materials and methods of research. The positional-dynamic structure of the urban landscape was selected through compilation and analysis of cartographic works of landscape strips, tiers and districts.

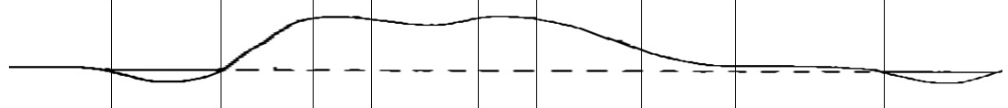
The smallest indivisible unit of a positional-dynamic territorial structure of the landscape is the ***landscape strip***, defined as the territory of the topical or choric level of 10^2-10^8 m. It is characterized by homogeneity of composition parameters, flow intensity and direction of horizontal flows in the landscape. Such processes are surface runoff, lateral geochemical migration and internal soil runoff.

These conditions are largely dependent on the following factors: morphometric parameters of the terrain, particle size distribution of the soil and their parent geological sediments. In the conditions of urban landscape, the establishment of the spatial structure and classification of urbogenic soils is a separate complex scientific task. For Kharkiv, it still remains unresolved. Therefore, the use of data on soil cover as one of the identifiers of landscape strips is considered a desirable but, in fact, unattainable requirement.

Identification and establishment of the territorial configuration of different types of landscape strips were based on the classical scheme of landscape locations' typology by water-geochemical regime, proposed by B. Polynov and supplemented by M. Glazovskaya (Glazovskaya, 2002), which includes 9 main types. A set of qualitative parameters is proposed, based on the characteristics of each type of landscape strips, by which they can be identified (Table 1).

The criterion for assigning the territory to a particular type of landscape strips is full compliance of its features with the whole combination of parameters of a certain type. In case when the areas with specifically combined groups of different parameters are established and regularly repeated, it is permissible to allocate intermediate "hybrid" types.

Table 1. Criteria for selection types of landscape strips by water-geochemical regime

The main types of landscape strips	Superaqual	Aqual	Transeluvial	Eluvial	Accumutive-eluvial	Eluvial	Transeluvial	Transeluvial accumulative	Trans-superaqual	Transaqual
Index	Saq	Aq	Tr-El	El	Ac-El	El	Tr-El	Tr-Ac	Tr-Saq	Tr-Aq
Profile / Parameters										
Hypsometric level	L	L	H	H	H	H	H	H	L	L
Surface slope	F	F	SSS	F	SS	F	SSS	SS	F	F
Surface curvature	F	CC	CS	F	CC	F	CS	CC	F	CC
Water table	CO	CO	D	D	D	D	D	CO	CO	CO
Incoming substances	A, C	P	B	A	A,B	A	B	B, C	A, C	P

Symbols: *Hypsometric level:* L - lowland, H - high; *Surface steepness* - F - flat or slightly inclined surface, SS – sloping surface, SSS – sloping or steeping surface; *Surface curvature* - F - flat surface, CC - concave surface, CS - convex surface; *Water table* - CO - close occurrence, D - deep occurrence; *Source of substances introduction:* A - mainly atmospheric, B - planar runoff, C - groundwater, P - surface water.

Technically, parameters were combined and territories' affiliation to certain types of landscape strips was determined by spatial analysis tools (in particular, reclassification and raster calculator) of initial data on morphometric relief parameters in ArcGIS.

Landscape strips, adjacent and similar in nature processes, interconnected by unidirectional substances horizontal flows, the intensity of which naturally decreases or increases, have been grouped into ***landscape tiers***. Typically, within a positional-dynamic area tiers occupy a certain range of heights and mostly combine landscape strips of the same type.

Positional-dynamic zoning of the studied area was implemented by comparing the obtained cartographic work of landscapes and strips of tiers with data on the direction of surface runoff. The units of positional-dynamic zoning are actually districts and positional-dynamic formations.

A positional-dynamic region is distinguished as a union of landscape tiers, within which the process of scattering (divergence) of horizontal flows begins with the hypsometrically highest watershed line of the upper tier. It is limited to channel watercourses of 4^{th} order and above. The study consideres positional-dynamic formations of two types as positionally dynamic regions: type 1 – its boundaries are represented by 2 channels, type 2 – its boundaries are from two or more channels of different orders that can be tributaries.

Subdistricts are determined within the district, depending on the macroexposure of the surface slope. Macroexposure means the exposure of the total slope of the catenary from the watershed to the main line of runoff concentration within the area. It should be noted separately that subdistricts are not elementary positional-dynamic formations. They only unite polycatenar positional-dynamic formations composed of landscape strips of different types. Structure elements of positional-dynamic formations, delineated by watercourses of different orders (from 1 to 5 orders of magnitude), were distinguished to reflect the specifics of streams scattering from the lines of local watersheds as additional units.

Results and their analysis. Composition and territorial configuration of position-dynamic landscape strips of the urban landscape are established as a result of systematization and processing of geodata parametric features of the water-geochemical regime (Fig. 1). Totally, 13 types of landscape strips with individual features were identified, united into 5 groups according to the types of lateral substances migration. This was done due to the peculiarities of their positionality (common position relative to the frame lines of flow directions) and similarities of landscape morphology, flow and transfer intensity of substances (Table 2). The identified regime types and the nature of the spatial distribution of the corresponding types of landscape strips are briefly characterized**.**

Landscape strips of the eluvial regime occupy the upper positions of subhorizontal and very slightly sloping plains with a deep level of groundwater (more than 5 m, different thickness). Predominant aerial supply of substances (with precipitation, dust, etc.) is common to this group. Introduction of the substance by surface runoff from adjacent landscape strips is

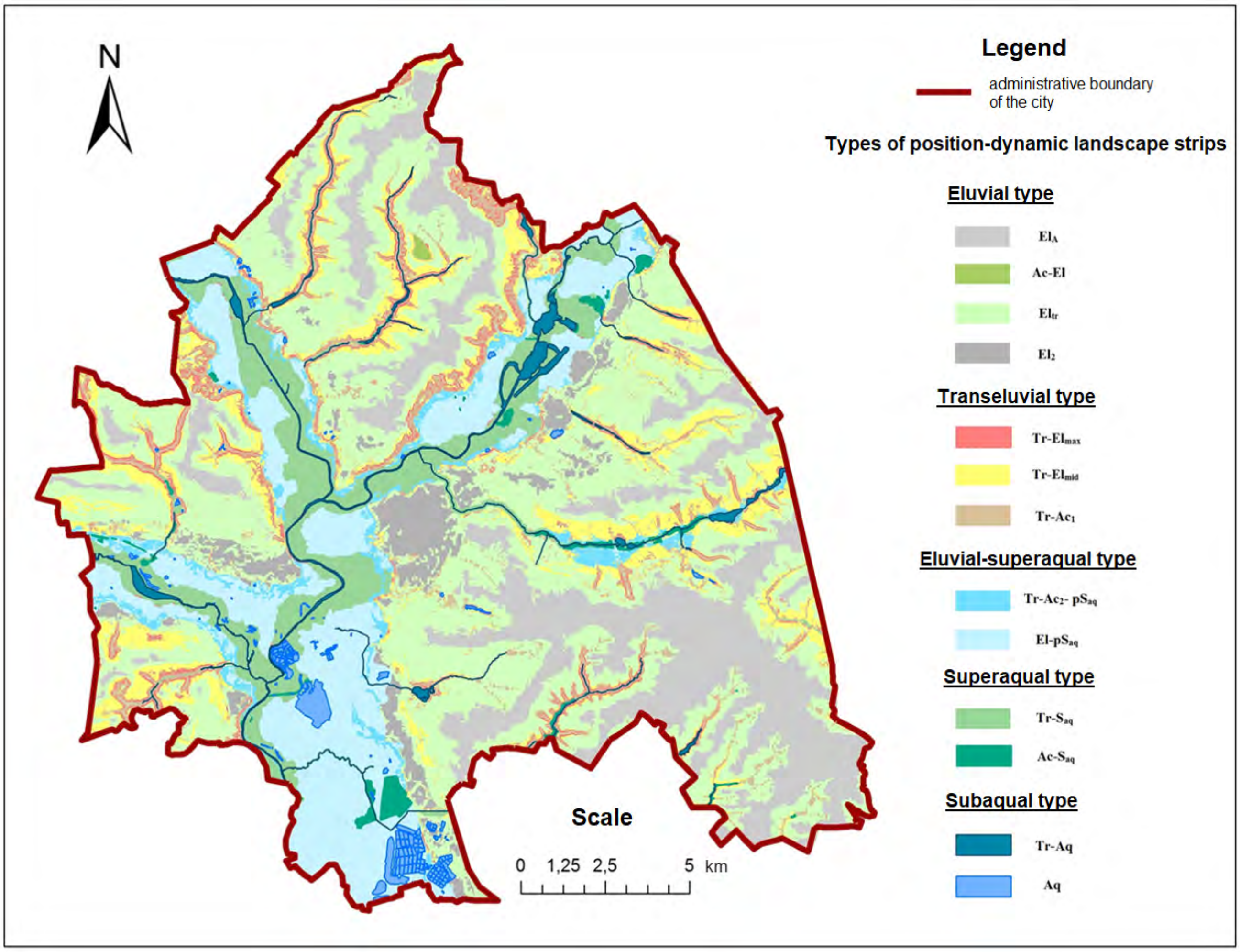


Fig. 1. Territorial structure of positional-dynamic strips of the urban landscape of Kharkiv

either absent or insignificant. In natural analogues of landscape strips of the eluvial regime substances are removed mainly in the vertical direction. Its inhibition is facilitated by the biological uptake of compounds and elements by plants and their retention in the biological cycle. However, in urban landscapes of eluvial regime, such a process of substances removal can be hindered by changes in the nature of the landscape: a significant proportion of waterproof surfaces (asphalting, high density of building foundations), presence of a canalized drainage system and reduction of areas occupied by plants. This leads to the formation of zonal landscapes different from the natural water regime.

Typical examples of "urban" transformations of the water-geochemical regime and their consequences of eluvial landscape strips within Kharkiv are:

formation of anthropogenic zones of deceleration and partial accumulation (road embankments, etc.) and increased transit of surface runoff (areas of artificial waterproof coverings, rainwater drainage) can lead to the formation of a wide range of variations in surface runoff formation conditions and geochemical migration of substances;

reduction of the vertical capacity of the leaching zone in the profile of urban eluvial landscape strips, which is potentially able to cause the accumulation of water-soluble compounds and relatively easily mobile elements in the upper soil horizons.

This group of landscape strips within the city of Kharkiv is represented by 4 types: autonomous-eluvial (El_A), accumulative-eluvial (Ac-El), eluvial secondary (El_2) and low-intensity transeluvial (El_{tr}) within which lateral transport of substances has typical differences.

The most typical for this regime are autonomous-eluvial landscape strips (El_A), which occupy large areas within the city (17.62%) and are confined to flat and slightly convex areas of watersheds and watershed plains with a surface slope of 0 to 1^0 and deep groundwater occurrence. Two subtypes can be distinguished with a certain conditionality within this type of landscape strips:

• full autonomous eluvial areas themselves, located on the most elevated positions, with undivided plains;

Table 2. Types of positional-dynamic landscape strips in urban landscape of Kharkiv

Index	Type of landscape strips	Combination of parameters of identificational features	General characteristics of transfer processes
Eluvial regime			
El_A	Autonomous-eluvial	Flat, subhorizontal (0-1^0) watershed plains, upper altitude positions	Removed substances with solid and liquid runoff
Ac-El	Accumulative-eluvial	Closed depressions, upper altitudes	Acculumation
El_{tr}	Transeluvial low intensive	Straight and slightly convex declivous slopes (1-3^0)	Weakly intensive transit, partial accumulation
El_2	Eluvial secondary of weak transit	Flat, sub-horizontal plains of alluvial terraces (0-1^0)	Weak transit, weak transit intensity
Transeluvial regime			
$Tr\text{-}El_{max}$	Transeluvial highly intense	Convex steep slopes (15-40^0)	Highly intensive transit
$Tr\text{-}El_{mid}$	Transeluvial moderately intense	Slightly convex slopes (5-15^0)	Intensive transit
$Tr\text{-}Ac_1$	Trans-accumulative slopes of erosional forms	Concave parts of steep slopes and open concave bottoms of erosion forms	Combined, accumulation and transit
Eluvial-superaqual regime			
$Tr\text{-}Ac_2$-pSaq	Transaccumulative base of slopes of valleys and cones of erosion forms	Sloping (1-3^0) footsteps of steep and sloping valley slopes, in places - cones of ravine-depth systems removal	Combined, accumulation and transit
El-pSaq	Eluvial-superaqual	Small hilly, shallow and leveled subhorizontal plains of the second (pine) floodplain terrace	Weakly intensive transit, accumulation
Superaqual regime			
Tr-Saq	Transsuperaqual	Flat subhorizontal plains, the lowest	Accumulation, weakly intensive transit
Ac-Saq	Accumulative-superaqual	Wetlands or floodplains	Accumulation
Subaqual regime			
Tr-Aq	Transaqual	Watercourses with active channel runoff	Accumulation of channel transit
Aq	Aqual	Lakes and drainless reservoirs	Accumulation

• eluvial areas of somewhat lesser degree of autonomy, located within the hypsometric ranges below the eluvial areas of complete autonomy. They are fragments of watershed plains "cut" by erosive landforms formed at the place of leveled ancient river terraces.

Accumulative-eluvial landscape strips (Ac-El) are represented by closed well-drained cavities in the relief, occupying elevated positions within the watershed plains. Substances introduced with atmospheric precipitation have the ability to accumulate, mobile water-soluble compounds usually have a tendency to radial removal. This type of landscape strips is not widespread within the city (less than 1%) and covers an area of 0.28 km^2. In total, 5 contours of this type have been installed, the largest of which is located within the catchment area of the Sarzhynka River with boundaries between Batumska street and Nova Pomerchanska street (Shevchenko district).

Eluvial secondary landscape strips (El_2) are well-drained plains or aligned subhorizontal (0-1^0) flat plains of alluvial younger terraces. Their share in the positional and dynamic structure of the urban landscape of Kharkiv is 4.04%.

The fact that this type of landscape strips is distinguished separately is explained by regime nature that differes from the autonomous-eluvial landscape strips. This uniqueness is due to the specificity of their location on the hypsometrically lower terraces of mostly Quaternary period, separated from the autonomous eluvial strips by landscape strips with more expressed lateral transit (transeluvial strips of varying intensity). Thus, the presence of this type of landscape strips in the structure of positional-dynamic areas indicates their stepped nature of the transverse profile of the tier that unites them.

This type of landscape strips has a specific nature of spatial distribution within the catchment areas of different rivers and certain positional variations in relation to landscape strips of other types. The territorial configuration of landscape strips of this type is diverse: it is represented by elongated liniments of different widths and spots of different sizes. The following hypsometric patterns can be noted in the nature of distribution:

• within the predominantly eastern part of the city, which corresponds to the left-bank parts of the catchment basins of the Kharkiv, Lopan and Uda rivers, successively flowing into each other, eluvial secondary landscape strips are mainly distributed on the sites of Pryluky-Udy terraces (typical altitude range 110-116 m), individual strips are found within the older terraces.

• in the catchment area of the Uda river before the confluence with the Lopan river. This type of landscape strips is found mainly on the higher positions of the Kaidat-Tyasmin terrace (113-128 m) on both bank of the valley.

• within the valley of the Lopan river to the place where the Kharkiv river flows into it, the distribution of secondary eluvial landscape strips is limited and occurs in small spotted areas, corresponding to separate subhorizontal sections of the Lubny-Tiligul, single-Kaidat-Tyasmin terraces.

Thus, we can conclude that determining the specifics of the landscape strips regime of eluvial-secondary type is characterized by some variability. To understand possible effects of processes other than eluvial, clarification is needed for each landscape strip, depending on its location and proximity to other types of landscapes.

Transeluvial low-intensity landscape strips (El_{tr}) are the most common in the positional-dynamic structure of the urban landscape of Kharkiv (33.54%) and correspond to straight and slightly convex slopes ($1\text{-}3^0$) of the watershed plains. With a certain degree of conventionality, they can be called an ecotonic type of landscape strips. Within these strips against the background of the predominant eluvial regime, the processes of weak lateral removal and accumulation of substances intensify. In cases when these landscape strips are under the active influence of removal from adjacent, located at higher positions of transeluvial moderate-intensity landscape strips, they significantly increase their role as areas of partial accumulation.

The group of transeluvial landscape strips incorporates slope locations with a combined supply of elements from the atmosphere and with a lateral inflow of substances from the eluvial landscape bands. Eluvial removal of substances is combined with the processes of transit and accumulation as to the profile.

In terms of composition and intensity of the prevailing processes, the landscape strips of the transeluvial regime are very heterogeneous. Thus, we can distinguish two types of transeluvial landscape strips that differ in genesis: slopes of erosive forms and valley river slopes. Based on the identified distinctive features determining the degree of intensity of lateral migrations and probable exogeodynamic processes, landscape strips of both types are divided into 3 types:

• transeluvial moderate-intensity strips ($Tr\text{-}El_{mid}$) correspond to straight and convex sloping (50-150) in upper and middle parts of the slopes. They occupy 11.86% of the administrative territory of the city, being marked by the potential danger of linear and soil erosion;

• transeluvial high-intensity strips ($Tr\text{-}El_{max}$) are represented by convex steep sections of slopes (150-400), occupying the upper and middle parts. These are areas of intensive transit of substances with a high risk of erosion and abrasive processes, soil erosion. They are distributed on 2.29% of the city;

• transaccumulative strips of lateral slopes of erosional forms ($Tr\text{-}Ac_1$) with expressed processes of runoff products accumulation and significant dependence on transeluvial strips of moderate and high intensity. They are distributed in the lower concave parts of the slopes and open gently concave bottoms of catchment areas in the upper reaches of erosive forms (valley gorges and ravines), occupying 2.63% of the territory.

The strips of the eluvial-superaqual regime found within the urban landscape are widespread in the territories that almost completely coincide with the contours of the territories of the Vitachiv-Bug (pine) terraces, occupying low-altitude positions with a shallow groundwater level (from 0 to 3 m, thickness 15-18 m).

The strips of this type have a hybrid regime of lateral migration, which combines the features of eluvial, transaccumulative and transsuperaqual regimes. Its nature is determined by the cyclical mechanisms of their development.This defines this regime as post-superaqual, functioning in conditions when there is a significant connection with groundwater, which gradually loses its strength in the upper soil horizons and only in the wettest years acquires the signs of superaqual regime.

Eluvial-superaqual (El-pSaq) strips are the main type of landscape strips within this regime, occupying a large area. Their area corresponds to 13.15% of the city. They can be described as lowland leveled and small hilly subhorizontal surfaces with a low level of groundwater, which is mostly beyond the reach of the root layer of soils with a high capacity for infiltration and radial removal of surface runoff. One of the unfavorable processes that can intensify within them is the dispersal of sod sandy loam and sandy underdeveloped soils.

Sloping (1-3°) "plumes" at the foot of a valley are not so widely spread (2.67%) in transaccumulative landscape strips (Tr-Ac_2-pSaq). In some places there are removal cones of ravine-gorge systems, in which removal products accumulate from transeluvial landscape strips in combination with probable periodic participation of groundwater in the processes of substances accumulation.

The superaqual regime of landscape strips is determined by close groundwater, the capillary border which reaches the root layer of the soil from one side, and incoming substances both from the atmosphere and from landscape strips of eluvial type. This creates favorable conditions for excess content relative to moving elements and water-soluble compounds.

Actual superaqual landscape strips associated with stagnant or low-flowing water of lakes and drainless reservoirs have not been mapped, as most of them are in the area of transsuperaqual-type landscapes. To determine the configuration of these strips for other landscape strips of this type it is necessary to do additional research of groundwater occurrence and the degree of humidity of the adjacent areas.

The trans-superaqual landscape strips (Tr-Saq) distribution covering 9.00% of the city area, coincides with the contour of floodplain areas. They occupy mainly lowland areas of flat plains, in places complicated by the remnants of channel banks and shallow depressions, influenced by running water with active water exchange.

Accumulative-superaqual landscape strips (Ac-Saq) of wet or swampy hydromorphic areas with a non-diurnal surface of the capillary border of groundwater occupy 0.74% of the territory, a significant part of which is of anthropogenic origin.

The final link in the accumulation of substances within river basins are landscape strips of the subaquatic regime, which, in addition to transit, are characterized by the accumulation of solid alluvions in bottom sediments,transforming into sapropel - organo-mineral deposits with high bitumen content.

Transaqual landscape strips (Tr-Aq) occupy 1.25% of the city's territory and represent the riverbeds of the Uda, Lopan, Kharkiv, Nemyshlya and other channel watercourses. Purely aqua landscape strips (Aq) are represented by numerous small in area (together occupying 1.13%) wastewater bodies of mostly anthropogenic origin (Osnovyansk quarry, settling tanks and aeration tanks of Dykanka and Bezlyudovka sewage treatment plants, etc.). Integrating landscape strips with the same or similar in composition, direction and intensity regimes of lateral migration made it possible to distinguish 4 landscape tiers: eluvial (1), transeluvial (2), eluvial-superaqual (3) and transsuperaqual (4) (Fig.2).

In these tiers of a positional-dynamic structure we notice the subordinative regularity of influence on each other that allows us to typologize them as follows:

- The autonomous tier combines landscape strips of the eluvial regime, which receive an influx of substances mainly from the atmosphere. Lateral movement of liquid runoff is inhibited by active radial removal, surface movement of solid runoff products is insignificant and is carried out slowly in the direction of sloping landscape strips by defluxation. Soil washout and erosion are unlikely.
- The tier of transit nature of landscape strips is represented by landscape strips of different types of regimes: both transeluvial and transsuperaqual and transaqual, etc., the location of which varies in a fairly wide range of heights. An integral feature of landscape strips within a given tier is their transit features, which determine the general trend for the movement of liquid runoff due to the significant slope of the relief surface within them. It is characterized by active processes of linear erosion, soil washout, in some places – accumulation of solid debris runoff, abrasion, landslides and suffusion.
- Tiers of accumulative nature occupy low-lying positions, as a result of what groundwater constantly or periodically participates in their functioning and there is an inflow from autonomous and transit tiers. Within these tiers, landscape strips of eluvial-superaqual, transsuperaqual, and subaquatic regimes are widespread. Potential processes within these tiers are the dispersal of soils and loose sands (mainly for eluvial-superaqual), salinization of the soil layer (including soda) and contamination by inorganic and organic pollutants.

Positional-dynamic zoning of the urban landscape of Kharkiv city allows to reveal the territorial configuration and internal structure of 4 districts: Mzha–Uda, Uda–Lopan, Lopan–Kharkiv and Kharkiv–Velykobabchansk (Fig. 3).

Mzha–Uda position-dynamic district is located in the north-western part of the city and is the smallest in terms of territorial distribution (5.5% of the total area). The Uda riverbed is the boundary of the district on the territory of the city. The district consists of 2

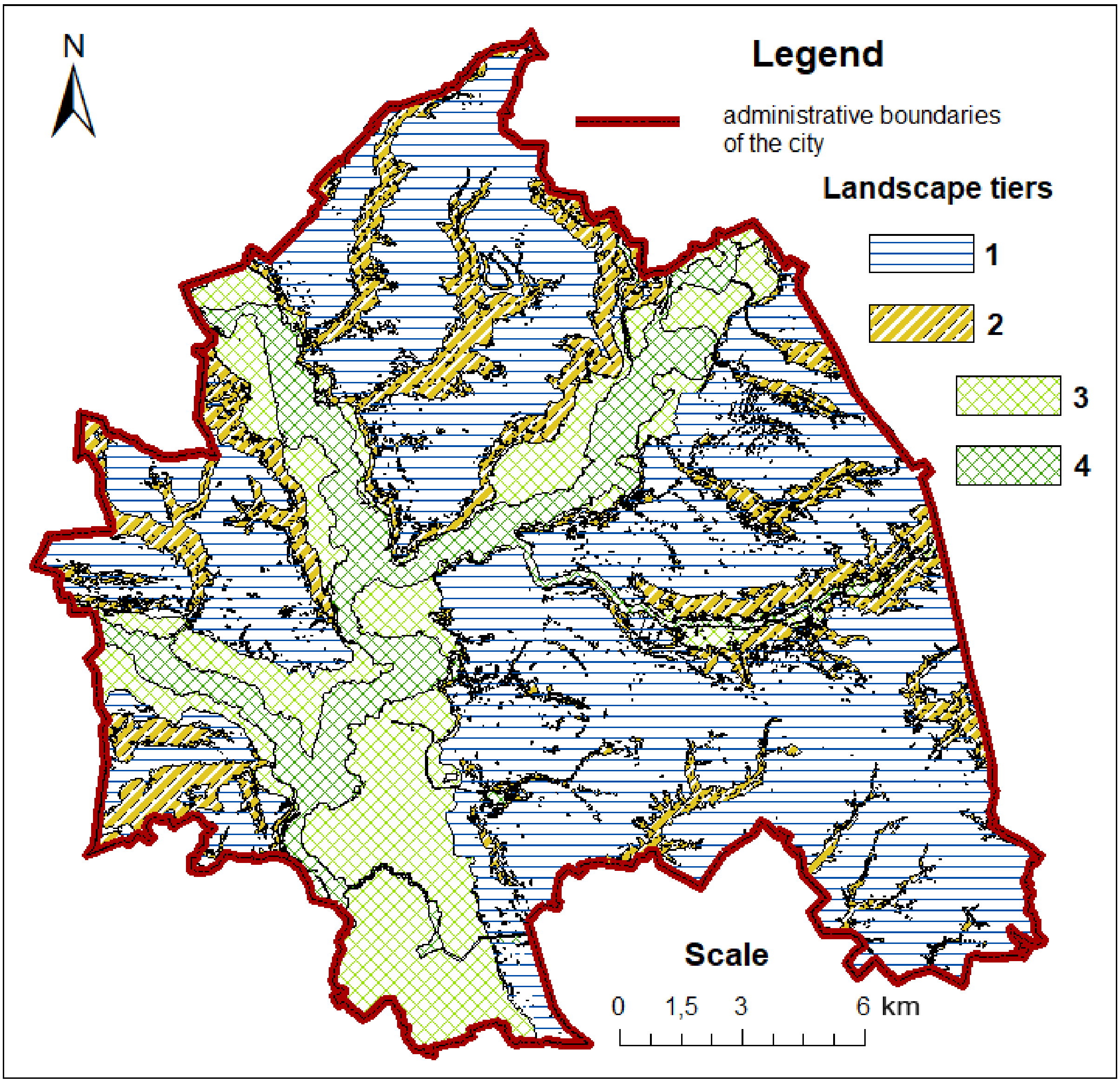


Fig. 2. Tiers of the positional-dynamic structure of the urban landscape of Kharkiv
(1 - eluvial, 2 - transeluvial, 3 - eluvial-superaqual,4 - transsuperaqual)

subdistricts of northern and eastern macroexposure with almost equal areas within the city.

The most common tiers of the district are eluvial and transeluvial (Fig. 4), accounting for 36% and 34%, respectively. Landscape strips of the eluvial-superaqual tier occupy 19%, superaqual – 11%.

Uda–Lopan positional-dynamic area covers the western part of the city. It occupies 14.4% of the city area. The boundaries of the district are the Uda and Lopan riverbeds, their shape resembles a slice. The area in the meridional direction is divided into subdistricts of southern and northeastern macroexposure with a close area.

Within the district, the largest areas are occupied by eluvial landscape strips (40%). Transeluvial, eluvial-superaqual and superaqual tiers occupy 19.8%, 21.6% and 18.38%, respectively.

Lopan-Kharkiv positional-dynamic district is located in the northern part of the city,covering 22.5% of its territory. The area is bounded by the riverbeds of the Lopan and Kharkiv rivers, merging at an acute angle, determining its wedge-shaped shape. Two thirds of the district belongs to the sub-region of the south-western macroexposure. The rest of the district belongs to the subregion of the southern macroexposure with a high degree of erosional dismemberment, most of the erosional forms of which “open” in the south-eastern direction. More than a half of the district area belongs to the eluvial tier (56.5%), about a quarter is occupied by the transeluvial tier (25.4%), the rest of the territory belongs to the eluvial-superaqual (11.3%) and superaqual tiers (6.8%).

Kharkiv-Velykobabchansk position-dynamic district is the largest district (57.6%), located in

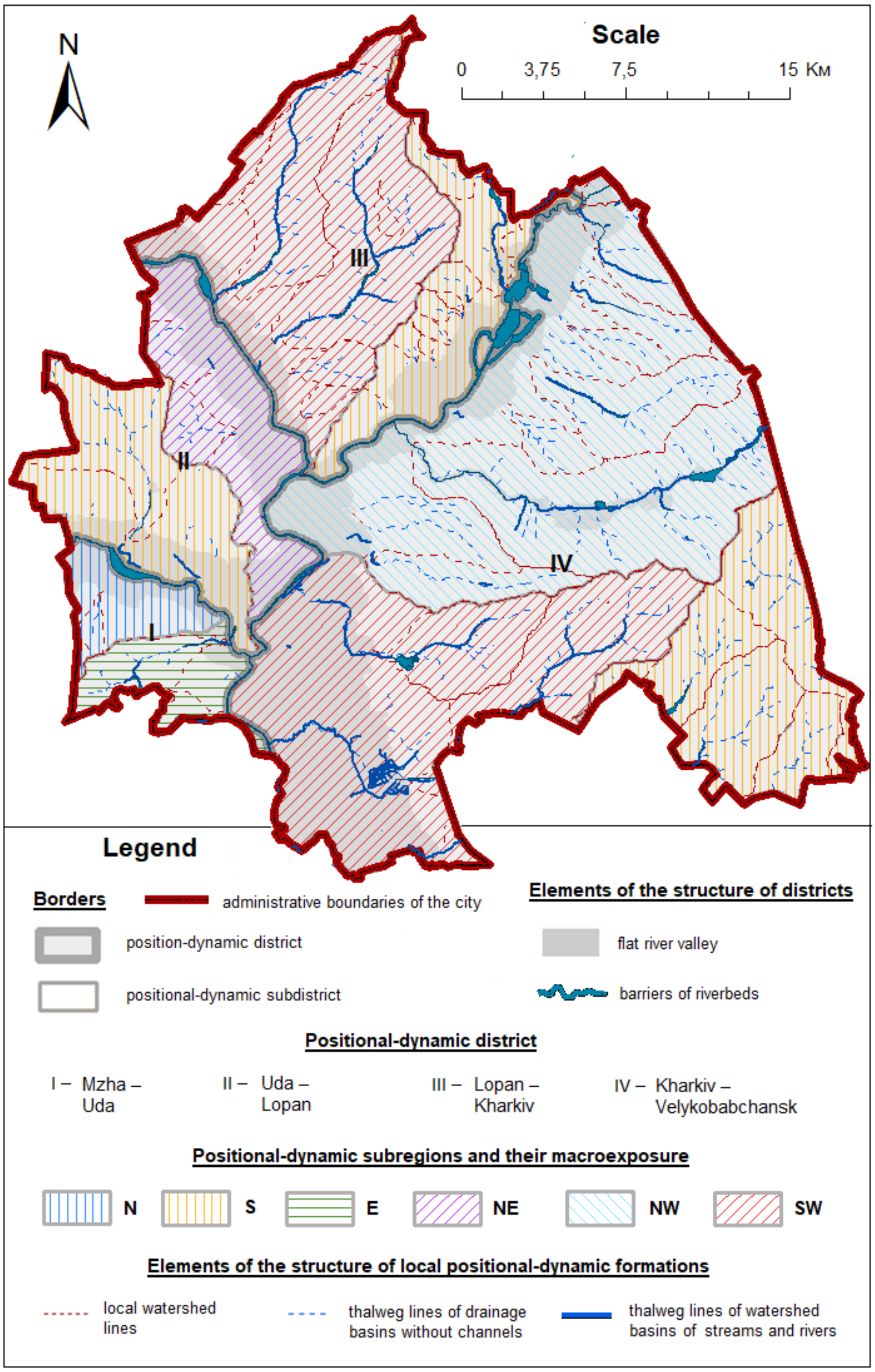


Fig. 3. Position-dynamic districts of the urban landscape of Kharkiv city

the north-eastern and southern part of the city. In general, this area has a shape close to the ellipsoid, and its boundaries are the Kharkiv River, Lopan River, Uda River, Siversky Donets River and Velyka Babka River (the last two are outside the city). There are 3 subregions: of north-western macroexposure, oriented mainly to the Kharkiv riverbed; south-western macroexposure – to the fragments of the Lopan and Uda riverbeds, which protrude beyond the boundaries; and the southern macroexposure, general orientation of which is directed towards the Uda riverbed in the lower course.

The district is characterized by the dominance of the eluvial tier (60.9%), a significant share in the structure is occupied by the eluvial-superaqual tier (18.47%), the share of transeluvial and trans-superaqual tiers is 12.45% and 8.11%, respectively.

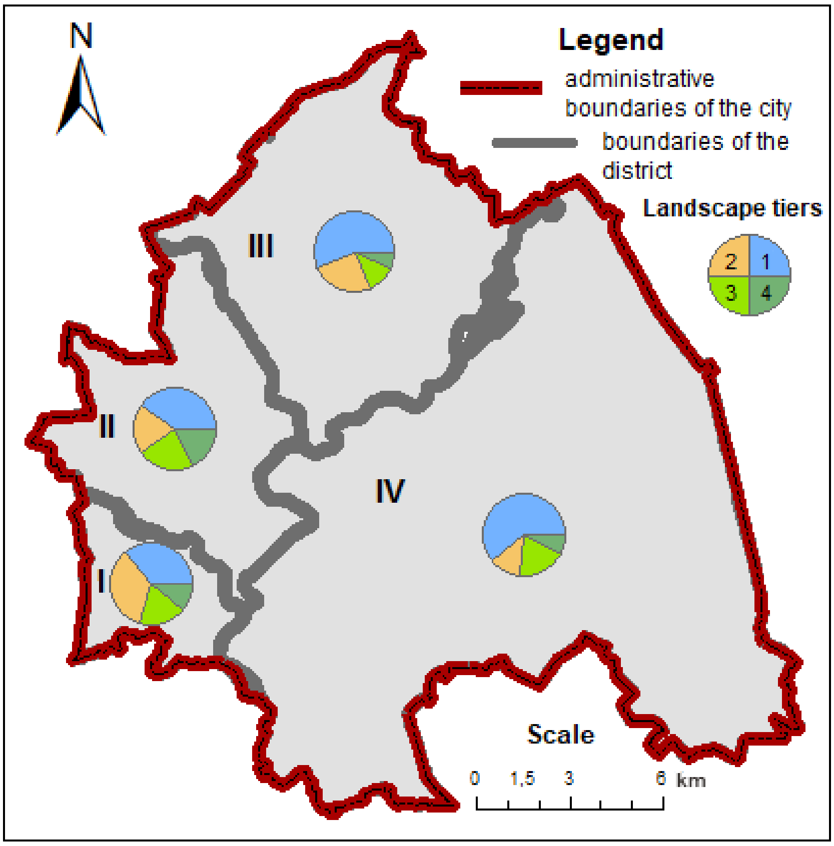


Fig. 4. Distribution of tiers within the positional and dynamic districts of the urban landscape of Kharkiv city *(1 - eluvial, 2 - transeluvial, 3 - eluvial-superaqual,4 - transsuperaqual)*

Conclusions

1. When implementing the first stage of landscape-ecological planning - inventory in the city, it is necessary to analyze the ratio of natural and anthropogenic factors in the formation of its territory, which will provide a basis for developing environmental management measures for sustainable nature management.

2. The positional-dynamic structure of urban landscape can be selected by compiling and analyzing cartographic works of landscape strips, tiers and areas, using spatial analysis tools (including reclassification and raster calculator) of initial data on morphometric parameters of relief in ArcGIS.

3. The composition and territorial configuration of position-dynamic landscape strips of the urban landscape have been established as a result of systematization and processing of geodata parametric features of the water-geochemical regime.

4. 13 types of landscape strips with individual features are identified in the territory of Kharkiv city. They are united into 5 groups according to the types of lateral migration of substances due to the peculiarities of their positionality (common position in relation to frame lines of changing flow directions) and similarity factors of relief morphology, the nature of the flow and the intensity of substances transfer.

5. Cartographic models of the positional-dynamic territorial structure of Kharkiv city, developed during the implementation of the inventory stage of landscape-ecological planning, make it possible to choose the directions of balanced nature management in environmental management of a particular area.

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Sedimentology and Geochemistry of Quaternary Sediments and Determination of Sediment Transport, Tectonic setting in the wetland of Saghalak-Sar Rasht

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Abstract. Wetlands as unique, rich, and fertile ecosystems are among the most vital environments in the world. Quaternary sediments of wetlands are the main components of our environment and an essential source of clastic, organic, and chemical substances that can be caused by natural processes and erosion or created by human intervention. This article broadly deals with the grain size and geochemistry of Quaternary sediments in Saghalak-Sar as one of the wetlands in Guilan province in the north of Iran. The 74 surface and subsurface samples (from 10 core) of the sediments were graded, and sedimentation parameters of the particles (Sorting, Skewness, and Kurtosis) were determined. Also, the frequency of elements oxides and sub-elements oxides were determined by ICP and XRF, respectively. The sediments were classified into eight sedimentary types including Slightly Gravelly Muddy Sand, Slightly Ggravelly Sandy Mud, Sandy Mud, Gravelly Muddy Sand, Gravelly Mud, Slightly Gravelly Sandy Mud, and Gravelly Sand. On the east of the wetland (core 1 to 8), the percentage of sand is less the mud, and on the south and west of the wetland (core 9 to13), the sand is higher, indicating more energy in the south and west. Sorting of sediments is poorly to moderately sorted and the Skewness in most samples is coarse Skewed. The number of sediment content is 2 to 3, but the sand content is the majority of the samples. According to these data, the sediments are transmitted to sedimentary basins by the river or muddy streams. The comparison of the oxide elements of the above samples with upper continental crust (UCC) indicated the mean value of SiO_2 (63.1%) in the wetland sediments is slightly less than the average of this oxide in the upper continental crust (66.6%), the average of CaO (0.8) less than the average of upper continental crust (except the 12 core and surface sediments sw1) and the amount of Na_2O (0.8) and K_2O (2.1) are less than the upper continental that indicates the destruction of plagioclases as a result of chemical weathering in the source or during the transport process. The comparison of MgO, Fe_2O_3, TiO_2 sediment samples at different depths and upper continental crust shows that the average of MgO (1.2) is lower than the upper continental crust ten but Fe_2O_3 (7.2), TiO_2 (1.2) are higher than the upper continental crust. The decrease of CaO, Na_2O, and SiO2 and the increase of Al_2O_3 and Fe_2O_3 indicate an increase in weathering during the transport process and the production of clay and aluminum oxide and iron oxide due to the decomposition of complex clays and non-clay minerals. Matching sediment samples on the two-axial diagrams of the main elements oxides, i.e., (Fe_2O_3 + MgO) versus Al_2O_3 / SiO_2 and TiO_2 and log (K_2O / Na_2O) versus SiO_2, as well as the triangular diagrams of the sub-elements Zr, Th, La, and Sc, indicate that the wetland sediments are more inclined towards the range of oceanic arc islands and continental arcs, and are composed of subduction rocks.

Keywords: Wetland, Sediment, Saghalak-Sar, Tectonic setting, Geochemistry

Седиментологія та геохімія четвертинних осадів та визначення транспортування осаду, тектонічні умови водно-болотних угідь Сагалак-Сар Рашт

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Анотація. Водно-болотні угіддя як унікальні, багаті та родючі екосистеми є одними з найважливіших середовищ у світі. Четвертні відклади водно-болотних угідь є основними компонентами нашого довкілля та важливим джерелом кластичних, органічних та хімічних речовин, які можуть бути спричинені природними процесами та ерозією або створені втручанням людини. Ця стаття найбільшою мірою стосується розміру зерен та геохімії четвертинних відкладів Сагхалак-Сар, як однієї із заболочених земель провінції Гуйлан на півночі Ірану. Були оцінені 74 поверхневих та підповерхневих зразків (з 10 кернових колонок) осадів та визначено параметри осадження частинок (сортування, відхилення та ексцес). Також частоту елементів оксидів та субелементів оксидів визначали відповідно за допомогою аналізаторів ICP та XRF. Осади були класифіковані на вісім осадових типів, включаючи дрібногравійний муловий пісок, слабогравелистий піскуватий мул, піскуватий мул, гравійно-муловий пісок, гравелистий мул, слабогравелистий піскуватий мул, піскуватий мул і гравелистий пісок. На сході водно-болотного угіддя (колонки 1 – 8) відсоток піску менше мулу, а на півдні та заході заболочених ділянок (колонки 9 до 13) піску більше, що свідчить про більшу енергію потоків на півдні та заході. Сортування відкладів від поганого до помірного та у більшості зразків грубо порушене. Кількість осадів становить від 2 до 3, але пісок є у більшості зразків. За цими даними, осади переносяться в осадові басейни річкою або каламутними потоками. Порівняння оксидних елементів вищевказаних зразків із верхньою континентальною земною корою (ВКК) показало, що середнє значення SiO_2 (63,1%) у відкладах водно-болотних угідь трохи менше, ніж середнє значення цього оксиду у верхній континентальній корі (66,6%), середнє значення CaO (0,8) менше середнього рівня верхньої континентальної кори (крім 12 колонок та поверхневих осадів sw1), кількість Na_2O (0,8) та K_2O (2,1) менше, ніж у верхній континентальній корі, що свідчить про руйнування плагіоклазів в результаті хімічного звітрювання у джерелі або під час транспортування. Порівняння MgO, Fe_2O_3 та TiO_2 у зразках осаду на різних глибинах та у верхній континентальній корі показує, що середнє значення MgO (1,2) нижче, ніж на десять порівняно з верхньою континентальною корою, але Fe_2O_3 (7,2), TiO_2 (1,2) вище ніж у верхній континентальній корі. Зниження CaO, Na_2O та SiO_2 та збільшення Al_2O_3 та Fe_2O_3 вказують на збільшення вивітрювання під час транспортування та одержання глинястого та алюмінієвого окису та оксиду заліза за рахунок розкладання складних глин та неглинистих корисних копалин. Узгодження зразків осаду на двоосьових діаграмах оксидів основних елементів, тобто (Fe_2O_3 + MgO) проти Al_2O_3 / SiO_2 і TiO_2 та log (K_2O / Na_2O) проти SiO_2, а також трикутних діаграм піделементів Zr, Th, La та Sc вказують на те, що відклади заболочених ділянок більш нахилені до ареалу океанічних дугових островів та континентальних дуг і складаються з гірських порід зони субдукції.

Ключові слова: водно-болотні угіддя, осад, Сагалак-Сар, тектонічне середовище, геохімія

Introduction. Wetlands ecosystems have many benefits and values, including water supply, storage of food from floodplains, wood production, storing river sediments, water storage, flood control, etc. (Kazanci et al., 2017; Bruland et al., 2004). Sediments are a reservoir of pollutants in aqueous media and therefore, it is used in most studies to determine the pollution load of aquatic environments (Salomons, 1984; Sobczyński, 2001; Eggleton, 2004; Ying Wang[, 2011). Also, wetlands play an important role in trapping river sediments and nutrients and reducing their transmission to seas (Bruland et al., 2006). These sedimentary environments play an effective role in sediment trapping and flood prevention. (Kazanci et al., 2004). The composition of siliciclastic sediments such as sand and mud in relation to tectonic position, origin and proximity has been studied by many researchers (Armstrong and Verma, 2005; Osae et al., 2006; Jafarzadeh; Al-Juboury et al, 2009; Adabi, 2011; Etemad Saeed and Barzi, 2009; Bite Gol and Barzi, 2011). The composition of these sediments is affected by transport factors such as aerodynamic rates, feature of origin rock, climate, tectonic activities and diagenetic effects (Whitmore et al, 2004; Von Eynatten, 2004). Also geochemical studies can complete lithological studies. The Caspian marginal wetlands were formed by longitudinal coastal sediment transport, the increase of Caspian Sea level, and or anticline syncline structures (Leontiev et al., 1977) and the third process forms the considered wetland. According to Leontief, the sediments of the Iranian coastal shores from the borders of Azerbaijan to Turkmenistan originate from the Alborz slopes. Therefore, studies of surface sediments and investigating their state in terms of sediment type and distribution of these wetlands can be a suitable basis for subsequent studies. Saghalak-Sar wetland is one of the Caspian marginal wetlands that formed by the anticline-syncline process. The origin of the Quaternary sediments of this wetland is Alborz Mountains, and it provides a large amount of the water used by the surrounding countryside for agriculture and animal husbandry, and so on. With regard to the increasing trend of drought, the decrease of groundwater, wetland maintenance and solving its environmental problems (sediment volume control, the potential for accumulation of human and natural contaminations in sediments, etc.) are particularly significant. This study was performed to investigate the sedimentary and geochemical characteristics of Quaternary sediments in this wetland. Also, using geochemical analysis results were identified source rock, tectonic setting, accumulation of different elements in wetland sediments and climatic conditions.

Methodology. At first, the sampling location was determined by GIS software (Coakley, 1991) and satellite imagery then 70 surface samples and 12 subsurface (From 10 core) samples were taken (Fig. 1). In each core, the samples were selected according to the apparent variation in grain size, color, and sediment composition. The samples were graded in the laboratory according to dry sieving and using a shaker and Anderson method (Anderson, 2004). Then, the statistical and sedimentation parameters of the particles (Sorting, Skewness, and Kurtosis) were determined. Also, percentage of sediment particles was plotted on (Folk, 1957) charts using the Gradistats software. The suspension content and the mutation and deflection of sediments and their turning point were recognized by using the accumulation diagram (Visher, 1969). Then, using the above data, based on the Folk method (1954), the sediment type was determined, and the lithology columns were drawn in 13 cores by Rock-work software.

Chemical analysis was performed by X-ray fluorescence (XRF) method on 66 samples of fine sediments (less than 62 microns) to determine the percentage of 13 oxide of elements. Also, 12 samples of fine-grained sediments were tested by the spectrophotometer radiation (ICP-OES, MS), and the percentage of 54 elements was detected. Finally, the sedimentary environment and the tectonic location of the source area was determined using Batia, Roser and Korsch diagrams (Roser & Korsch, 1988 and 1986).

Geographic location and sampling points. Saghalak-Sar Lake is 15 km off the south of Rasht, in the village of Lakan in Gilan province, in the geographical location of 37°,09′,23″N and 49°,31′,30″E (Fig. 1). The elevation of wetland is 64 meters above the sea level, with about 600 meters length, 500 meters wide, and calculated are of 15 hectares. According to the Karimkhani (Karimkhani, 2016), the studied area is located on the Delta of the Sefid Roud River.

Geology of the region. The studied area is in the southwest of Rasht and in the northwest of the Alborz structural zone (Stoklin, 1968). Tectonically, it is in Gorgan-Rasht zone and south of Alborz fault (Nabavy, 2005). According to the classification by Eftekharnejad (1980), this zone is the Caspian Sea subsidence, and the time of the emergence of this zone is Precambrian according to the transformed Schists of the southern Gorgan (Nabavy, 1976). The presence of alkaline tensile lava in Jurassic sedimentary, volcanic units up to Cretaceous indicates the development of the Caspian Basin (Darvishzadeh, 1991). The oldest rocks in this area are Slate-Phyllite deposits of Carboniferous (Hercynian) age, and the youngest units are the river, delta, and coastal deposits. The lithology of the rocks around the study area includes: Schists and Phyllites of the southern Lahijan (CSP), Argelite and Sublitarnite deposits of Shemshak (Rjsh), Biomicrite Limstone and Silty Limestone ($k_1$1), Volcanic horizons of the Andesite to Basaltic- Andesite (k_1v), the flood-river facies (Q_1da), and Silty-Clay alluvial facies (Q_1al) (Fig. 2).

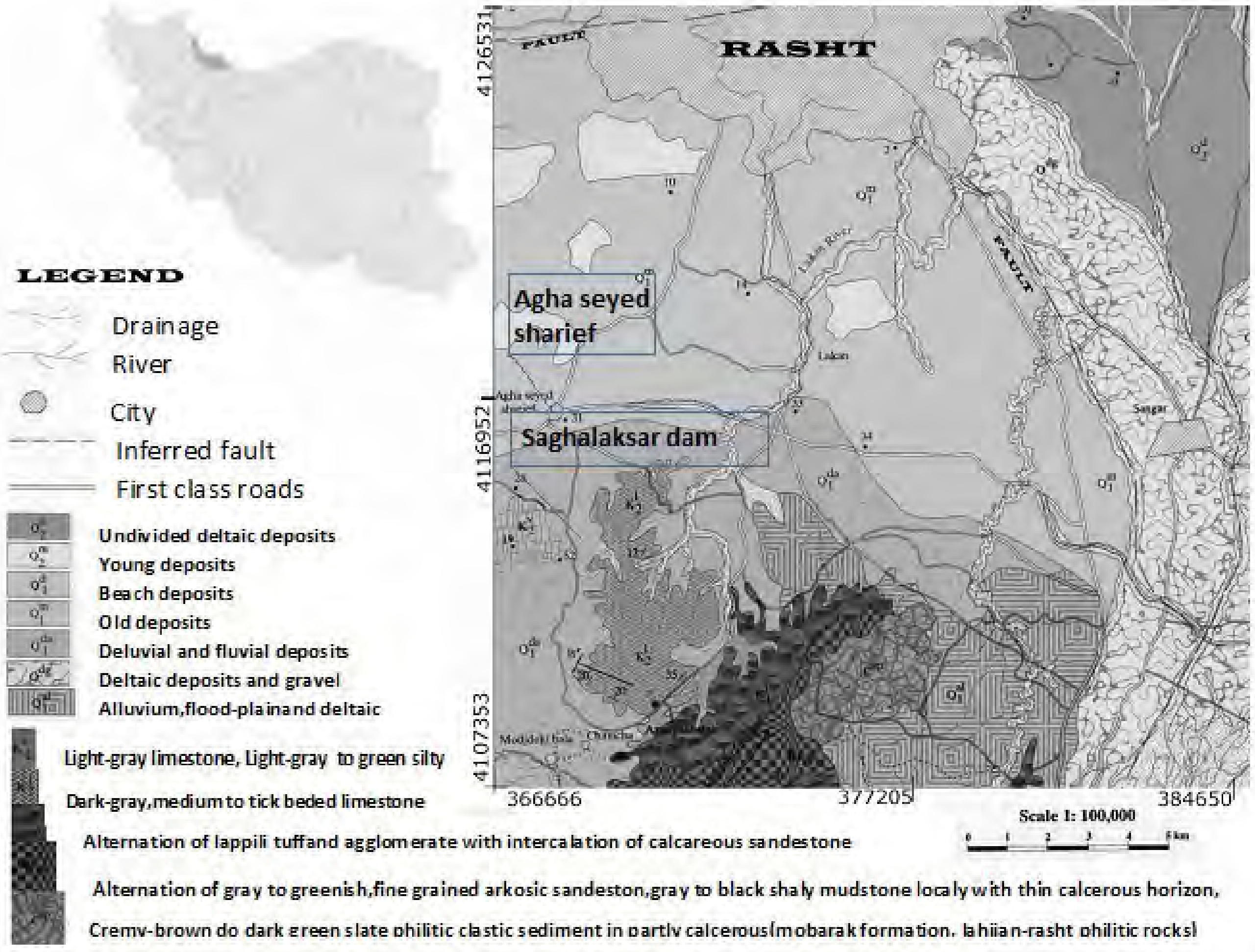

Fig.1. Geological map of the studied area taken from map 1: 100000 Rasht

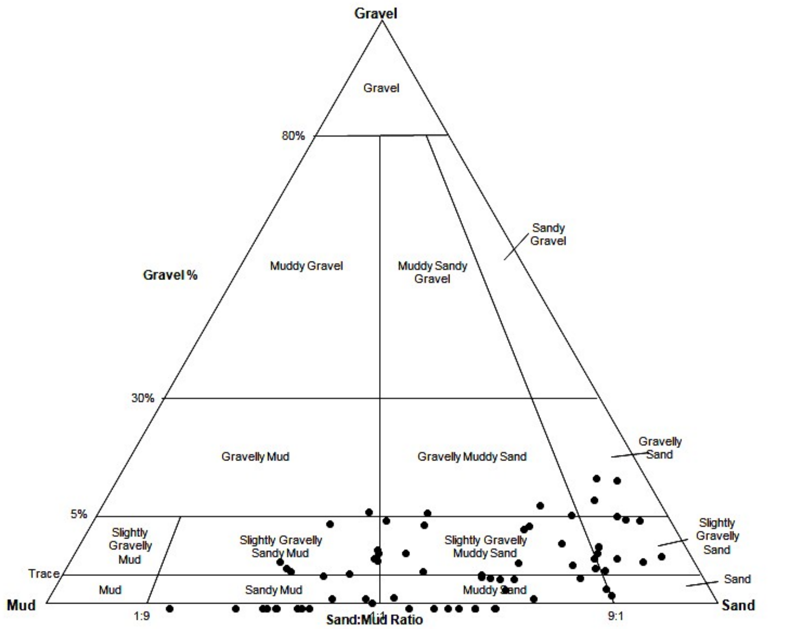

Fig. 2 Sediments type in the studied area

Discussion. Study of the characteristics of sediments (facies and texture and structure, color, mineral type) transported to the wetland is important for geological assessment of the area (such as origin of sediments, the ancient tectonics, the processes during transmission) (Das [28] et al., 2006). This research has been done in two different directions including sedimentology and geochemical studies.

1. Sedimentary facies in subsurface deposits. After being sieved, determining the percentage of each category of particle size by weighting them, the particle size dispersion charts have been plotted. Also statistical parameters have been obtained.

Since the prevalence of coarse grains in sediments, even to a slight level, is valuable for interpreting the environmental energy and the type of environment (Harami, 2004). Sedimentary facieses were determined by triangular Folk diagrams (Fig3). Facieses in the sediments of subsurface (core) was identified as follows: Slightly Gravelly Muddy Sand, Slightly Gravelly Sandy Mud, Sandy Mud, Muddy Sand, Gravelly Muddy Sand, Gravelly Mud, Slightly Gravelly Sandy, and Gravelly Sand).

Nearly in the majority of the sediments, the sand is the main component of the sediment name and forms the most abundant grain (Fig. 3). Two types of sediment are observed more at a depth of about 20-40 cm. (Fig. 2). On the east of the wetland (core 1 to 8), the percentage of sand is less the mud, and on the south and west of the wetland (core 9 to13) the sand is higher (Fig. 3). The above data indicated the transport energy in the east of the wetland was lower than in the south and west.

The bell-shaped curve of particle is leptokurtic in a number of samples (in the core 4, 8, 3, 6, 2) and show that sand grains is well sorted but the rest of the samples have a mesokurtic to platykurtic curve that indicating sands is poorly sorted maturing resulting from sedimentation in muddy or river flows (Ramanathan et al. 2009). Also coarse Skewed (less than zero) is showing environment had high energy (Feiznia, 2008; Harami, 2004).

According to the classification of standard deviations and sorting (Folk and Ward, 1957; Friedman , 1961), sediment sorting in most samples is medium to poor. Moderate to poorly sorting is seen in the sediments of rivers and mud flows (Opreanu et al., 2007; Ganjoo and Kumar, 2012). However, at the depths of 80 to 100 and 100 to 120cm, the sorting is excellent in most of the core, suggesting that the sedimentation factor in the wetland has had higher energy at this time (Lewin& Brewer, 2002; Feiznia, 2008).

The deposits have three communities. The rate of the suspension (mudd, clay) varies between %5 and 70%, and the rate of sand content is between 29% and 92%. Its gravel content is very low in most samples, and varies from 0 to 14 percent and can result from the river flow (Opreanu et al., 2007) However, at a depth of about 20 to 40 cm, suspension content increase, and the sand content reduced that probably results from mudflows (Mycielska–Dowgiałło et al., 2011; Feiznia, 1999) (Fig. 3).

2. Sedimentary facies in surface deposits. The subsurface sediments (sw1 to sw12) are Gravelly Sand facies and have a high amount of sand and a low percent of mud and gravel. In some surface samples such as Sw11, the rate of gravel is more indicating higher carrying energy (Harami, 2004).

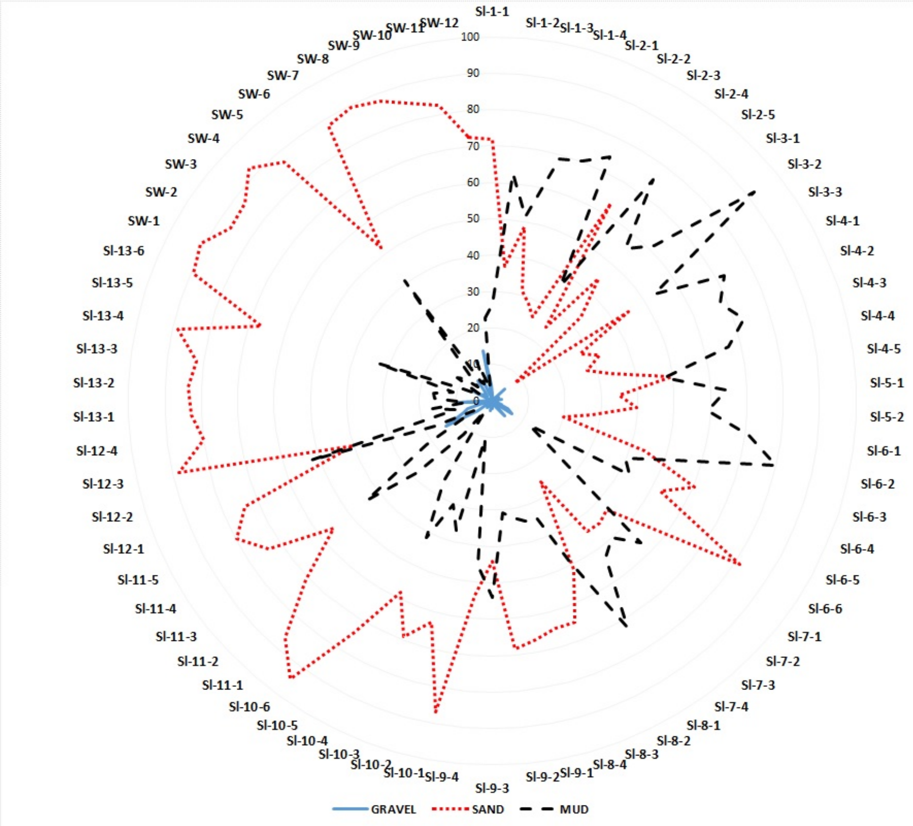

Fig. 3. Characteristics of sediment particles

This sediments are poorly sorted and have coarse Skewed (less than zero).

Also the sand content in these sediments are high (more than 70%). Slope of line of this content (in cumulative curve) is moderate, indicating moderate sorting of sand grains (Mycielska -Dowgiałło, 2004). The gravel content is negligible. Therefore, the present surface sediments are thought to be transported mainly by river branches and from the source close to the wetland (Feiznia, 1999; Opreanu et al., 2007).

3. Geochemical studies. The main elements oxides and sub- elements of the sedimentary deposits depend on factors such as the composition of the source rock, topography of region, and the weather (Day et al, 2009; Taylor & McLennan, 1985; Cullers, 1995 & 2000). Therefore, the ancient conditions of the sedimentary basin can be detected by using graphs such as Batti, Rosser, Cyrus and Michelin and so on, which are presented by different scholars (Bhatia, 1983; Bhatia & Crook; 1986; McLennan et al., 2001; Roser & Korsch).

Before examining the results of geochemistry on the commonly used charts and their interpretation, it is necessary to describe the statistical processing of the decomposition of the main elements. The comparison of the oxide elements of the above samples with upper continental crust (UCC) is evident in Table 1 and Fig. 4.

As shown in Table 1, the mean value of SiO_2 in the wetland sediments is 63.1%, which is close to but slightly less than the average of this oxide in the upper continental crust (SiO_2 = 66.6%). Its value varies from 50 (in surface sample 11 and core 10) to 69% (in core 8 and 11), which shows the Mature sediment, especially in core 8 and 11. The average of CaO is 0.8, and it is less than the average of upper continental crust. The rate of CaO On the northwest of the wetland (in core 12 and surface sediments sw11) increases and has reduced the SiO_2 (Das et al., 2006; Bhatia and Crook, 1986).

The amount of Na_2O and K_2O in all samples is less than the upper continental crust that indicates the destruction of plagioclases as a result of chemical weathering in the source or during the transport process. Also, the amount of K_2O far more than Na_2O that can be due to the presence of Feldspar or Mica (Oni et al., 2014).

The comparison of MgO in sediment samples at different depths and upper continental crust shows that the average of this oxide is 1.2, which is lower than the upper continental crust (2.2). However, the comparison of the Fe_2O_3 content in the samples with the upper continental crust shows that the amount of this element is higher and indicates the weathering of

Table 1. Frequency of main elemental oxides in sediments in percent

Sample	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	TiO_2	MnO	L.O.I.*
SL1-1	65.7	13.7	6.1	0.5	1.1	0.8	1.9	1.2	0.12	8.13
SL1-2	62.7	14.4	7.5	0.6	1.1	0.7	2.1	1.2	0.3	8.71
SL1-3	65.2	13.8	7	0.6	1.2	0.8	2.1	1.2	0.3	7.28
SL1-4	66.9	14.1	6	0.5	1.2	0.9	2.2	1	0.1	6.78
SL2-1	66.4	13.5	6.4	0.5	1.2	0.8	2.1	1.3	0.1	7.36
SL2-2	67.2	13.6	5.1	0.5	1.2	0.9	2	1.2	0.1	7.87
SL2-3	68.3	13.6	5.7	0.4	1.1	0.9	2	1.1	0.1	6.44
SL2-4	67.2	13.4	6.9	0.5	1.1	0.9	2.1	1.2	0.2	6.26
SL2-5	65.9	14.2	6.9	0.5	1.2	0.8	2.3	1.2	0.2	6.5
SL3-1	66.1	13.4	5.4	0.4	1.1	0.8	2.1	1.2	0.2	9
SL3-2	68	13.5	5.9	0.5	1.1	0.7	2.2	1.2	0.2	6.29
SL3-3	64.2	14.9	7	0.5	1.2	0.7	2.1	1.2	0.2	7.66
SL4-1	67.4	13.6	6.2	0.4	1.1	0.8	2.2	1.4	0.3	6.46
SL4-2	65.4	14.6	6.6	0.5	1.2	0.7	2.2	1.3	0.2	7.09
SL4-3	64.5	15.3	6.9	0.4	1.2	0.8	2.2	1.2	0.1	7.27
SL4-4	64	15.3	7.2	0.4	1.3	0.7	2.2	1.1	0.1	7.39
SL4-5	63.6	15.1	7.4	0.4	1.2	0.7	2.5	1.2	0.1	7.57
SL5-1	67.5	13.7	5.9	0.5	1.1	0.7	2.1	1.4	0.3	6.52
SL5-2	63.4	15.4	7.6	0.6	1.2	0.6	2.1	1.3	0.2	7.35
SL6-1	65.2	13.8	5.8	0.5	1.1	0.7	2	1.2	0.2	9
SL6-2	67.3	14.2	6.2	0.4	1	0.8	2	1.2	0.2	6.45
SL6-3	65.5	15.1	6.7	0.4	1.1	0.7	2	1.1	0.1	7.13
SL6-4	59.2	17.5	8.1	0.5	1.4	0.7	2.1	1	0.1	9.17
SL6-5	65.4	15.2	6.6	0.5	1.1	0.8	2.1	1.2	0.1	6.94
SL6-6	58.6	17.3	8	0.8	1.7	0.8	2.2	1.1	0.1	9.25
SL7-2	66.4	13.4	6.3	0.7	1.1	1	2.4	1.2	0.1	7.1
SL7-3	66.8	14.1	6.2	0.6	1.2	0.9	2.3	1.1	0.2	6.35
SL7-4	63.2	14.9	7.9	0.7	1.3	0.8	2.2	1.1	0.2	7.44
SL8-1	69.7	12.7	5.1	0.5	0.9	1	2	1.2	0.1	6.7
SL8-2	64.5	13.9	7.4	0.7	1	0.8	1.9	1.2	0.1	8.36
SL8-3	57.1	17.2	9.3	0.7	1.3	0.5	2.1	1	0.2	10.23
SL8-4	59	16.4	9.2	0.6	1.2	0.6	2	1.1	0.1	9.81
SL9-1	62.9	14.3	6.8	0.8	1.4	1	2.4	1.2	0.1	8.9
SL9-3	60.4	15.5	7.8	0.9	1.6	0.7	2.3	1.2	0.2	9.05
SL9-4	61.7	14.8	7.5	0.9	1.6	0.8	2.2	1.2	0.2	8.85
SL10-1	59.1	15	7.9	0.9	1.6	0.6	2	1.3	0.2	11.18
SL10-2	57.8	15.3	9.5	0.8	1.6	0.5	1.9	1.3	0.2	10.9
SL10-3	55.5	16.4	10.7	0.8	1.7	0.5	1.8	1.2	0.2	11.07
SL10-4	50.5	14.7	16.4	1	1.4	0.4	2.2	1.6	0.1	11.69
SL10-5	54.7	17	10.2	0.8	1.7	0.5	1.9	1.1	0.1	11.72
SL10-6	56.7	16.5	9.1	0.7	1.5	0.6	2.2	1.1	0.2	11.2
SL11-1	67.5	12	4.9	0.4	0.9	0.9	1.9	1.2	0.1	10
SL11-2	69.9	12.9	4.8	0.5	1	0.9	1.9	1.2	0.1	6.44
SL11-3	68.7	13.1	5.7	0.5	1	0.9	2	1.3	0.2	6.38
SL11-4	68.7	13.8	5.5	0.5	1.1	0.9	2	1.2	0.2	5.92
SL11-5	64.5	15.1	7.1	0.5	1.2	0.9	2.3	1.1	0.3	6.82
SL12-1	62.9	14.6	7.9	0.8	1.1	0.7	1.9	1.2	0.4	7.92
SL12-2	56.3	13.8	7.7	4.7	1.2	0.8	2.1	1	0.2	11.18
SL12-3	58.6	16.3	9.1	0.9	1.3	0.8	2.5	1.2	0.3	8.79
SL12-4	59.2	17.6	8.3	0.7	1.5	0.7	2.5	1.1	0.2	8.01
SL13-2	54.8	14.2	10.4	2.5	1.2	0.5	2.3	1.2	0.2	11.52
SL13-3	55.8	15.1	9.7	2.1	1.3	0.8	2.4	1.1	0.3	10.75
SL13-4	57.6	17.3	8.1	1.3	1.7	0.7	2.2	1.1	0.1	9.71
SL13-5	67	13.8	4.8	0.6	1.2	1	2.1	1.1	0.1	7.88
SL13-6	58	17.4	8.2	1.1	1.7	0.6	2.2	0.9	0.1	9.39
SW2	64.6	13.8	5.7	0.6	1.2	0.8	2	1.2	0.1	9.56
SW3	67.8	13.7	5.3	0.5	1.1	0.8	2.1	1.1	0.2	7.1
SW4	67.9	13.1	5.5	0.6	1	0.8	2.1	1.3	0.3	7.13
SW5	67.5	13.5	5.5	0.5	1	0.9	2	1.2	0.1	7.47
SW6	67.2	13.4	5.6	0.6	1.1	0.9	2.2	1.1	0.1	7.41
SW7	64.8	14	6.5	0.7	1.2	0.8	1.9	1.2	0.1	8.48
SW8	60.7	14.8	6.9	0.8	1.5	0.8	2.3	1.2	0.1	10.47
SW9	68.6	13.2	5.5	0.5	1	0.8	2	1.1	0.1	6.73
SW10	62.6	14	7.1	0.7	1.4	0.7	1.8	1.5	0.3	9.52
SW11	52	13.9	8.3	5.2	1.1	0.7	2	1.1	0.3	13.24
SW12	57	15	7.5	1.7	1.3	0.7	2.1	0.9	0.2	12.01
AVEREG	63.1	14.6	7.2	0.8	1.2	0.8	2.1	1.2	0.2	8.4
UCC	66.6	15.4	2	3.6	2.5	3.3	2.8	0.6	0.1	
LCC	54.4	16.1		8.5	6.3	2.8	0.3	1		

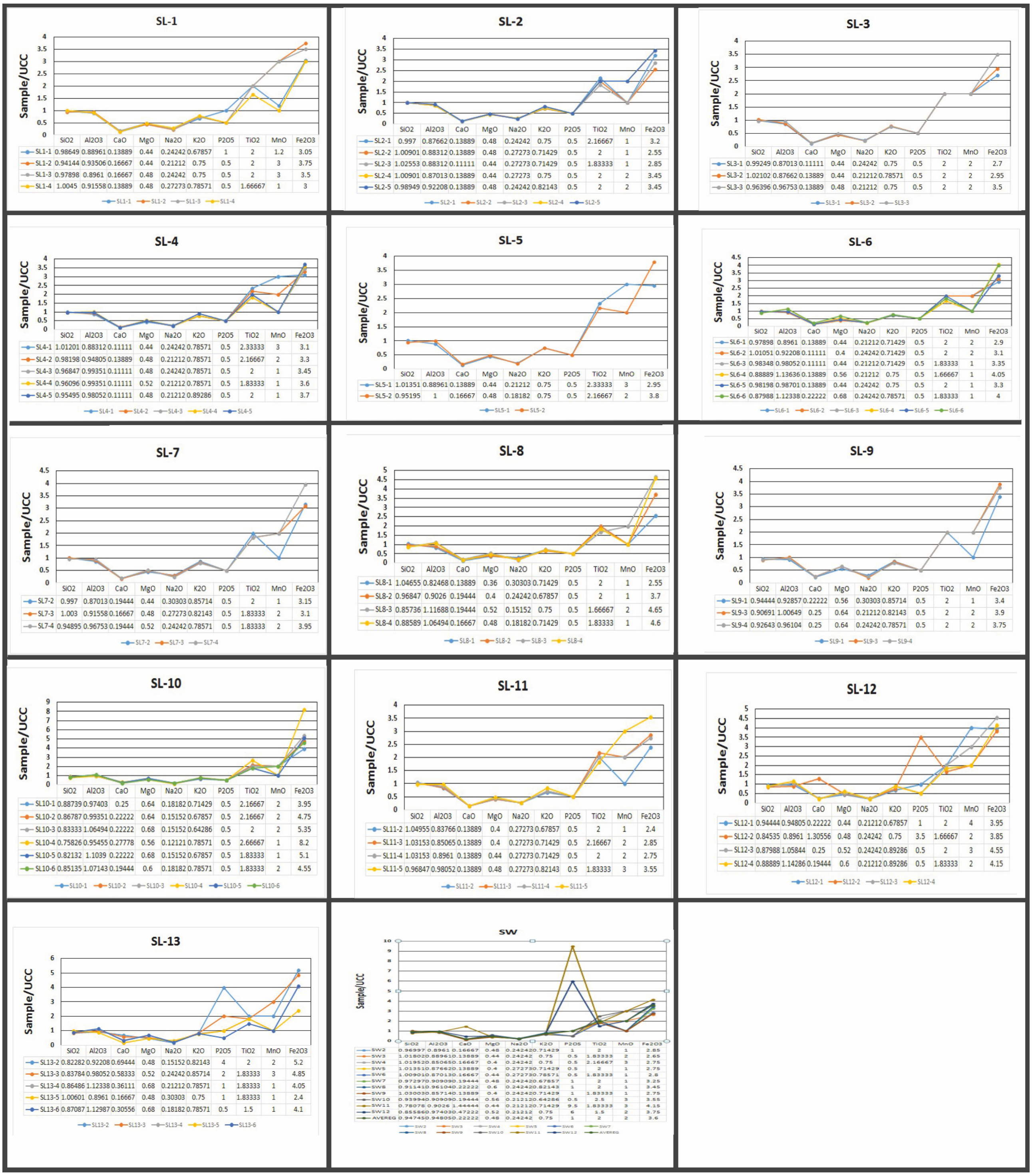

Fig. 4. Normalization of the major oxides in comparison to the composition of the upper continental crust (UCC) (Talor & McLennan, 1985, Das et al., 2006)

iron minerals during the erosion and transport (Lee, 2005). The average of TiO_2 (1.23) in all samples is higher than the upper continental crust, which indicates the acidic and felsic source rock (Oni et al., 2014).

The average of Al_2O_3 is about 14.6, which is approximately equal to the percentage, of the upper continental crust and varies from 12 (in core11) to 17.5% (in core10 and 6).

According to Lee (2005), the decrease of CaO, Na_2O, and SiO_2 and the increase of Al_2O_3 and Fe_2O_3 indicate an increase in weathering during the transport process and the production of clay and aluminum oxide and iron oxide due to the decomposition of complex clays and non-clay minerals. According to the studies, Babeesh, used geochemical map diagrams including the relation between Al_2O_3 and other existing oxides for sediments (Madukwe & Obasi, 2015; Babeesh,

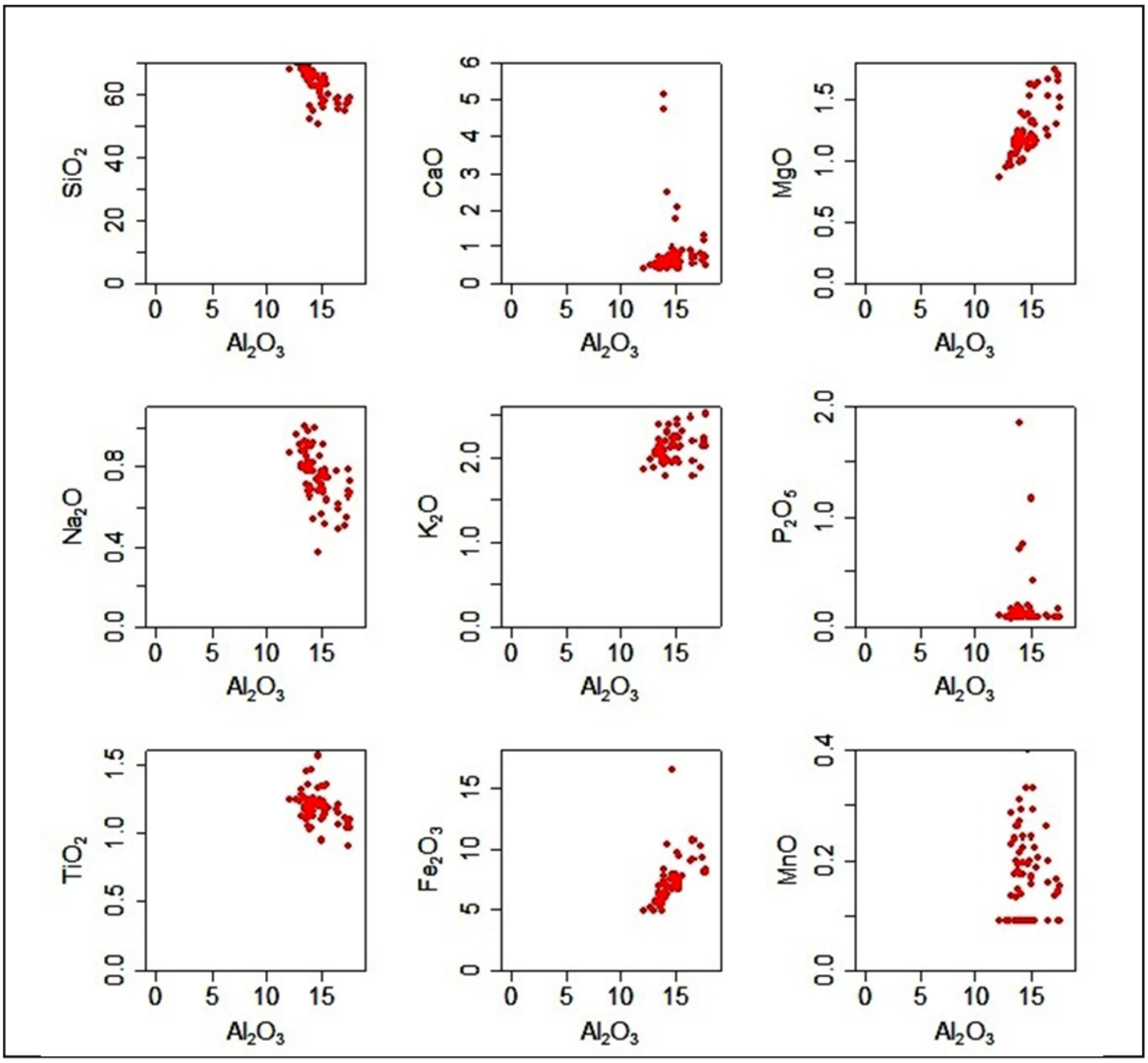

Fig. 5. Charts of Al2O3 variations against other oxides (Babees, 2017; Madukwe & Obasi, 2015)

2017), too (Fig. 6) and the diagrams were plotted for the fine-grained sediments (Fig. 6). As can be seen, Al_2O_3 has a positive correlation, with Fe_2O_3, MgO and K_2O, and a negative relationship with SiO_2 and TiO_2, but it has no special correlation, with P_2O_5, MnO, and CaO. The positive relationship between Al_2O_3, Fe_2O_3 and K_2O can be due to the presence of these elements in clay minerals and mica, which have been produced due to weathering during transportation and erosion (McLennan et al., 2001; Jin et al., 2006). Furthermore, K_2O can represent aluminum-rich phase, especially Illite (Lee, 1999; Das et al., 2006) (Fig. 5). These changes are observed in core 10 and 12, and surface sample 11, indicating severe weathering during the transport in these two parts of the wetland.

The comparison of the sub- elements of the sediments of the studied zone with the combination of the upper continental crust (Fig. 6) shows the average of Zr, Yb, Y, Ti, Sm, Ce, Hf, Tb, Nd, U, La, Cs are higher, the average of Sr, Nb, and K are lower, but the rates of HF, TA, U, Th, Ba, and Rb are approximately equal. The only difference in the core 12 at a depth of 20 to 30 cm where the value of Ta decreases and the rate of Sr and Hf value increase (Table 1 and Fig. 6).

4. Tectonic setting. Plate tectonic is the basis for the complete development of the foreland basins in the active margins (Saengsrichan et al., 2011). Formation and evolution of foreland basins are initially accompanied by the processes of compression, accumulation, and shortening near the orogeny. The tectonic setting is influenced by sedimentation, diagenesis, and sediment composition. The plate tectonic stages have a significant share in the remaining geochemical signs (Oni et al., 2014). Thus, tried to identify the tectonic setting and the source rock by relying on the previous tectonic and geochemical findings.

Fine-grained sediments have very low permeability and can retain the composition of the source rock (Bhatia, 1983; Chamley, 1990). That is why they are of great importance in the studies of provenance (Hessler and Lowe, 2006). Therefore, geochemical

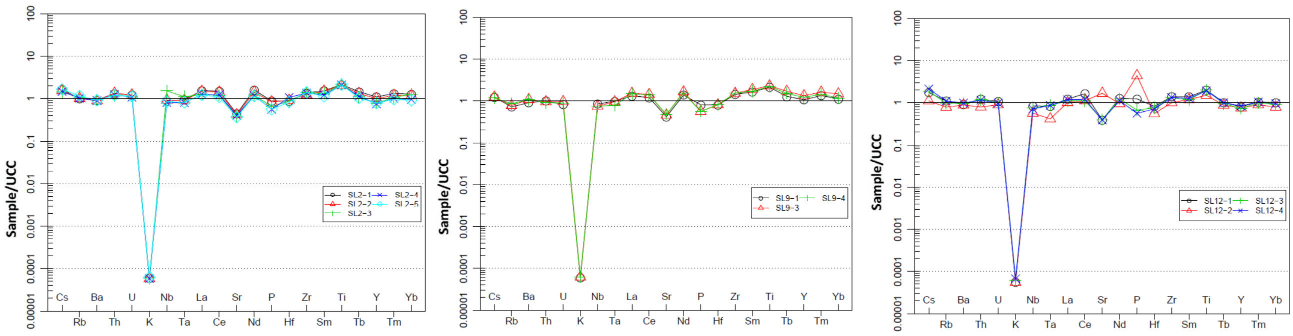

Fig. 6. Normalization of the sub- elements in comparison to the composition of the upper continental crust (UCC) (Talor & McLennan, 1985)

studies of sediments and siliceous rocks be used for determining the tectonic setting (Nesbitt and Young, 1982; Bhatia, 1986; Roser and Korsch, 1988; Herron, 1988; Kroonenberg, 1994; Cox et al., 1995; Fedo et al.,1995).

Based on changes in the values of the main elements, it is possible to separate the clastic deposits resulting from the erosion of the oceanic archipelago, the continental arc islands, the active continental margin and the passive margin from each other (Roser &

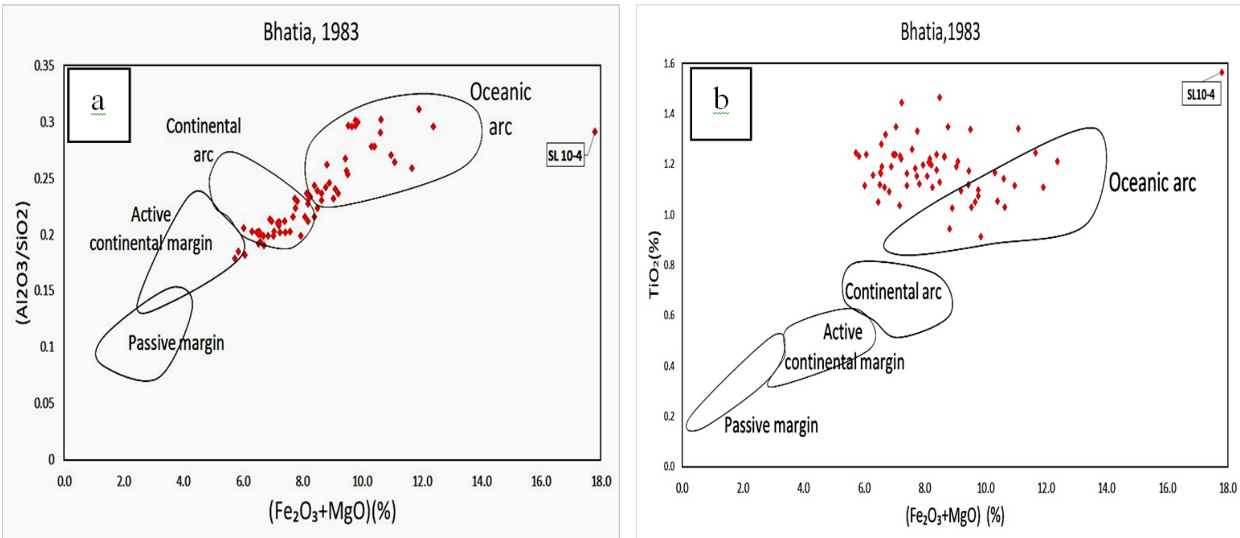

Fig.7. a: Plots of samples on Bathia's (Bhatia, 1983) two-dimensional diagram to determine the tectonic origin of sediments using Al_2O_3 / SiO_2 versus Fe_2O_3 + MgO
b: Plots of samples on the Bathia's (Bhatia,1983) two-dimensional diagram to determine the tectonic origin of sediments using the percentage of TiO_2 versus Fe_2O_3 + MgO

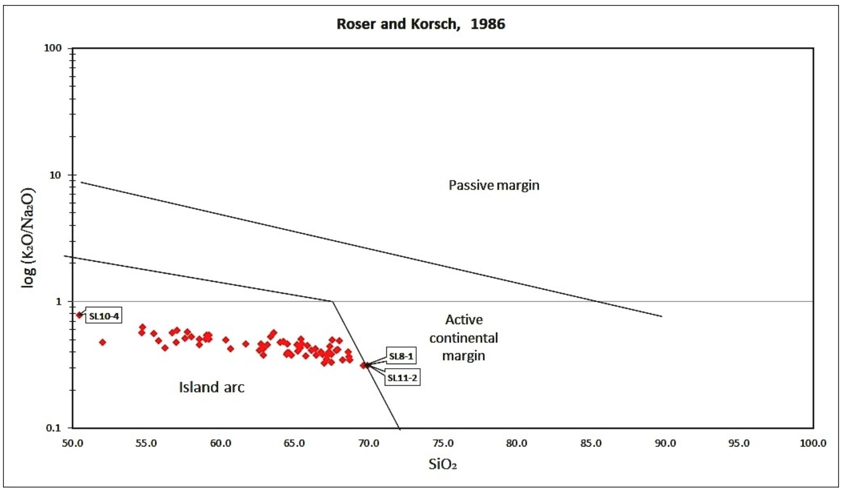

Fig. 8. Plots of samples on Bathia and Crook (Bhatia & Crook, 1986; Babeesh et al., 2017; Das et al., 2008) two-dimensional diagram to determining the tectonic origin of sediments using log (K_2O / Na_2O) versus SiO_2

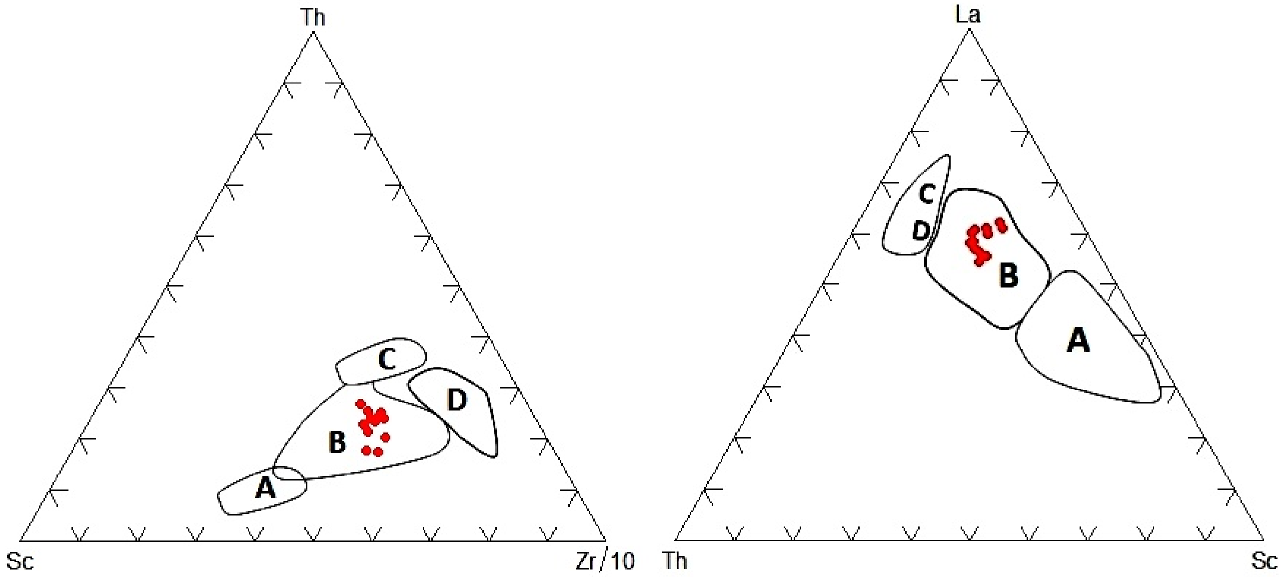

Fig. 9. Plots of samples on the three-dimensional graph of Sub-elements of Bathia and Crook (Bhatia & Crook, 1986; Das et al, 2006) to determine the tectonic origin of sediments. A: Oceanic island arc, B: continental island arc, C: active continental margin, D: passive continental margin

Korsch, 1988). The main oxides of K_2O and Na_2O, Al_2O_3, SiO_2 are used to determine the long-standing tectonic setting of sediments. Moreover, the Sub-elements and rare elements such as Cr, Y, Ti, Zn, Sc, Th, La are less affected due to non-mobility in weathering, diagenesis, and moderate transformation. Therefore, they remain in the sediments and are good indicators for understanding their long-standing tectonic setting (Bhatia & Crook, 1986).

Dual diagrams (Babeesh et al., 2017; Roser & Korsch,1986; Bhatia & Crook,1986) show that the sediments of this wetland are oceanic arc and continental arc, also some of the samples are active continental margins (Fig. 7, 8, 9). Also geochemical data of igneous rocks (Asiabanhan & Foden, 2012) confirm that the origin of these sediments are igneous rocks in continental or oceanic arcs.

Furthermore, plotting the samples on the triangular diagram diagram (such as (Bhatia & Crook, 1986; Das et al., 2006) of the sub elements confirms the tectonic origin of the continental island Arc (Fig. 9).

Conclusion.

1. Statistical data showed that sediments of Saghalak-Sar wetland have poor to moderate sorted, also most of the samples have a mesokurtic to platykurtic curve indicating that the sand has poor sorting , therefore they are carrier, and deposited by muddy flow(in rainy seasons) or river.

2. According to geochemical results, lower amount of K_2O , Na_2O compared to the continental crust indicated the weathering of the feldspars aslo decrease of Na_2O, K_2O, SiO_2 and increase of Al_2O_3, Fe_2O_3 indicate intense weathering and production of iron clays.

3. The geochemical results and the correlation of a number of oxides of the main elements (K_2O, Na_2O, Fe_2O_3, MgO, Al_2O_3) and Sub-elements (Th, Zr, Sc, La) on the standard triangular and dual diagrams show the tectonic setting of these sediments with continental and oceanic arc islands and active continental margins. This multiplicity is characteristic of post-collision and near-source basins, which is the result of active tectonics of the region and the formation of the small sedimentary basins within the foreland, but inevitable the source rocks of the above sediments are formed by a subduction boundary.

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Changes in particle sizes and geochemistry of Siyah Keshim lagoon sediment of Gilan province to determine origin and tectonic position of sediment

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Abstract. Useful information was obtained about the environmental condition of this region such as energy, sediment location, origin, sediment carrying path, pond evolutionary process, and tectonic conditions and origins of sediments by studying physical and geochemical sediment changes processes in place and time, distribution of sediments and elements in lagoon bed, and also identification the effective factors on sediment distribution model. In this regard, 59 sediment samples were taken from Siyah Keshim lagoon and were analyzed chemically and aggregation by XRF and ICP-MS technic. Adaptation of data by Folk diagrams showed that this region is placed in a range of sand, muddy sand, sand with a little gravel, muddy sand with a little gravel, and silty sand. Weak to medium sorting and negative tilting shows sediment in a coastal area. Geochemical evidence shows that SiO_2/Al_2O_3 ratio in these sediments is 2.6-3.7. In addition, Na_2O value shows relatively low sediment investigation for sediments of this lagoon. Moreover, determination of the weathering effect in origin place by the chemical index of alteration (CIA) and chemical weathering index (CWI) shows intensive chemical alternation on sediments. Index of combined variety was averagely 1.54 in the studied sediments and show that sediments resulted from the first cycle sediment. Using tectonic separating diagrams based on the primary and secondary oxidants percentage show the sediment in the active continent margin (ACM), continent-island arc (CIA), and oceanic island arc (OIA) and shows that the studied sediments are related to subduction margin**.**

Key words: Siyah Keshim, lagoon, sorting, sediment, geochemistry

Використання змін розмірів частинок та геохімії осадів лагуни Сія Кешим провінції Гілан для визначення походження та тектонічного положення осадів

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Анотація. Отримано корисну інформацію про стан навколишнього середовища дослідженого регіону, зокрема щодо енергії, поширення осадів, їх походження, шляхів переносу відкладів, процесу еволюції водоймища, тектонічних умов та походження відкладів шляхом вивчення фізичних та геохімічних процесів зміни осадів у місці та часі, розподілу відкладів та елементів у річищі лагуни, а також виявлення ефективних факторів на моделі розподілу осадів. Для цього із лагуни Сія Кешим було взято 59 зразків осаду, які були проаналізовані хімічно та агрегатно за допомогою техніки XRF та ICP-MS. Адаптація даних за діаграмами Фолка показала, що ця область розміщена в діапазоні піску, мулистого піску, піску з невеликою кількістю гравію, мулистого піску з невеликою кількістю гравію та мулистого піску. Від слабкого до середнього сортування та негативний нахил свідчить, що осад формувався у прибережній зоні. Геохімічні дані показують, що співвідношення SiO_2 / Al_2O_3 у цих відкладах становить 2,6-3,7. Крім того, значення Na_2O свідчить про відносно низьке дослідження осадів для відкладів цієї лагуни. Більше того, визначення ефекту звітрювання в місці походження за хімічним індексом зміни (CIA) та індексом хімічного звітрювання (CWI) показує інтенсивне хімічне змінення відкладів. Індекс комбінованого різноманіття становить у середньому 1,54 у досліджуваних відкладах і показує, що відклади були результатом осаду першого циклу. Використовуючи тектонічні розділові діаграми на основі процентного вмісту первинних та вторинних окисників, можна побачити наявність осадів на ділянці активного континенту (ACM), дузі континент-острів (CIA) та острівній океанічній дузі (OIA) та показує, що досліджені відклади пов’язані із субдукційною границею.

Ключові слова: Сія Кешим, лагуна, сортування, осад, геохімія

Introduction. Lagoons have many advantages for having hydrological characteristics. Lagoons not only supply a part of underground waters, but also provide an environment as the best ecosystem to supply many birds and aquatics foods (Nuri, 2009). In addition, lagoon prevents penetration of salty waters and floods prevalence by setting water flow and has a significant role in preventing dessert (Nuri, 2009). In addition to the mentioned cases, lagoons have a significant role in preventing erosion of coastal lines, stabilization of the region›s air based on rainfall and ambient temperature, livestock feed, agricultural usages, minerals extraction such as potassium and phosphorus, and air purification of adjacent areas, etc. (Mohammadi et al., 2012). Anzali lagoon is one of the international protected lagoons that were studied by researchers (Amini Ranjbar, 1998; Riyahi et al, 2005, Sharifi, 2006). This lagoon is an ecosystem of many endangered species and has a more effective role in preventing flood and acts such as sediment traps (Kazanci et al, 2004).

Anzali lagoon was made because of coastal sediment growth as coastal tabs and dams. The expansion of sand stripe masses separated a part of coastal waters that finally formed coastal back lakes after enclosure. Alzali lagoon is one of these coastal back lakes that formed a part of Caspian Sea coastal waters in the past. This lagoon developed a lot in the past but was filled gradually by alluvial-delta sediment of Sefidrud branches and rivers of Rasht, Fuman and Masal region. Anzali lagoon is the tectonic resulted lethargy that became separated from Caspian seawater recession and formed by the sand blade (the area between Anzali and Kapurchal) caused by sea movements and its waves (Ranjbar, 2012).

Siyah Keshim area that is in the southwest of lagoon has the average depth of 1m and us mostly covered by vegetable plants, especially reed, Cattail, and Azolla. The relationship between Anzali lagoon and Siyah Keshim area is possible through the narrow strait in its northeast (Mohammadi et al., 2005).

Sediment granulation is used as the most principal and important characteristics of sediment particles to discern and analyze particle size and classification of sediment environment, sediment origin, transmission history, and erosion conditions (Bui et al, 1990; Folk & Ward, 1957; Friedman,1979).

Since the sediment particles are in varied sizes and can be observed in various sizes, their granulation is based on their highest diameter that was produced by Adon and Wentworth for the first time. Wentworth scale is a logarithmic scale in which each grade is twice bigger than the next smaller grade. Phi scale is shown by Φ is the changed form of Wentworth scale that was invented by Chrombin in 1937, and scaling boundaries must change to Φ values.

$$\Phi = -\log 2d$$

where *d* – particle diameter (mm)

Sediment was geochemically studied in the next step to fill and confirm the obtained information from granulation. Using the geochemical element to determine the old environment conditions is significantly important, and distribution of the main and secondary elements in sediment depends on mineralogical composition, temperature, fluid composition, oxidation, and reduction conditions (Adabi, 2004). Studies show that elements amounts and compositions are sensitive to environmental conditions, sai. Analysis of the main (Mg, Ca) and secondary (Sr, Mn, Na, Fe) elements of sediments open a way of understanding sedimentary environmental time by indicating their dispersion and distribution. The element geochemistry for the present elements in each sample is a good guidance for climate changes because some elements in the soil are sensitive to environmental conditions in a way that some elements report the certain conditions; for example, high amounts of Fe, Mn shows reduction environment, (Nekukhu, 2003). The elements geochemistry can show temperature and raining conditions well. Elements of Mn, Sr, Mn replace with elements such as Ca under the specific climate conditions in crystal network. Changes in Mg/Ca, Sr/Ca, Mg/Ca ratios along cores show changes in lake conditions chronically (Taghavi et al., 2013).

Methods and materials. ***Geographical conditions and geometry of the studied region.*** Siyah Keshim lagoon of Gilan province (Fig. 1) is limited to Anzali city from north to Sowme'eh Sara city from south, to Rasht city from east, and to Kapurchal and Anzali waterfront from the west.

Based on the geographical map studies of Bandar-e Anzali in 1: 100000 from publications of Geological Survey & Mineral Explorations of Iran (GSI) Tehran (Khabaznia et al., 2005) of Anzali lagoon region contains rocks of Paleozoic and Caucasian periods and has specific characteristics, but Siyah Keshim lagoon is very new geologically and its creation can be known for about 7 centuries ago.

The altitudes of the catchment area of this wetland are related to Cretaceous to Jurassic courses and also the third period in the context of limestone, conglomerate, and sandstone. Based on the structural geology of the studied region, a resulted face of the earth performance shear-stress structure is made by the rock of diatomaceous deposits from the Paleozoic era and other sedimentary deposits and Azar Caves

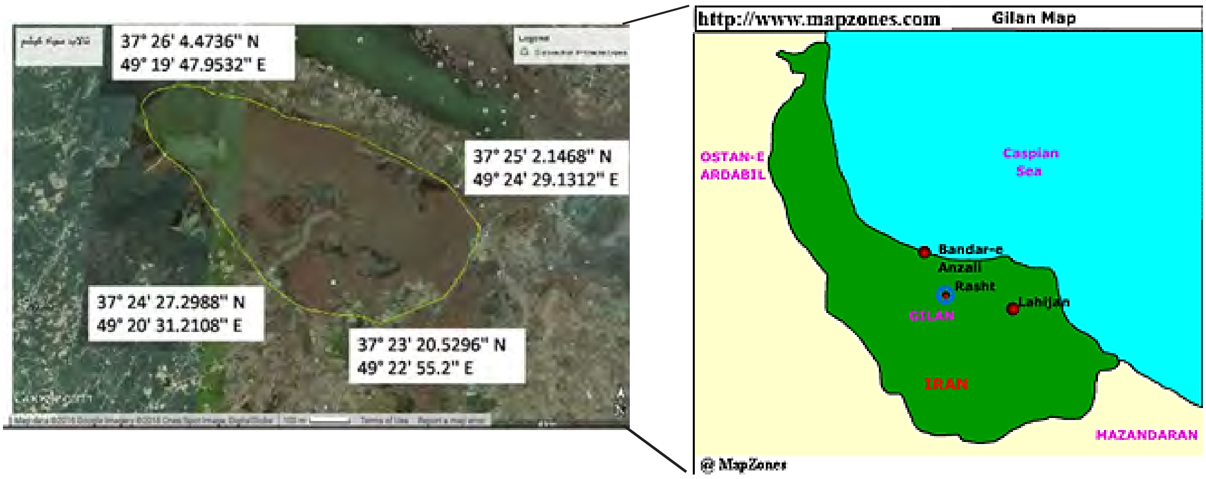

Fig. 1 The geographical condition of the studied region

related to the Mesozoic era. Strain-slip faults are one of the most vivid structural element seen in this region. Anticlines and syntaxes in the north-east axis of the Southwest were seen in the southwest of the studied region that changes in center and northwest to west-east and northwest-southeast line. Most of these buildings were unidirectional and classified in conical faults, Aghanabati, (2006).

Sampling methods and data analysis. Sampling was conducted in August 2016. Therefore, two stations were selected in various lagoons parts (Fig. 3). And the sedimentary cores were conducted in the Egher machine in the sediment of the lagoon. Thus, the first core section had 675cm depth with 34 samples and the second core section had 486cm depth with 25 samples (Fig. 2).

Samples were transferred to the laboratory to prepare for granulation, studying sedimentary characteristics, mineralogy nature, determination of the major and trace elements. After hydrometric tests, the related calculations to correct data were conducted by calculating laboratory temperature and silt and clay weight percentages were obtained (Feyznia, 2008).

To calculate these parameters, first, the accumulative frequency diagrams of each sample were drawn after performing granulometric tests by Gradistat and Excel software. Then, total skewness index (SKI) and total standard deviation index (SDI), mean (Mz), kurtosis (KU) was calculated as following using relations Folk (1980) and Ward (1957) using values of Ø84, Ø75 , Ø50 , Ø25 ,Ø16, Ø5. Since these diameters are based on mm and the obtained formula for statistical parameters are based on ϕ, the related percentage diameters changed from mm to ϕ and then were inserted in formulas (Table 1).

These samples were sent to calculate the major elements (Mg, Ca) and secondary (Sr, Mn, Na, Fe) to Geochemical Laboratory of Geological Survey of

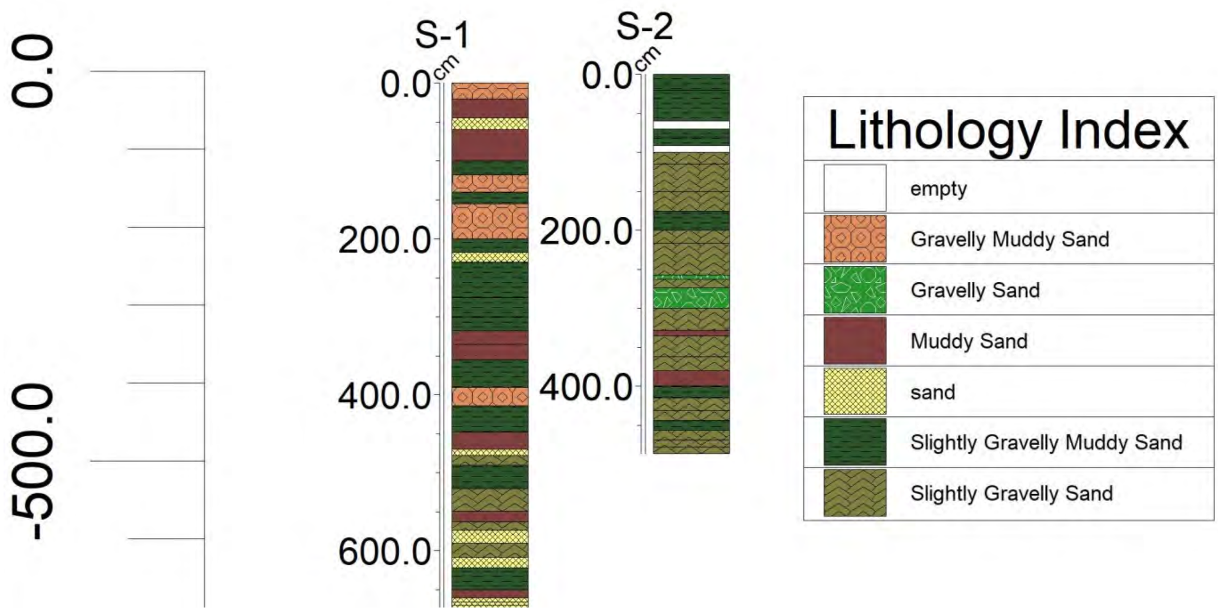

Fig. 2 1st and 2nd cutting sedimentary column of the studied region

Table 1. Sedimentary parameters and the related relations were tested for geochemical studies

index	mean diameter	sorting	skewness	kurtosis
formula	$M_Z = \frac{\phi_{16} + \phi_{50} + \phi_{84}}{3}$	$\sigma_I = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_5}{6{\cdot}6}$	$Sk_I = \frac{\phi_{16} + \phi_{84} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_5 + \phi_{95} - 2\phi_{50}}{2(\phi_{95} - \phi_5)}$	$K_G = \frac{\phi_{95} - \phi_5}{2{\cdot}44(\phi_{75} - \phi_{25})}$

Iran. The range of the major element (Mg, Ca) and secondary ones (Sr, Mn, Na, Fe) was calculated mg/g by OES, XRF ICP-MS, ICP- methods. Plots of major oxides and sub-elements on different diagrams (Basu et al., 1975; Bhatia., 1983); Dickinson et al., 1983; Roser and Korsch., 1986; Bhatia and Crook., 1986); Suttner and Duta., 1986) helped to obtain the related results to the origin, tectonic position, and climatic conditions of these sediments.

Discussion and conclusion. Folk diagrams (1954) were used to determine the name of sediments of this region based on their constitutional particles that showed the sediments of this region were placed around sand, mud sands, gravel sand with slightly muddy sandstone, and silty sand (Fig. 3).

Based on the obtained information from the statistical calculation, and the related tables and diagrams using Excel and Gradistat indicated that sediment sorting of this area is 0.7-1.9, sediment kurtosis is 0.1-0.3, and kurtosis is in 0.6-0.9 (Folk, 1980).

The sediments of this area are wide based on kurtosis, negative skewness (toward big particles), and medium to bad sorting (Feyznia, 2008). The previous studies on this lagoon confirmed this fact that the sediments of this area are medium to tiny particles (Sabzivala et al., 2011).

Determination of tectonic position of sediments based on geochemistry of the major elements. The tectonic position has two characteristics of studying the origin places including continental blocks, volcanic arc system, and collision belts and examining the boundary type among sheets including rift or inactive continental margins, active or orogeny continental margins, or striped fault margins (Dickinson and Suczek ,1979; Dickinson et al, 1983; Garzanti et al, 2003; Garzanti et al, 2007).

The similar results were obtained in the determination of sediments tectonic position by drawing Rusar and Kurosh tectonic separating diagrams (Roser and Korsch., 1986) and 2d and Bhatia functional separating diagrams (Bhatia, 1983) (Fig. 4&5).

These diagrams based on the logarithmic ratio of K_2O/Na_2O versus SiO_2 percent (Fig. 4) and TiO_2 and Al_2O_3/SiO_2 values versus Fe_2O_3+MgO were drawn. Their formation in Arctic islands is confirmed for sedimentary samples. As it is observed in these diagrams, it can be claimed that TiO_2 and total values of Al_2O_3+Fe_2O_3+MgO in arctic islands reduced to inactive margins (Fig. 6).

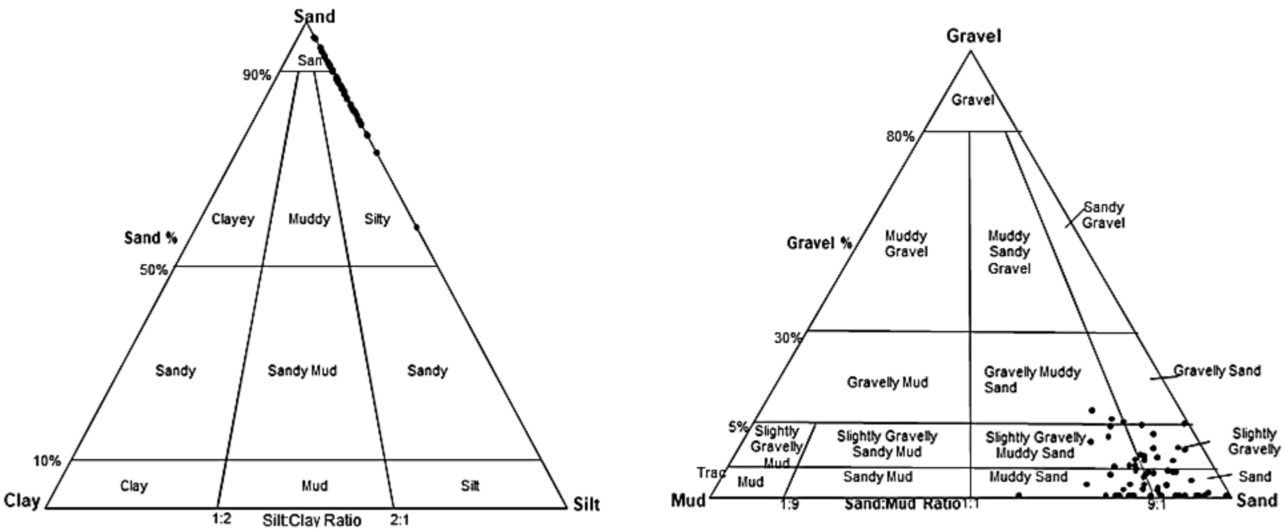

Fig. 3 Sediment based on its constitutional particles (folk, 1954)

Determination of the tectonic rank of sediments based on the geochemistry of the secondary elements

Changes in secondary elements in clastic rocks are in low weathering and diagenetic conditions

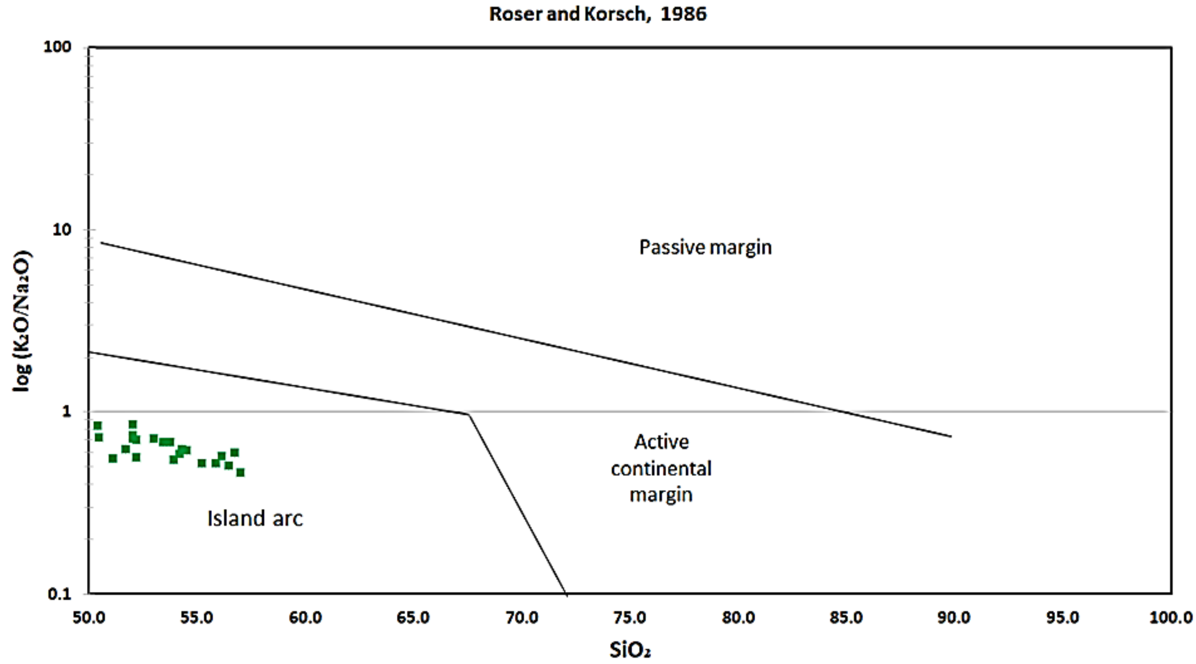

Fig. 4 Tectonic separating diagrams of sediments based on K_2O/Na_2O versus SiO_2 percent logarithmic ratio.

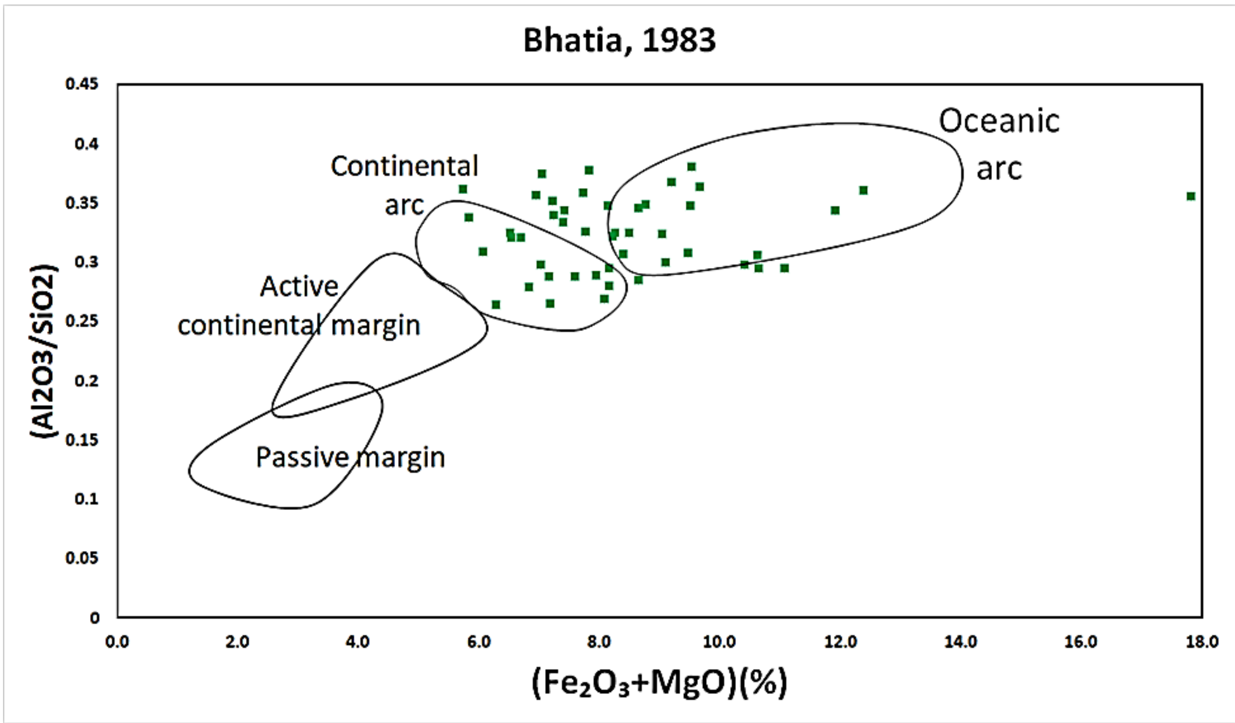

Fig. 5 Tectonic separating diagrams of sediments based on Al_2O_3/SiO_2 percent versus Fe_2O_3+Mgo logarithmic ratio

(McLennan et al., 1993). Therefore, the secondary elements are significantly mentioned in the determination of tectonic origin and place (Bhatia and Crook., 1986; McLennan., 2001; Eriksson et al., 1994) which cause many studies on the present secondary elements in the sedimentary rocks to determine the tectonic position and their origin (Bahlburg., 1998); Burnett and Quirk., 2001; McLennan et al., 1993; Zimmermann and Bahlbarg., 2003).

Therefore, 3d diagrams for the secondary elements were drawn to determine the tectonic position and the obtained results of them in confirmation the resulted diagrams for the major elements showed that the tectonic position of Quaternary sediments of Siyah Keshim lagoon is an arctic continental island (Fig. 7). The related area to the firmed sediments in active and inactive continental margins was overlapped in the La-Th-Sc 3d drawing, while these two environments are completely separated in Th-Sc-Zr/10 3d drawing (Fig.7) (Adabi, 2004).

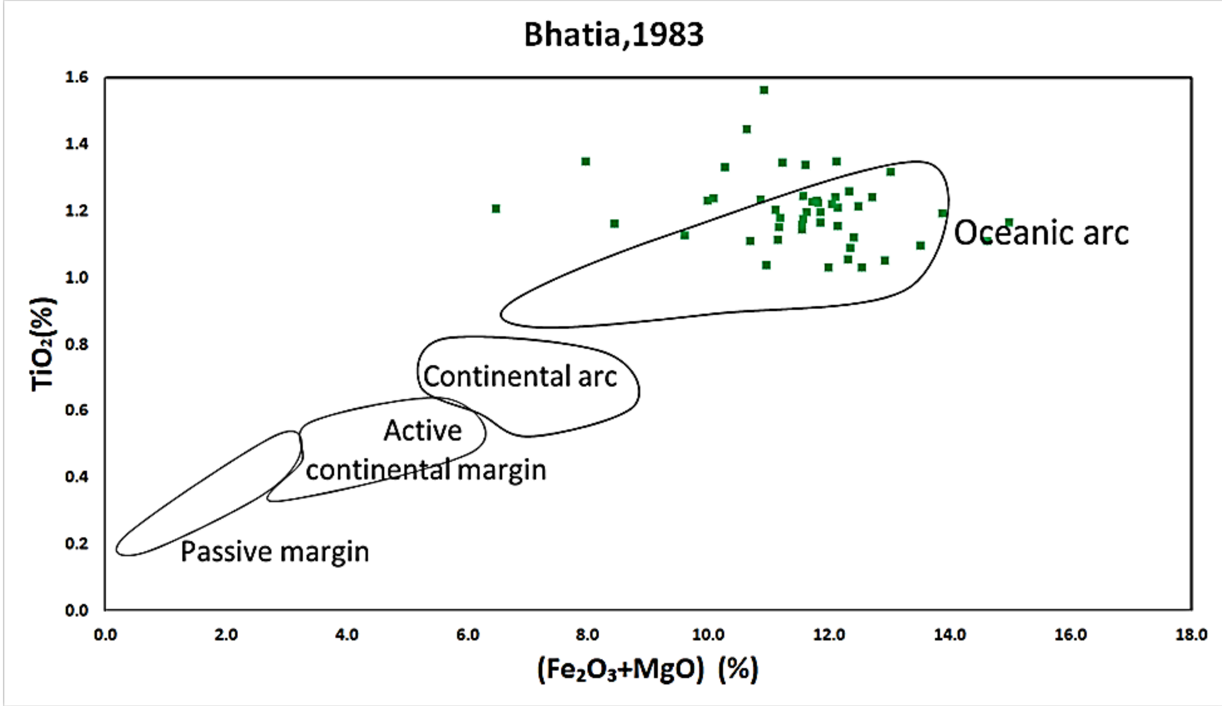

Fig. 6 Tectonic separating diagrams of sediments based on TiO_2 percent versus Fe_2O_3+MgO logarithmic ratio.

Based on drawing the paired Ti/Zr elements versus La/Sc that is shown in Fig. 8, sediments tectonic position in Suyah Keshim area of Gilan province shows arctic continental margin (ACM) and arctic continental island (CIA). Moreover, the mentioned rocks tectonic environments by diagram (Schandl & Gorton, 2002) are shown in Fig. 9 and 10 based on the secondary elements. All the studied samples are around ACM based on this diagram.

The determined areas include A: oceanic arctic islands, B: arctic continental island, C: active continental margin, D: inactive margins

Based on the obtained results from drawing the high geochemical diagrams based on the oxidants percentage of the major and secondary elements that show the tectonic position of this region sediments of continental and oceanic arctic island, continental active margin, and inactive continental margin. It can be concluded based on citing studies (Asiabanha & Foden, 2012) that the related studied sediments are related to subduction margin.

Interpretation of origin area weathering. The mobility of the major elements during weathering, transportation, and processes after sediment can be used to determine the chemical maturity of sediments, (McLennan et al., 1993).

The very low concentration of Na_2O in sediments shows high sedimentary maturity (Fig. 11). Moreover, SiO_2 /Al_2O_3 ratio is the usable index to determine sediment maturity (Potter, 1978). SiO_2 /Al_2O_3 ratio higher than 5-6 in sedimentary rocks show their high sedimentary maturity (Roser et al., 1996). SiO_2 /Al_2O_3

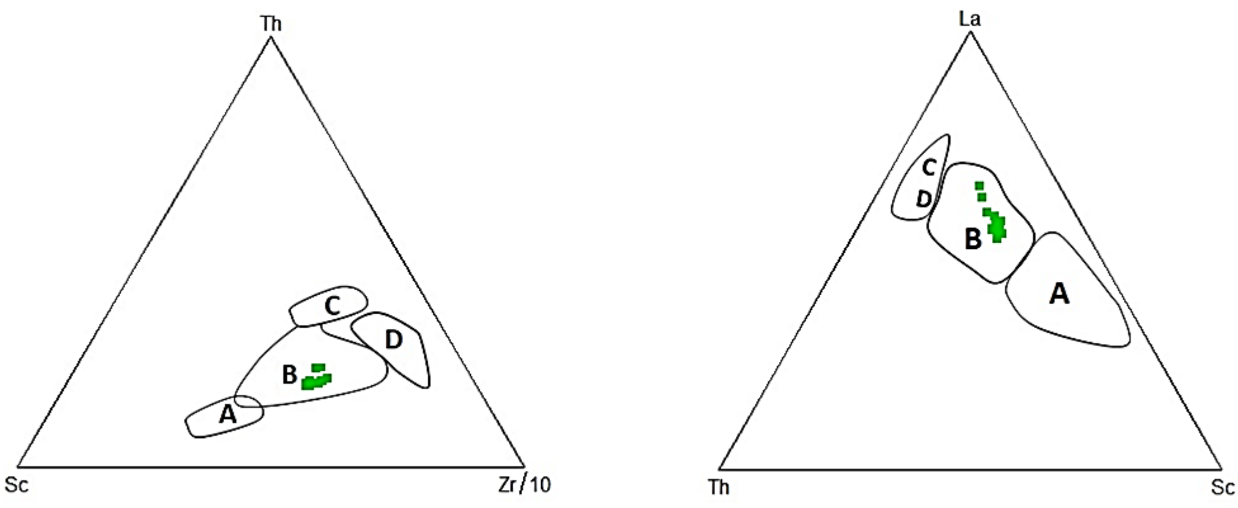

Fig. 7 Tectonic separating diagram of sediments based on the secondary elements frequency (Bhatia & Crook, 1986)

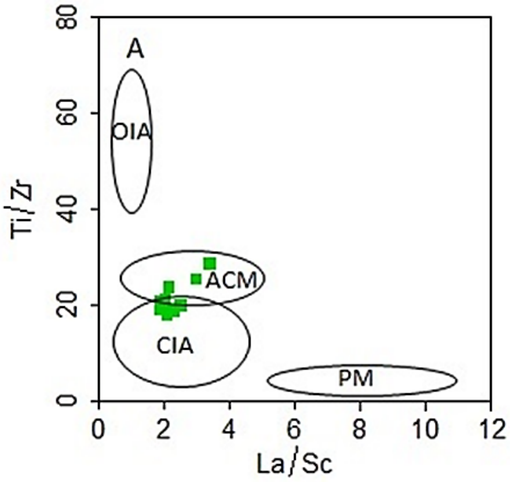

Fig. 8 Tectonic separating diagram based on Ti/Zr versus La/Sc ratio for the studied samples (Bhatia & Crook, 1986)

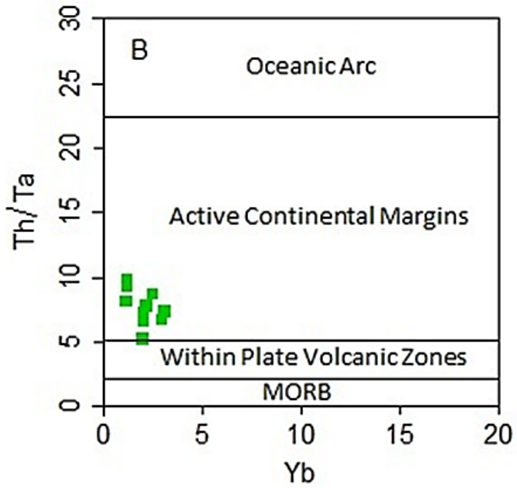

Fig. 9 The diagram of tectonic environment determination based on Th/Ta versus Yb ratio (Schandl & Gorton, 2002)

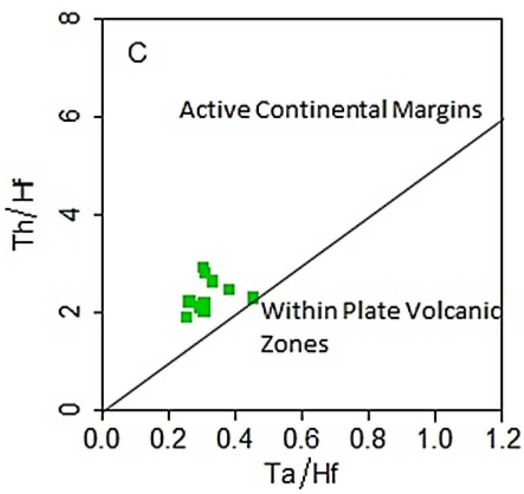

Fig. 10 The diagram of tectonic environment determination based on Th/Hf versus Ta/Hf (Schandl & Gorton, 2002)

ratio in samples is varied in 2.6-3.7. These numbers show relatively low maturity in the studied region sediments.

ICV combined variety can be used to determine the first cycle sediment or the obtained sediments from the second cycle (Cox et al., 1995) that is obtained from the following formula:

$$ICV=(Fe_2O_3 + K_2O + Na_2O + CaO + MgO + MnO + TiO_2)/Al_2O_3$$

Samples with higher ICV than 1 are probably for the first cycle sediments, and which with smaller

ICV than 1 may be from the second cycle sediments or the severely weathered sediments from the first cycle sediments (Cullers & Podkovyrov, 2002). The calculated values from ICV in quaternary sediments of this region are 0.9-5.35 with an average of 1.54. Thus, it can be stated that the most sediments of the studied lagoon are related to the first cycle sediments.

Weathering history of the clastic rocks is mostly estimated by calculating the mobile oxides ratio of K_2O, Na_2O, and CaO than non-mobile oxide Al_2O_3 (Nesbitt & Young, 1982). The most used index in this formula is alternation chemical index (Nesbitt & Young, 1982). This index is obtained by the following relation and oxides in it was stated in mole.

$$CIA=[Al_2O_3/Al_2O_3+CaO+Na_2O+K_2O]\times100$$

CaO is the present calcium in rock silicate components, and this value must be modified in samples that high CaO is related to diagenesis cement. CIA range may be low, medium, and high varied from 50 to 100. Increasing CIA from down to up is related to alternation chemical degree. Low CIA shows no alternation or very low alternation and is a reflection of cold and dry climate conditions, while medium and high CIA with mobile cations transmission such as (K+, Na+, Ca_2+) and remaining the constituters (Ti_4+ and Al_3+) is related to less mobility (Nesbitt & Young, 1982). Samples were considered with higher CaO than 5% to determine CIA precisely and CaO removal from carbonate cement (Batumike et al., 2006, Nesbitt, 2003, Garcia et al., 2004).

The calculated CIA for the studied samples was 0.78-63 and is 72 averagely in samples which show severe chemical alternation in sediments. Chemical index of weathering (CIW) is extensively used to determined rock weathering degree and is obtained by the following formul (Harnois, 1988).

$$CIW=[Al_2O_3/Al_2O_3+CaO+Na_2O]\times100$$

The mean of this index for the sediments of Siyah Keshim area is 80.73. Using CIA and CIW indexes in samples with high CaO changes doesn't show interesting results (Cullers, 2000). In this regard (Cullers, 2000), another weathering index can be offered for samples with high CaO. This index is stated as follows:

$$CWI'=[(Al_2O_3/Al_2O_3+Na_2O)]\times100$$

In which, oxides are considered in molecular ratio. The mean of this index in the studied samples is 95.47 that show the severe weathering of these samples.

This result was obtained finally based on the calculated indexes in which the sediments of Siyah Keshim area is for the first sedimentary cycle with relatively low sedimentary maturity, and has severe chemical weathering on then and alternate them.

Conclusions. Sediments are considered as data in environmental studies and its conditions are the most important evidence particularly in the previous environmental conditions. Many other pieces of

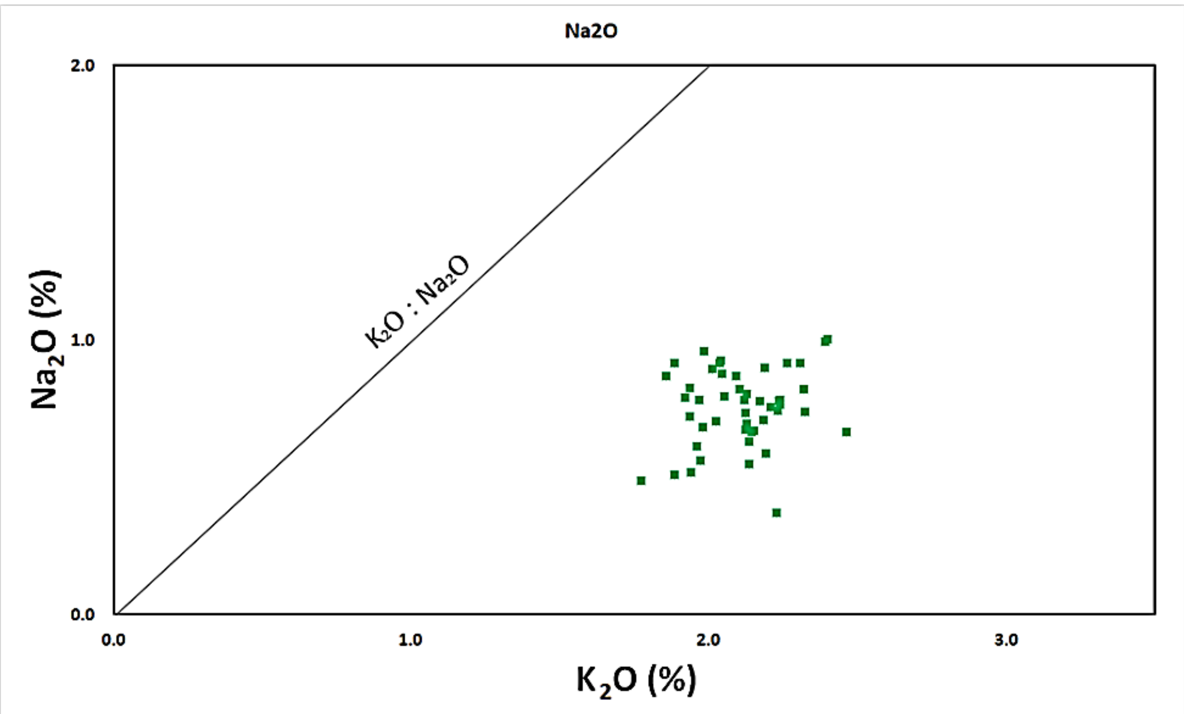

Fig. 11 Drawing Na_2O versus K_2O

evidence such as paleontology, botanical, and biological effects generally and even hum civilization effects are evaluated by sedimentary data.

In other words, the real history of the earth and its conditions are hidden in the body of the earth sediments. Sediments can be examined through various views such as particles size and diameter, ration of the formed particles of a sediment, sorting, particles kurtosis, skewness, rounding, and some other statistical parameters such as mean, mode, standard deviation, etc. each of these cases shows genre, origin, and environmental conditions that formed sediments.

Studying quaternary sediments for two studied sections of Siyah Keshim lagoon in Gilan province showed that this area has a sandy texture, mud sands, sand with slightly gravel, sandy mud with slightly gravel, and silty sand through sedimentology view. Sediments sorting are medium to weak, negative skewness, and many big particles and plate kurtic through kurtosis view which show sediment in the coastal area. Regarding the obtained results from drawing the geochemical diagrams based on the major and secondary elements oxides, it can be concluded that the studied sediments are related to a subduction margin. Moreover, geochemical evidence shows that SiO_2/Al_2O_3 ratio in these sediments is 2.6-3.7 and also Na_2O has the relatively low sedimentary maturity for the sediments of this lagoon. The mean coefficient weathering indexes such as ICV, CIW, CWI, and CIA also show that the mentioned sediments are mainly related to the first sediment cycle and tolerate high chemical weathering.

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Optimization of the tourist route by solving the problem of a salesman

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Abstract. The article is devoted to the problem of constructing the optimal transport route of a bus excursion tour of a tour operator according to the minimal length criterion. Transportation expenses are an important part of a bus tour cost, and their minimization is a required condition for route development and planning. To solve this problem, the authors used the tour route calculating method as a kind of transport task, namely the task of the salesman. To solve this problem, one of the varieties of the transport problem, namely the salesman traveling problem, is applied. The essence of the traveling salesman problem is to find the shortest route between cities, if the distances between them are known. The beginning of the route and its end coincide, that is, the route is cyclic. The most popular in Ukraine sightseeing tours of tour operators to the Transcarpathian region are taken for the optimization. A mathematical model of the traveling salesman problem is made to construct an optimal transport route. The solution was found using the Microsoft Excel's Solver add-in application program package. To solve the problem by this method, it was reduced to a special form and additional variables were introduced. The analysis helped the tour operator to check the existing sightseeing bus routes by the minimal length criterion. The results allowed making assumptions about the need to change some popular routes of Ukrainian tour operators in order to reduce transport costs. The method of bus tours evaluation of tour operators according to the minimal length criterion allows to check the tourist transportation optimality while planning the route and developing their own tourist product. The introduction of modern digital technologies and software to optimize the territorial organization of tourist routes is proposed, which will help tour operators of Ukraine in the design of bus tourist trips to nature and recreational locations in tourist regions. The development of an optimal model for the transportation of tourists on the highways and the reduction of their costs for consumption of transport services will contribute to the development of tourist trips in Ukraine. The necessity of using methods of geolocation of tourist resources for the construction of routes for visiting natural and cultural-historical monuments and tourist centers has been determined. The application of the proposed method will allow ~~tour~~ operators to reduce transport costs and, as a consequence, the total cost of the tourist product.

Keywords: tourist route, Transcarpathian region, tour operator, traveling salesman problem, optimization, solution search

Оптимізація туристичного маршруту за допомогою вирішення завдання комівояжера

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Анотація. Стаття присвячена проблемі побудови оптимального транспортного маршруту автобусного екскурсійного туру туроператора за критерієм мінімальної довжини. Транспортні витрати є важливою складовою вартості автобусного туру, їх мінімізація є необхідною умовою при розробці та плануванні маршруту. Для вирішення зазначеної проблеми авторами застосовано метод розрахунку руху маршруту туру як різновиду транспортної задачі, а саме завдання комівояжера. Сутність задачі комівояжера полягає у знаходженні мінімального маршруту між містами, якщо відомі відстані між ними. Початок маршруту та його закінчення співпадають, тобто аналізований маршрут циклічний. Для оптимізації маршруту взято найпопулярніші в Україні екскурсійні тури туроператорів у Закарпатський регіон. Для проектування оптимального транспортного маршруту побудовано математичну модель задачі комівояжера. Розв'язок задачі знаходився за допомогою прикладного пакету «Пошук рішення» електронних таблиць MS EXCEL. Для вирішення задачі зазначеним методом її було зведено до спеціального вигляду і введено додаткові змінні. Проведений аналіз надає змогу туристичному оператору перевірити наявні туристичні автобусні маршрути за критерієм мінімальної довжини. Отримані результати дозволили зробити припущення щодо необхідності зміни напрямків руху деяких популярних маршрутів українських туроператорів з метою зменшення транспортних витрат. Розроблена методика оцінки автобусних турів туроператорів за критерієм мінімальної довжини шляху, дозволяє перевірити оптимальність перевезення туристів при плануванні маршруту та розробки власного туристичного продукту. Запропоновано впровадження сучасних цифрових технологій та програмних продуктів щодо оптимізації територіальної організації туристичних маршрутів, що допоможе туроператорам України в проектуванні автобусних туристичних подорожей до природно-рекреаційних локацій в туристичних регіонах. Проведені дослідження будуть сприяти розробці оптимальної моделі транспортування туристів на автошляхах. Визначено необхідність використовування методів геолокації туристичних ресурсів для побудови маршрутів щодо відвідування природних та культурно-історичних пам'яток, туристичних центрів. Практичне застосування запропонованого методу дозволить операторам зменшити транспортні витрати та, як наслідок, загальну вартість туристичного продукту.

Ключові слова: туристичний маршрут, Закарпатський регіон, туроператор, завдання комівояжера, оптимізація, пошук рішення

Introduction. The increase in competitiveness between enterprises rendering tourist services is of great importance for the economic growth of the regions in the context of international integration of the tourism market. Competing with each other, tour operators are looking for new ways to meet the needs of tourists, while trying to use optimally available natural and material resources. In 2018, the number of tourists in Ukraine has increased more than one and a half times compared to 2016. In 2018, tour operators and travel agencies provided services to more than 4 million 557 thousand people. The Travel and Tourism Competitiveness Index of Ukraine has raise by 10 positions, ranking 78th place (Ukraine has improved its position in rating among the most attractive countries for tourists in 2019).

Transport services are an integral part of the tourism industry. The quality and comfort when traveling significantly affect the overall impression of a tourist from vacation. The idea of scientific consideration of the tourism impact belongs to the Swiss scientist W. Hunziker (1972), who believes that tourism is a set of relationships and phenomena that result from the movement of people and their stay outside their place of residence, when staying is not a permanent place of residence and is not linked to earning a profit. Further development of the research field of transport tourist traffic is acquired in the works of Claude Kaspar (2018). The English scientist John R. Walker believes that the history of tourism development as a whole is divided into two parts: the first - to the appearance and use of transport mass modes; the second - after their appearance, which in turn consists of separate stages according to the emergence of new types of vehicles, namely: the railways age, the cars age, the jet aircraft age and the cruise age on seagoing ships (Walker 2009). The researchers analysed the experience of the development of geotourism destinations, which has become the new global phenomenon in recent years (Kaygili, Sinanoglu, Aksoy, & Sasmaz, 2018).

Ukrainian scientists draw attention to the infrastructural support for the development of the potential of the sphere of recreational services and tourist trips (Kiptenko et al., 2017; Nezdoyminov, Milashovska, 2019), the creation of geo-information systems of tourist destination for the infrastructure of highways and tourist locations (Matviychuk, Lepky, Kostenko, 2016). Researchers made analysis of the transport network for tourism development in the western region of Ukraine (Grytsevych, Podvirna, Senkiv, 2019). Studies of the passenger traffic in 2018 in Ukraine shows that road passenger transportations reduced by 5.6% to 1 906.9 million passengers compared to 2017, passenger turnover decreased by 2.5% to 34.611 billion passenger-km due to deterioration of the fleet of carrier vehicles and increase of transportation tariffs. Passenger transport services were used by 4486.7 million passengers, or 96.5% from 2017 (Statistical yearbook: Transport and Communication of Ukraine – 2018, 2019).

There are a number of objective and subjective contradictions in the transport services market: between the quantitative load of transport flows and tourist destinations; between the concentration of passenger flows and the time interval; between the cost of transport services and the pricing policy of tourist operators; between the existing road transport infrastructure and the tourist transportation speed. This work is devoted to one of the methods of eliminating these contradictions.

Rail and road transport dominates in short-distance passenger traffic. There is a great demand among Ukrainian tourists for bus tours, which allow to view tourist sites, cultural monuments and terrain directly along the route and excursions. A tour operator charts a tourist route according to the following criteria: minimizing the time spent on moving between the main points of the route and ensuring maximum information of the trip. The scheme of this routing is called "the traveling salesman task".

The traveling salesman task is a partial case of the General transport task formulated for the first time by G. Monge (1781). The mathematical model of the problem was formulated by F. Hitchcock (1941), for the first time an algorithm for solving the problem was given in the works of G. Dantzig (1951). Despite the known general methods of solving transport problems, their practical application requires the development of new methods for finding the initial and optimal solutions. Thus, the work of Padmabati and Monalish (2017) provides a method of approximation and approximate calculation of the optimal solution in problems of sufficiently large size with a fuzzy income function. Modern scientists have proposed an algorithm for creating a travel route using a traveling salesman problem (TSP) and k-means clustering method to develop a web application that will help travellers to plan their route (Rani, Kholidah, Huda, 2018). The development of travel routes based on visitor profiles, distances and travel costs is explored in the paper (da Silva, Morabito, Pureza, 2018), solved the problems of optimizing the route of the "day tour" (Mao, 2019). The authors consider the problems of forming a single cloud architecture to manage a variety of multimedia content of tourist destinations routes (Pierdicca, Paolanti, Frontoni, 2019), to build routes for visiting the monuments, the researchers propose to use the methods of graph theory with the use of modern information technologies (Mikhailov, 2019). A study of classical heuristics methods for solving transportation problems was carried out in the work of Polish scientists (Szwarc, Boryczka, Twaróg and Szołtysek, 2019).

It is worth noting that in the scientific literature there is no single approach and a common algorithm for the process of constructing the itinerary of the tourist tour and evaluation of its optimality. The urgency of solving these issues defined the choice of the topic of our study, determined its purpose and objectives.

The aim of the article. The purpose of the article is to develop technological and management decisions to optimize the geographical route of tourist's transportation by the method of "traveling salesman" as one of the tools for solving problems of tourist transportation by motor transport. On the basis of this research, to determine the optimal algorithm of transportation of tourists on the regional highways of Ukraine, which will help to reduce the expenses of the trip organizer for transport services, to build schemes of routes to natural and cultural-historical monuments, tourist centres.

Material and methods of research. To determine the route of bus travel between territorial tourist locations and to form an optimal transport route, a mathematical model of the traveling salesman problem was constructed. The solution was found using the Microsoft Excel's Solver add-in application program package. To solve the problem by this method, it was reduced to a special form and additional variables were introduced. The methods of estimation of bus tours of tour operators according to the criterion of the minimum length of the path are used, which allows to check the optimality of transportation of tourists when planning a route and developing a tour operator own tourist product.

Results and analysis. In general, the traveling salesman problem can be formulated as follows. A salesman must visit n cities. The distances between these cities are known. It is necessary to build a route with a minimal total length of travelling. The mathematical model of the problem has the following form:

$$f(x) = \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij} \cdot x_{ij} \to \min$$

$$\sum_{j=1}^{n} x_{sj} = 1, (i = \overline{1,n}), \qquad \sum_{i=1}^{n} x_{sj} = 1, (j = \overline{1,n}),$$

$$x_{ij} \in \{0;1\}, (i = \overline{1,n}; j = \overline{1,n}), \tag{1}$$

where $c_{ij}, (i = \overline{1,n}; j = \overline{1,n})$ – the distances matrix elements between cities,

$x_{ij} \in \{0;1\}, (i = \overline{1,n}; j = \overline{1,n})$ – the distances matrix elements of the route.

Scientists have developed quite effective methods of solving this problem. The most common method is a complete and random selection of routes. More advanced versions of these methods are the algorithms of Dijkstra (1959), Little et al. (1963), elastic mesh and others. The development of computer technology and software has allowed to obtain the so-called metaheuristic optimization methods, the most famous of which are Hopfield neural networks (Hopfield, 1982) and the ant colonies algorithm, proposed by the Belgian researcher Marco Dorigo (1997), the Lin-Kernighan-Helsgaun algorithm (Helsgaun, 2014). Modern researchers consider a heuristic approach to the development of individual tourist routes for heterogeneous tourist groups (Zheng, Liao, 2019) and propose heuristic algorithms in the process of solving the transport problem using the Modified Distribution Method (MODI).

The ant colony optimization algorithm is based on the following assumptions: the number of graph vertices is equal to the number of ants; each ant begins its path from its graph vertices (its city); to the beginning of the movement the pheromone the intensity is the same; the choice of the first vertex is determined by the distance minimization rule, and each subsequent one by the rule

$$P_{ij,k}(t) = \frac{[\tau_{ij}(t)]^{\alpha} \cdot [1/c_{ij}]^{\beta}}{\sum_{j \in J_{i,k}} [\tau_{ij}(t)]^{\alpha} \cdot [1/c_{ij}]^{\beta}}, \; j \in J_{i,k}; \; P_{ij,k}(t) = 0, \; j \notin J_{i,k}, \quad (2)$$

where $\tau_{ij}, (i = \overline{1,n}; j = \overline{1,n})$ – the number of pheromones on the path *(i, j)* at time ***t***, that is, the attractiveness of the path *(i, j)* for an ant; *α, β* – parameters that specify the trail of the pheromone;

$J_{i,k}, (i = \overline{1,n}; k = \overline{1,n})$ – the cities visited by an ant *k*, which is in the city *i*.

The ant colony optimization algorithm is probabilistic and can be programmed in most application packages. The vehicle route construction is carried out step by step by selecting the next point until all cities are traversed. The ant selects the next city from the list of available cities, after which the target function is updated, and changes occur in the list of cities available for visiting. Then the available city is selected again. The ant returns to the original city in case of passing all the cities. The route total length is calculated as the target function value of the complete route that the ant has travelled. The use of ant algorithms is highly effective in the case of a large number of cities to visit.

The algorithm for solving the traveling salesman problem using Microsoft Excel's Solver add-in application program package is also an effective tool. For this purpose, the problem (1) is reduced to the form

$$f(x) = \sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij} \cdot x_{ij} \to \min$$

$$\sum_{i=1}^{n} x_{sj} = 1, (j = \overline{1,n}), \qquad \sum_{j=1}^{n} x_{sj} = 1, (i = \overline{1,n}), \quad (3)$$

$$u_i - u_j + (n-1)x_{ij} \le n-2,$$

$$x_{ij} \in \{0;1\}, (i = \overline{1,n}; j = \overline{1,n}),$$

Additional variables u_i, u_j are needed to avoid the so-called cyclic routes, that is, the traveling salesman arrives in each city only once and there are no return routes.

One of the most popular tours "Warm Weekend: Transcarpathian region and Thermal Waters" was chosen to check the optimality of the tourist transportation route. The tour program is available on the official website of one of the largest Ukrainian tour operators "Accord Tour" (https://www.accordtour.com/tours/1118340/). The route covers favorite places of rest, cultural monuments and ancient fortresses of the Ukrainian Carpathians and Transcarpathian region and is composed as follows: Lviv – Mukachevo – Koson – Synevyr Lake – Shypit Waterfall – Borzhava – Uzhhorod – Karpaty (palace of Counts Schoenborn) – Lviv. The tourist sights and locations of the tour route are shown in Fig. 1.

Along the route, tourists are offered a visit to the thermal pools. The construction of a unique thermal natural resort in the Berehiv region began in 1988. Later, the first "Twin Baths" were built there, which were a copy of the Eger Thermal Baths (Hungary). Over time, the complex "Kosyno" began to receive actively tourists from different cities of Ukraine and Europe. The bus tour route also includes Synevyr Lake, which is fairly considered the most valuable natural treasure of the National Park having the same name and one of the visiting cards of the Ukrainian Carpathians. It is located at an altitude of 989 m above sea level. The scheme of the bus route of the "Accord-tour" tour operator is shown in the figure 2.

A task to substantiate a route scheme optimization for a tourist trip can be solved on the basis of the geo information systems. The table which indicates the distance between the points of tourist movement is created to determine the route total length, using the Google map of the specified area. According to table 1, the total length of the tourist route is 987 km.

We will check the route optimality with the help of the Microsoft Excel's Solver add-in application program package. Figure 3 shows a MS EXCEL worksheet with the problem solution.

The results obtained with the help of the "Solution Search" show that the route planned by the tourist operator is not optimal in terms of the shortest distance. The minimal route length was found: Lviv - Shypit Waterfall - Synevyr Lake - Borzhava - Koson - Uzhhorod - Mukachevo - Karpaty (palace of Counts Schoenborn) - Lviv. A plan of this 771 km route is shown in the figure 4. It should be noted that transportation on the found route will significantly reduce the transportation costs for the organization of the tour and provide tourists with accommodation facilities in the village Koson. The obtained optimal route is 216 km shorter than the original one. It should be noted that transportation by the found route will significantly reduce transport costs for the tour organization. For example, according to technical specifications, the gasoline consumption for the Neoplan Euroliner at 60 km / h per 100 km is 26 liters. The average cost of purchasing gasoline for 216 km is 1460 UAH in prices as of 01.02.2020. According to the official site of the tour operator "Accord-tour", it is planned to conduct 22 routes on this route in 2020. According to

Fig.1. Tourist sights and locations of Transcarpathian region *Resource: http://ruraltourism.com.ua/index3.php?a=viewoblast&id=21*

our calculations, the annual cost of the tour operator at the expense of fuel savings on route optimization can be reduced by 32124 UAH.

An example of the route optimization of the popular bus tour "Warm Weekend: Transcarpathian region and Thermal Waters" of the Accord Tour showed

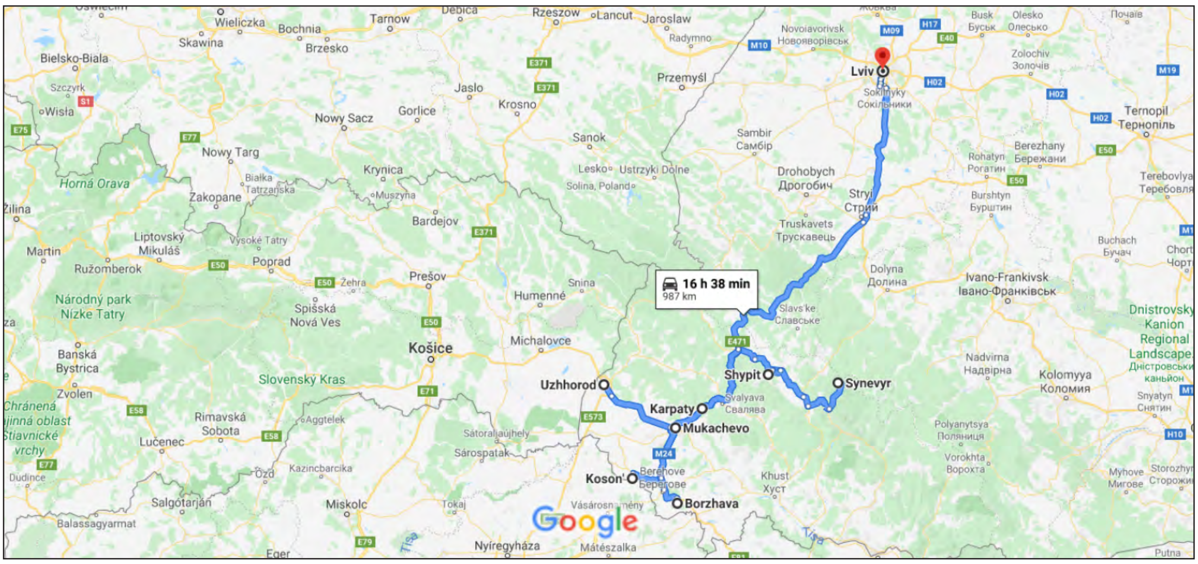

Fig. 2. The bus route plan of the tour "Warm Weekend: Transcarpathian region and Thermal Waters" *Resource: prepared by the authors according to the scheme of the tour operator "Accord-tour" and using the image Google Maps (https://www.google.com ›maps)*

Table 1. The distance between cities of the tourist route

Cities / points	Lviv	Mukachevo	Koson	Synevyr Lake	Shypit Waterfall	Borzhava	Uzhhorod	Karpaty (palace of Counts Schoenborn)
Lviv		229	264	252	198	270	267	213
Mukachevo	229		43	136	82	44	41	17
Koson	264	38		177	123	33	63	58
Synevyr Lake	252	136	177		60	141	175	121
Shypit Waterfall	198	82	123	60		124	121	67
Borzhava	270	44	33	141	124		80	59
Uzhhorod	267	41	63	175	121	80		56
Karpaty (palace of Counts Schoenborn)	213	17	58	121	67	59	56	

Resource: prepared by the authors using the Google Maps (https://www.google.com.ua maps)

that operators do not always construct the shortest route. We have tested several more tours of domestic tourism on the minimum distance criterion. Drawing up the salesman's problem and its solutions helped to conclude that:

- the total minimal distance criterion is achieved for most circular routes;
- radial routes, i.e. routes with a base departure point for daily excursions, do not meet the criterion of minimizing transport costs;
- some of the combined routes are also not optimal in the sense of achieving the shortest overall route length.

There are other potential areas where the considered route can be optimized. Thus, in the optimization of tourist routes, it is advisable to analyze the movement of tourists within the studied geographical visit points in the further development. For example, it is possible to optimize the route of tourists within the city of Mukachevo, etc.

The modern development of the tourist industry and the organization of itinerary tours require the search and use of various types of software technologies working with graphical information, geoinformation systems and provide extended spatial GIS analysis. For example, the ArcGIS Online World Routing Service module also programs and solves the problem of building the shortest route. Minimizing the total transport costs of the tour operator for the tourist transportation is an important component of the tourist route planning. However, there are a number of restrictions related to the tour intensity, the cost and quality of accommodation, the comfort of travel. The tourist transportation logistics requires a comprehen-

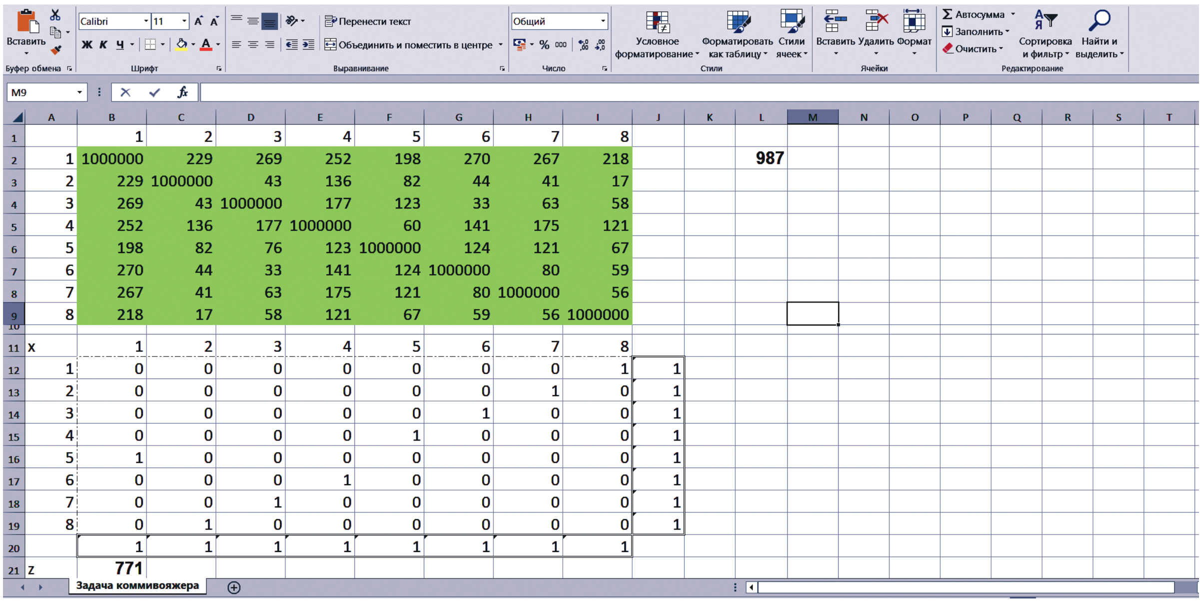

Fig. 3. Solving the traveling salesman problem with the help of the "Solution Search" package
Resource: prepared by the authors using the "Solution Search" package

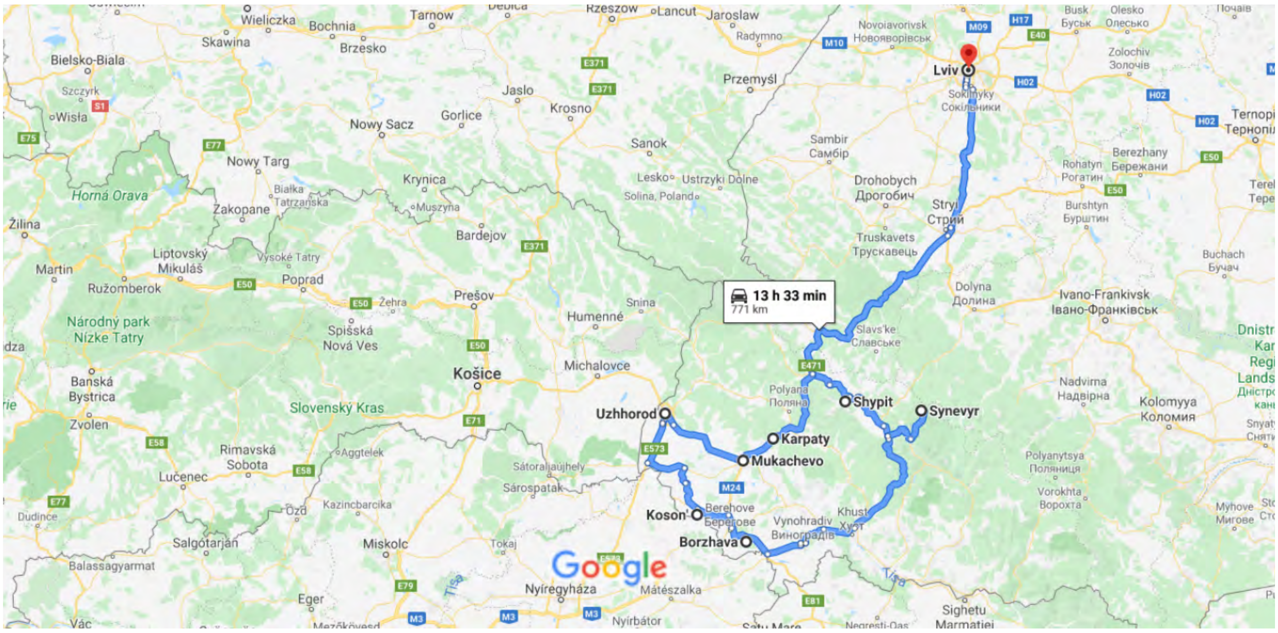

Fig. 4. An optimal scheme of the bus route of the tour "Warm weekend: Transcarpathian region and Thermal Waters"
Resource: prepared by the authors using the Google Maps (https://www.google.com.ua maps) and "Solution Search" package

sive solution to the problems arising from the tourist operator during the tour route planning. Competitive struggle in the tourist market makes strict conditions to the bus tourist routes organization. The winner in this fight is the operator that better uses modern geo-information systems, business planning technologies, marketing strategies, analysis of consumer demand and preferences, and so on. It should be noted that the organization of tourist trips on the internal highways of Ukraine, will promote the introduction of modern digital technologies to optimize the territorial organization of tourism and will assist the tour operators of Ukraine in the design of bus geotourism routes to the historical, cultural and nature-recreational sites.

Conclusions. The authors have proved that the design of bus routes by tourist operators according to the programs of visiting and acquaintance with cultural heritage, natural and recreational resources in the regions of Ukraine require the use of modern digital technology tools to optimize the traffic of tourists. The article considers the bus tours evaluation method by the minimal route length criterion. This criterion significantly affects the total cost of the tourist transportation and is important while planning a tour. It is proved that the circular routes meet the minimal length criterion, and radial, on the contrary, do not meet. To estimate the smallest distance between cities of tourist movement the linear programming theory, namely, the traveling salesman problem was applied. The solution was found using the Microsoft Excel's Solver add-in package. The obtained results support and complement the algorithm of bus tour route estimation to improve the competitiveness of the tour operator's product, as proposed in studies on the development and evaluation of tourist routes (Friggstad et al., 2018).

The next stage of the logistic analysis of tourist bus routes is to check the optimality of the international tour routes in European cities. As the size of the problem will increase significantly, it is necessary to apply the ant spatial GIS analysis and algorithm described in the article for its solution.

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Patterns of spreading of heavy metals in soils of urbanized landscapes (on the example of Brovary city)

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Abstract. Results of the study about pollutants content in soils of urbanized landscapes are presented. Patterns of their migration and accumulation in main soil types of Brovary are grounded. Correlation relationships between the individual components of ecological-geochemical system of urbanized territory were analyzed. Dependences of landscape resistance to technogenic pollution on the level of conservation of natural geochemical parameters of soils, degree of their anthropogenic transformation and level of heavy metals were determined. According to geochemical criteria technogenic associations of heavy metals in soils are determined, which are represented by the following elements: Cu>Pb>Zn>Co>Cr>V>Mo>Mn>Ni. Level of gross content of chemical elements compounds in soils of different zones of the city is heterogeneous. City zones with the highest polyelement contamination of soil have been identified. Maximum technogenic load is recorded in urban areas of transport infrastructure zone and zone of production and communal-warehouse facilities. Ecological and geochemical assessment on the total index of pollution by using methods of Y.E. Saeta, is shown. Value of this topsoil parameter in Brovary (0-10 cm) ranges from 30 to 106, the average is 65, which corresponds to hazardous level of soil pollution. According to the total indicator of technogenic pollution, Brovary belongs to cities with high pollution level. Soils in all parts of the city, except for residential areas, are classified as hazardous. Studied soils of the city are characterized by plumbum geochemical specialization. High levels of zinc, manganese, cobalt and chromium were also found (the maximal permissible concentrations in soil exceeds by 1.7-4.7 times). Especial attention is paid to the patterns, mechanisms of pollutants influence on the complex of soil properties and processes that determine the ecological condition of soils and their resistance to anthropogenic flows. Soil contamination by pollutants leads to changes in their physical and chemical properties (cation exchange capacity pH, organic matter content) which causes a low buffering capacity of soil cover of the city.

Keywords: heavy metals, gross content, mobile forms, urban soil, migration, spreading patterns

Закономірності розподілу важких металів у ґрунтах урбанізованих ландшафтів (на прикладі м. Бровари)

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Анотація. Наведено результати дослідження вмісту забруднюючих речовин у ґрунтах урбанізованих ландшафтів. Обґрунтовано закономірності їх міграції та акумуляції в основних типах грунтів м. Бровари. Проаналізовано кореляційні зв'язки між окремими компонентами еколого-геохімічної системи урбанізованої території. Встановлено залежності стійкості ландшафтів до техногенних забруднень від рівня збереження природних геохімічних параметрів ґрунтів, ступеня їхньої антропогенної перетвореності та рівня надходження важких металів. За геохімічними критеріями визначено техногенні асоціації важких металів у ґрунтах, які представлені такими елементами: Cu>Pb>Zn>Co>Cr>V>Mo>Mn>Ni. Рівень валового вмісту сполук хімічних елементів в ґрунтах різних зон міста різнорідний. Виявлено зони міста з максимальним поліелементним забрудненням ґрунтів. Максимум техногенного навантаження зафіксовано в урбаноземах зони транспортної інфраструктури та зони виробничих та комунально-складських об'єктів. Наведено еколого-геохімічну оцінку за сумарним показником забруднення з використанням методик Ю.Є. Саєта. Значення цього показника поверхневого шару ґрунту м. Бровари (0-10 см) коливається від 30 до 106, середній показник – 65, що відповідає небезпечному рівню забруднення ґрунтового покриву. За сумарним показником техногенного забруднення м. Бровари відноситься до міст з високим рівнем забруднення. Ґрунти всіх зон міста, за винятком житлової, віднесені до категорії небезпечних. Досліджувані ґрунти міста характеризуються свинцевою геохімічною спеціалізацією. Встановлено також досить високі рівні цинку, мангану, кобальту та хрому (перевищення ГДК у ґрунті в

1,7-4,7 рази). Окрему увагу приділено закономірностям, механізмам впливу забруднюючих речовин на комплекс ґрунтових властивостей і процесів, що визначають екологічний стан грунтів і їх стійкість до техногенних потоків. Забрудненість грунтів полютантами призводить до змін їх фізико-хімічних властивостей (катіонно-обмінна ємкість, pH, вміст органічної речовини), що зумовлює низьку буферну здатністю ґрунтового покриву міста.

Ключові слова: важкі метали, валовий вміст, рухомі форми, урбаноземи, міграція, закономірності розподілу

Introduction. Methodological component of the ecological-geochemical assessment of urbanized territories is landscape-geochemical analysis of the environment conditions. An important area of such analysis is studyi of pollutants migration, transformation of technogenic flows and accumulation of pollutants in individual components of the landscape, taking into account the natural conditions and reactions of natural landscape systems to anthropogenic impact.

Intensive development of industry and increase of economic activity types of society are the reason and consequence of urbanization processes growth. In Ukraine, there is a steady upward trend in the share of urban population. Presently, the urbanization rate is 67%, but according to the UN forecasts the proportion of urban population in Ukraine will reach 79.0% in 2050. Constantly growing pollution of natural systems, as a result of anthropogenic activities and low efficiency of methods for extraction of pollutants pose a threat to the human health and the environment as a whole.

Under the influence of urbanization-technogenic processes, geochemical transformation of soils takes place, which leads to the violation of their properties and structure. The most significant geochemical changes in soils are confined to the top soil horizons, into which a significant amount of dust and aerosols containing pollutants comes from the atmosphere. In particular, small dust fractions, humus substances increase the absorption capacity of urban soils and carbonate dust falling leads to an increase in the pH of the top layer soil horizons. Topsoil burdened by the accumulation of pollutants, including heavy metals (HM) and radionuclides. The most common pollutants found in the soil of cities are: plumb on the example of the city of Brovary, Kyiv region (Pb), mercury (Hg), chromium (Cr), cuprum (Cu), nickel (Ni) and zinc (Zn) content (Zhovinskiy et al., 2002; Zhovynskyi et al., 2012). Technogenic geochemical anomalies in the topsoil of cities are more stable than in adjacent environments. Therefore, degree of contamination of soil cover is the main environmental and geochemical criterion for characterizing anthropogenic impacts.

The purpose of this work is ecological-geochemical assessment of urban areas; establishment of the degree of contamination by HM of individual components of urban landscapes, revealing patterns of their behavior in topsoil.

Theoretical basis of the modern ecological-geochemical studies of urban areas is the basic scientific concepts of geochemistry of landscapes (Polynov, 1952, 1956; Hlazovska, 1972, 1976; Perelman, 1975, 1979, 1999; Kasymov, 1982, 1995, 2004, 2013). The studies of B.F. Mitskevycha (1971, 1981), E.Ia. Zhovynskoho (1976, 1979, 1980, 1981, 1991, 1992, 2005, 2012), A.I. Samchuka (1982, 1993, 1998, 2002, 2005, 2006, 2012), I.V. Kuraievoi (1996, 2014, 2002, 2010, 2011, 2012, 2013, 2015, 2019), L.L. Malyshevoi (1997, 2000), H.M. Bondarenka (2000, 2002, 2004), V.O. Yemelianova (2004), V.V. Dolina (2004, 2011, 2011b, 2011), H.V. Lysychenka (2009), O.Iu. Mytropolskoho (2004, 2006), V.M. Shestopalova (2011) including other scientists have made a significant contribution to ecological-geochemical studies of individual components of the landscape in Ukraine. Studying of the content of toxic elements in the topsoil cover of urban areas is devoted to the following works: S.S. Voloshchynskoi (2008, 2012), Y.V. Henyka (1994, 1996), P.P. Nadtochii (2012), M.V. Pelypets (2000), T.K. Klymenko (2005), V.S. Homicha (1996, 1997, 2004, 2005, 2013), A. Greinert (1995, 1998, 1999), C. Ferguson (1999), P. *Wieczorkowski (2002, 2005)*, Wang KY, Han P, Zhang SZ. (2012), Stockmann, U. (2015), Schneider, A.R. (2016) including other researchers. However, most of the studied urban agglomerations did not lend themselves to the complex landscape-geochemical analysis.

The current study focuses not only on the determination of HM in urban landscapes within the areas of impact of man-made objects, but also on the analysis of the conditions of their lateral migration in the soil cover of the urban environment.

Materials and methods of the study. The sdudy object is the landscape complexes of Brovary, located within areas of influence of large industrial enterprises and municipal-warehouse facilities.

Research was performed using analytical, cartographic, statistical methods, as well as methods of landscape-geochemical researches with the use of GIS-analysis tools. Basic information on the landscape-geochemical structure of the territory is supplemented by detailed geochemical studies of landscapes in key areas.

Methodology of soil-geochemical survey provided for the selection of pooled soil samples (for each field and soil sections, respectively) according to the current DSTU (State Standards of Ukraine) 4287: 2004, DSTU (ISO) 10381-2: 2004; study of particle size distribution of soils - DSTU 4730: 2007; determination of total soil humus - DSTU 4289: 2004; soil pH – GOST (All Union State standard) 2621291. Methods for determining composition and properties of soils; pH of the water extract - GOST 17.5.4.01-84. Soil sampling was carried out according to the regular network of key sites, taking into account the features of the functional zoning of Brovary. 1674 soil samples from 7 zones of the city were selected and analyzed in total.

To determine the geochemical parameters the following modern physicochemical methods were used: emission spectral analysis, atomic absorption, potentiometric, etc. For all key areas of the study, total technogenic contamination (Zc) was calculated using the formula (Saet, 1990):

$$Zc = \sum Kn_{si} - \ldots(n-1),$$

where *n* is the number of anomalous elements;

Soil samples determined their basic physicochemical properties and total trace element content. The particle size distribution was determined by the Casa-grandex isometric method, the pH potentiometrically in a suspension of 1 mol dm^3 of HCl solution. Hydrolytic acidity and exchange cations – Ca^{2+}, Mg^{2+}, K^+, Na^+ are determined by the Kappen method.

Content of HM was determined by mass spectral (ICP-MS) and atomic emission methods (ICP-AES) with inductively coupled plasma on Elan-6100 devices and Optima-4300 DV (Perkin-Elmer, USA) also ICP–MS analyzer ELEMENT-2 (Germany) at the Institute of Geology of the Polish Academy of Sciences and the Institute of Geochemistry, Mineralogy and Ore Formation of the NAS of Ukraine named after M.P. Semenenko.

Correlation coefficients were calculated for the statistical evaluation of test results. These coefficients and content of HM in the soil samples were compared with the values that determine the geochemical background of soils according to the National Science Center "*Institute of soil sciences named after Sokolovsky*" as well as the normative indexes of the GDK values of gross content and GDK of mobile forms of pollutants in soils (Dobrovolskiy, 1983; Fatieiev et al., 2003). To assess soil contamination, Kc concentration coefficient was calculated using the formula: Kc = C / Sf, where: C is the actual content of the contamination; SF is the background content.

Results and discussion. Content and distribution of HM in soil profiles is determined by the amount of organic matter, physical and chemical properties of soils and the course of the soil-forming processes. The natural content of trace elements in the soil depends primarily on the type of parent rock, which is their main source of genesis (Kabata-Pendias, 1989; Samonova et al., 1998; Vorobyova et al., 1980 Zhovinskiy et al., 2002).

Typical features of urban soils are neutral or alkaline reaction, increased bulk weight, reduced moisture and compaction. This complicates an ability to identify the dependence of physicochemical changes occurring in soil cover and contributes to the fixation of pollutant elements.

Territory of the city is polluted with elements of I-III class of hazardous - plumbum, zinc, cobalt, cuprum, etc. Plane pollution exceeds background values and some man-made fields have indicators in excess of MPC. The study was allocated to areas with a high content of chemical elements that form the plane and pinpoint anomalies (Table 1).

During the landscape-geochemical study of the territory of Brovary, special attention was paid to the territories under the influence of enterprises, characterized by high level of air emissions: State-owned powder metallurgy plant, CJSC "Brovarskyy zavod plastmass", JV "BROVARSKYI FACTORY AUCTION ENGINEER, CO", Municipal Enterprise "KZASK LTD", "Polymer Color LLC".

Plumbum. The Earth's crust plumbum accumulates almost exclusively as Pb^{2+}, sporadically Pb^{4+}. In igneous rocks, Pb is present in dispersed form, mainly in feldspars and biotites. Plumbum has high sulphide tendencies, which are appeared in the formation of sulphide minerals. It is highly dispersed in sulfide liquids and is converted to residual sulfide products. It shows high geochemical affinity with zinc, forming common geochemical anomalies (Avessalomova I.A., 1978; Kabata-Pendias A., 1989).

The presence of a plumbum in city soils is directly related to the mineralogical and granulometric composition of soil rocks. Plumbum, due to the poor solubility of minerals, migrates in the soil less intensively than Cadmium and Zinc. Elevated levels of plumbum in the topsoil layers are largely associated with anthropogenic influence production and communication of emissions. Acidic reaction of soils, their poor absorption capacity and low humus content increase the absorption of plumbum by plants (Alloway, 1995; Avessalomova, 1978; Bakker et al., 1997; Samonova, 1998; Vorobyova et al., 1980).

Plumbum compounds from anthropogenic sources accumulate in the surface soil layer of

Table 1. Coefficients of HM concentration by functional zones of Brovary (calculated based on results of own research)

Chemical element	Public area	Residential area	Land-scape and recre-ational area	Area of transport infra-structure	Area of engineering infrastructure	Area of pro-duction and municipal-warehouse facilities	Special pur-pose area	Regional background values (by A.I. Fateev)
Mn	**400**	**380**	**220**	**760**	**670**	**910**	**830**	395
Kc	1.01	0.9	0.5	1.9	1.7	2.3	2.1	
Ni	**9.4**	**8.3**	**8.1**	**10**	**7.5**	**11**	**10**	12
Kc	0.7	0.69	0.67	0.83	0.6	0.9	0.8	
Co	**5.6**	**4.7**	**4.1**	**6.4**	**32**	**52**	**44**	10
Kc	0.56	0.47	0.4	0.64	3.2	5.2	4.4	
V	**14**	**9.5**	**11**	**10**	**32**	**43**	**29**	16
Kc	0.87	0.59	0.68	0.62	2	2.6	1.8	
Cr	**42**	**55**	**28**	**82**	**110**	**138**	**102**	39
Kc	1.07	1.4	0.7	2.1	2.8	3.5	2.6	
Mo	**2.1**	**1.9**	**1.7**	**4.2**	**5.1**	**6.4**	**4.5**	2.4
Kc	0.87	0.79	0.7	1.7	2.1	2.6	1.8	
Cu	**31**	**43**	**38**	**115**	**340**	**540**	**490**	8
Kc	3.8	5.3	4.7	14.3	42.5	67.5	61	
Pb	**55**	**18**	**16**	**82**	**76**	**78**	**62**	11
Kc	5	1.6	1.4	5.8	6.9	7	5.6	
Zn	**35**	**55**	**32**	**110**	**165**	**230**	**170**	42
Kc	0.8	1.3	0.76	2.6	3.9	5.4	4	

urban areas. Dispersion of plumbum in all surface environments is associated with its widespread use in the production of batteries and gasolines with the addition of its compounds. A part of the plumbum accumulated in the soil is formed by the incineration of waste. Its compounds are used for the production of paints, pesticides, plastic stabilizers and metallic lead in accumulators, alloys and pipes receiving sewage channels after production (Kabata-Pendias, 1989).

High coefficients of plumbum variation within the city indicate the sporadic nature of spreading of the pollutant, which is a consequence of anthropogenic origin. Gross content of plumbum (Pb) in urban soils of all functional zones of Brovary exceeds its background content (25-28 mg / kg). The low level of gross Pb content is characterized by soils of landscape-recreational and residential zones (16-21 mg / kg) while in the soils of transport and engineering infrastructure zones (80-400 mg / kg) its content varies from medium to very high. In 58% of the city soils, the gross plumbum content is 1.1-3.2 MAC. Excess of the maximumal permissible concentration of plumbum by 1.2-3.5 times is observed in 70% of the territory of industrial and municipal-warehouse facility zones and by 1.1-2.0 times in 39% of the residential territory.

The highest concentrations of plumbum (348, 400 mg / kg) were recorded along Gagarin Street and within the engineering corridor along Onikienko street. Very high level of soil pollution (more than 400 mg / kg) was found in 2% of the city territory (urban soils of the public zone) by 9% (urban soils of the transport infrastructure zone) - medium and high (250-370 mg / kg) and only 15% - low (80-120 mg / kg), which is associated with the high transport loads in the suburban area of Kiev.

Cuprum. In soils, cuprum is found in various forms, usually creating sedentary compounds in the form of precipitation of carbonate and sulfate. Cuprum is highly sorbed by organic substances and clay minerals. Absorption of cuprum connected inversely with the reaction soil acidity; decrease in pH increases the availability of this element, with increase in soil pH, level of absorption of the element decreases (Avessalomova, 1978; Kabata-Pendias, 1989; Vorobyova et al., 1980 Vinohradov, 1957).

Cuprum is widely used in electrical engineering, decorative products both in pure form and in alloys (bronze and brass). Cuprum compounds are also used in the manufacture of plastics, plant protection products, fertilizers, paints, pharmaceuticals and other industries (Kabata-Pendias, 1989).

Soils of the city are characterized by increased cuprum content. In most tested samples, concentration limits exceed the background (8 mg / kg) and MPC (33 mg / kg) by a factor of ten. The maximum cuprum content (1000 mg / kg) was fixed in the sample No 231, taken from the lawn around Peronna street. Data on the gross content of cuprum (Cu) in the soils of production and municipal-warehouse facilities zone (600-1000 mg / kg) and residential zone (80-100 mg / kg), public zone (400-600 mg / kg) can be united into a single generalized unity. It is characterized by an increased and high level of the content of this metal, while in the soils of the landscape-recreational zone (30-50 mg / kg) the cuprum content is relatively low. In 90% of soil samples taken in different parts of Brovary, MPC is exceeded by gross cuprum content by 30 times; this is primarily typical for urban soils in the production and municipal-warehouse facilities and special-purpose zones.

A similar situation is observed for the gross ***vanadium*** content. The level of this metal in the soils of the public zone is assessed as average (10-18 mg / kg), whereas in soils of production and municipal storage facility zones their excess amount is (> 40 mg / kg) and in 20% of the studied territories the MPC exceeds by 3.1 types in average and makes 150 mg / kg.

Nickel and cobalt. Soil cover of the territory plays a decisive role in the spreading of nickel and cobalt, content of which depends on their amount in the parent rock. The maximum values of Ni and Co are confined to the humus horizons of soil. In gley horizons, at high concentrations of iron, noticeable decrease in pollutants occurs compared to ungleened (Vorobyova et al., 1980; Vinohradov, 1957; Zhovinskiy et al., 2002; Zhovynskyi et al., 2012.).

Analysis of the studies shows the clear trend in uniform distribution of pollutants in the soils of the city. Nickel and cobalt content does not exceed the upper limit of permissible concentrations in the surface horizons of the soil (Ni - 8-10 mg / kg, Co - 4-6 mg / kg). Only in the area of Metallurgov, Schelkovskaya and Onikienko streets, their content exceeds the MPC by 2-4 times (reaching 100 mg / kg).

Zinc. Pollutants accumulate in top layer horizons, where it is sorbed by organic matter and clay particles. Interacting with humus forms stable compounds, and the adsorption level depends on pH. In alkaline environment zinc is absorbed by the mechanism of chemisorption, and in the acidic environment of the ion adsorption Zn weakens due to competition with other ions, which leads to the desorption from the solid phase into the soil solution and leaching Zn. Proportion of mobile zinc increases with increasing of acidity (Alloway, 1995; Samonova et al., 1998).

Soils of the city are characterized by contrast distribution of zinc: from 60 to 1000 mg / kg. In most samples zinc content does not exceed 120 mg / kg, with a regional background value of 42 mg / kg. Zinc is one of the most heavily used non-ferrous metals. In general (more than 90%), it is used in metal state and is used to coat steel sheets and metal caster for corrosion protection (for example, in automobiles, construction). Alloys (bronze, brass) are widely used for the manufacture of machine parts and accessories. Dispersion of zinc in metal form is small, but its compounds are easier to migrate, which are used in the manufacture of rubber, plant protection products, fertilizers, pharmaceuticals and cosmetics. An important source of soil zinc pollution is paint production, coal burning, tire detrition, sewage discharges, as well as leaching from landfills (Vorobyova et al., 1980; Samonova et al., 1998).

Increased content of zinc in soils is observed mainly in the northeast and northwest of the region - within the territory of most industrial and adjacent to the main roads. The highest concentration of zinc was observed in soils located on Lisova, Bandery, Fialkovskoho, Symonenka streets. The maximum content of zinc (1050 mg / kg) was found near the "KZASK LTD" plant.

Very high zinc content (530-827 mg / kg) is typical for soils nearby the enterprises: CJSC "Brovarskyy zavod plastmass", JV "BROVARSKYI FACTORY AUCTION ENGINEER, CO". Content of 347 mg / kg of zinc was also found on Pereyaslav Shlyakh and Stepana Bandery streets.

Mangan. Significant accumulation of manganese in the top layer horizons of soil cover is associated with the fixation of this element with humic substances (Alloway, 1995; Avessalomova, 1978). Manganese compounds are well soluble, especially during the acidic reaction of the environment.

Soil cover of the territory contains relatively high manganese content, but the concentration coefficient in soils does not exceed 6 in average, and more than 40% of the surveyed areas contains from 360 to 540 mg / kg of this element. The maximum manganese content was recorded in the area of industrial and municipal storage facilities (2300 mg / kg). Moreover, the concentration within the city varies from 320 to 1900 mg / kg. Manganese soil pollution is especially significant near the enterprises: State-owned powder metallurgy plant (1910 mg / kg) and OJSC "Building constructions plant".

Chromium. Chromium content in soils is mainly determined by its content in the parent rock [1]. The main part of chromium in soils is in trivalent form. In acidic soils, chromium compounds are almost station-

Table 2. HM concentration coefficients by functional zones of Brovary (Calculated according to our own research results)

Chemical element	Public area	Residen-tial area	Landscape and recreational area	Area of trans-port infra-struc-ture	Area of engineering infrastruc-ture	Area of produc-tion and munic-ipal-warehouse facilities	Special pur-pose area	Regional background values (by A.I. Fateev)
Mn	**400**	**380**	**220**	**760**	**670**	**910**	**830**	395
Kc	1.01	0.9	0.5	1.9	1.7	2.3	2.1	
Ni	**9.4**	**8.3**	**8.1**	**10**	**7.5**	**11**	**10**	12
Kc	0.7	0.69	0.67	0.83	0.6	0.9	0.8	
Co	**5.6**	**4.7**	**4.1**	**6.4**	**32**	**52**	**44**	10
Kc	0.56	0.47	0.4	0.64	3.2	5.2	4.4	
V	**14**	**9.5**	**11**	**10**	**32**	**43**	**29**	16
Kc	0.87	0.59	0.68	0.62	2	2.6	1.8	
Cr	**42**	**55**	**28**	**82**	**110**	**138**	**102**	39
Kc	1.07	1.4	0.7	2.1	2.8	3.5	2.6	
Mo	**2.1**	**1.9**	**1.7**	**4.2**	**5.1**	**6.4**	**4.5**	2,4
Kc	0.87	0.79	0.7	1.7	2.1	2.6	1.8	
Cu	**31**	**43**	**38**	**115**	**340**	**540**	**490**	8
Kc	3.8	5.3	4.7	14.3	42.5	67.5	61	
Pb	**55**	**18**	**16**	**82**	**76**	**78**	**62**	11
Kc	5	1.6	1.4	5.8	6.9	7	5.6	
Zn	**35**	**55**	**32**	**110**	**165**	**230**	**170**	42
Kc	0.8	1.3	0.76	2.6	3.9	5.4	4	

Notes. Kc is the concentration coefficient

ary and at pH 5.5 precipitate (Avessalomova, 1978). The main man-made sources of chromium include the chemical industry (Vorobyova et al., 1980; Vinohradov, 1957; Zhovynskyi et al., 2012.).

Pollutant enters the soil from ore dumps, scrap metal and household chromium-containing waste.

Regional background value of chromium for city soils is 39 mg / kg. The average content in sandy and clay soils is 37 mg / kg. It is proved that the average content of gross forms of Cr in soils of the city, in particular in soddy-low-podzolized sandy and sub-sandy, is 32-42 mg / kg. Little fluctuations of Cr content in some soils were detected and more of these elements correspond to light gray, clay loamy and alluvial sandy loam soils - 60-80 mg / kg of soil. Maximal values are fixed for special purpose areas (102 mg / kg) and engineering infrastructure (110 mg / kg). High chromium content (92-140 mg / kg) is also typical for the soils of production and municipal storage facility zones.

In residential area of Brovary the accumulation of HM in soils occurs similarly to nutrients in a concentric type. This is due not only to the type of parent rocks, but also to temporary differences in the development of these territories.

Local technological anomalies, taking into account regional characteristics, allow to identify the concentration coefficients we calculated (Table 2). HM content in the soils of Brovary is increased (Ks> 1.0) compared to the background territories that do not experience significant anthropogenic impact.

According to the values of this coefficient in the city soils there is an increased gross content of HM in comparison with the background values. Content of Cu, Pb, Zn is increased (Kc>3) in zones of engineering infrastructure and production and municipal-warehouse facilities; Pb, Zn, Co – in area of engineering infrastructure; Pb and Cu in public area; Zn, Ni, Pb i Cu – in area of transport infrastructure.

For gray soils - Pb, Cu; for sod-podzolic soils – Pb i Cu; for sod-podzolic silt and meadow soils – Cu i Zn; for urban soils the main pollutants are Cu, Zn, Pb (Kc> 4.0);

In general, Brovary has found the presence of polyelement contamination of urban soils. In soils of technogenic and anthropogenic zones of the city the main pollutants are: Cu, Pb та Zn. Ranges of accumulation of the gross forms of HM in accordance with the Kc in the functioning of the city are as follows:

Public area:
Pb>Cu>Cr>Mn>V>Mo>Zn>Ni>Co;
Residential area:
Cu>Pb>Cr>Mn>Zn>Mo>Ni>V>Co;
Landscape Recreation Area:
Cu>Zn>Pb>Mo>Cr>Mn>V>Ni>Co;
Transport infrastructure area:
Cu>Pb>Zn>Cr>Mn>Mo>Ni>Co>V;
Engineering Infrastructure Area:
Cu>Pb>Zn>Co>Cr>Mo>V>Mn>Ni;
Area of production and municipal-warehouse facilities: Cu>Pb>Zn>Co>Cr>V>Mo>Mn>Ni;
Special Purpose Area:
Cu>Pb>Co>Zn>Cr>Mn>V>Mo>Ni.

Soils of landscape and recreation zone are characterized by the lowest content of heavy metals: for many elements Kc <1, accumulation is observed only for Cu and Pb. One of the highest concentrations of pollutants in the city has been identified in the area of production and municipal l-warehouse facilities and special purpose area. Pb, Zn (Kc = 5.8 i 2.6) as well Cr, Mo, Ni (0.8-2.1) usually accumulate near major highways. V (0.62) was found in lower concentrations. Localization of HM anomalies is recorded in the urban industrial area and near highways.

In residential area of the city soils of one-apartment buildings and zones of multi-apartment small and medium-sized buildings are different. The processes of accumulation and scattering of HM in soils of private buildings are less intense than multi-apartment, despite their significant emission. Areas of single-family buildings are characterized by a weak geochemical transformation of soil curve: for most elements Kc <1,0, except Zn, Pb. In the area of multi apartment building higher concentrations of pollutants were found: for Cr and Cu (Kc = 1.4 i 5.3 relatively). In the background soils and in the landscape and recreational zone of the city, except for the association of Cu>Zn>Pb>Mo>Cr>Mn>V>Ni>Co the association Cu>Pb>Cr>Mn>Zn>Mo>Ni>V>Co is observed. Composition of associations in soils of private building areas is close to the background values and values of the landscape and recreational area.

When comparing the background and urban areas anthropogenic association is highlighted: Cu>Pb>Zn>Co>Cr>V>Mo>Mn>Ni. It is dated to production and municipal-warehouse objects and zones of special purpose, investigated HM are characterized by high technophilicity.

The mobile forms of HM are in the particular content in the estimation of the ecological-geochemical state of soils is, which are able to pass from solid phases to soil solutions and be absorbed by living organisms. That is why we have evaluated the content of mobile forms of HM both in soils of main functional zones of the city and in main types of soils within the city of Brovary.

Unlike the gross content, a concentration of mobile forms of plumbum in soils of all studied functional zones of the city does not exceed the MPC. Exceedance of sanitary and hygienic indicators is also not noted for cobalt and nickel. Unlike the gross content of HM in soils, which shows a clear difference between anthropogenic and man-made areas of the city the series of accumulations of HM by Kc for all functional zones of the city are similar. The most dangerous pollutants are the mobile forms of Zn and Pb (Table 3).

The content of mobile forms of zinc in soddy-slightly podzolic sandy and sandy loamy soils is within acceptable values, while the soils of production and municipal storage facility zone are beyong the MPC. 58% of the territory of the special zone and transport infrastructure zone of mobile zinc in the soil exceeds the MPC by 1.1-2.7 times. Soil of all functional zones of Brovary exceeds the MPC in terms of the

Table 3. Content of mobile forms of HM in functional zones of Brovary (according to our own research)

Functional area	Ni	Co	Cr	Cu	Pb	Zn
Public area	0.59	0.27	0.26	2.8	0.61	4.10
Residential area	0.29	0.31	0.21	5.7	0.34	4.30
Landscape and recreational area	0.31	0.33	0.32	2.9	0.58	3.88
Area of transport infrastructure	0.56	0.50	0.41	4.30	1.03	4.90
Area of engineering infrastructure	0.42	0.72	0.38	3.87	0.93	5.60
Area of production and municipal -warehouse facilities	0.68	0.81	0.49	6.80	0.88	6.80
Special purpose area	0.52	0.58	0.51	9.70	0.94	6.60
MPC of mobile forms Kysel V.I., 1997 (acetate-ammonium buffer, pH 4.8)	4	3	6	3	2	23

content of movable cuprum. In 90% of the territories of production and municipal storage facility zone objects and special purpose zone, regardless of the soil type, content of movable cuprum reaches 1.4-3.2 MPC, in 32% of the residential zone (urban soil) - up to 1.1-2, 3 MPC. In soddy viscous sandy loam soils 34% and in light gray soils 19% there is an excess of MAC for mobile copper, which is 1.2-3.4 MAC and 1.1-1.6 MAC, respectively.

The content of mobile forms of iron in the soils of residential and public areas of the city is within the normal range (0.24 mg / kg), and in the soils of the landscape-recreational zone there is a sharp increase in its content (0.52 mg / kg). Accumulation of iron in these soils can be associated both with the features of parent rocks and with destruction of glandular compounds entering the soil with well-preserved plant residues.

We have identified the following associations of accumulation of mobile forms of heavy metals, typical for various functional zones of the city:

Public area: Zn>Cu>Pb>Ni>Co>Cr;

Residential area: Zn>Cu>Pb>Co>Ni>Cr;

Landscape and recreational area: Zn>Cu>Pb>Co>Cr>Ni;

Area of transport infrastructure: Zn>Cu>Pb>Ni>Co>Cr;

Area of engineering infrastructure: Zn>Cu>Pb>Co>Ni>Cr;

Area of production and municipal-warehouse facilities: Zn>Cu>Pb>Co>Ni>Cr;

Special purpose area: Cu>Zn>Pb>Co>Ni>Cr.

Natural background soils by the content and degree of contamination of mobile forms of heavy metals have low content of Ni, Co, Cr and average – Cu, Pb and Zn (Table 4).

7% of the public and residential area soils and 32% of the landscape and recreation area soils are poorly polluted with Cu, 11% territory of the engineering infrastructure zone and 21% of the city areas occupied by light gray loamy soils have a high degree of soil contamination by this pollutant.

Background soils of the city accumulate mobile forms of HM in the following order of declining:

Light gray sandy: Cu>Zn>Ni>Pb>Cr>Co;

Light gray loam: Zn>Cu>Ni>Pb>Co>Cr;

Turfy slimy slightly saline light-loamy: Zn>Cu>Pb>Ni>Co>Cr;

Turfy -slightlypodzolic sandy-loamy: Zn>Cu>Ni>Co>Pb>Cr;

Alluvial layered sandy loam: Zn>Cu>Co>Pb>Ni>Cr.

According to the summed indicator of the soil pollution by mobile forms of heavy metals, the studied functional zones of the city experience a moderately hazardous technogenic load.

Comparing values of Zc in gross content of HM with content of their mobile forms, it can be assumed that in the soils of production and municipal storage facility zone, most of the HM is in a form readily available to plants. While the soils of residential and landscape recreational areas are characterized by opposite tendency, the metals here accumulate mainly in fixed, stationary forms. In turfy - slightlypodzolic sandy-loamy and turfy loam soils of the background areas of the city no significant fluctuations in gross contents of Cr, Ni and Co are observed along the soil profile. Compared to urban soils, the accumulation of heavy metal compounds from deep soil horizons is observed in the soils of background territories. Obviously, this is due to a significantly lower level of technogenic load and increased acidity of top layer horizons of natural soils, compared to urban soils. Under such conditions solubility of compounds of the most HM increases and their migratory capacity increases. Low content of HM in top layer humus horizon and overwhelming accumulation of them in the lower soil horizons is also explained by the absence of woody vegetation forms in the background. Obviously, this prevents the movement of HM from parent rocks to the top layer horizons of the soil and land. In this case, a low contrast biogeochemical barrier associated with the formation of plant biomass is observed. The only exception is zinc, whiches content in the top layer soil horizon is slightly higher. Urban soils are heavily polluted by HM compared to natural background soils. Maximum concentrations of contaminant elements in most cases are confined to the top layer organogenic horizon, where the process of humus creation is intensively taking place, which contributes to the binding of HM and their accumulation.

Other horizons of the studied soils are characterized by low humus content (up to 0.4%), reaction of soil solution medium changes and soil density increases with depth. These properties lead to a decrease in the microbiological activity of soils and mobility of heavy metals. Spreading of the part of HM (Pb, Zn, Cu) in soils of functional zones of the city is subject to general trends: in soils of natural and anthropogenic zones along the profile of HM they are distributed evenly, as in soils of the background territory with a small accumulation in the top layer horizon. For technogenic and anthropogenic zones of the city, regardless of soil type, there is a clear accumulation of metals in the top layer soil horizon.

Table 4. Content of gross and mobile forms of HM in the background soils of Brovary, mg / kg (according to the results of own research)

№	Soil	Ni	Cr	Zn	Co	Cu	Pb
1	Light gray sandy	15	21	45	4	11	32
		1.6	0.26	2.1	0.18	2	0.38
2	Light gray loam	20	34	55	6	23	38
		1.5	0.36	1.9	0.38	3.1	0.43
3	Turfy slimy slightly saline light-loamy	12	29	38	8	34	35
		0.49	0.32	4.52	0.37	2.37	0.47
4	Turfy -slightlypodzolic sandy-loamy	19	21	58	8	32	24
		1.3	0.27	3.42	0.9	3.18	0.33
5	Alluvial layered sandy loam	11	19	34	6	26	20
		0.26	0.24	2.1	0.53	1.12	0.29
	MPC of mobile forms Kysel V.I., 1997 (acetate-ammonium buffer, pH 4.8)	4	6	23	3	3	2

This is primarily due to the aerotechnogenic nature of the pollution of these soils. The accumulation of these metals is also affected by the sorption barrier, which manifests itself in the fixation of metals by organic matter and clay components. For example, Cu and Zn, being trace elements, can accumulate in the upper horizon and due to biogenic accumulation (Avessalomova, 1978; Bakker et al., 1997).

Spreading of Ni, Mn, and V has its own characteristics. In the background territories soil accumulation of Ni, Mn, humus eluvial at a depth of 8-10 cm, and V accumulates in the transition to the soil-forming rock horizon, at a depth of 28 cm.

Similar patterns are typical for Ni in the soils of all technogenic and anthropogenic zones of the city for Mn - in soils of industrial and municipal - warehouse facilities zone, for V - in soils of both engineering infrastructure zone and landscape and recreation zone. In soils of residential and public zones, Mn and V accumulate in the top layer humus horizon.

Thus, accumulation of HM in soils of the city is affected by degree of man-made and anthropogenic load, features of polluting element itself and biogeochemical barriers. In the spreading of mobile forms of HM along the profile of urban soils, regardless of their type, general patterns could not be identified. Obviously, they are largely associated with the physicochemical composition of soils. Most migration capacity of mobile forms of Pb is observed in soils of transport infrastructure area and the area of industrial and municipal storage facilities, where the holding capacity of HM varies with a reduced content of organic carbon and depending on the absorption capacity of soils. In soils of residential and public areas, the maximal accumulation of Pb was recorded in transition horizon to soil-forming rock, since pH level, which is maximal in it, plays a decisive role. In most territories of natural and anthropogenic zones of the city, Pb accumulation is observed in illuvial-humus horizon. Spreading of mobile Zn forms along the soil profile of background soils and soils of residential and landscape-recreational zones is uniform also for light gray sandy loamy soils is a similar pattern of spreading of its gross forms. In soils of production and municipal storage facilities zone, two maximums of zinc mobile forms accumulation are observed: in top layer horizon, most enriched in humus and in the lower, where the pH of soil solution increases. Accumulation of mobile forms of Cu and Co in urban soils and soils of the background territory is approximately similar in profile, with the exception of soils of the special-purpose zone, where two accumulation maximals are observed in Cu, as in Zn and in Co - one in the illuvial-humus horizon with signs of urban pathogenesis.

The pH of the soil solution also affects the accumulation of Ni in the transition to the soil-forming rocks horizon of the zone of production and municipal-warehouse facilities. In the soils of the residential zone and landscape-recreational zone, Ni accumulation occurs in top layer horizons and decreases down the profile and in gray forest loamy soils, as a rule, two accumulation maxima are observed.

Based on the values of concentration coefficients, the total pollution index Zc (65) was calculated, which reflects the total content of HM in soils, both for the main functional zones of the city and for the main types of city soils (Fig.1).

According to the total indicator of technogenic pollution, residential zone of the city belongs to a moderately hazardous category of soil pollution. While all the functional areas of the city can be classified as hazardous.

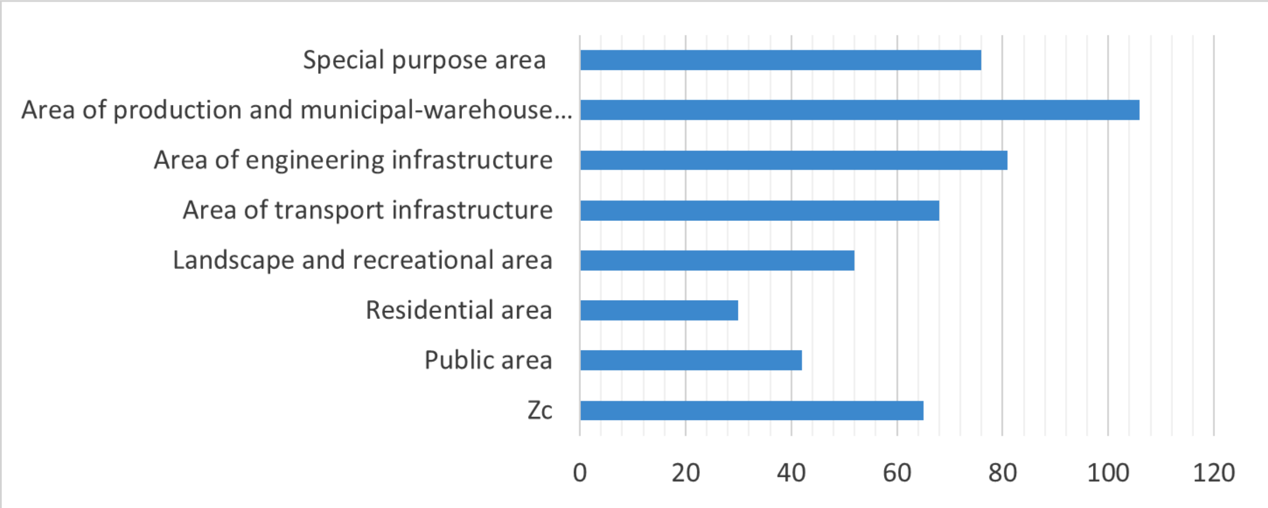

Fig. 1. The total pollution factor of Brovary

According to the gross content of HM in the soils of technogenic and anthropogenic zones of the city, main pollutants are Cu and Pb. While the most dangerous soil pollutants of all functional zones of the city are mobile forms of Zn and Ni.

Spreading of metals on the soil profile of natural and natural-anthropogenic zones of the city has similar trends. Pollution of HM of various types of soils of Brovary by humus-accumulative nature, that is, the maximum accumulation is noted in the top layer horizon. It is primarily associated with their aerotechnogenic input, strong fixation on biogeochemical sorption barriers by binding to soil humic substances and due to biological accumulation.

The determining factor in the distribution of HM in the city is the content of humus, that is, the activity of biogeochemical barrier. In slightly humus soils (<0.6%), the content of HM increases with increasing of pH. In soils with a higher humus content (0.7-1.0%), HM are fixed by clay particles, especially the level of pollution increases in the range of their content from 11.2 to 15.2%. In soils with a relatively high (>1%) humus content, the accumulation of HM is determined by the amount of physical clay and carbonates. Maximal content of pollution in the city is confined to soils with a light particle size distribution and a high content of carbonates. In soils with a physical clay content of > 13%, pollution index increases at pH < 7.5, which may be due to the combined effect of sorption barrier and transition of individual pollutants during acidification of medium into non-mobile forms (Mo).

Pollution level of 38% of the territory is moderate - these are landscapes of almost the entire landscape-recreational and residential zone and individual sections of public zone. Moderate pollution is typical for transport infrastructure zones territory, engineering infrastructure and special purpose zones. Area of production and municipal-warehouse facilities has a high level of pollution (Zc> 46). Anomalous concentrations of Zn, Cu, Ni, as well as an increased content of other HM were found in soils in the area of production and communal storage facilities and the sphere of its influence in soils. In residential area, Pb, Cu, as well as Cr, Zn accumulates. Local anomalies increase the variability of concentrations of HM in urban soils creates a high spatial heterogeneity associated with the discreteness of pollution sources. Ni, Co, Cr is characterized by an increased content in soils of production and municipal storage facilities zone, due to activities of construction enterprises.

Conclusions. It was established that polyelement pollution of the soil cover is present in Brovary. According to the gross content of HM in the soils of technogenic and anthropogenic zones of the city, main pollutants are Cu and Pb. Concentrations of gross and mobile forms of HM exceed background values and MAC values by 17-28 times.

Modern urbanized soils of the city are characterized by the following technogenic geochemical association of heavy metals: Cu>Pb>Zn>Co>Cr>V>Mo>Mn>Ni. Dominant association is distributed throughout the city mosaic, forming geochemical anomalies depending on the source of pollution. The maximum of technogenic load was recorded in the urban soils of transport infrastructure zone and production and municipal storage facility zone. Soil contamination with pollutants leads to changes in their physicochemical properties (cation-exchange capacity, pH, organic matter content) which cause a low buffering capacity of the soil cover of the city.

According to the total index of technogenic pollution, Brovary refers to cities with a high level of pollution. Soils of all areas of the city, with the exception of residential area, are classified as hazardous.

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Long-term forecast of changes in soil erosion losses during spring snowmelt caused by climate within the plain part of Ukraine

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Abstract. The paper deals with the forecast of changes in erosion soil losses during the spring snowmelt due to climate change in the regions of Ukraine in the middle of the 21st century (during 2031–2050) and at its end (during 2081–2100) compared with the values of the baseline period (1961–1990). The forecast is based on the use of the so-called "hydrometeorological factor of spring soil loss". This factor is a part of the physical-statistical mathematical model of soil erosion loss during spring snowmelt, developed at the Department of Physical Geography of Odesa I. I. Mechnikov State (since 2000 — National) University during the 1980s – 1990s. The long-term average value of the hydrometeorological factor is linearly related to the long-term average value of spring erosion soil loss. Therefore, the relative change in the hydrometeorological factor corresponds to the relative change in soil erosion losses. The developed methodology for assessing climate-induced changes in soil erosion losses in five regions of Ukraine (North, West, Center, East and South) takes into account the change in water equivalent of snow cover at the beginning of snow melting, the change in surface runoff and its turbidity, and changes in soil erodibility. The forecast of changes in erosion soil loss was carried out using projections of annual and monthly average air temperatures and precipitation for 2031–2050 and 2081–2100 in accordance with scenario A1B from AR4 of the IPCC. As a result of the research, it was found that both in the middle and at the end of the 21st century a decrease in the rate of soil erosion during the period of spring snowmelt is expected. During 2031–2050, the expected soil losses will be less than corresponding baseline period values within the West region by 79%, within the North and East regions by 81%, and within the Center region by 85%. In the South region, the spring soil losses will be zero due to the lack of snow cover. During 2081–2100 snow cover will be absent not only in the South region, but also in the Center and East regions. In the regions North and West snow cover will remain, but the spring soil erosion losses will decrease by dozens of times and will be so small that they can also be ignored.

Keywords: climate change, period of spring snowmelt, erosion soil losses, forecast until 2100, plains part of Ukraine

Довгостроковий прогноз обумовлених кліматом змін ерозійних втрат ґрунту в період весняного сніготанення в рівнинній частині України

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Анотація. Стаття присвячена прогнозу ерозійних втрат ґрунту в період весняного сніготанення під впливом зміни клімату в регіонах України в середині XXI століття (протягом 2031-2050 рр.) і в його кінці (протягом 2081-2100 рр.) в порівнянні з базовим періодом (1961-1990 рр.). Прогноз ґрунтується на використанні так званого «гідрометеорологічного фактору весняних втрат ґрунту, який є складовою частиною фізико-статистичної математичної моделі ерозійних втрат ґрунту в період весняного сніготанення, розробленої на кафедрі фізичної географії Одеського державного (з 2000 р. – національного) університету імені І. І. Мечникова в 1980-х – 1990-х роках. Багаторічне середнє значення гідрометеорологічного фактору лінійно пов'язано з багаторічним середнім значенням весняних ерозійних втрат ґрунту, тому відносна зміна гідрометеорологічного фактору відповідає відносній зміні ерозійних втрат ґрунту. Розроблена методика оцінки обумовлених кліматом змін ерозійних втрат ґрунту по п'яти регіонах України (Північ, Захід, Центр, Схід і Південь) враховує зміни запасів води в сніговому покриві на початок сніготанення, поверхневого весняного стоку, його каламутності, а також піддатливості ґрунту ерозії. Довгостроковий прогноз зміни ерозійних втрат грунту виконаний з використанням проекцій середніх річних і місячних температур повітря і атмосферних опадів для 2031-2050 рр. і 2081-2100 рр., розроблених відповідно до сценарію A1B з AR4 IPCC. В результаті виконаних досліджень встановлено, що як в середині XXI сторіччя, так і в його кінці очікується зниження ерозійних втрат грунту в період весняного сніготанення. Протягом 2031-2050 років очікувані втрати ґрунту в період весняного сніготанення будуть менше відповідних значень базового періоду в межах Західного регіону на 79%, в межах Північного і Східного регіонів

– на 81%, в межах Центрального регіону – на 85%. В регіоні Південь змив грунту в період весіннього сніготанення буде дорівнювати нулю в зв'язку з відсутністю снігового покриву. Протягом 2081-2100 рр. сніговий покрив буде відсутній не тільки в регіоні Південь, але також в регіонах Центр і Схід. У регіонах Північ і Захід сніговий покрив збережеться, але весняні ерозійні втрати ґрунту зменшаться в десятки разів і будуть настільки малі, що їх також можна буде не враховувати.

Ключові слова: зміна клімату, період весняного сніготанення, ерозійні втрати грунту, прогноз до 2100 р., рівнинна частина України

Introduction. Water erosion of soils is the most widespread soil degradation process in Ukraine (Fig. 1*a*), the negative consequences of which affect almost all components of landscape systems, but primarily the soil cover. According to the National Report on Soil Fertility State in Ukraine (Balyuk et al., 2010) the country's area of eroded agricultural land is equal to 15.953 million hectares or 38.4% of their area or 26.4% of the country's total area. The most eroded lands are situated in the south of the Forest–Steppe zone and in the north of the Steppe zone (Fig. 1b). Here within some administrative regions in varying degrees eroded soils occupy more than 80% of agricultural land (Balyuk et al., 2010; Kozyra et al., 2017). At the same time, the area of eroded lands in the country is constantly increasing. During the first decade of the 21st century, for example, this area increased by an average of 200 thousand hectares per year or by 1.5% annually.

Rainstorm erosion is predominant in the south of Ukraine, accounting for about 90% of the total soil losses. In the central part, the share of the rainstorm erosion is on average 60-70%. However, in the west and northwest of the country the contribution of erosion by rainstorms and snow melting to the erosion losses of soil is quite comparable. Thus, despite the predominant role of rainstorm soil erosion in the country, the forecast of changes of soil erosion by snowmelt waters in Ukraine, as in several other countries of the temperate climatic zone, has important theoretical and practical significance.

In recent decades to the problem of changing soil erosion under influence of the climate change is given a lot of attention in connection with the ongoing global warming and available climate change projections (Climate Change, 2007; Climate Change 2013, etc.). However, only rainstorm erosion is the subject of study in most researches devoted to the long–term forecasting of changes in soil erosion(Ciscar et al., 2009; Routschek et al., 2014; Paroissien et al., 2015; Li et al., 2016; Eekhout and DeVente, 2019; Perović et al., 2019 and others). The number of publications dedicated to the long–term forecast of changes in soil erosion by melt waters is relatively small. In this regard, the results of many years monitoring of soil erosion by melt water and its factors (such as accumulation and melting of snow, soil freezing, and runoff of

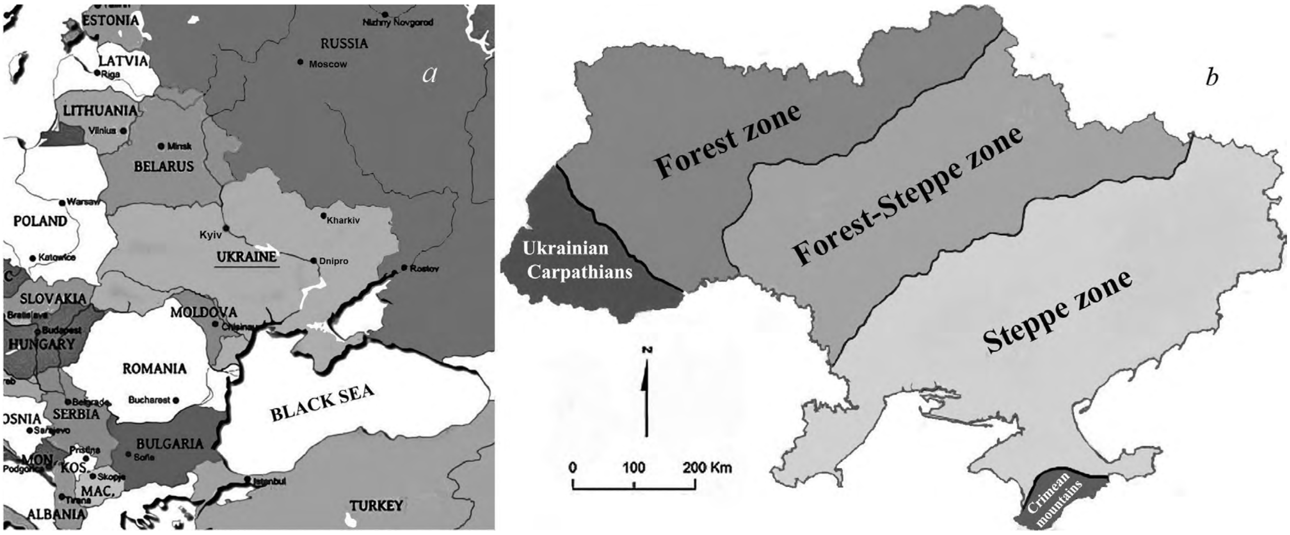

Fig. 1. Position of Ukraine on the map (*a*) and physical-geographical zoning of Ukraine (*b*)

Within the flat part of Ukraine, which occupies about 95% of the country's territory, rainstorm erosion during the warm season of the year (May-October) is a leading kind of soil erosion. However, taking into account the large size of the territory of the country (603.6 thousand square kilometers) and the large distance from north to south (about 900 km), the relationship between rainstorm erosion and erosion by snowmelt water significantly varies by area.

melt waters) conducted in different countries are very important. They allow identification of trends in modern temporal dynamics of spring soil erosion.

Long-term monitoring conducted within the within the East European Plain revealed a strong tendency to reduction of spring surface runoff and soil erosion in the recent decades (Barabanov et al., 2016; Golosov et al., 2011; Gusarov et al., 2018; Medvedev et al., 2016; Petelko and Panov, 2014; Petelko and Barabanov, 2016; Sobol et al., 2015). Medvedev et al. (2016) and Gusarov et al. (2018) believe that the main reasons for reduction of the spring surface runoff and soil erosion are decrease of water equivalent of snow by the beginning of snow melting and decrease of soil freezing depth. It has been revealed (Barabanov and Panov, 2012; Komissarov and Gabbasov, 2014) that spring surface runoff wasn't observed regardless of water equivalent of snow cover, soil moisture and type of vegetation in the years when the freezing depth of soils was less than a certain critical value.

The earlier spring snow melting is another consequence of the current climate warming. According to the research of Stone et al. (2002) in northern Alaska since the mid 1960s to 2000, the melting date has advanced on average by 8 days. On the rivers of plain part of Ukraine, the beginning of the snowmelt-induced flood during 1989-2008 was observed on average two weeks earlier than in the previous period (Grebin, 2008). With further warming, this trend will undoubtedly continue. In particular, based on the long-term forecasting of snowmelt and runoff for two mountain watersheds in South Korea, it was established that at the end of the 21st century their beginning will shift to earlier dates by approximately a month (Shin et al., 2008).

As for studies directly devoted to the long-term forecast of climate-induced changes in erosion soil losses during spring snowmelt, their results are contradictory.

The IPCC Technical Paper (Bates et al., 2008), in particular, notes that "the shift of winter precipitation from less erosive snow to more erosive rainfall due to increasing winter temperatures enhances erosion". Only the results of mathematical modeling of soil loss using the WEPP erosion model in the Palouse region (northwest United States) received by Farrell and others (2015) are consistent with the trend stated by Bates et al. (2008). In this research, it was obtained that the predicted warming by 4 °F (2.2 °C) in the middle of the 21st century compared with 1979–2009 and a significant increase in winter precipitation will lead to increasing of soil loss on agricultural land under conventional tillage from 0.17 to 0.5 t $a^{-1}yr^{-1}$, that is, by 192%. At the same time, at the end of autumn soil loss will increase by 30% and in winter—by several times. It should be noted that historically the main part of precipitation in this region falls during the cold season and the most intensive soil erosion is observed in October–January. Erosion losses in spring here are insignificant.

In study by Trotouchaud (2015) based on simulations using RCP scenarios (Climate Change, 2013) it was found that in the 21st century in Tuflon, Georgia (USA) the average monthly soil loss will vary differently in different months of the year. Projected soil losses in January-March and November will decrease by 20-40%, while in December they will significantly increase (by 40-60%) in accordance with increasing of precipitation. The study (Wang et al., 2018) found that within the southern part of the Great Lakes region (USA) occupied by crops and grasses, soil losses are expected to decrease in spring, mainly due to increasing of air temperature.

In Ukraine, studies about long-term forecasting of changes in the soil erosion by thawed waters due to climate change have not been conducted. Unfortunately, the lack of an appropriate information base makes it impossible to use here dynamic physically based models of soil erosion such as WEPP for solving the reviewed problem. Under such conditions, regional forecast of changes of spring soil erosion can be carried out based on reliable regional empirical mathematical models of soil erosion. In the 1970s–1990s, several such models were developed in Ukraine (Shvebs, 1974, 1981; Sribnyi and Vergunov, 1993; Svetlitchnyi,1999). Availability of such models, projections of main climate characteristics for the regions of Ukraine for 2031–2050 and 2081–2100 (Krakovska et al., 2013; Shestoe…, 2013) and results of studies of modern features of spring runoff within the plain part of Ukraine (Gopchenko et al., 2012; Loboda and Bozhok, 2016; Ovcharuk, 2018; Shakirzanova, 2015) created preconditions for a quantitative assessment of expected changes of spring erosion within the investigated territory.

Accordingly, the aim of this study is a spatially distributed long-term (until 2100) forecast of changes in spring erosion soil losses on agricultural lands within the plain part of Ukraine under the influence of climate change using the considered prerequisites. At the same time, the impact on soil erosion of changes in such its factors as the structure of sown areas, a set of crops, and their cultivation technologies is not considered in this paper.

Material and Methods. General approach to assessment of climate-induced changes in soil erosion during spring snowmelt. As a basis for assessment of climate-induced changes of the characteristics of soil erosion during spring snowmelt the so-called "hydrometeorological factor of spring soil erosion" (or spring soil loss) K_{HMS} was used. The K_{HMS} is a part of physical-statistical mathematical model of erosion-sedimentation developed in Odesa I. I. Mechnikov State (since 2000 National) University (Shvebs, 1974, 1981; Prokopenko, 1986; Svetlitchnyi, 1999; Svetlitchnyi et al., 2004). The model is designed to calculate the average annual soil losses at a given point of a slope or agricultural field (t ha^{-1} yr^{-1}) and is the product of the average annual value of the hydrometeorological factor and factors of relief, soil, vegetation (crop rotation) and soil protection measures, i.e., has a structure similar to USLE/RUSLE. It is important that in accordance with this model the value of soil erosion loss is linearly related to the value of the hydrometeorological factor. Therefore, the relative change of the hydrometeorological factor corresponds to the relative change in the erosion soil losses.

The average annual value of the hydrometeorological factor K_{HMS} (g·m^{-2}) is described by the equation

$$K_{HMS} = 10^{-5} h \cdot \rho, \quad (1)$$

where h is the average annual depth of spring surface runoff (mm); ρ is the average annual concentration of sediments in the surface runoff (water turbidity) during the melting of snow in spring(g·dm^{-3}).

Changes in the hydrometeorological conditions of spring soil erosion due to climate change are primarily associated with changes in surface runoff (h). A change in the spring runoff inevitably affects the sediment concentration in the surface runoff during the period of spring snowmelt (ρ). Based on (1), the dimensionless coefficient k_{HMS}, which characterizes the change in the hydrometeorological factor of the spring erosion due to climate change, has the form:

$$k_{HMS} = \frac{K_{HMS\_proj}}{K_{HMS\_base}} = \frac{h_{proj}}{h_{base}} \frac{\rho_{proj}}{\rho_{base}} = k_h k_\rho, \quad (2)$$

where K_{HMS_proj}, h_{proj}, ρ_{proj} are the average projected values of the hydrometeorological factor, depth of the spring runoff and sediment concentration in it, respectively; K_{HMS_base}, h_{base}, ρ_{base} are the annual average values of the hydrometeorological factor, depth of the spring runoff and its turbidity, respectively, for a period that is considered as the baseline one; k_h and k_ρ are the dimensionless coefficients characterizing the changes under the influence of the climate of the spring runoff depth and the sediment concentration in the surface runoff, respectively.

Taking into account (2) the long–term average annual value of the hydrometeorological factor for the forecast period will be:

$$K_{HMS\_proj} = k_h k_\rho K_{HMS\_base}. \quad (3)$$

However, climate warming affects not only the factors of spring soil erosion, which are taken into account by the hydrometeorological factor. Climate warming also affects the properties of soils, which determine the erodibility of soil cover. Possible changes in soil erodibility can be divided into related to a) changes in temperature regime in the cold season and b) changes in agricultural activities aimed at adaptation to climate change (changes in the structure of sown areas, in a set of crops, in soil cultivation system, in amount of fertilizers, etc.). Changes in soil erodibility due to the changes in agricultural practices are a separate research topic and in this paper were not considered.

In this case

$$k_j = \frac{j_{proj}}{j_{base}}, \quad (4)$$

where k_j is the dimensionless coefficient that takes into account the climate-induced change of soil erodibility; j_{proj} is the predicted soil erodibility taking into account influence the temperature regime of cold season; j_{base} is the soil erodibility for the baseline period.

The product of coefficients taking into account the climate-induced change in the hydrometeorological factor (k_{HMS}) and in soil erodibility (k_j) will characterize the relative change in spring erosion (k_W):

$$k_W = k_{HMS} k_j, \quad (5)$$

As the baseline period the standard climatic period 1961–1990 is used in the paper. The maps of the average annual air temperatures, spring surface runoff and the hydrometeorological factor, which are used in the study as the baseline maps, were constructed using the data of observations and field studies during this period. Climatic norms for weather stations presented in the Climate Cadastre of Ukraine (Klimaty`chny`j …, 2006) correspond to this period as well.

Periods 2031–2050 and 2081–2100 are considered as the forecast periods. The first period allows us to estimate the change in the hydrometeorological conditions of spring erosion compared to the baseline period in the middle of the current century, the second – at the end of the century.

Method of assessment of changes in spring surface runoff depth. It is known that the spring surface runoff depth (h, mm) is equal to the sum of water equivalent of snow cover at the beginning of snow melting (S_m, mm) and precipitation amount during snow melting (ΔP, mm) multiplied by the surface runoff coefficient (η, dimensionless), that is

$$h = (S_m + \Delta P) \cdot \eta. \quad (6)$$

To estimate the predicted values of the surface runoff depth, the regression models developed for the plain territory of Ukraine (Gopchenko et al., 2012; Ovcharuk, 2018) were used. The models were developed using data from 103 meteorological stations about water equivalent of snow cover, from 315 stations about precipitation, and from 340 hydrological stations about spring runoff. The models have the form:

$$\bar{S}_m = 147.8 - 12.906\,\bar{T}, \quad (7)$$

$$\bar{\eta} = 1 - 0.102\,(\bar{T} - 4), \quad (8)$$

where $\bar{S}_m$, $\bar{T}$ and $\bar{\eta}$ are the average annual amounts of water equivalent of the snow at the beginning of snow melting (mm), air temperature (°C), and spring surface runoff coefficient, respectively. The coefficient of determination (R^2) for both models is equal to 0.81; the correlation coefficient (r) is equal to 0.90.

Method of assessment of changes in sediment concentration in spring surface runoff. The expected changes in sediment concentration in the spring surface runoff were determined using the power dependence of the sediment concentration in the springrunoff of the runoff depth, according to which

$$k_\rho = \left(\frac{h_{proj}}{h_{base}} \right)^m, \quad (9)$$

where m is an exponent.

In accordance with the model of spring soil losses (Instrukcija…, 1979) developed using data of runoff plots located throughout the territory of the former USSR, the exponent m in (9) varying for agricultural land depending on their use (ploughed land, winter crops, stubble, perennial grass) from 0.3 to 0.6 with a modal value of 0.4. This value corresponds well with the exponent in empirical formulae of transport capacity of streams, close to 0.5 (Karaushev, 1977). In the formula by Govers (1990), the volumetric transport capacity of overland flow is proportional to its depth with an exponent, which is approximately equal to 0.35. This formula has been used successfully, in particular, in soil erosion models LISEM(De Roo et al., 1996) and EUROSEM (Morgan et al., 1998).

Method of assessment of changes in soil erodibility.The quantitative assessment of changes in erodibility of the soils of plain part of Ukraine is based on the correlation dependence of the soil erodibility index of the aggregation factor of topsoil according to Baver and Rhoades (1932) established by Bulygin and Lisetskiy (1992):

$$k_j = \left(\frac{K_{a\,proj}}{K_{a\,base}} \right)^{-0.25}, \quad (10)$$

where K_{a_proj} and $K_{a_base}$are the Baver-Rhoades aggregation factors for the forecast and baseline periods, respectively.The Baver-Rhoades aggregation factors are determined for the sizes of soil aggregates and soil particles (mm) satisfying the condition 0.25 > d > 0.05.

The main reason for the change in soil aggregation during the cold season is the periodic freezing and thawing of the topsoil at transition of the air temperature through 0 °C (Chornyy et al., 2015).

Information database.To estimate h_{proj} based on (6)–(8) the projections of average annual and monthly values of air temperature and precipitation for 2031–2050 and 2081–2100 developed at the Ukrainian Hydrometeorological Institute (UkrHMI) (Krakovska et al., 2013; Shestoe…, 2013) are used. The projections were carried out for five regions of Ukraine (Fig. 2) using ten regional climate models for air temperature and four models – for precipitation for the most likely scenario of greenhouse gas dynamics A1B from the AR4 of IPCC (Climate Change, 2007).

The forecast values of the average annual air temperatures and average February precipitation for the regions of Ukraine given in Tables 1 and 2.

Considering the large size of the territory of Ukraine, its location within three physical-geographical zones (Fig. 1*b*) and distinct spatial variability of hydrometeorological conditions of spring soil erosion within Ukraine, solution of the problem was carried out using geoinformation (GIS) technologies. The digital spatial database includes raster maps of the average for the baseline period annual values of air temperature (T_{base}) (Fig. 3*a*), spring surface runoff depth (h_{base}) (Fig. 3*b*) and the hydrometeorological factor (K_{HMS_base}) (Fig. 3*c*).

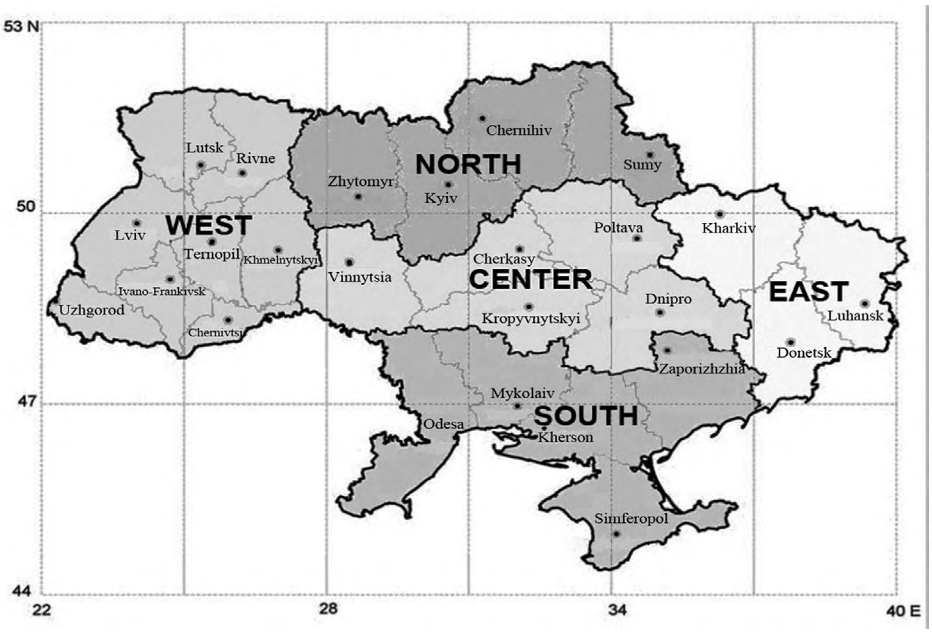

Fig. 2. Division of the territory of Ukraine into regions (Krakovska et al., 2013; Shestoe…, 2013)

As a basis for creating a digital raster map of the average annual air temperature, the corresponding map from the monograph Climate of Ukraine (Lipinsky et al., 2003) was used to create a map of the average annual spring runoff depth – the corresponding map from the electronic Atlas of Ukraine (Atlas…, 2000). Both base maps were constructed using observational data prior to 1990. The digital raster map of the hydrometeorological factor of spring soil loss was built based on the corresponding paper map (Prokopenko, 1986), which was supplemented with information concerning the southern part of the region South.

To create digital maps, the WGS84 UTM coordinate system was used. All the maps have the same raster size of 934 x 1315 and cell size of 1000 m. The subsequent analytical transformations of the digital maps were performed using the capabilities of the PCRaster package (PCRaster…, 2018).

Results.

Validation of the model (6)–(8). Evaluation of the model (6)–(8) adequacies was performed using averages for the baseline period of input and output data averaged over five regions of Ukraine (Fig. 2).

During the baseline period, in the south of Ukraine spring flood began on average February 20–25, in the center and in the east—March 1–5, in the west and in the north—March 5–10. Duration of the influx of melt water into the network of canals varied from 100 to 200 hours (4–8 days) in the south to 250–450 hours (10–19 days) in other regions (Shakirzanova, 2015). Thus, in the spring the surface runoff in the south of the country was observed on an average in the last decade of February, its average dura-

Table 1. Projections of the average annual air temperature [°C] for the regions of Ukraine (Krakovska et al., 2013; Shestoe…, 2013)

Periods, years	Regions of Ukraine				
	North	West	Center	East	South
2031–2050	9.5	9.3	10.2	10.2	11.8
2081–2100	11.2	11.1	12.0	12.0	13.7

Table 2. Projections of the average monthly February precipitation [mm] for the regions of Ukraine (Krakovska et al., 2013; Shestoe…, 2013)

Periods, years	Regions of Ukraine				
	North	West	Center	East	South
2031–2050	38	39	31	43	28
2081–2100	42	42	33	42	30

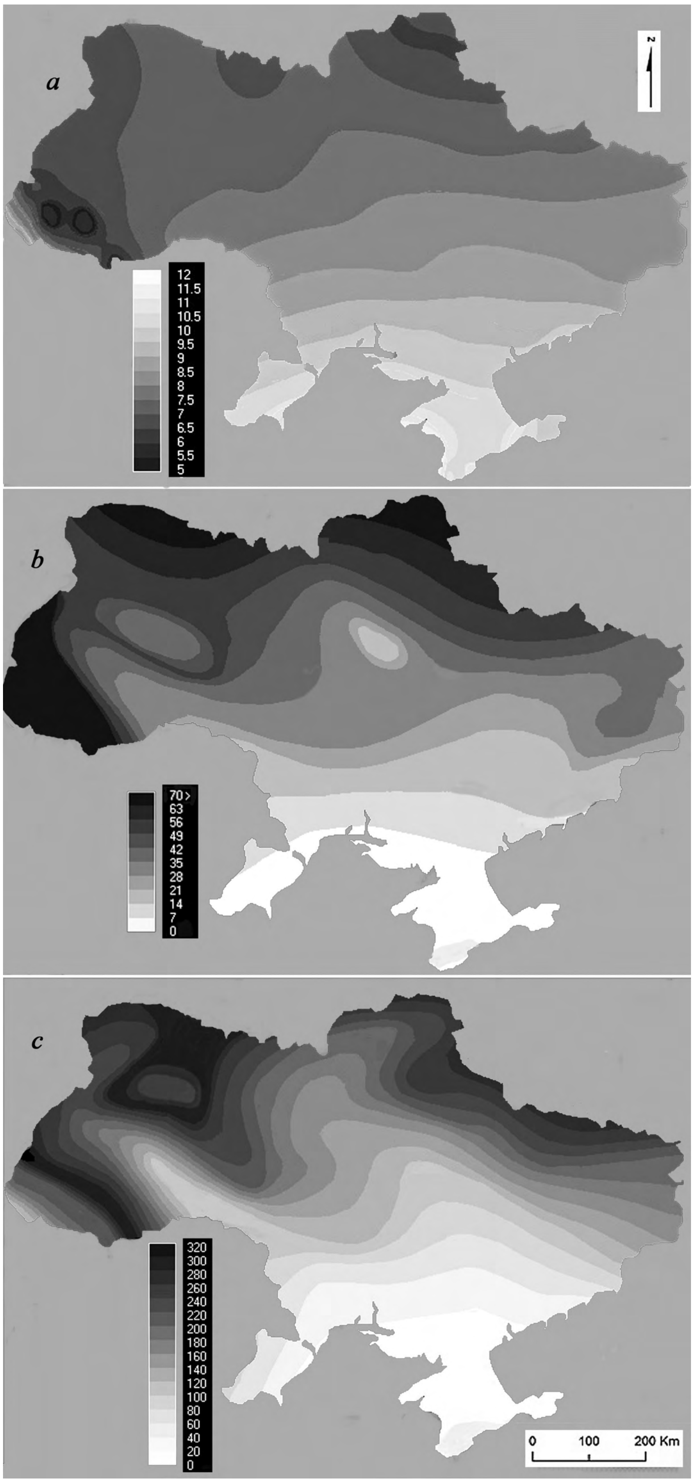

Fig. 3. Maps of average annual for the baseline period air temperature [°C] (a), spring surface runoff depth [mm] (*b*) and the hydrometeorological factor [g·m^{-2}]

tion was equal to six days or one fifth of the month. In other regions of Ukraine the runoff of thawed water occurred in March, its duration on average was equal to 14.5 days, that is, almost half a month. Based on the assumption that precipitation is evenly distributed throughout the month, it can be assumed that in the formation of spring surface runoff in the South region 20% of the February precipitation participated, in other regions—50% of March precipitation.

The results of testing the possibility of using the model (6)–(8) for the average annual spring surface runoff depth (h_{calc}) assessment for the regions of Ukraine are shown in Table 3 and Fig. 4. The actual average values of air temperature (T_{act}) and spring runoff depth (h_{act}) for regions were obtained by averaging the corresponding digital raster maps (Fig. 3*a* and 3*b*) within the regions (or their plain parts, as for the regions West and South) in the PCRaster

Table 3. Calculation of the average depth of spring surface runoff for the regions of Ukraine for the base period (1961–1990) (see details in the text)

Regions	T_{act}, [°C]	P [mm]	$\bar{S}_m$ [c] [mm]	$\bar{\eta}$ [d]	h_{calc} [mm]	h_{act} [mm]
North	7.0	37[a]	57.5	0.69	52.7	51.3
West	7.0	34[a]	57.5	0.69	51.7	51.6
Center	7.9	32[a]	45.8	0.60	37.2	34.0
East	8.0	33[a]	44.6	0.59	36.1	34.9
South	9.5	32[b]	25.2	0.44	13.9	12.2

[a] March precipitation, [b] February precipitation, [c] annual average water equivalent of snow cover at the beginning of snow melting, [d] annual average spring surface runoff coefficient.

package environment. The average monthly precipitation amounts of February for the South region and of March for other regions were determined by averaging the corresponding data for individual meteorological stations from the Climate Cadastre of Ukraine (Klimaty`chny`j …, 2006).

Comparison of the actual (h_{act}) and calculated (h_{calc}) regional average runoff depth (Fig. 4) showed linear relationship between them with an angular coefficient close to 1.0 (0.97) and high coefficient of determination R^2 (0.99). Thus, the validation of the model (6)–(8) confirmed that it could be used to solve the problem under consideration.

Forecast of the spring surface runoff depth. Taking into account the expected significantly higher average annual air temperature in 2031–2050 (11.8 °C) compared to the baseline period (9.5 °C) (Table 1), in the mid-21st century in the south of Ukraine in accordance with (7) water equivalent of snow cover will be zero ($S_m = 0$).In the rest of the country, spring snowmelt will shift to mid-February and take place over a shorter time, taking into account the predicted dynamics of air temperature and the tendency that has already formed (Grebin, 2010; Ovcharuk, 2018).

At the end of the century (2081–2100) in accordance with (7) the water equivalent of snow cover will be zero not only in the south, but also in the center and in the east of Ukraine. In the north and in the west of the country, where the snow cover will remain ($S_m > 0$), one can expect a shift of spring snowmelt to the beginning of February and a further decrease in its duration.

The results of forecast of average depth of the spring runoff for the 2031–2050 and 2081–2100 using the model (6)–(8) are presented in Tables 4 and 5. Herewith, the projections of average February and annual values of air temperature and precipitation of the corresponding periods for the regions (Tables 1 and 2) were used.

Comparison of the predicted values of the spring surface runoff depth for 2031–2050 with the baseline values shows that in the middle of the century the surface runoff will decrease in all regions of Ukraine (Table 4). In the West region the spring runoff will

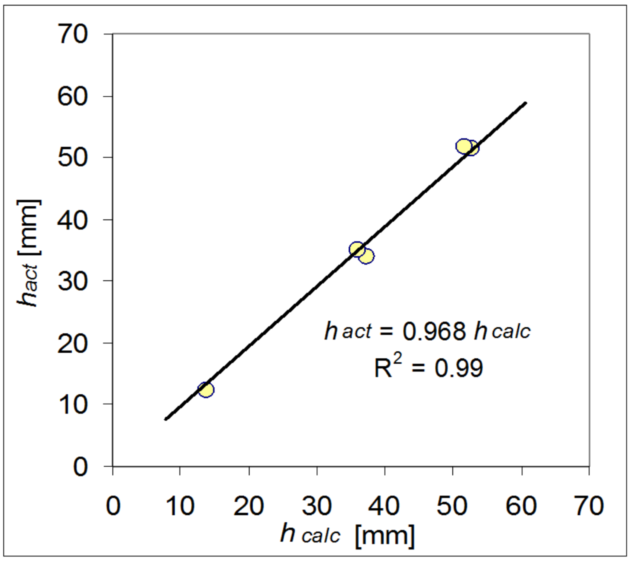

Fig. 4. Ratio between average regional values of h_{act} and h_{calc} for the baseline period

Table 4. Forecast of the annual average spring surface runoff depth for the regions of Ukraine for 2031–2050 (see text for more detail)

Regions	T [°C]	P_{Feb} [mm]	$\bar{S}_m$ [mm[	$\bar{\eta}$	h_{proj} [mm]	h_{proj}/h_{act}
North	9.5	38	25.2	0.44	18.3	0.36
West	9.4	39	26.5	0.45	21.3	0.41
Center	10.2	31	16.2	0.37	10.5	0.31
East	10.2	43	16.2	0.37	12.5	0.36
South	11.8	28	–[a]	–[a]	–[a]	–[a]

[a]No snow cover.

decrease by 59%, in the North and East regions—by 64%, in the Center region—by 69%. In the South region, meltwater runoff in spring will be absent due to the lack of snow cover.

At the end of the 21st century (2081–2100) within the territory of Ukraine in accordance with performed forecast, snow cover and runoff of melt waters will retained only in the North and West regions. The forecast values of spring runoff depth for these regions are 4.3 and 4.5 mm, respectively (Table 5), which is more than 10 times less than the corresponding values for the baseline period.

Table 5. Forecast of the average spring surface runoff depth for the regions of Ukraine for 2081–2100

Regions	T, [°C]	P_{Feb} [mm]	$\bar{S}_m$ [mm]	$\bar{\eta}$	h_{proj} [mm]	h_{proj}/h_{act}
North	11.2	42	3.6	0.27	4.3	0.08
West	11.2	42	4.2	0.27	4.5	0.09
Center	12.0	33	–[a]	–[a]	–[a]	–[a]
East	12.0	42	–[a]	–[a]	–[a]	–[a]
South	12.0	30	–[a]	–[a]	–[a]	–[a]

[a] No snow cover.

Forecast of changes of sediment concentration in surface runoff. The forecast of climate-related changes of sediment concentration in the spring surface runoff (k_ρ) is carried out using the equation (9) and predicted values of the spring surface runoff depth (Tables 3, 4 and 5). The obtained values of the coefficient k_ρ for the middle and end of the 21st century are presented in Table 6.

Table 6 shows that for those regions of Ukraine where the snow cover will remain the decrease of sediment concentration in the surface runoff in the middle of the century will be 30–38%, at the end of the century–62-63%.

Forecast of changes in soil erodibility. To assess the change of soil erodibility related to changes in the temperature regime of the cold season the results of laboratory studies of changes in the state of aggregation of soils of the Steppe Zone of Ukraine (Chornyy et al., 2015) were used. In these studies it was established that after thirty freezing-thawing cycles of the soil sample (60 transitions through 0 °C), the content of aggregates with a diameter of more than 0.25 mm decreased from 88.7 to 82.3%.

Analysis of the data from meteorological station Askania Nova, located approximately in the center of the South region, showed that during October–March 1961–2010 the number of air temperature transitions through 0 °C varied within 72–170 with an average value equal to 116. At the same time, there was a clear tendency to decrease in the number of temperature transitions through 0 °C with increasing air temperature. For the Askania-Nova weather station the dependence of the number of air temperature transitions through 0 °C (n) of the average annual air temperature (T, 0 °C) is approximated by a linear function $n = 340 - 22.147 \cdot T$ with a correlation coefficient (r) equal to 0.67. In accordance with this dependence at an air temperature of 11.8 and 13.7 °C, which correspond to the projections of the air temperature for the South region for 2031–2050 and 2081–2100 (Table 1), the average number of transitions of air temperature through 0 °C will be 79 and 37, respectively.

Table 6. Values of the coefficient k_ρ[dimensionless] for the middle and end of the 21st century

Regions	h_{base}[mm]	2031–2050		2081–2100	
		h_{proj}[mm]	k_ρ	h_{proj}[mm]	k_ρ
North	51.3	18.3	0.66	4.3	0.37
West	51.6	21.3	0.70	4.5	0.38
Center	34.0	10.5	0.62	–[a]	–[a]
East	34.9	12.5	0.66	–[a]	–[a]
South	12.2	–[a]	–[a]	–[a]	–[a]

[a] No snow cover.

For other regions of Ukraine located to the north of the South region with a more stable winter the number of air temperature transitions through 0 °C is less and the impact of climate warming is not so significant. In particular, for weather station Lubny located in the Center region the average number of air temperature transitions through 0 °C for October-March 1961–1970 will equal 110, and for the period 2001–2010 equal 106, that is, only 4 units less. For weather station Askania-Nova, these figures are 127 and 106, respectively.

Thus, the warming of the climate will inevitably lead to a decrease in the number of air temperature transitions through 0 °C during the cold season, accompanied by periodic freezing-thawing of the soil and the destruction of soil aggregates. Consequently, with the climate warming the ability of soils to resist destruction by thawed waters will increase.

However, analysis shows that the expected change in the number of transitions of air temperature through 0 °C will not lead to a significant change in the erodibility of soils of the territory under consideration. In accordance with (10), even in 2081-2100 a decrease in soil erodibility due to a decrease in the number of soil freezing-thawing cycles will not exceed 20% of the baseline period values. Almost the same change (up to 15%) in the K-factor of the USLE can be obtained using the Soil Erodibility Nomograph (Renard et al., 1997) when the soil structure changes by one class. A larger change in soil structure during the cold season because of climate warming is hardly possible even by the end of the century. On this basis, for the middle of the century (2031-2050) the coefficient of soil erodibility change (k_j) for the South and West regions was taken equal to 0.85, for other regions of Ukraine—0.90.

Forecast of changes of the hydrometeorological factor and spring soil loss. The forecast of the hydrometeorological factor for 2031–2050 and 2081–2100 for the regions of Ukraine is presented in Table 7. The product of the correction factors k_h and k_ρ gives a relative change in the hydrometeorological factor in relation to the baseline period (k_{HMS}). Multiplication of this product by the K_{HMS} value for the baseline period in accordance with (3) gives the forecast value of the hydrometeorological factor.

As follows from Table 7, in accordance with the climate projection under scenario A1B from AR4 IPCC (2007), in the middle of the 21st century and at its end the decrease of the hydrometeorological factor of spring erosion throughout Ukraine is expected.

In the middle of the 21st century, the hydrometeorological factor will decrease relative to the baseline period values in the West region by 75%, in the North and East regions by 79%, in the Center region by 83%. In the South region, the spring erosion

Table 7. Forecast of the hydrometeorological factor of spring soil loss ($K_{HMS\_proj}\cdot10^5$) for the regions of Ukraine for 2031–2050 and 2081–2100

Regions	$K_{HMS\_base}\cdot10^5$ [g·m^{-2}]	k_h		k_ρ		$k_h\cdot\mathbf{k}_\rho$		$K_{HMS\_proj}\cdot10^5$ [g·m^{-2}]	
		2031–2050	2081–2100	2031–2050	2081–2100	2031–2050	2081–2100	2031–2050	2081–2100
North	209	0.36	0.08	0.66	0.37	0.21	0.02	44	4
West	227	0.41	0.09	0.70	0.38	0.25	0.03	57	7
Center	127	0.31	–[a]	0.62	–[a]	0.17	–[a]	26	–[a]
East	170	0.36	–[a]	0.66	–[a]	0.21	–[a]	41	–[a]
South	36	–[a]	–[a]	–[a]	–[a]	–[a]	–[a]	–[a]	–[a]

[a] No snow cover.

by meltwaters will be completely absent due to lack of snow cover. The expected changes in soil losses due to climate, taking into account changes both the hydrometeorological factor and soil erodibility, will be less than the baseline period values for the West region by 79%, for the North and East regions by 81%, for the Center region by 85% (Table 8).

Table 8. Forecastof changes in soil losses during spring snowmelt for 2031–2050 and 2081–2100 compared with the baseline period

Regions	$k_h \cdot \mathbf{k}_\rho \cdot \mathbf{k}_j$		Changes of soil loss [%]	
	2031–2050	2081–2100	2031–2050	2081–2100
North	0.19	0.02	–81	–98
West	0.21	0.02	–79	–98
Center	0.15	–[a]	–85	–[a]
East	0.19	–[a]	–81	–[a]
South	–[a]	–[a]	–[a]	–[a]

[a] No snow cover.

At the end of the 21st century due to the expected further warming of the climate and the absence of snow cover, the soil erosion by melt water will be absent not only in the South region, but also in the Center and East regions. In the North and West regions decreasing of the hydrometeorological factor as well as of the soil losses relative to 1961–1990 are projected by dozens times (Table 8). Due to this, the soil losses by melt waters in these regions can be ignored because of their small values. Thus, at the end of the 21st century erosion hazard within the whole territory of Ukraine will be determined only by liquid precipitation.

Discussion. The fulfilled forecast confirms the tendency of decreasing spring erosion losses of soil by melt waters outlined in recent years (Barabanov et al., 2016; Golosov et al., 2011; Gusarov et al., 2018; Komissarov and Gabbasov, 2014; Medvedev et al., 2016; Petelko and Panov, 2014; Petelko and Barabanov, 2016; Sobol et al., 2015). In Ukraine, it is a decrease of the surface runoff of melt waters that will play the main role in the predicted very significant decrease in the magnitude of erosion soil loss. Changes in soil erodibility because of increase in the temperature of the cold season will be insignificant (–10 ... –20% of the baseline values).

It should be noted that for the territory of Ukraine the replacement of solid precipitation (snow) with liquid precipitation (rain) in cold season is unlikely to lead to a significant increase in the erosion hazard of the territory. Due to the relatively high water permeability of soils of the plain part of Ukraine, the soil erosion process can be formed only because of rains of high intensity. However, such rains (showers) are formed at substantially higher air temperatures than in the cold season in Ukraine. During the baseline period in all regions of Ukraine except the South region erosion-hazardous rains are observed only in May–October. In the South region, such rains observed from the end of April to the beginning of November, but the contribution of April and November to the annual soil loss was not more than 2% (Chornyy, 1996; Svetlitchnyi et al., 2004).

Proceeding from this, the predicted increase in air temperature will only slightly widen the erosion-hazardous period by adding parts of April and November .In the remaining months of the cold period (December–March), due to the relatively low predicted air temperatures (Tables 9 and 10) and the absence of soil freezing, the erosion soil loss will be not significant.

The expected contribution to the annual soil loss of November and April is different. The forecasted air temperature of November will not higher than the average October temperature of the baseline period, and the predicted change in monthly precipitation is insignificant (–3 ... +11%). Based on this, it can be assumed that November's contribution to annual soil losses in the middle and in the end of 21st century will analogous to the October's contribution of the baseline period. That is, it will be equal to 1–2%. The expected contribution of October will be more significant than

Table 9. Average monthly and annual air temperatures [°C] for the Center region of Ukraine for different periods (Krakovska et al., 2013; Shestoe…, 2013)

Periods, years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1961–1990	–6.4	–5.2	–0.1	8.6	15.5	18.6	19.8	18.9	13.9	7.5	1.4	–3.1	7.5
2031–2050	–1.7	–1.8	3.1	10.5	16.4	20.4	23.1	22.3	16.3	10.2	4.0	–0.3	10.2
2081–2100	–0.3	0.0	4.7	11.9	17.9	22.2	25.5	24.7	18.4	11.4	5.8	1.4	12.0

Table 10. Average monthly and annual air temperatures [°C] for the South region of Ukraine for different periods (Krakovska et al., 2013; Shestoe…, 2013)

Periods, years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1961–1990	–3.1	–2.0	2.2	9.6	15.6	20	22.4	21.6	16.4	9.6	4.4	0.3	9.8
2031–2050	0.1	0.1	4.6	10.8	17.0	21.7	24.7	24.2	18.3	12.3	6.2	2.0	11.8
2081–2100	1.5	1.8	6.2	12.4	18.6	23.9	27.4	26.6	20.6	13.6	8.0	3.5	13.7

before, both because of higher air temperatures and an increase in monthly precipitation by 19-27%. Most likely, this increase will be a few percent. Similarly, April's contribution will increase slightly. However, quantification of this increase requires separate consideration and is beyond the scope of this paper.

Conclusions. 1. In accordance with the climate change scenario A1B from AR4 IPCC, in the middle and at the end of the 21st century, a decrease of erosion soil loss during spring snow melting compared to the base period 1961-1990 is predicted throughout the whole territory of Ukraine.

2. The expected changes in soil period values for the West region of Ukraine are by 79%, for the North and East regions by 81%, for the Center region by 85%. In the South region, permanent snow cover and, accordingly, spring snowmelt and soil erosion by melt water will be absent.

3. At the end of the 21st century (2081–2100), due to predicted further warming of the climate in Ukraine, the soil erosion by melt water will be absent not only in the South region, but also in the Center and East regions. In the North and West regions decrease is projected of the hydrometeorological factor and spring erosion relative to the baseline period by dozens of times. In this regard, at the end of the century erosion hazard within the whole territory of Ukraine will be determined only by liquid precipitation.

4. In accordance with preliminary assessment, some expansion of the warm season and the replacement of solid precipitation (snow) by liquid precipitation (rain) in the cold season will not lead to a practically significant increase in the soil erosion danger within the plain territory of Ukraine. However, this question requires further study.

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Basin systems of small rivers of Western Podillya: state, change tendencies, perspectives of nature management and nature protection optimization

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Abstract. The level of anthropogenization of the natural processes and the geocomponents of the basin geosystems of small rivers in Western Podillya has been estimated and rated as ecologically dangerous from the viewpoint of sustainable and conflict free functioning. The scales of the transformation of the components of natural environment by economic activities since 1774 were revealed using the method of comparative-geographic analysis of cartographic sources. The scales of deforestation were determined, as well as the scales of the influences of drainage meliorations on wetlands, river floodplains and riverbed complexes. It has been established that such transformations of the state of the components of landscape systems have caused the manifestation of a set of unfavorable processes and phenomena (lowering of ground water level, promoting desiccation, soil erosion and deflation, soil dehumification, decreasing landscape and biological diversity, etc.). Calculated indices of the anthropogenic modification of natural components testify that the strongest adversary impacts on river systems and basin landscapes are caused by agriculture, deforestation, and drainage meliorations. Our analysis of the current state of reclaimed lands in the basins of the rivers Dzhuryn and Nichlava confirmed the conclusions of B. I Kozlovsky on the effects of drainage reclamation on groundwater in drained lands and of the formation within them and around drainage systems of negative hydrogeological zones of different widths. In the absence of precipitation for 30-45 consecutive days in summer there is a sharp decrease in groundwater levels, and overdrying of soils, which causes the manifestation and intensification of deflation, shallowing and even drying of the upper reaches of rivers and streams. At the final stage of the study, a system of measures aimed at ensuring the sustainability of river basin geosystems was substantiated. The introduction of an optimization model of land use in the basin geosystem is one of the priority tasks in the context of negative changes in the water regime of watercourses and the water balance of river basin systems. Optimization measures provide for the transformation of the part of degraded and unproductive lands towards the grasslands and the planting of gardens (slopes up to 7°) and afforestation (surface steepness over 7°) to improve the quality of environment and to form the environmentally secure land use system. Regional indices of anthropogenic transformation for the existing and proposed land structure as a normative regional indices of nature utilization optimality are calculated. Substantiation of schemes of basin nature protection networks was based on taking into account the role of protected areas in maintaining certain functional features at the sources, in the middle and lower parts of river basins. Based on the results of field surveys, it is proposed to create nine protected areas within the Dzhuryn Basin and eight protected areas within the Nichlava river basin, which will increase the share of protected areas of the Dzhuryn basin to 8% (compared to present 4.8%) and Nichlava to 19%. At the same time, it is proposed to change the structure of the nature reserve fund of the Nichlava river basin, taking into account the existing high share (77%) of general zoological reserves, inefficient from the standpoint of conservation of natural complexes, instead creating six landscape reserves on an area of about 800 hectares. The paper considers the possibility of further development of the tourist and recreational sphere in the near-Dnister sections of the river basins of Dzhuryn and Nichlava, and proposes the creation of Borshchiv Regional landscape park in the picturesque valley of the Nichlava River.

Key words: river basin system, anthropic changes, land use optimization, basin nature protection network, recreational nature utilization

Басейнові системи малих річок Західного Поділля: стан, тенденції змін, перспективи оптимізації природокористування та охорони природи

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Анотація. Оцінено ступінь антропізації природних процесів і геокомпонентів басейнових систем малих річок Західного Поділля та визнано його як еконебезпечний з позиції стійкого безконфліктного функціонування. Методом порівняльно-географічного аналізу картографічних джерел з'ясовано масштаби перетворення компонентів природного середовища господарською діяльністю за період з 1774 року. Визначені масштаби вирубки лісів та осушувально-меліоративного впливу на водно-болотні угіддя і заплавно-руслові комплекси річок. Встановлено, що ці зміни стану компонентів ландшафтних систем спричинили прояв низки несприятливих процесів та явищ (зниження рівня ґрунтових вод, активізацію посушливих явищ, ерозію і дефляцію ґрунтів, їх дегуміфікацію, збіднення ландшафтного і біотичного різноманіть тощо). На прикладі аналізу стану меліорованих земель продемонстровано масштаби змін ґрунтоутворювальних процесів і рівня ґрунтових вод та формування в межах і навколо осушувальних систем зон негативного гідрогеологічного впливу шириною від 900 м до 3-5 км. За відсутності атмосферних опадів впродовж 30-45 днів у літню пору відбувається різке зниження рівня ґрунтових вод, пересушення ґрунтів, що зумовлює прояв та посилює інтенсивність процесів дефляції, обміління і навіть пересихання верхів'їв річок і потічків. На заключному етапі дослідження здійснено обґрунтування системи заходів, спрямованих на забезпечення підтримки стійкості річково-басейнових геосистем. Запровадження оптимізаційної моделі природокористування в басейновій геосистемі є одним з пріоритетних завдань в умовах негативних змін водного режиму водотоків і водного балансу річково-басейнових систем. Оптимізаційними заходами передбачено переведення частини деградованих і малопродуктивних земель під залуження і формування садів та ягідників (схили крутизною до 7^0) і заліснення (поверхні крутизною понад 7^0) для покращання якості довкілля і формування екологічно безпечної системи землекористування. Розраховано регіональні індекси антропогенного перетворення для існуючої і пропонованої структури земельних угідь в якості нормативного регіонального індексу оптимальності природокористування. Обґрунтування схем басейнових природоохоронних мереж базувалось на врахуванні ролі заповідних територій у підтриманні певних функціональних особливостей на витоках, у середній та нижніх частинах басейнів річок За результатами проведених натурних обстежень запропоновано створення 9 заповідних об'єктів в межах басейну Джурина та 8 заповідних територій в межах басейну річки Нічлави, що сприятиме збільшенню заповідності басейну Джурина до 8% (проти існуючих 4,8%) та Нічлави до 19%. Водночас запропоновано змінити структуру природно-заповідного фонду басейну р. Нічлави, зважуючи на існуючу високу частку (77%) малоефективних з позиції збереження природних комплексів загальнозоологічних заказників, створенням 6 ландшафтних заказників на площі близько 800 га. У статті розглянуто можливість подальшого розвитку туристсько-рекреаційної сфери на придністерських ділянках річкових басейнів Джурина і Нічлави, запропоновано створення Борщівського регіонального ландшафтного парку у мальовничій долині р. Нічлава.

Ключові слова: річково-басейнова система, антропічні зміни, оптимізація землекористування, басейнова природоохоронна мережа, рекреаційне природокористування

Introduction. The study of small rivers, assessment of their ecological status, the degree of the anthropogenization of processes and components of basin landscapes, the technogenic changes in the state of river basin systems (RBS) in the current environment is an important task, aimed at providing the restoration of the river flow and the support of sustainable functioning of basin geosystems. The small rivers of Western Podillya not only perform important water management and fishery support functions, they are also valuable recreational facilities, the decorations of local landscapes, their valley host unique natural complexes and objects which under increasing anthropogenic impact require special forms of protection. Implementation of the state program of formation of the national ecological network, preservation of landscape and biotic diversity, introduction of the basin principle of monitoring and management of water resources put before researchers new tasks of diversified study of river systems, primarily the small river basin systems. Whereas the renowned naturalist, one of the founders of landscape science V. V. Dokuchaev claimed that the soil is a mirror of the landscape, today we can say with confidence that the ecological status of small rivers mirrors the peculiarities of nature utilization within their basins. From this point, the aim of the paper is to reveal the modern tendencies of transformation of small rivers of Western Podillya – Dzhuryn and Nichlava and to justify the optimization measures, namely – the increase in the extent of protected areas in their basins.

Literature review. Material and methods. The problems of small rivers in Western Ukraine have long attracted the attention of researchers. Worth mentioning are the dissertations of Kovalchuk I. P. (1981), Shtoika P.I. (1992), other publications of these researchers (Kovalchuk & Podobivskyi, 2014; Kovalchuk & Shtoyko, 1992), monographs by I. P. Kovalchuk and his co-authors, dedicated to the coverage of the results of researches on the structure of river systems on different-time slices of their state and estimating the scale of transformation processes in river basin systems (Kovalchuk A. & Kovalchuk I., 2018; Kovalchuk, 1997; Kovalchuk & Pavlovska, 2008). The same topic is covered in the works of disciples of professor Ivan Kovalchuk: Mykhnovych A. V. (1998), Pylypovych O. V. (Kovalchuk, Mykhnovych, Pylypovych, 2000; Pylypovych & Kovalchuk, 2017), Andreychuk Yu. M. (Andreychuk, 2012; Andreychuk, Ivanov, Kovalchuk, 2015), Kruta N. S. (2014), Shvets O. I. (Kovalchuk, Shuber, Shvets, Andreychuk, 2013), Zhdaniuk B. S. (Kovalchuk, Andreychuk, Zhdanjuk, Shvets, 2013), Kurhanevych L. P. (Western Bug river basin), Pavlovska T. S. et al. (Kovalchuk & Pavlovska, 2008; Kovalchuk, Pavlovska, Savchuk, 2011). This research area is being developed by Chemerys M. P. (1994), Yushchenko Yu. S. (2018) and his disciples – Kyryliuk A. O., Kyryliuk O. V., Melnyk A. A., Pasichnyk M. D., Palanychko O. V. (Kirilyuk, 2015; Palanychko, 2009) et al. Monograph by Kovalchuk A. I. and Kovalchuk I. P. and a set of papers are dedicated to the creation of geoecological atlases of river-basin systems (Kovalchuk A. & Kovalchuk I., 2018; Kovalchuk I. & Kovalchuk A., 2019). These ideas are of high importance for the purpose of mapping the states of RBS.

Among the foreign researchers there should be mentioned a team of authors led by Golosov V. M. (Gusarov, Golosov, Ivanov, Sharifullin, 2019), that for a long time have been studying the scale of development of degradation processes in the river systems of the Eastern European plain under the influence of erosion-accumulation processes in their watersheds; works by Polish researchers Krzemień K., Laiczak A., Vyzhga B., Zawiejska J. et al. (Krzemień, 2003; Zawiejska, Krzemień, 2004), which study the impact of human activities on the channels and floodplains of mountain and plain rivers, the processes of siltation of reservoirs; works by T. Bryndal, P. Franczak, R. Kroczak (Bryndal, Franczak, Kroczak et al., 2017), who studied the impact of extreme rainfall on the process of flood risk management and changes in the relief of small Carpathian watersheds under the influence of exogenous processes and human economic activity; research on this topic is also conducted in other countries – Germany, France, Bulgaria.

In recent years, under the leadership of Professor P. L. Tsaryk similar work is being unfolded in Ternopil Volodymyr Hnatiuk national Pedagogical University. For instance, in 2006 expeditionary researches were carried out of river Hnizna, in yrs. 2008-2009 – of rivers Dzhuryn and Vilhovets. Their main tasks were: 1) assessment of the geoecological conditions of the valley-channel complexes of these rivers; 2) identification of sources of surface water pollution; 3) identification of the natural objects in the river valleys and basins promising for conservation; 4) exploring the possibilities of river valleys to properly perform the functions of connecting areas of regional and local ecological networks. According to the results of the surveys, a number of papers were published and the submission for the creation of a number of protected areas and objects of the nature-reserve fund was substantiated (Tsaryk L., Tsaryk P., Vitenko I., 2010; Tsaryk P. & Tsaryk V., 2019). Further comprehensive studies of river basins were focused on identifying adverse processes and phenomena caused by irrational economic activities in the Dzhuryn river basin (2015-2017). The results are the monographs “Transformational geoecological processes of the Dzhuryn River basin” (Bakalo O., Tsaryk L., Tsaryk P., 2018) and “Nature management and nature protection in small river basins” (Tsaryk L., Tsaryk P., Kuzyk I., 2019). In 2018-2019, the object of research was the Nichlava river basin. Based on the results of this field research and generalization of the collected materials, a number of articles on the problems of optimization of nature management and nature protection have been published in scientific journals (Kuzyk I. & Kuzyk Z., 2018; Tsaryk L., Burtak O., Tsaryk V., 2018; Tsaryk, 2019).

While preparing the publication, the following methods were used depending on the stages of the study. At the first stage – that of the collection of materials, methods of field geoecological researches and the collection of statistical materials have been used. The in-house stage of materials processing is connected with the application of mathematical and cartographic methods of data processing, production of tables, optimization models of land use, etc. At the third stage of the research, analytical and evaluation methods of the assessment of geoecological processes and phenomena were used. At the final stage, the results of the study are summarized, and conclusions are drawn.

Results and their analysis. The small rivers of Western Podillya have been under anthropogenic pressure for a long time, as evidenced by the high level of economic development of their catchments (share of arable land in the Dzhuryn river basin – 74.5%, in the Nichlava river basin – 66.1%; share of build-up area in these river basins is, respectively, 4.53 % and 5.40%). Analysis of cartographic materials from the middle of the XVIII century showed that 170 years ago the degree of economic development of the area within the studied river basins was already high. What has changed in the structure of land use since the eighteenth century to the present day? The forest cover area decreased by 1.5 – 2.4%, area covered by wetlands also significantly decreased (by 18.2% in the Dzhuryn river basin and by 11.5% in the Nichlava river basin). Decrease of the share of wetlands in the river basins has led to the set of geoecological problems. In fact, reclaimed agro-landscapes which have been used for growing crops have appeared in the place of wetlands. Here the hydrological and hydrogeological regime and the soil properties have radically changed, the species composition of vegetation and fauna has become impoverished. In the basins of these rivers there was a reduction of areas under natural vegetation by an average of 14–19%, resulting in simplification of the structure of natural landscapes, reduction of biotic and landscape diversity (in wetlands and meadows communities), changes in the pace and direction of soil formation, reduction of water discharges in small rivers (Fig. 1). Measurements of drainage and discharge water runoff at the mouths of reclamation systems and 12 water measuring posts showed that the total volume of water discharged from drained lands in the water intakes of Ternopil region during the year was about 110 million m^3 (Kozlovsky, 2005).

or gypsum, which are often covered with a layer of clay, today are almost totally plowed and drained, their microrelief being blurred. The larger area of these landscapes in the past is evidenced by maps of the land cadastre of 1779 and 1824 yrs. (Kovalyshyn. Hulyk, 2009). Intensive agricultural use of meadow-steppe landscapes on the background of drainage led to the development of degradation processes, which manifested themselves in increased mineralization of organic matter, compaction of the arable layer and the formation of lumpy soil structure, in the increased deflation and water erosion.

Groundwater levels are falling along drainage canals. The zones of influence of drainage systems

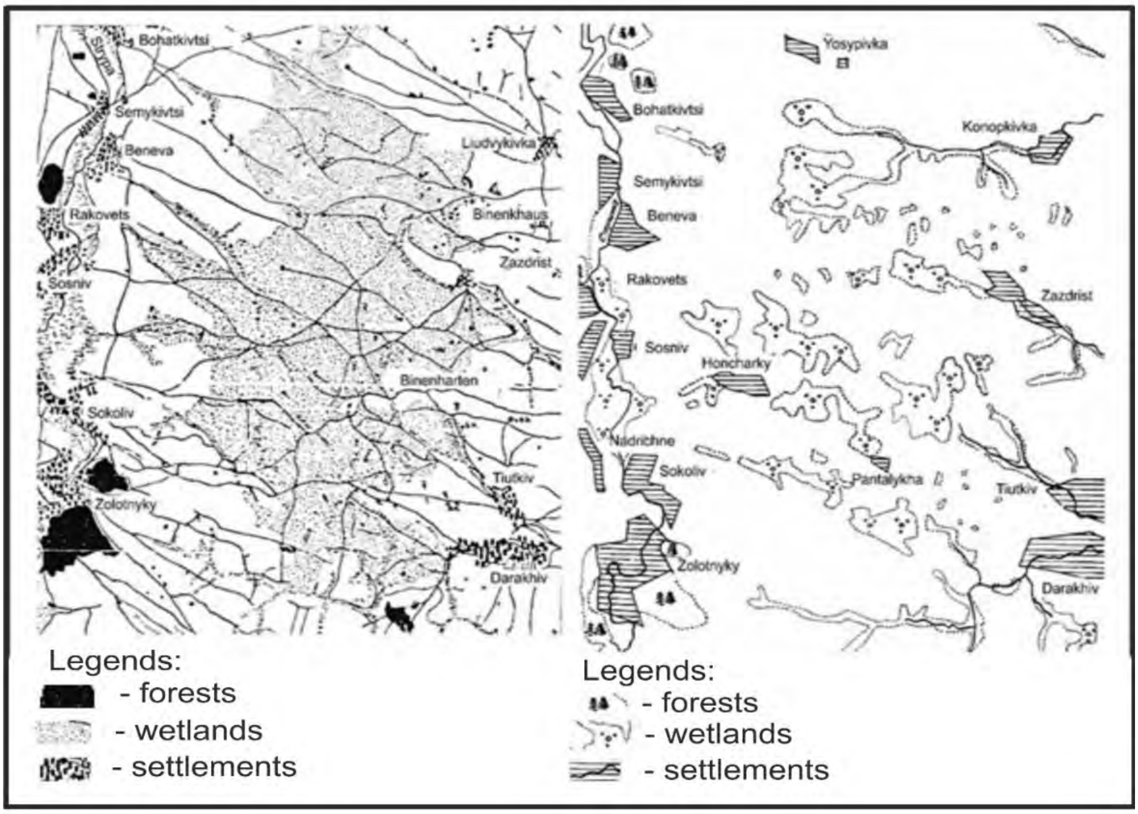

Fig. 1. Reduction of wetlands of the "steppe" of Pantalykha on the interfluve of Seret and Strypa rivers for the period from 1774 (A) to 1930 (B).

Drained lands in the absence of reversible regulation of water regime in the context of global and regional climate changes have become ecologically unstable lands with regular manifestations of unfavorable soil-ecological and hydrological-geochemical processes.

There have been significant changes in the processes of soil formation on reclaimed lands. As noted by D. I. Kovalyshyn: "Meadow-steppe landscapes, which are common only on flat plains, on poorly drained watersheds, where loess lies on the washed-out surface of lithotamnium limestones

do not stabilize over time, but constantly increase, sometimes overlapping each other. In the interfluves in the southern part of the Ternopil region there are no wetlands left that would support the groundwater levels in the basins of small rivers-tributaries, not allowing them to fall far beyond the optimal level of occurrence. According to the results of research performed within Small Polissia (Kozlovsky, 2005), in the first 5–10 years after the start of operation of drainage systems a zone of hydrogeological influence is formed around them with a width of 900 m to 3–5 km. Our surveys of reclaimed lands in the basins of the Podolian rivers have shown that in some cases it is 2 times or more larger than the size of drainage systems themselves and can cover up to 36% of the area of adjacent lands. This negatively affects the water supply of river sources and streams. Currently in some tributaries of the Dzhuryn and Nichlava river heads have shifted downstream by 1–3 km (Tsaryk, 2006; Tsaryk et al., 2010).

The decrease in groundwater levels takes place under the influence of an increase in the number of dry days, a decrease in humidity, which in turn leads to a decrease in productive moisture stock and reduced yields by an average of 20 – 50% (Ekologichnij pasport Ternopil's'koi oblasti, 2018). Over-dried lands have appeared on the flat interfluve surfaces and floodplains in the upper reaches of the rivers, which has radically changed the composition of the flora and led to the emergence of xerophyte vegetation. In summer, groundwater levels are falling below the dug drainage channels.

Generalization of the results of our research and materials of other authors (Kovalchuk, 1997; Shtoyko, 1992) indicates that the meadow-steppe river valleys landscapes of Western Podillya in their development under the influence of human economic activity have passed three stages: 1) "steppe" with shallow lakes, which water level was constant throughout the year; 2) swampy meadows (poplavy), which were periodically flooded; 3) reclaimed meadows, which are no longer flooded with water and are gradually transformed into arable lands. Each of them reflects the changes that have taken place under the influence of drainage of wetlands, plowing and the final transformation of natural landscapes into agro-landscape geosystems.

Changes in the heat balance of arable drained lands are caused, in addition to natural changes in the radiation balance, also by changes in the intensity of their warming in the sunny and warm conditions and faster cooling at night and in the cooler season. There are daily and seasonal changes in the heat balance, which affects the daily and seasonal rhythms of bioproductivity of soil microorganisms, and thus the processes of soil formation, regeneration and stability of soils. Changes in heat balance in the conditions of climate aridization do not favor the establishment of optimal correspondence between heat and moisture, and thus deteriorate the conditions for soil biota, change the nature and direction of biogeochemical processes (Bakalo et al., 2018).

Under the hot weather, in the absence of precipitation for 30–45 consecutive days, there happens a sharp decrease in groundwater levels, overdrying of soils, which causes the manifestation and increases the intensity of deflation processes, the shallowing and even drying of the upper reaches of rivers and streams.

Mineral metabolism in soils is disturbed as a result of agricultural cultivation, when mineral fertilizers and pesticides are added and the mineral substances are removed from the fields together with the crop. Up to 65 kg of basic active substances are removed from the soil annually with a yield of one ton of grains (Ekologichnij pasport Ternopil's'koi oblast, 2018). The excessive amounts of mineral fertilizers cause their accumulation in soil horizons, and hence in plant organisms.

Some changes in the biological turnover of substances are associated with the processes of soil and humus formation. Withdrawal of significant amounts of organic matter from the geosystem with crop products in the process of agricultural production, lack of application of sufficient amounts of organic fertilizers leads to dehumidification of soils, decreasing the thickness of their humus layer, reducing fertility, and ultimately to their depletion and degradation. In river basins, the application of organic fertilizers has decreased tenfold on average – from 14 t/ha in 1990 to 0.34 t/ha in 2018 (Grodzynskyi, 2005), and on large areas of land they are not applied at all.

Pollution of lands in the basins of the mentioned rivers is caused by the introduction of mineral (0.9 t/ha) and organic fertilizers (0.34 t/ha), pesticides (2.6 kg/ha) and their subsequent getting into groundwater and river channels with washed-out fertile soil layer (Ekologichnij pasport Ternopil's'koi oblasti, 2018).

In addition, about 5,000 tons of solid waste are generated annually within the Dzhuryn river basin, and 21.5 thousand tons (0.5 tons / person) in the Nichlava river basin (Ekologichnij pasport Ternopil's'koi oblasti, 2018). Much of them are confined to spontaneous landfills, which are local geochemical anomalies in river basins.

Residual contamination of lands with cesium-137 and strontium-90 radionuclides persists within Polivetska, Palashivska and Bazarska village councils located in the middle part of the Dzhuryn River basin (Tsaryk P. L., 2019). Within the basin of the Nichlava River, radiation pollution is confined to the outskirts of the settlements of Shmankivchyky, Kolyndyany, Davydkivtsi, Mykhalkiv, Pylypche, Ustya (Fig. 2). Radionuclides in watersheds have migrated deep into soil profiles and accumulated at a depth of 80–100 cm.

The development of degradation processes under long-term anthropogenic loads causes the basin system to lose its stability. In the presence of

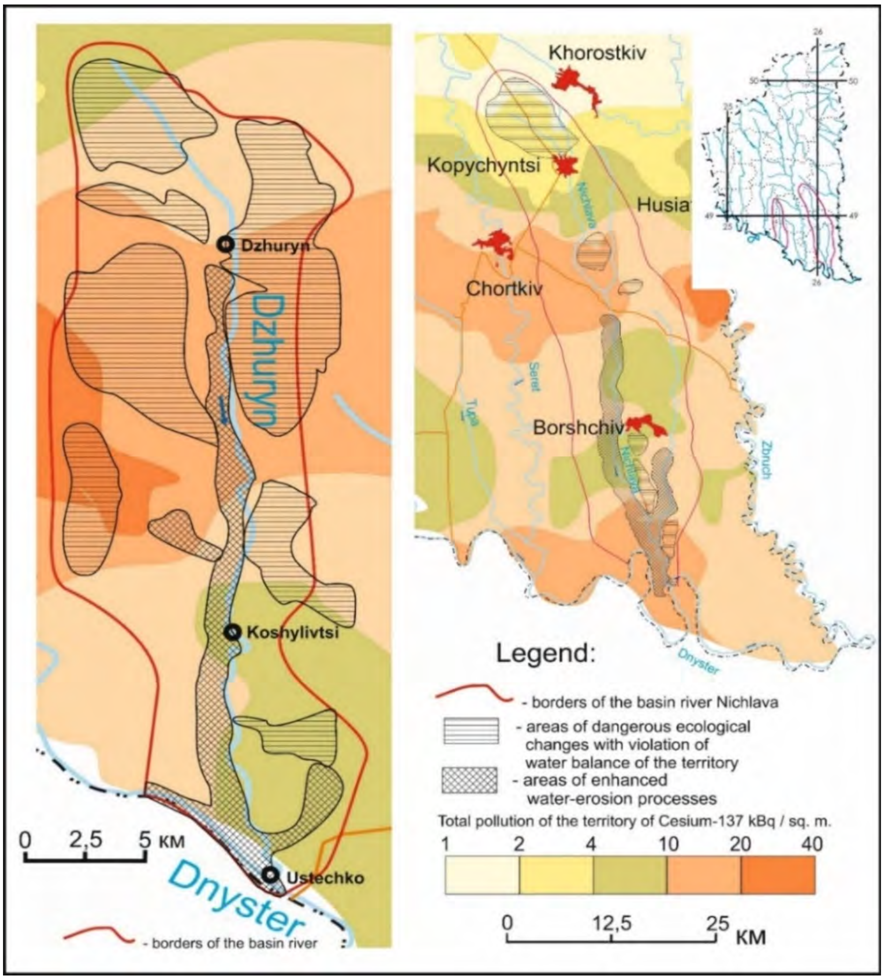

Fig. 2. Areas of the spread of dangerous geoecological processes and phenomena within the river basins of Dzhuryn (A) and Nichlava (B) (Tsaryk, 2019).

grasslands in riverine areas, rapid river flow and insignificant regulation of river runoff, in the absence of unpredictable disturbances, the river system manages to maintain a certain level of stability, which also affects the geo-ecological state of the river's floodplain-channel complex. Therefore at the final stage of the study the system of measures aimed at ensuring the stability of river-basin geosystems in modern conditions was justified. Implementation of an optimization model of nature management in the basin geosystem is one of the priority tasks in the conditions of a sharp change in the water regime of watercourses and the water balance of the territory. The already developed measures for the rational use of natural resources written in the passports of rivers are focused on the 80 – and 90-ies of the XX century (Pasport richki Dzhuryn; Pasport richki Nichlava) and require significant improvements, and sometimes a fundamental revision. The agricultural use of the territory has changed radically due to the decline of the livestock industry, the transformation of the nature and structure of crop rotations, and the features of economic water and land use. The lack of a proper amount of organic fertilizers makes systemic changes in the process of soil formation, causes an imbalance in the humus formation, an activation of dehumidification of agricultural land soils, and so on.

At the same time, there are some positive trends of the removal of degraded and unproductive lands from the structure of the arable land fund, increasing the financial capacities of local communities by changing the emphases of budget funding, improving the provision of farms with new agricultural equipment, introducing new tillage technologies.

Basin systems of small rivers remain out of the reach of the projects and schemes of district planning, organization of agricultural land use on a landscape-ecological basis. Therefore, a systematic analysis of land use in basin systems is important for the purpose of safe and inexhaustible use of its natural resource potential.

Discussion. Approaches to the analysis of the river basin from complex geographical positions were initiated by V. V. Dokuchaev, O. I. Voeikov, and V. V. Alyokhin. The discovery of a number of topological regularities in river systems in the 30s – 60s of the

XX century gave geographers and ecologists the opportunity to consider the river basin and its structure from a new perspective. The functional unity of the basin and its territorial distinctness served as the basis for the development of basin-based schemes for erosion protection of land, nature protection, the formation of an eco-network, and the analysis of nature and land use of basin systems.

Thus, complex ecological and geographical studies of the Koropets river basin within the Western Podillya were carried out by Yu. M. Andreychuk (Andreychuk, 2012; Andreychuk et al., 2015), the assessment of the ecological and geographical condition of the river-basin system of the Lug river was given by N. S. Kruta (2014), Smotrych river basin – by V. Samar (2012), ecological-geomorphological analysis of the upper part of the Dniester basin – A. V. Mykhnovych (1998), its geo-ecological assessment – by O. V Pylypovych and I. P. Kovalchuk (Pylypovych & Kovalchuk, 2017), assessment of the state and functioning of the river-basin system of Berezhnytsia in the Ivano-Frankivsk region – by O. I. Shvets (Kovalchuk, Andreychuk, Zhdanjuk, Shvets, 2013), atlas geoecological mapping of the river-basin system of Bystrytsia (Ivano-Frankivsk region) – by A. I. Kovalchuk & I. P. Kovalchuk (2018), geoecological analysis of river basins in the Sumy region – by O. S. Danilchenko, assessment of the geoecological state of Luga river basin within the Volyn upland – by N. Edinak, I. M. Netrobchuk, assessment of the state and functioning of Goryn river basin – by I. P. Kovalchuk and T. S. Pavlovska (Kovalchuk & Pavlovska, 2008; Kovalchuk et al., 2011), and the river systems of the Precarpathians – by Y. S. Yushchenko (Yushchenko, 2018), O. V. Kirilyuk (Kirilyuk, 2015), O. V. Palanychko (Palanychko, 2009), the scale of horizontal deformations in the Dniester riverbed – by H. V. Burshtynska and M. V. Shevchuk, anthropogenic transformation of geosystems of the Ternopil region – by L. V. Yankovs'ka (Yankovs'ka, 2018) and others. In most cases, a set of soil and water protection measures were justified by these researchers, and recommendations for optimizing the structure of land use in basin geosystems were put forward. Optimization measures will include the implementation of a number of approaches based on the M. D. methodology. Grodzynskyi (2005) and take into account the zonal features of natural conditions and landscapes, terrain and soil properties. Optimization measures will involve the implementation of a number of approaches based on the method of M. D. Grodzynskyi (2005) and take into account the zonal features of natural conditions and landscapes, relief and soil properties.

The proposed model of optimization of nature management and nature protection of river-basin geosystems is based on the principle of maintaining balanced priorities of the development of economy and nature protection. This means that the utilization of land and other natural resources and the development of economic activities in the study area should not deteriorate the quality of the environment and the state of natural geosystems and their geocomponents. Optimization measures provide for improving the quality of the environment and creating an environmentally safe system of environmental management (Kovalchuk, 1997; Pylypovych, Kovalchuk, 2017; Tsaryk, 2006).

Considering the excessive and ecologically dangerous levels of tillage development in Dzhuryn river basin (share of arable land is 74.5%) it is calculated that from 25 to 50 t / ha of soil are lost annually due to the active development of erosion processes. Thus, the share of arable land needs to be reduced by an average of 20.0% (Tsaryk L. P., 2006). Reduction in the area of arable should be achieved by means of the removal of highly eroded and unproductive lands from the arable, which are confined to the steep sloped areas of the upper and middle parts of the river basin. At the same time, part of these lands with slope steepness of more than 7° is recommended for afforestation, which will increase the forest cover of the territory to an average of 17.0%. The rest of the withdrawn arable land with slope steepness of less than 7° will be subject to planting gardens (4%) and meadows, which will increase the share of pastures and hayfields to 10.0%. Carrying out such optimization measures will increase the share of natural environmentally stabilizing lands from 17.0% to 40.0%.

A regional index that reflects the level of anthropogenic transformation of landscape systems in a variant with an optimal land use structure can be considered as a normative regional index of optimal nature management. Regional indices of anthropogenic transformation of the natural environment of the river-basin system (RBS), calculated for the actual (existing at the moment), as well as for the proposed optimal variant of the projected structure of nature management in the river basin, are shown in Table 1. They were determined by the method of K. H. Hoffmann (Hoffmann, 1982), improved by O. F. Balatsky (Balatsky, 2007). The index of anthropogenic transformation of the territory was defined as the product of the transformation rank (determined by an expert judgment) and the percentage of each type of land use located within the river-basin system.

Table 1. Regional indices of anthropogenic transformation of nature RBS

Land use types in river-basin system	Anthropogenic transformation rank	Percentage of each type of land use in RBS, %			Index of anthropogenic transformation of nature in RBS (in provisional points)		
		Normative	Factual	Projected	Normative	Factual	Projected
Protected areas	1	11.0	2.80	8.4	11.0	2.80	8.4
Forest-covered lands	2	22.0	8.60	17.0	44.0	17.20	34.0
Lands under pastures	3	18.0	7.72	9.0	54.0	23.16	27.0
Lands under hayfields	4	2.0	0.79	1.0	8.0	3.16	4.0
Perennial plantations.	5	4.0	0.54	5.0	10.0	2.70	25.0
Arable lands	6	33.0	74.5	54.0	198.0	447.0	324.0
Rural build-up	7	5.5	4.53	5.0	38.5	31.71	35.0
Industrial objects, roads	8	4.3	0.51	0.5	34.4	4.08	4.0
Lands under landfills and dumps	9	0.2	0.01	0.1	1.8	0.09	0.9
Total in the river basin	-	100	100	100	399.7	532.43	462.3

Comparison of these regional indices with the normative regional index of anthropogenic transformation allows to estimate the degree of ecological optimality of the actual and projected land use structures from the standpoint of their approximation to the optimal (normative) structure. The normative structure of nature management was determined taking into account the proposals of many researchers. In particular, Yu. Odum (Odum, J., 1986) justified the optimal ratio between natural and anthropogenic lands as 60% to 40%, while the share of arable lands should not exceed 30%. For the zone of mixed and deciduous forests, forest cover at the level of 23–40% is considered optimal (Grodzynskyi, 1993). The optimal share of natural reserves, provided that the biotic and landscape diversity is preserved, would be 10–12%.

The difference in the values of the index of anthropogenic transformation of landscape geosystems of RBS can be used as a generalizing characteristic of the level of environmental friend-liness of the projected options for changing the structure of land use. The level of environmental friendliness is understood here as the process of approximation of the projected structure of land to the optimal one. As can be seen from Table 1, the regional index of anthropogenic transformation due to optimization measures would decrease by 78.13 points (from 532.43 to 462.3) thanks to the significant changes in the existing structure of agricultural land use and the redistribution of part of arable between forests, grasslands, and perennial plantations, as well as through the creation of new protected areas. Its difference from the standard (optimal) regional index of anthropogenic transformation is explained by a still relatively high degree of ploughing of the territory, together with relatively low shares of meadows, afforested areas and natural reserves in the basin system.

Based on these initial points, optimization modeling of the land use structure of the Nichlava river basin was carried out, which showed the possibility of achieving better optimized correspondence between natural ecosystems and anthropogenic land uses (Fig. 3).

An important component of optimization measures, in our opinion, should be the creation of new objects of the nature reserve fund, which would ensure the optimization of the existing ecological network. Therefore, recommendations for the creation of new protected areas are focused on the formation of an integrated nature protection network of river basins of right tributaries of the Dniester River within the Western Podolian physical-geographical region. Each part of the river basins would have to represent its landscapes by means of existing and prospective protected areas and objects. Thus, at the headwaters of rivers it is important to ensure the accumulation of slope runoff, the formation of optimal river discharge, thus hydrological reserves will be important. In the middle courses of rivers the intensification of erosion processes and processes of ravine formation can be checked by the creation of locality reserves, natural monuments, etc. that occupy steeply sloped areas and floodplain-channel complexes. The lower parts of river basins have a high potential for recreational resources; their effective utilization and conservation

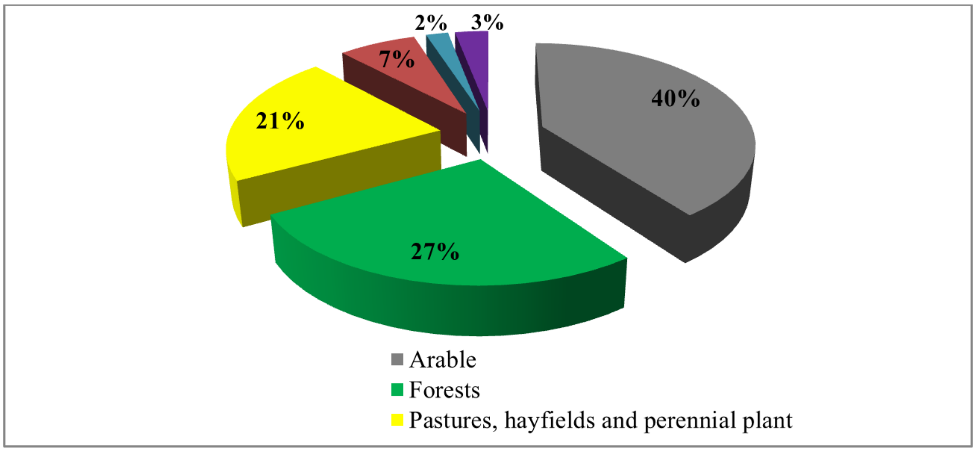

Fig. 3. Optimized land use structure in Nichlava river basin (Kuzyk, I., Kuzyk, Z., 2018)

will be supported by the existing National Nature Park (NPP) and Regional Landscape Park (RLP), as well as promising for the conservation Landscape reserve between the settlements of Koshilivtsi and Podillya (Dzhuryn basin), which will include objects within the forest tract, as well as hydrological, geomorphological, and botanical objects within the slopes of the river valley. In the Dzhuryn river basin, as of 2018, there are 11 protected areas and objects created in the period 1969 – 2014 (Table. 2). Field studies conducted in the period 2015 – 2017 make it possible to justify a number of promising objects for conservation (the numbers of objects in Table 2 correspond to the specified numbers on the map scheme (Fig. 4).

Table 2. Existing and perspective protected objects of the Dzhuryn river valley (Bakalo et al., 2018)

№	Protected object	Area, ha	Date and number of governmental decree, decision, proposal	Location (village, range, forestry), quarter, plot	Short characteristic	Land users or land owners
1	«Dzrudlo» spring	0.10	Decision of Ternopil regional council, 18.09.2014 №761	Northern outskirts of Dzhuryn village, near railway bridge, Dzhuryn river valley	Groundwater spring, having a significant historical, cultural, wellness and aesthetic functions.	Dzhuryn village council
2	«Pralo» spring	0.10	Decision of Ternopil regional council, 18.09.2014 №761	Southern outskirts of Dzhuryn village, Dzhuryn river valley	Groundwater spring, having a significant historical, cultural, wellness and aesthetic functions.	Dzhuryn village council
3.	«Red well» spring	0.42	Decision of Ternopil regional council, 26.02.1999, № 50	Bazar village, near Chervonyy stream	Five springs flowing from under the layers of Devonian sandstone form a water stream. Cultivated with red sandstone and are called «Red Well». In 1995 a chapel was built and an arboretum was established	Bazar village council
4.	National Nature Park "Dniester canyon"	790.0	Decree of the President of Ukraine, 03.02.2010, №96/2010 "On creation of NPP "Dnister canyon""	Dorohychiv forestry (quarters 5-13,16-24, 49,50, 55-67, 69, 74, 86-88)	The unique landscape of the Middle Dnister valley, characterized by a unique microclimate, picturesque landscapes and rich in monuments of nature, history, culture, etc.	State enterprise "Buchach forestry" (1859.5 ha), Zalishchyky raion state administration (1416.6 ha)
5	Regional Landscape Park "Dniester canyon"	1100.0	Decision of executive committee of Ternopil regional council, 30.08.90, №191 and 29.11.90, №273	Northern boundary runs along the road between villages Dorohychivka – Shutromynci – Nyrkiv – Nahiryany Dorohychiv forestry (quarters 14, 15, 51-54, 68, 85, 91)	The unique landscape of the Middle Dnister valley, characterized by a unique microclimate, picturesque landscapes and rich in monuments of nature, history, culture, etc.	State enterprise "Buchach forestry" (389.0 ha), Nyrkiv, Ustechkiv village councils (inside the settlements)

6.	Nahiryanska» cave	5.00	Decision of Ternopil regional council, 18.03.94.	Nahiryany village, left slope of Porosiachka river valley	Unique cave with a large diversity of secondary crystalline formations	Nyrkiv village council
7.	Chervonohorodsky waterfall	0.70	Decision of executive committee of Ternopil regional council, 23.10.72, №537	Between villages Nyrkiv and Nahiryany, Dzhuryn river	Unique nature monument. In the Dzhuryn river canyon falls from the height of 16 м.	Ustechkiv village council
8.	Sorbus oak grove in Shutromynci	13.80	Decision of executive committee of Ternopil regional council, 17.11.69, №747, and 19.11.84, №320	Sadky village, forest tract «Nyrkiv», Dorohychiv forestry, quarter 21, plots 4,5,7,8	Stand composition: 8 oak, 1 hornbeam + birch; age – 55 yrs., bonitet – II, fullness 0,7, average diameter – 22 cm, average height – 20 m., conditions of growth – D2, stock of wood 170 m^3/ha. It is a part of the protected area of Regional Landscape Park “Dnister canyon”	State enterprise “Buchach forestry”
9.	Shutromynci oaks	0.08	Decision of executive committee of Ternopil regional council, 14.03.77, №131	Sadky village, forest tract “Shutromynci”, Dorohychiv forestry, quarter 20, plot 10, qr. 21, p. 15	Three oaks older than 200 yrs., with diameter 110 sm	State enterprise “Buchach forestry”
10.	Black hazelnut (plot № 6)	1.00	Decision of executive committee of Ternopil regional council, 13.12.1971, № 645	Podillya village, forest tract «Chagor», Dorohychiv forestry, quarter 3, plot 3	Highly productive hazelnut grove	State enterprise “Buchach forestry”
11	Ustechkiv plot	1.10	Decision of executive committee of Ternopil regional council, 27.12.76, №636	Ustechkiv village, forest tract «Nyrkiv», Dorohychiv forestry, quarter 65, plot 6	Site of rocky vegetation on Devonian deposits	State enterprise “Buchach forestry”
12	Hydrological monument «Semeniv stream”	0.90	Proposal by Professor of TNPU L. P. Tsaryk (2011)	Bazar village council, eastern outskirts	Protection and preservation of springs that feed the Dzhuryn river	Bazar village council
13.	Pond in village Dzhuryn Slobidka	52.0	Perspective	Dzhuryn headwaters, Dzhuryn village council, eastern outskirts of. Dzhuryn Slobidka village	Performs an important function of runoff regulation in Dzhuryn headwaters	Dzhuryn village council
14.	Two springs near the spring “Pralo”	0.02	Perspective	Southern outskirts of Dzhuryn village, Dzhuryn river valley	Groundwater springs that perform important historical, cultural, wellness and aesthetic functions.	Dzhuryn village council
15.	Pond in Polivtsi village	4.0	Perspective	Outside the Polivtsi village	Floodplain pond is a runoff regulator	Polivtsi village council
16.	Pond in Bila river valley, Slobidka village	11.0	Perspective	Right tributary of Dzhuryn – Bila stream	Left tributary of Dzhuryn river, pond is a runoff regulator	Slobidka village council
17.	Maintained spring of St. Anna	0.2	Perspective	Southern outskirts of Slobidka village	Maintained spring in the second terrace of the left slope of Dzhuryn river valley	Slobidka village council
18.	“Chagor” locality, botanical monument	210.0	Perspective	Podillya village, forest locality “Chagor”, Dorohychiv forestry, quarter 3, plot 3	Enlargement of the locally important botanical monument	State enterprise “Buchach forestry”
19.	Hydrological monument:spring and stream in valley of Koshylivtsi	0.2	Perspective	Koshylivtsi village	Slope on the right bank of Dzhuryn river; flows out of forest tract	Koshylivtsi village council
20.	Landscape reserve “Above the Dzhuryn”	954.0	Perspective	Between villages Koshylivtsi and Sadky	Valuable forest tracts performing important water protection, erosion protection, and recreation functions. Regionally rare plant species.	Koshylivtsi and Sadky village councils

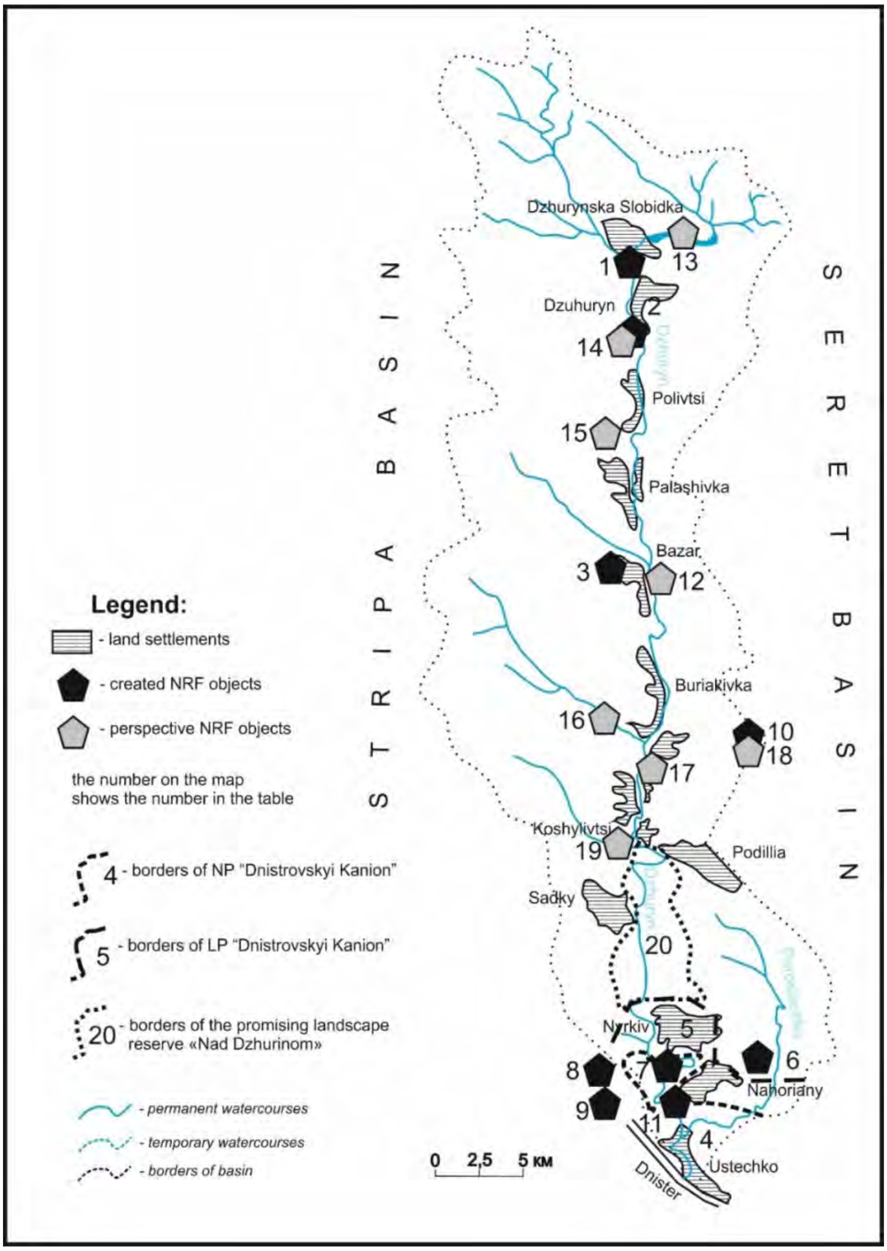

Fig. 4. Network of existing and prospective protected sites in Dzhuryn river basin (Bakalo et al., 2018)

The share of protected areas in the Nichlava river basin is much higher than in the Dzhuryn river basin and is about 15%. However, the area distribution of the categories of protected areas is extremely unbalanced. General zoological reserves make up 77% of the protected areas and are characterized by very high shares of agricultural lands and settlement lands, which only provisionally can be referred to as reserved areas, considering also the historical and ethnographic features of the distribution of local population and its economic activities that should be taken into account when creating an RLP. That is why it is proposed to create a network of landscape reserves and a Regional landscape park within the middle and lower reaches of the river basin on an area of more than 800 hectares. When conducting field research in 2019, the authors identified areas of natural vegetation with an area of 80 to 200 hectares within the lower segment of the Nichlava river valley, prospective for creating landscape reserves (Tsaryk L., Tsaryk P., Kuzyk I., 2019).

Within the lower reaches of river basins, landscapes have significant potential of natural recreational resources. That is why the first in Ukraine Regional Landscape Park "Dniester canyon" was established here (1990), as well as the National Nature Park of the same name (2010). The most visited tourist attractions are located here: Chervone tract, Chervonogorodsky waterfall, "Girl`s tears" waterfall (Fig. 5), dozens of unique gypsum caves. Hundreds of tourists come here during the weekend. During the summer holidays, one can meet here tourists from all over Ukraine and from abroad. However, the lack of necessary recreational infrastructure, reliable access roads, and eventually a balanced investment policy hinder the development of one of the most promising sectors of the economic complex in the region.

Fig 5. Unique tourist and recreational attractions Dzhuryn canyon

The implementation of a set of reasonable measures will enable to significantly improve the ecological status of river basin systems, optimize nature management, develop industries that are more adapted to market conditions, improve living conditions of local people, reduce the risks of nature management inflicted by global climate changes.

Conclusions.

1. Long-term researches of river systems of Western Podillya carried out by authors, inquiries on the conditions of valley and basin landscapes and nature management in them using methods of field survey, historical and cartographic comparisons, analysis of archival and literary sources and methods for determining the level of anthropogenic transformation of landscape components made it possible to assess their current state (on an example of RBS Dzhuryn and Nichlava), and identify the causes of adverse changes. In particular, it was found that the processes of sheet and linear erosion, chemical and physical weathering, landslides, floods and mudslides have intensified here, and the environmental conditions of surface waters and groundwater have been deteriorating. These circumstances prompted us to study in detail the state of the RBS, to identify the scales of transformation processes, to reveal the causes and factors that caused them, and to find ways to solve the complex of geoecological problems of river basin systems in Podillya.

2. As a result of studies of small river basin systems of Western Podillya, it was found that drainage of wetlands in interfluves and floodplains, deforestation and the use of these lands for agricultural production braked the ecological balance in the river basin systems of the region. Drained lands under the absence of reversible regulation of the water regime have become ecologically unstable lands, with local manifestations of adverse soil-ecological and hydrological-geochemical consequences. The development of degradation processes in slope and river-valley geosystems under conditions of long-term anthropogenic loads has caused basin systems to lose their stability and ability to self-regulate.

3. A number of adverse geoecological processes and phenomena being revealed during field and comparative-geographical studies within the river basins of Western Podillya (in this case on the examples of RBS Dzhuryn and Nichlava) have served as an information base for constructive-geographical substantiation of a complex of nature protection measures to optimize the nature management and nature protection within them. Based on the results of these studies, optimization models of land use in river basins are proposed, which will help to improve the ecological and geographical situation, reduce the manifestation of existing ecological risks and the likelihood of new ones, improve living conditions of local population.

4. Field research of small river basins typical of Western Podillya made it possible to identify and suggest to allocate 1232.5 ha (4.0% of the area of the Dzhuryn river basin) as a part of the prospective landscape reserve «Above Dzhuryn», together with six hydrological and one botanical nature monuments of local importance, thus increasing the share of protected areas from 4.2% to 8.2% of the total area. Within the Nichlava River basin, it is proposed to create six landscape reserves, a botanical nature monument, and the regional landscape park "Forest Song" on the outskirts of Borshchiv on an area of over 800 hectares. These measures would promote more effective preservation of typical landscapes and unique natural objects in the basins of small rivers of Western Podillya, will improve the environmental conditions of the region, reduce environmental risks for the economic complex of Ternopil region and the local population. We believe that researches of this kind should also be carried out for other small river basin systems, because the functioning and geoecological status of high-ranking rivers depend on the ecological states

of small RBS and on measures aimed at ensuring the rational nature management and nature protection within them.

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