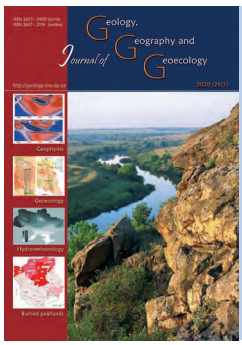

Journal of Geology, Geography and Geoecology

Journal home page: geology-dnu-dp.ua

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ.Geol.Geograph. Geology, 29(3), 606–620.
doi: 10.15421/112055

Basin systems of small rivers of Western Podillya: state, change tendencies, perspectives of nature management and nature protection optimization

Ljubomyr P. Tsaryk[1], Ivan P. Kovalchuk[2], Petro L. Tsaryk[1], Bogdan S. Zhdaniuk[3], Ihor R. Kuzyk[1]

[1] *Ternopil Volodymyr Hnatiuk national Pedagogical University, Ternopil, Ukraine*
[2] *National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine, kovalchukip@ukr.net*
[3] *Lesya Ukrainka Eastern European National University, Lutsk, Ukraine*

Received: 16.04.2020
Received in revised form: 24.05.2020
Accepted: 05.07.2020

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

Л.П. Царик[1], І.П. Ковальчук[2], П.Л. Царик[1], Б.С. Жданюк[3], І.Р. Кузик[1]

[1] *Тернопільський національний педагогічний університет імені Володимира Гнатюка, м. Тернопіль, Україна*
[2] *Національний університет біоресурсів і природокористування України, м. Київ, Україна, kovalchukip@ukr.net*
[3] *Східно-Європейський національний університет імені Лесі Українки, м. Луцьк, Україна*

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 обгрунтування 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. Обгрунтування 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

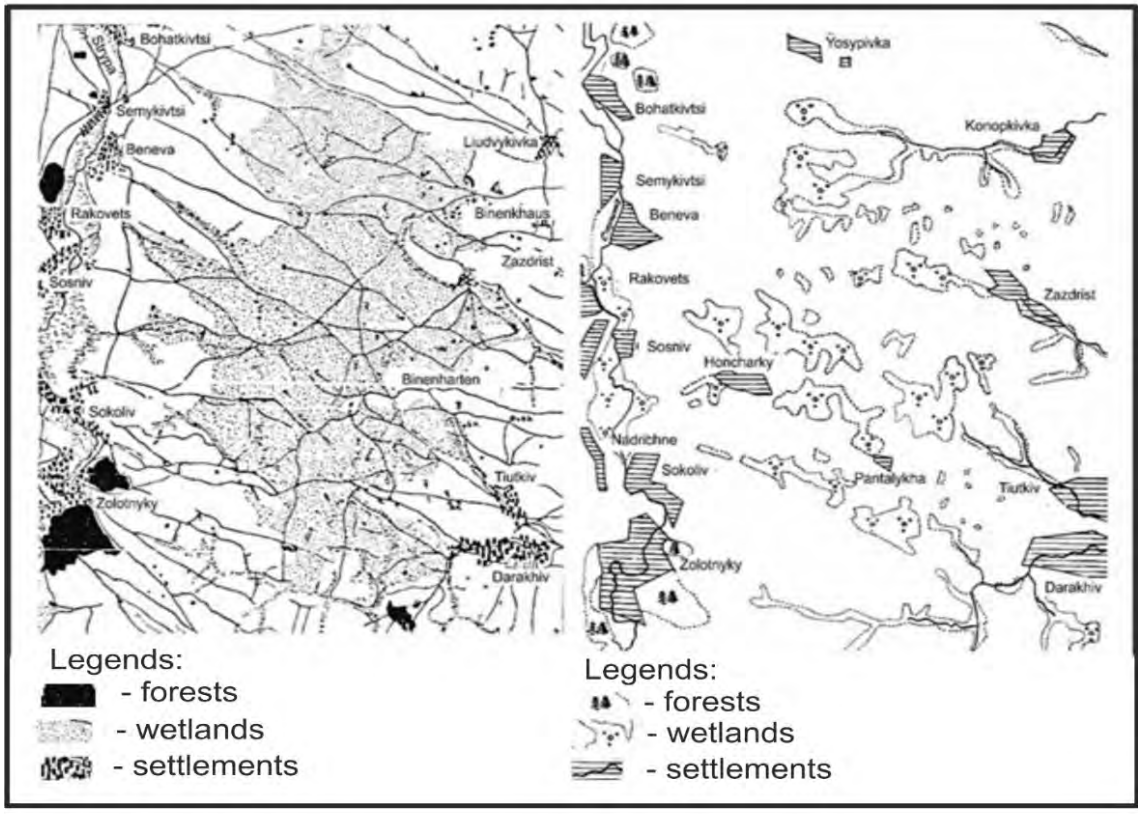

Fig. 1. Reduction of wetlands of the "steppe" of Pantalykha on the interfluve of Seret and Strypa rivers for the period from 1774 (A) to 1930 (B).

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

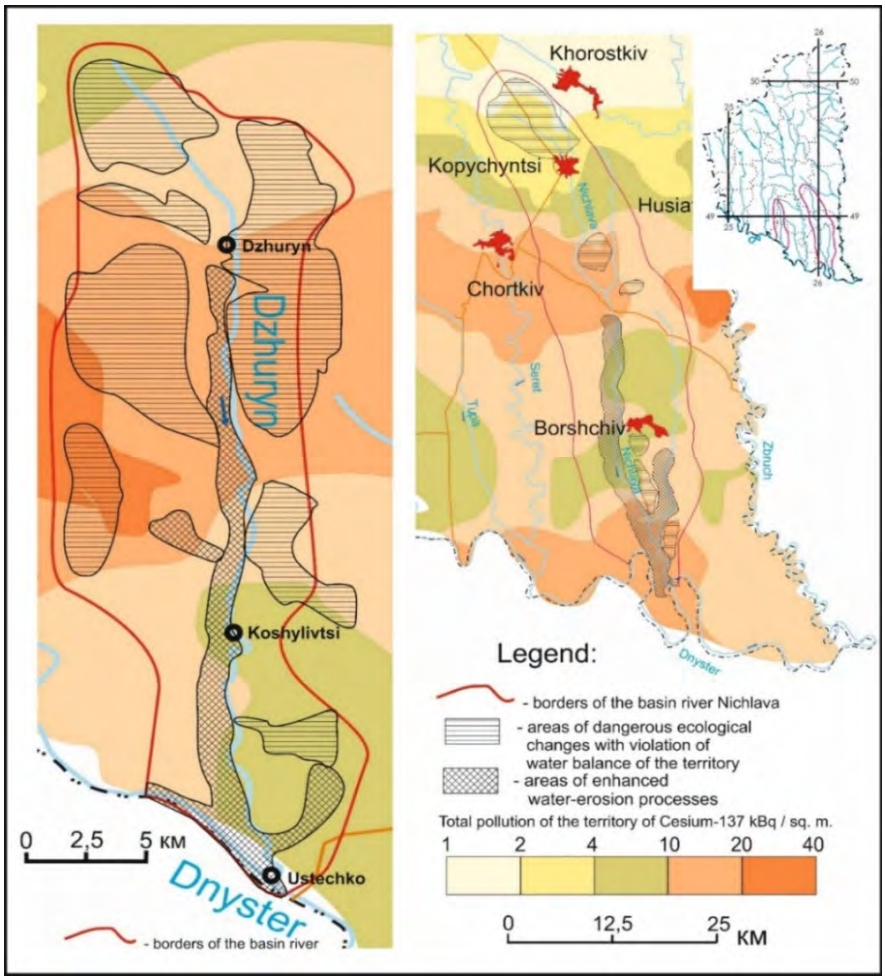

Fig. 2. Areas of the spread of dangerous geoecological processes and phenomena within the river basins of Dzhuryn (A) and Nichlava (B) (Tsaryk, 2019).

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

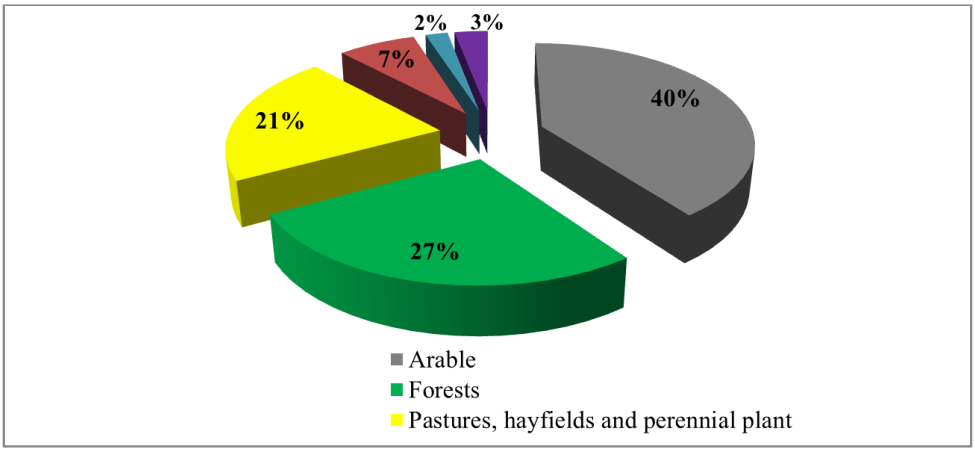

Fig. 3. Optimized land use structure in Nichlava river basin (Kuzyk, I., Kuzyk, Z., 2018)

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 "Dniester 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

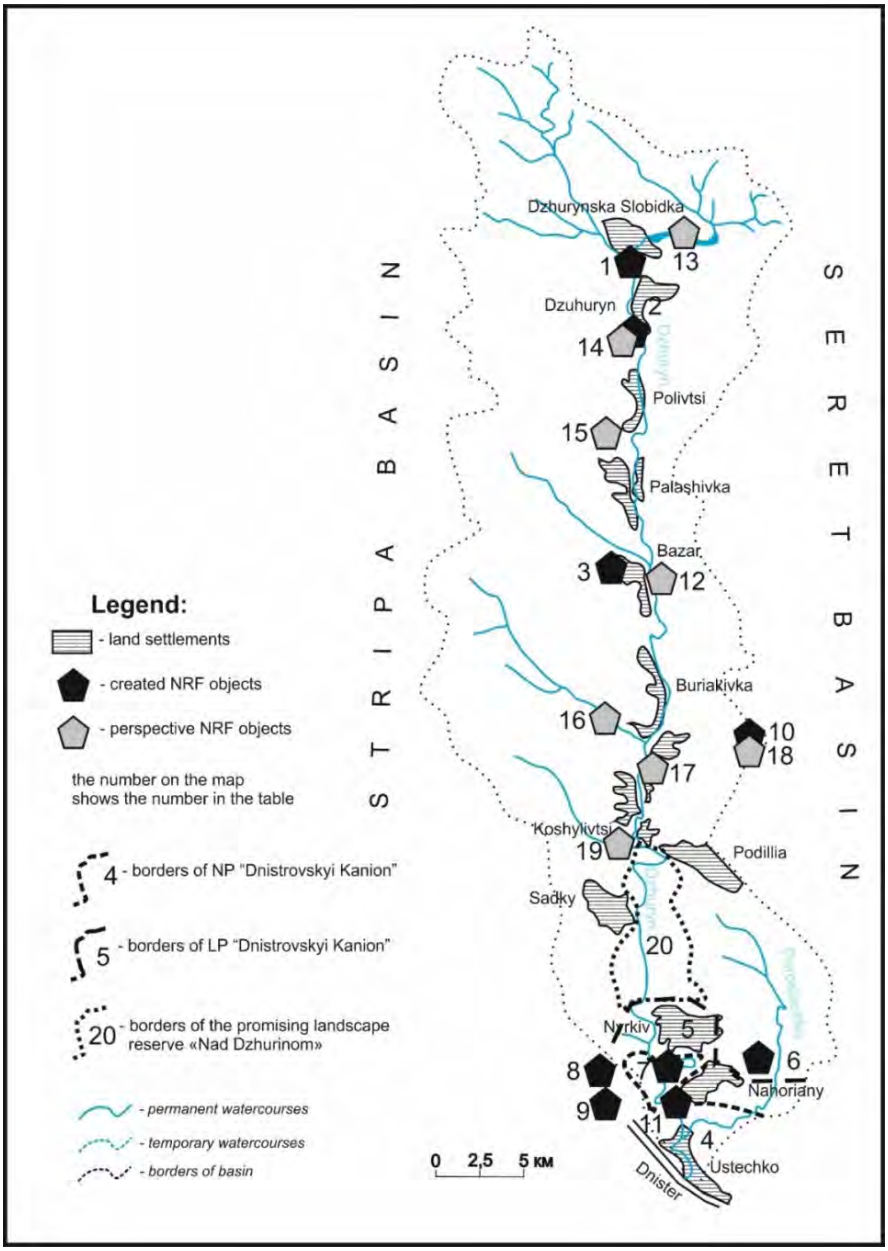

Fig. 4. Network of existing and prospective protected sites in Dzhuryn river basin (Bakalo et al., 2018)

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.

References

Andreychuk, Yu.M., 2012. Geoinformacijne modeljuvannja stanu basejnovih sistem (na prikladi pritoki Dnistra richki Koropec'). [Geoinformation modeling of the status of basin systems (on example of the tributaries of Dnister River tributary Koropets)]. The abstract of the dissertation of the candidate of geographical sciences 11.00.11. Ivan Franko Lviv National University. (in Ukrainian).

Andreychuk, Yu. M., Ivanov, E.A., Kovalchuk, I. P., 2015. Vikoristannja GIS v doslidzhennjah antropogennih transformacij basejniv malih richok (na prikladi richki Koropec'). [The use of GIS in studies of anthropogenic transformations of small river basins (on the example of the Koropets River)]. Scientific-production journal. Land management, cadastre and land monitoring. 2(3), 55-64. Retrieved from: http://journals.nubip.edu.ua/index.php/Zemleustriy/article/viewFile/6675/6531 (in Ukrainian).

Bakalo, O.D., Tsaryk, L.P., Tsaryk, P.L., 2018. Transformacija ekologo-geografichnih procesiv basejnu richki Dzhurin. Monografija. [Transformation of ecological-geographical processes of the Dzhurin river basin. Monograph]. SMP «Tayp», Ternopil. Retrieved from: http://dspace.tnpu.edu.ua/bitstream/123456789/12360/1/Bakalo_Caruk_Dzyrun.pdf (in Ukrainian).

Balatsky, O.F., 2007. Antologija jekonomiki chistoj sredy. [Anthology of Clean Environment Economics]. Sumy (in Russian).

Bryndal, T., Franczak, P., Kroczak, R. et al., 2017. The impact of extreme rainfall and flash floods on the flood risk management process and geomorphological changes in small Carpathian catchments: a case study of the Kasiniczanka river (Outer Carpathians, Poland). Nat Hazards 88, 95–120. https://doi.org/10.1007/s11069-017-2858-7.

Chemerys, M.P., 1994. Formirovanie pojmenno-ruslovogo kompleksa Volynskogo Poles'ja v uslovijah osushitel'nyh melioracij. [The formation of the floodplain-riverbed complex of Volyn Polesie in the conditions of drainage reclamation]. The abstract of the dissertation of the candidate of geographical sciences 25.00.25. Lomonosov Moscow State University (in Russian).

Ekologichnij pasport Ternopil's'koi oblasti za 2018 rik. [Ecological passport of Ternopil region for 2018]. Retrieved from: http://ecoternopil.gov.ua/images/OVD/ecopasport2018.pdf. (in Ukraine).

Grodzynskyi, M.D., 2005. Piznannja landshaftu: misce i prostir. Monografija. [Knowledge of the landscape: place and space. Monograph]. Kiev. (in Ukrainian).

Grodzynskyi, M.D., 1993. Osnonvi landshaftnoyi ekologiyi: pidruchnik. [Fundamentals of landscape ecology: a textbook]. Kiev. (in Ukrainian).

Gusarov, A. V., Golosov, V. N., Ivanov, M. M., Sharifullin, A. G., 2019. Influence of relief characteristics and landscape connectivity on sediment redistribution in small agricultural catchments in the forest-steppe landscape zone of the Russian plain within European Russia. Geomorphology. 327, 230–247.

Hoffmann, K. Kh., 1982. Social'no-jekonomicheskie aspekty razrabotki regional'nyh programm prirodopol'zovanija. [Socio-economic aspects of the development of regional environmental management programs]. Socialism and nature. 93-120. (in Russian).

Kirilyuk, O.V., 2015. Antropogenez dejakih basejnovih sistem Verhn'ogo Prutu ta riziki, pov'jazani z nim. [Anthropogenesis of Some Upper Prut Basin Systems and the Risks Related to It]. Scientific Herald of Chernivtsy University: collection of scientific papers. Geography. 744-745, 14-17. (in Ukrainian).

Kovalyshyn, D.I., Hulyk, S,V., 2009. Kontaktno-lugovi chornozemi Zahidnogo Podillja ta yih misce v klasifikaciyi. [Contact-meadow chernozems of Western Podillya and their place in the classification]. Materials of the international scientific-practical conference «Problems of soil classification and diagnostics». Agronomy and Soil Science. 69, 42-47. (in Ukrainian).

Kovalchuk, A.I., Kovalchuk, I.P., 2018. Atlasne kartografuvannja richkovo-basejnovih sistem. Monografija. [Atlas mapping of river basin systems. Monograph]. Prostir-M, Lviv (in Ukrainian).

Kovalchuk, I. P., 1981. Dinamika jerozionnyh processov v Zapadnoj Podolii. [The dynamics of erosion processes in Western Podolia]. The abstract of the dissertation of the candidate of geographical sciences 11.00.04. Lomonosov Moscow State University (in Russian).

Kovalchuk, I. P., 1997. Regional'nij ekologo-geomorfologichnij analiz. [Regional ecological-geomorphological analysis]. Lviv. (In Ukrainian).

Kovalchuk, I. P., Andreychuk, Yu.M., Shvets, O.I., Zhdanjuk, B.S., 2013. Geoinformacionnye tehnologii istoriko-geograficheskih issledovanij zapadnogo regiona Ukrainy. [Geoinformation technologies of historical and geographical research of the western region of Ukraine]. Geography Issues. 136, 459-475. Retrieved from: http://journals.nubip.edu.ua/index.php/Zemleustriy/article/viewFile/6675/6531 (in Russian).

Kovalchuk, I.P., Kovalchuk, A.I., 2019. Cifrovij atlas richkovo-basejnovoyi sistemi jak instrument monitoringu yiyi geoekologichnogo stanu ta

upravlinnja prirodokoristuvannjam. [The digital atlas of the river basin system as a tool for monitoring its geo-ecological status and environmental management]. Periodical scientific collection. Hydrology, hydrochemistry and hydroecology. 3(54), 195-196. (in Ukrainian). http://www.library.univ.kiev.ua/ukr/host/viking/db/ftp/univ/ggg/ggg_2019_53.pdf

Kovalchuk, I., Mykhnovych, A., Pylypovych, O., 2000. Transformacija strukturi richkovih sistem basejnu Dnistra ta yih gidrologichnogo rezhimu. [Transformation of the structure of the Dniester river basin systems and their hydrological regime]. Investigation of the Upper Dniester Basin Ecosystem. Collection of scientific works. Lviv. 34-43. (in Ukrainian).

Kovalchuk, I.P., Pavlovska, T.S., 2008. Richkovo-basejnova sistema Gorini: struktura, funkcionuvannja, optimizacija. Monografija. [Gorin River Basin System: Structure, Functioning, Optimization: Monograph]. RVV «Vezha», Lutsk. (in Ukrainian).

Kovalchuk, I.P., Pavlovska, T.S., Savchuk, D.V., 2011. Prirodno-zapovidnij fond basejnu r. Stohid: suchasnij stan, jogo kartografichna model', shljahi optimizaciyi funkcionuvannja. [Stokhid Basin Nature Reserve: current state, its cartographic model, ways of optimizing its functioning]. Cartography Journal: Collection of Scientific Papers. 3, 82 -91. Retrieved from: http://esnuir.eenu.edu.ua/bitstream/123456789/7790/1/pzf_stohid.pdf (in Ukrainian).

Kovalchuk, I.P., Podobivskyi, V.S., 2014. Geoekologija Gologoro-Kremenec'kogo krjazhu. Monografija. [Geoecology of the Gologor-Kremenets ridge. Monograph]. Kiev. (In Ukrainian).

Kovalchuk, I.P., Shuber, P.M., Shvets, O.I., Andreychuk, Yu.M., 2013. Transformacija strukturi richkovoyi merezhi basejnovoyi geosistemi richki Berezhnicja. [Transformation of the structure of the river network of the Berezhnytsya basin geosystem]. Visn. Lviv Univ. Ser. Geograph. 46, 186-194. (In Ukrainian). http://dx.doi.org/10.30970/vgg.2013.46.1470

Kovalchuk, I.P., & Shtoyko, P.I., 1992. Izmenenija pechnyh sistem Zapadnogo Podol'ja v XVIII-XX vekah. [Changes in the river systems of the Western Podillya in the XVIII-XX centuries]. Geomorphology. 2, 55–72. (in Russian).

Kozlovsky, B.I., 2005. Meliorativnij stan osushuval'nih zemel' zahidnih oblastej Ukrayini. [Land reclamation state of the drained lands in western regions of Ukraine]. Evrosvit, Lviv (in Ukrainian).

Kruta, N.S., 2014. Ekologo-geografichnij stan richkovo-basejnovoyi sistemi Lugu (pritoka Dnistra): ocinjuvannja, monitoring, optimizacija. [Ecological and geographical state of the river basin system of the Luga (Dniester tributary): evaluation, monitoring, optimization]. The abstract of the dissertation of the candidate of geographical sciences 11.00.11. Ivan Franko Lviv National University (in Ukrainian).

Krzemień, K., 2003. The Czarny Dunajec River, Poland, as an example of human-induced development tendencies in a mountain river channel. Landform Analysis. 4, 57–64. http://geoinfo.amu.edu.pl/sgp/LA/LA04/a057_KRZEMIEN.pdf

Kuzyk, I., Kuzyk, Z., 2018. Suchasnij stan ta naprjamki optimizaciyi zemlekoristuvannja basejnu richki Nichlava. [Modern state and trends for the optimization of land use in the basin of the river Nichlava]. Visnyk Ternopil Division of the Ukrainian Geographical Society 2, 44-48. (in Ukrainian).

Lajczak, A., Margielewski, W., Raczkowska, Z., Swiechowicz, J., 2014. Contemporary Geomorphic processes. Episodes. 37(1), 21-32. https://doi.org/10.18814/epiiugs/2014/v37i1/003.

Mykhnovych, A., 1998. Struktura richkovih sistem basejnu Verhn'ogo Dnistra ta yiyi transformacija pid vplivom prirodno-antropogennih faktoriv. [The structure of river systems of the Upper Dniester basin and its transformation under the influence of natural-anthropogenic factors]. Visn. Lviv Univ. Ser. Geograph. 21, 161-167. (in Ukrainian).

Odum, Yu., 1986. Jekologija: v dvoh tomah. [Ecology: in two volumes]. Moscow (in Russian).

Palanychko, O.V., 2009. Analiz antropogennogo vplivu na rusla ta zaplavi richok Peredkarpattja. [Analysis of anthropogenic impact on the river beds and floodplains of the Precarpathian rivers]. Scientific Herald of Chernivtsy University: collection of scientific papers. Geography. 495, 70-72. (in Ukrainian).

Pasport richki Dzhuryn. [Passport of the Dzhuryn River]. Materials of the Regional office of water resources in Ternopil region (In Ukrainian).

Pasport richki Nichlava. [Passport of the Nichlava River]. Materials of the Regional office of water resources in Ternopil region (in Ukrainian).

Pylypovych, O.V., & Kovalchuk, I.P., 2017. Geoekologija richkovo-basejnovoyi sistemi verhn'ogo Dnistra. Monografija. [Geoecology of the Upper Dniester River Basin System. Monograph]. Lviv-Kiev. (in Ukrainian).

Samar, V., 2012. Transformacija richkovoyi merezhi v mezhah basejnu richki Smotrich [Transformation of river networks within the basin of the Smotrych]. Scientific Notes Ternopil Volodymyr Hnatiuk National Pedagogical University. Series: Geography. 2(32), 43-51. (in Ukrainian). http://catalog.library.tnpu.edu.ua:8080/library/DocDescription?doc_id=554495

Shtoyko, P.I., 1992. Izmenenija landshaftov Zapadnogo Podol'ja v XV-XX vekah. [Changes in the landscapes of the Western Podillia in the 15th-20th centuries]. abstract of the dissertation of the candidate of geographical sciences 11.00.01. (in Russian).

Tsaryk, L., Burtak, O., Tsaryk, V., 2018. Geoekologichna situacija u basejni richki Nichlava. [Geoecological situation in the river Nichlava basin]. Scien-

tific Notes Ternopil Volodymyr Hnatiuk National Pedagogical University. Series: Geography. 2(45), 147-153. Retrieved from: http://geography.tnpu.edu.ua/wp-content/uploads/2019/01/19.pdf (in Ukrainian).

Tsaryk, L.P., 2006. Ekologo-geografichnij analiz i ocinjuvannja teritoriyi: teorija ta praktika. Monografija. [Ecological-geographical analysis and evaluation of the territory: theory and practice. Monograph]. «Navchalna kniga – Bogdan», Ternopil (in Ukrainian).

Tsaryk L., Tsaryk P., Kuzyk I., 2019. Prirodokoristuvannja ta ohorona prirodi u basejnah malih richok. Monografija [Environmental management and nature conservation in small river basins. Monograph]. SMP «Tayp», Ternopil. (in Ukrainian).

Tsaryk, L., Tsaryk, P., Vitenko, I., 2010. Perspektiva stvorennja zapovidnih teritorij u dolinah richok Gnizni, Dzhurina, Vil'hovec'. [Prospects for the creation of protected areas in the valleys of the Hnizny, Dzhuryn, Vilkhovets rivers]. Scientific Notes Ternopil Volodymyr Hnatiuk National Pedagogical University. Series: Geography. 2(45), 236-242. (in Ukrainian). http://catalog.library.tnpu.edu.ua:8080/library/DocDescription?doc_id=512026

Tsaryk, P., 2019. Prirodno-zapovidnij fond basejnu richki Nichlava. [Natural reserve fund of the basin Nichlava river]. Visnyk Ternopil Division of the Ukrainian Geographical Society 2, 39-43. (in Ukrainian).

Tsaryk, P., Tsaryk, V., 2019. Suchasnij stan ta perspektivi rozvitku prirodno-zapovidnogo fondu basejnu richki Gnizni. [The current state and prospects of development of the natural reservation fund of the Hnizny River basin]. Podilsky reading. Ecology, environmental protection, conservation of biotic and landscape diversity: science, education, practice. Proceedings of the International Scientific and Practical Conference. Khmelnytskyi. 201-204. (in Ukrainian).

Yankovs'ka, L.V., 2018. Antropogenna transformacija geosistem Ternopil's'koyi oblasti. Monografija. [Anthropogenic transformation of geosystems of Ternopil region. Monograph]. TNPU, Ternopil. (in Ukrainian).

Yushchenko, Yu., 2018. Problemi social'no-ekonomiko-geografichnih ta gidroekologichnih doslidzhen' richkovih rusel ta zaplav. [Problems of socio-economic-geographical and hydro-ecological studies of river beds and floodplains]. Scientific Herald of Chernivtsy University: collection of scientific papers. Geography. 795, 102-108. (In Ukrainian). https://drive.google.com/file/d/1SftJciYLOwiY-OIVads8p9sr4nzIxLWV/view

Zawiejska, J., & Krzemień, K., 2004. Human impact on the dynamics of the upper Dunajec River channel: a case study. Geograficky Časopis. 56, 111–124. file:///D:/Users/User/Desktop/Krzemie%20%20-%20The%20Czarny%20Dunajec%20River.pdf