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Formation of the Surface Runoff of the Rivers of the Carpathian Region during the Urbanization of Slope Areas

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ABSTRACT

Anthropogenic factors cause an increase in the impact on the natural system as a whole and its components. An increase in the intensity of this influence is predicted in the 21st century, and its forms are very diverse and unevenly distributed across the globe. This is most noticeable in industrialized countries, but at the same time this influence largely depends not only on the industrial potential and the level of technology, but also on the population density and urbanization of territories. Currently, much attention is being paid to the ecological problems of river catchments, which are significantly transformed as a result of technogenic influence on the natural environment. Surface runoff of water and sediments is usually formed in the river basin as slope runoff entering the river network. The river basin regulates the surface runoff formed as a result of atmospheric precipitation, which discretely falls on its surface, transferring a significant part of it into the underground runoff. The state of forest landscapes plays an important role in the formation of floods in the Dniester basin. The forest performs important ecological functions, including water protection and soil protection. Forests stabilize soils, preventing their erosion. The presence of a sufficient area of forests contributes to the regulation of surface runoff and the hydrological regime, the prevention of soil erosion and the stabilization of riverbeds. The use of water and mineral resources, construction on the banks of rivers and the laying of engineering communications through them are always different forms of artificial influence on the natural course of channel processes, which change it to varying degrees. Measures that change the channel-forming activity of the river, disrupt the flow of sediments, or radically change the hydraulic characteristics and structure of the flow have a particularly negative impact. The generalization of the dynamics of the channel process and ecological indicators within the territories of the Carpathian region will allow us to assess their impact on the state of the river network, the change in the quality of natural waters, and predict floods.

Keywords: anthropogenic load, water objects, pollution of riverbeds, erosion processes, bottom sediments, ecological indicators, channel process.

INTRODUCTION

Anthropogenic factors cause an increase in the impact on the natural system as a whole and its components. An increase in the intensity of this influence is predicted in the 21st century, and its forms are very diverse and unevenly distributed across the globe. This is most noticeable in industrialized countries, but at the same time this influence largely depends not only on the industrial potential and level of technology, but also on the population density and urbanization of territories [Baryshnikov, 2016].

Currently, much attention is being paid to the ecological problems of river catchments, which are significantly transformed as a result of technogenic influence on the natural environment. Surface runoff of water and sediments is usually

formed in the river basin as slope runoff entering the river network. The river basin regulates the surface runoff formed as a result of atmospheric precipitation, which discretely falls on its surface, transferring a significant part of it into the underground runoff. The type of soil, lakes, swamps, forest plantations and others have a significant influence on the regulation of the flow in the basin. However, various types of economic activity also have a direct impact on the river basin, namely deforestation followed by plowing the territory for agricultural purposes, construction of settlements, industrial enterprises, mining, construction of roads and railways, and others [Baryshnikov, 2016; Karpenko, 2018].

Increasing rates of urbanization and population growth lead to the fact that the anthropogenic load on water bodies is constantly increasing. Extraction of a significant part of river runoff and discharge of wastewater into rivers leads to progressive pollution and siltation of riverbeds. The analysis of the peculiarities of the dynamics of the river flow, ecological indicators and channel processes within the territories of the Carpathian region is necessary for the assessment and study of the effects of these factors on the state of the adjacent river network [Bayaraa et al., 2011].

Mountain ecosystems of the Carpathians are of great importance for climatic processes in a large area of all Prykarpattian territories. A feature of this area is the predominance of internal mountain-valley air circulation in the summer. At the same time, conditions are formed over the mountains that often provoke intense rains and storms, increasing the risk of flash floods, which lead to an increase in the rate of water erosion.

The state of forest landscapes plays an important role in the formation of floods in the Dniester basin. The forest performs important ecological functions, including water protection and soil protection. Forests stabilize soils, preventing their erosion. The presence of a sufficient area of forests contributes to the regulation of surface runoff and the hydrological regime, the prevention of soil erosion and the stabilization of riverbeds.

The rapid growth of floods, the formation of landslides and destructive mudflows are facilitated by the hydrogeological features of the region. Half of the areas of the Carpathian slopes are affected by landslides processes, and 70% of mountain catchments are subject to mudslides of varying intensity. At the same time, the regime of coastal protective strips is violated almost everywhere, no measures are taken in accordance with environmental protection programs regarding their planting and afforestation. This additionally increases the activity of surface runoff, increases water erosion and siltation of riverbeds and sources that feed them.

The use of water and mineral resources, construction on the banks of rivers and the laying of engineering communications through them are always different forms of artificial influence on the natural course of channel processes, which change it to varying degrees. Measures that change the channel-forming activity of the river, disrupt the flow of sediments, or radically change the hydraulic characteristics and structure of the flow have a particularly negative impact. The state, in the form of law enforcement, control and water management bodies, allowed large-scale barbaric mining of river stone, gravel and sand simply in the channels of the Carpathian rivers and on the lands of the water fund. This illegal, unregulated practice intensifies the destructive effect of floods, causes the migration of riverbeds, creates emergency areas, the threat of washing away large areas of the coast, including in populated areas [Chalov, 2022; Neglect of the principles, 2008].

The survey of soils in the Lviv region showed the intensive development of erosion, its dependence on soil properties, slope features, afforestation, climatic and other conditions, the main of which is the degree of plowed land. One of the manifestations of the irrational use of natural resources is the intensive plowing of slopes and the almost complete absence of anti-erosion measures. The intensification of erosion processes of the surface of the soil cover is also caused by the decline of forest reclamation, the deterioration of the condition of the field protection forest strips, and the neglect of the basic rules of land use. Soil erosion occurs in all regions of the region. Research for the foothills and mountainous regions of the Carpathians is especially relevant.

The increase in soil erosion leads to a sharp increase in the removal of sediments into rivers, especially from ravines. There are known cases when the removal of soil through ravines in just one flood amounted to several million cubic meters, which led to the formation of shoals in the mouths of large rivers, such as the Dnipro, which were then eroded over several decades. The arrival of such a large amount of sediment in small rivers, along with a sharp decrease in the border flow, can lead to the death of these rivers [Baryshnikov, 2016].

Changes in river systems are also characterized by a significant change in the chemical composition of water and precipitation, which is caused by a significant increase in emissions of pollutants, their diversity and areas of influence. Some of the pollutants entering water sources form compounds and are sorbed into particles that can be stored in sediments for a very long time, which allows them to be detected by studying sediments [Heim and Schwarzbauer, 2013; Dhivert et al., 2022]. These sediments can provide information on spatial and temporal changes in sediment pollutants at the catchment scale, as well as long-term changes in the depositional environments of bottom sediments [Dhivert et al., 2022, Vauclin et al., 2021]. The negative impact on the water quality of the rivers of the Carpathian region is caused by the ingress of polluted agricultural and municipal sewage, as well as household and industrial waste into the natural environment, especially the remains of oil products from the surrounding areas [Snitinskyi et al., 2020].

More than 90 percent of the territories in the mountains are slopes. Soil erosion, landslides and mudflows are the consequences of non-normative use of mountain areas, which leads to their degradation and the development of negative processes in mountain areas [Solodkyi et al., 2013]. In recent years, landslides, mudslides and erosion have become the main causes of soil degradation in the Ukrainian Carpathians and Precarpathians. It should be noted that these dangerous slope processes are activated under the influence of natural and anthropogenic factors. The study of fluctuations in the maximum water flow of rivers is of important scientific and practical importance. Knowledge of the variability of water flow of Carpathian rivers contributes to the development of new methods for its determination and forecasting of floods and inundation of adjacent territories [Horbachova and Barandych, 2016].

The catastrophic natural phenomena of 2008 and 2010 in the Carpathian region were caused by the simultaneous action of natural factors, namely excessive saturation of the soil with moisture and heavy rains, which were intensified by anthropogenic factors. At the same time, it is recognized that among the reasons that contributed to the activation of landslides and mudflows, the development of soil erosion in the mountains, along with excessive precipitation, is excessive deforestation [Solodkyi et al., 2013].

According to the intensity of manifestation and consequences of natural processes, the Carpathians belong to the regions dominated by destructive phenomena. These are floods, soil erosion, mudslides, landslides, windstorms, snow avalanches, which often cause human casualties and cause significant damage to the economy. In general, the Carpathians account for 32% of adverse meteorological phenomena in Ukraine. During the last three catastrophic floods in 1998, 2001 and 2008, the damage amounted to over UAH 4 billion and 50 people died. According to the scale of harmful phenomena, the region ranks first in the country [Oilynyk, 2011].

Excessive moisture, mountainous terrain and low soil strength of the Carpathians create conditions for frequent floods and contribute to erosion processes. The main natural measure to prevent these negative phenomena is forest cover [Oilynyk, 2012]. An integral indicator of the hydrological role of the forest is the degree of its influence on the formation of the river flow regime. Therefore, when assessing the hydrological role of the forest for river basins, it is suggested to first of all take into account the main factors of the water regime of the mountain area. As the main indicator of the absorptive capacity of the forest cover in such catchment basins, it is recommended to take the percentage of forest cover, and indicators of its effectiveness. This is a decrease in the maximum flow of water during floods and an increase in the limit flow in the dry seasons of the year [Rak, 2018].

MATERIALS AND METHODS

All water flows are affected by the environment and conditions of formation of surface water flow. Dangerous natural factors and anthropogenic influences caused by human economic activity deteriorate water quality as a result of the appearance of pollutants in rivers. Water quality is a characteristic of the composition and properties of water as a component of the aquatic ecosystem and the habitat of hydrobionts, as well as its suitability for water use. Ecological understanding of water quality is based on the fact that natural surface water is the most important component of aquatic ecosystems and the only possible habitat for aquatic plants and animals.

The study of the influence of geomorphological conditions was carried out by the

morphographic method, using a textual description of the relief, graphics, profiles and photographs [Pylypovich and Kovalchuk, 2017; Hnativ and Snitynskyi, 2017]. We conducted a survey of the slope areas of the catchment basin of the Stryi River, where we observed the intensification of erosion processes caused by economic activity.

Hydrological conditions were studied according to methods consisting of long-term observations at special hydrological stations and posts and data analysis of the Carpathian hydrometeorological observatory in the city of Stryi. Changes in the components of water regimes, namely flow levels, flow speed and intra-annual distribution, were analyzed. Hydroecological conditions were studied according to the methods described in [Romanenko, 2006].

The analysis of the selected water samples was carried out in the laboratories of drinking water research and the analysis of effluents of sewage treatment plants of ME «Stryivodokanal» on the basis of the relevant normative documents in force in Ukraine.

The purpose of the paper is to develop recommendations for optimizing water level monitoring for flood forecasting and detecting changes in channel processes.

To achieve this goal, the following tasks are solved:

- assessment of changes in the average flow of surface waters of the Stryi River and changes in flow parameters for 2010-2018, as well as seasonal fluctuations in the flow of suspended and mobile sediments;
- assessment of the parameters of sediment transport and accumulation in the Stryi riverbed.

RESULTS AND DISCUSSION

The main problems in the protection of land resources in the foothills are the decrease in the content of nutrients in the soil, their water erosion and insufficient land reclamation. The peculiarity of agriculture in the Carpathian region is that it is carried out on significant slopes.

Mass deforestation in the studied region was carried out on huge areas stretching from the river valleys to the upper limit of the forest. This caused the activation of harmful geomorphological processes, namely planar and linear erosion of mountain soils, mudflows and catastrophic floods. This caused the activation of harmful geomorphological processes, namely planar and linear erosion of mountain soils, mudflows and catastrophic floods. The extraction of large volumes of gravel and pebble sediments in channel quarries has a significant effect on the deformation of mountain riverbeds [Volosetskyi and Shpirnal, 2013].

The development of various branches of the economy of Ukraine, the construction of a large number of industrial enterprises, hydrotechnical structures, residential and other construction caused an increase in the volume of extraction of non-metallic materials. One of the cheapest ways of obtaining them was the extraction of sand and gravel from riverbeds and floodplains with the help of various dredges. However, the negative impact on the ecological state of the environment was not taken into account. The intensification of the extraction of gravel-sand mixtures from riverbeds has led to a number of negative consequences. The main one is the decrease in water flow levels, which often reaches about 4–5 m and leads to the exposure of water intakes and water outlets, as well as the washing away of bridge piers and transitions of oil and gas pipelines, violation

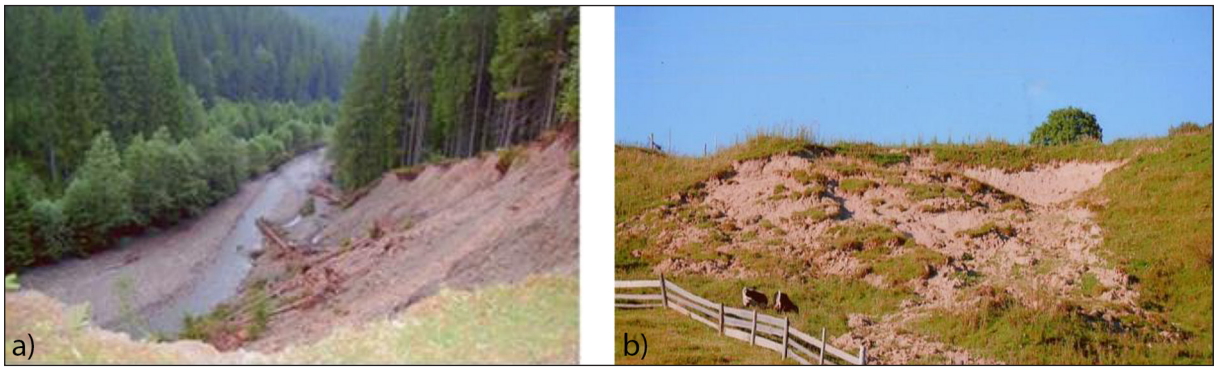
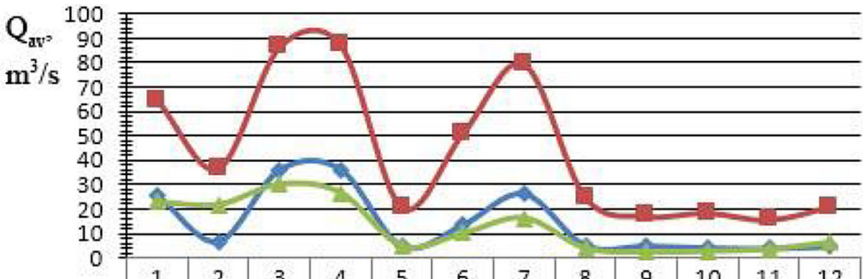


Figure 1. Development of erosion processes as a result of economic activity [Solodkyi et al., 2013]: (a) destruction of soil and plant cover by complete deforestation; (b) cattle grazing

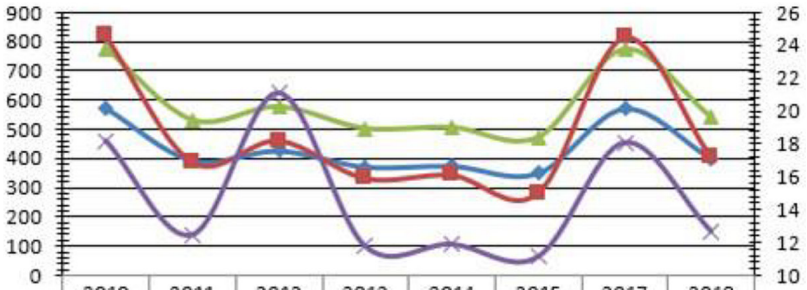
of the stability of structures. Quarries disrupt the morphological structure of rivers and thereby significantly affect their water and channel regimes. The degree of this influence is directly dependent on the size of the pits in relation to the size of the river. Therefore, careers are usually divided into small and large. Single quarries occupying a small part of the river bed or floodplain are classified as small. Such quarries do not have a significant impact on the channel and water regimes of rivers, because their surface is almost completely covered by the vortex area, which prevents the influence of the transit river flow on the bottom of the quarry. In addition, such quarries are quickly

Figure 2. Location of construction on the coastal protective strip of the Stryi River in 2020: (a) Tyshivnytsia village; (b) V. Synovydne town



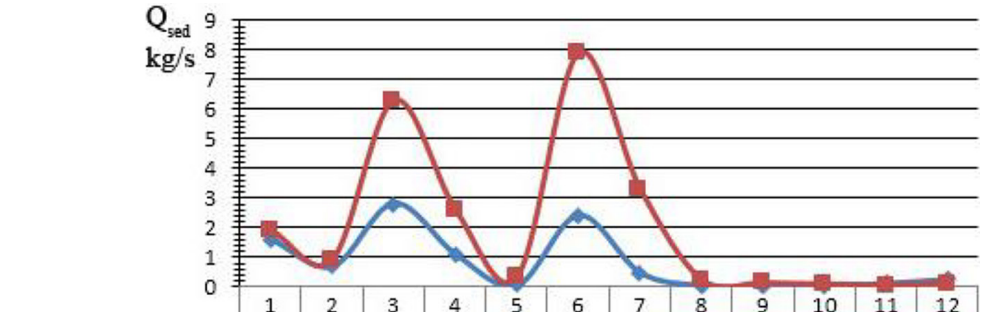
	1	2	3	4	5	6	7	8	9	10	11	12
Yasenytsia village	25,4	6,69	35,8	36	4,7	13,4	26,1	4,98	4,76	4,04	3,74	4,55
V. Synovydne town	64,7	36,8	86,4	87,2	20,9	51	79,5	25	17,2	18,6	15,7	21
Zavadivka village	22,9	21,8	30,2	26,7	4,89	10,1	16,4	4,06	2,45	2,8	3,6	6,4

Figure 3. Change in the average flow of surface waters of the Stryi River in 2018



	2010	2011	2012	2013	2014	2015	2017	2018
W, million m³	574	394	427	372	375	350	571	401
H, mm	776	532	577	503	507	473	772	542
M, l/s km²	24,6	16,9	18,2	15,9	16,1	15	24,5	17,2
Q, m³/s	18,20	12,47	21,10	11,78	11,90	11,13	18,08	12,69

Figure 4. Change in flow parameters for 2010–2018. in the basin of the Stryi River (near Zavadivka village): W – flow volume; H – drainage layer; M – flow modulus; Q – the average flow of surface water



	1	2	3	4	5	6	7	8	9	10	11	12
Zavadivka village	1,6	0,69	2,8	1,1	0,059	2,4	0,48	0,05	0,016	0,023	0,12	0,25
V. Synovydne town	1,9	0,9	6,3	2,6	0,32	7,9	3,3	0,23	0,12	0,084	0,048	0,11

Figure 5. Change in seasonal costs of suspended and mobile sediments of the Stryi River in 2018

filled with sediments coming from higher reaches of rivers. A much more complicated ecological situation arises due to channel deformation in the area of a large quarry [Baryshnikov, 2016].

Surveys of power territories in the catchment basin of the Stryi River were carried out. The intensification of erosion processes as a result of economic activity was studied (Fig. 1). Violation of the requirements of the Water Code of Ukraine was established, namely the location of residential buildings, spontaneous landfills and other potential sources of pollution in the coastal protective strips of the river (Fig. 2). The research we conducted made it possible to establish changes in the average flow of surface waters of the Stryi River and runoff parameters for 2010–2018, as well as seasonal fluctuations in the flow of suspended and mobile sediments (Figs. 3–5).

CONCLUSIONS

The conducted studies showed a possible complication of the general water management and ecological situation, especially on water bodies with a significant anthropogenic load, with the deterioration of water quality due to the limitation of the volume of dilution of polluted discharge waters and the impossibility of natural washing of riverbeds, up to the drying up of small watercourses.

The need to prevent soil erosion processes through the introduction of soil protection technologies and the implementation of other measures to preserve and restore soil fertility has been established.

The generalization of the dynamics of the channel process and ecological indicators within the territories of the Carpathian region will allow us to assess their impact on the state of the river network, the change in the quality of natural waters, and predict floods.

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