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The impact of hydropower on the riverbed processes of the Middle Dniester

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ABSTRACT

The article examines the impact of hydropower on channel processes and landscape changes of the Middle Dniester within the canyon section. Both positive aspects of hydropower development are analyzed, in particular its role as a renewable energy source and a tool for water resource regulation, as well as negative consequences associated with the transformation of the natural environment. The research methodology is based on the integrated use of cartographic materials from different time periods (two-verst maps of the early 20th century, General Staff maps of the second half of the 20th century) and modern satellite imagery. Methods of geospatial analysis were applied, including georeferencing, vectorization, and comparison of changes in the water surface area, tributary lengths, and transformation of riparian territories. The results reveal a significant increase in the water surface area of the Dniester as a result of reservoir creation: more than twice compared to its natural state according to mid-20th century maps and approximately five times according to modern data. Substantial changes in the morphometric characteristics of tributaries were identified, including their shortening and transformation into bays of various configurations. Changes in riparian areas were also analyzed, including flooding, partial destruction, and relocation of settlements, which led to further landscape and socio-economic transformations. It is shown that hydropower facilities significantly affect the hydrological regime, channel morphology, and river ecosystems. The obtained results emphasize the necessity of an integrated approach to hydropower planning and development, taking into account environmental constraints, preservation of natural and cultural heritage, and ensuring sustainable use of water resources.

Keywords: hydropower, Dniester River, reservoir, geographic information systems, remote sensing, landscape changes, hydrological regime, anthropogenic impact.

INTRODUCTION

Hydrologists and specialists in the conversion and use of water energy from the Earth's surface into electrical energy consider hydropower methods to be the most efficient source of clean energy and point out that hydropower is one of the most widespread types of energy in today's world [Kowalczyk-Juśko et al., 2017; Stefanyshyn et al., 2022].

In the report "Hydropower of Ukraine in the Context of Global Trends", authors compare the successes of Ukraine and developed countries in using hydropower to meet the population's electricity needs and point out that global hydropower capacity in 2020 provided about 20% of the world's total electricity generation. After the turmoil of the Russian-Ukrainian war, the share of hydropower in Ukraine's national energy balance has declined significantly in recent decades, although before the war, national plans for the development of the electricity sector envisaged a further increase in the capacity of both large and small hydropower plants in the country [Khodnevych et al., 2017]. The destruction of the Kakhovka hydroelectric power plant on the Dnieper River, which had a catastrophic impact on nature, is considered a disaster. At present, it is necessary to apply an approach to the regulation of hydropower that would include the adoption of a separate law on hydropower, taking into account environmental control and the protection of nature conservation areas. Historical lands and monuments should also be protected [Lindström and Ruud, 2017; Stefanyshyn, 2018]. In total, the installed capacity of hydroelectric power generation in 2020 exceeded 1300 GW [Law…, 2012; National…, 2019]. It is emphasised that hydropower effectively complements other renewable energy sources, primarily solar and wind, and is the most efficient technology for electricity generation in terms of efficiency (up to 96%) [Cabinet…, 2016]. The positive effects of hydropower include a reduction in the impact of factors associated with climate change and the positive effect of hydroelectric power plants during significant flooding.

Civil servants consider stricter requirements for environmental protection projects to be applicable to both new and existing facilities, regardless of their capacity and ownership, ensuring compliance by investors, project developers, individuals and organisations that build and operate various facilities, including hydropower [Musonda et al., 2025]. It is important to analyse primary sources of information, which include: scientific publications and manuals, guidelines and manuals, websites of government agencies and environmental organisations, regulatory acts, other official documents in the field of hydropower, and analytical publications in the media. After searching for and identifying patterns in primary sources of information, proposals for improving the current situation in hydropower should be analysed by addressing the problems identified in the study, taking into account international experience in legislative regulation, minimising environmental impact, and establishing no-go areas. The goal of developing new approaches to new policies in the field of hydropower is to preserve river ecosystems and achieve environmental standards in the hydropower industry at the level of advanced countries. The experience another countries shows that hydropower has a chance for environmentally sustainable development in the future only if environmental and social challenges are taken into account, in particular, the identification of areas where the construction of new hydropower facilities would be considered unacceptable for environmental or socio-environmental reasons [Fry et al., 2022; Hite, 2025; Quaranta, 2023].

It is emphasised that hydropower provides a double benefit in the fight against climate change. Hydropower not only provides clean energy with significantly lower greenhouse gas emissions than most other technologies, but also supports the development of other renewable energy sources (RES) thanks to its manoeuvrable capacities. This reduces dependence on fossil fuels and avoids around 4 billion tonnes of additional greenhouse gas emissions per year (compared to coal-fired power generation, according to the 2020 State of Hydropower Report). The second advantage is the ability of hydropower to provide water supply services and act as a water storage facility. Hydropower provides storage capacity for water that can be used for irrigation, drinking water supply, flood control, navigation and other services. Reservoirs are necessary to adapt to growing water needs [Kondolf et al., 2014; Ring, 1956].

Since the beginning of the 20th century, hydropower has played a leading role in the electricity sector of many European countries and contributed to their industrialisation processes. After the Covid-19 pandemic, many vital climate initiatives were put on hold. However, the UN Climate Change Conference took place from 31 October to 12 November 2021. The concept of carbon neutrality is much emphasized in IPCC Spatial Report on Global Warming [Intergovernmental…, 2018]. A plan of action to reduce carbon emissions and accelerate the transition to a green economy was discussed and adopted. In line with the goals of the Paris Agreement, governments must take measures to promote the transition to cleaner and low-carbon technologies to achieve long-term temperature goals [Huang and Zhai, 2021]. Once again, the issue that is considered one of the most important in the world has arisen: the search for renewable energy sources, among which hydropower occupies a priority place. According to a recently published global forecast by the International Renewable Energy Agency, in order to support the commitments under the agreement, the global hydropower industry will need an additional 850 GW of installed capacity by 2050 [International…, 2024].

Although hydropower plants help combat climate change, they themselves can be vulnerable to changing climatic conditions. Fluctuations in temperature and precipitation, anthropogenic changes in catchments, increased frequency of droughts and extreme weather events significantly affect river flow [Papadaki and Dimitriou, 2021; Sharma, 2025]. An increase or decrease in river flow affects water availability and, in turn, electricity production, creating significant challenges for hydropower managers. Much of the world's hydropower potential remains untapped, especially in developing countries where reliable and affordable clean energy is lacking. Particular attention should be paid to the issues of rational management of water resources. Changing the natural flow of rivers affects water levels, temperatures and chemical composition, which in turn causes soil erosion and changes in humus content [Mazur et al., 2016; Nile et al., 2025]. Hydropower plants alter riverbed processes by disrupting the flow of solids [Grill et al., 2019; Korpak, 2007]. Globally, it is stated that less than one-third of the world's large rivers remain free-flowing due to cascades of hydropower plants [Kondolf et al., 2014], and after the construction of dams, the channel morphology and hydraulic characteristics of rivers change [He et al., 2024]. Hydropower plants cause environmental and biotic changes [Morris, 2020], and also influence the processes of accumulation and erosion of bottom sediments before and after the dams [Directive…, 2000; Moschynskyi et al., 2018; Ring, 1956]. As a result, the channel geometry, the grain size distribution of bed sediments and the morphodynamics of river systems are altered [Brandt, 2000; Petts and Gurnell, 2005; Williams and Wolman, 1984]. The construction of hydroengineering structures is one of the main factors in the anthropogenic transformation of river channel processes. Modern studies indicate that the impact of hydropower structures on river channel processes is a global issue characteristic of diverse physiographic conditions. In particular, for rivers in Asia, Africa, and the Middle East, dam construction has been shown to cause significant alterations in hydrological regimes and disrupt sediment transport, which in turn leads to transformations in channel morphology. For example, in the Yangtze River, a sharp decrease in sediment discharge has been recorded following the construction of a cascade of hydropower plants, accompanied by changes in channel forms and the granulometric composition of deposits [Hamidifar and Nones, 2023; Ji et al., 2022; Kondolf, 1997].

Similar trends are observed for the Huanghe, Minjiang and Tekeze rivers, where flow regulation esults in sediment deficits, channel erosion, and incision [Annys et al., 2020; Liro et al., 2020; Liu et al., 2024]. Studies of mountain rivers confirm that the dam wall of reservoirs alters the hydrodynamic characteristics of the flow, reducing flow velocity and shear stress, which affects accumulation and erosion processes [Yao et al., 2020]. Thus, regardless of the region, hydropower is one of the key factors in the anthropogenic transformation of river channel processes, necessitating research into its impact on changes in these processes.

MATERIALS AND METHODS

The study was conducted in the Middle Dniester River from Khotyn to Novodnistrovsk on the Ukraine. The Dniester Canyon was formed as a result of the specific geological structure of the area, as well as tectonic movements and processes of water and wind erosion. It is located in the western part of Ukraine. The canyon is home to numerous nature reserve sites in Ukraine, including: Dniester Canyon National Nature Park; Dniester Canyon Regional Landscape Park; Dniester Regional Landscape Park; and Bakot Bay. The Dniester Canyon stretches from the mouth of the Zolota Lipa to the mouth of the Zbruch, with a length of about 250 km. It is one of the largest canyons not only in Ukraine but also in Europe. In the valleys of the Dniester and its tributaries, a powerful complex of sedimentary strata is exposed, ranging from the youngest anthropogenic to the oldest silurian deposits of the palaeozoic era.

On the right bank of the Dniester near the village of Bukivna, as well as on the left bank, on the Tanutynska Mountain near the village of Dibrova in the Ivano-Frankivsk region, various rocks of the Mesozoic era are exposed - deposits of the Upper Jurassic, which is the only similar exposure over a significant area of the East European Platform. These deposits, represented mainly by yellowish-white, organogenic-clastic and oolitic limestones, contain imprints of several species of fossil marine algae and various fossil fauna. Three types of relief have formed in the Dniester Canyon: sculptural-erosional, hilly-mountainous and accumulative-flat (mainly on the right bank) [Ivchenko, 2004].

Figure 1 shows the location of hydroelectric power plants and a diagram of a section of the Dniester River, including the Dniester Hydroelectric Power Stations 1 and 2, the Dniester Pumped-Storage Power Station, the Dniester Main Reservoir 1 and the Dniester Reservoir 2 (buffer reservoir), as well as nearby settlements.

Their main goal was to identify changes and deformation processes in the riverbed and riparian areas of the Middle Dniester canyon, caused by the direct impact of hydroelectric power plants and related anthropogenic factors. Based on their own research and ananalysis of literature sources examining the impact of hydroelectric power plants on the Ukrainian economy and the effects of their operation on the natural environment, in particular river deformation phenomena, changes in the hydrological characteristics of the Dniester and its tributaries, and changes in riparian areas, the authors examined their impact on these processes. Specifically, changes in the surface area of retention reservoirs, the mirror surfaces of riverbeds, changes in river tributaries, and landscape changes in adjacent areas resulting from changes in the distribution of settlements were determined. The structural diagram of the study is presented in Figure 2.

To determine the landscape, channel and hydrological changes in the Dniester riverbed in the selected area, cartographic materials were used: two-verst maps (1900–1926) and General Staff maps (1977–1984), as well as medium-resolution satellite imagery (2025) (Figure 2). While on the 2-verst maps the water surface of the river corresponds to its natural course, on the other two images the areas of the mirror surfaces of the riverbeds have undergone significant changes due to flooding caused by the construction of a dam to cool the hydroelectric power plant equipment.

Description of input materials:

- two-verst maps (2 versts per inch) 1:84000, contours drawn at 4 fathoms in height (1 fathom = 7 English feet = 84 inches = 2.134 metres), (1 verst = 1000 fathoms).
- XXXVIII-20-21 (Bessarabia, Khotyn and Kamianets-Podilskyi provinces) - map of the military-topographical department of Petrograd, surveyed in 1871, reconnaissance in 1910–1911, printed in 1917.
- XXXVII-21 (Poland, Ukrainian SSR and Bessarabia, Kamianets-Podilskyi) surveyed in 1871 and 1900-1-2, reconnaissance in 1926.
- XXXVII-22 (Bessarabia and Ukrainian SSR, Stara Ushytsia) – Geokartprom cartographic factory in Rostov-on-Don, surveyed in 1871 and 1900, reconnaissance in 1926.
- XXXVIII-23 (Bessarabia and Ukrainian SSR, Murovani Kurylovtsi) – 1907–1908.
- General Staff maps 1:100000:
- M-35-125 (Ukrainian SSR, Ternopil, Khmelnytskyi and Chernivtsi regions, Khotyn) Created based on a 1:50000 map using data from a 1949 survey, updated in 1977, printed in 1978.
- M-35-126 (USSR. Ukrainian SSR Khmelnytskyi, Chernivtsi regions, Moldavian SSR, Kelmentsi) Created based on a 1:50000 map using data from a 1949 survey, updated in 1982 and 1984, printed in 1985.
- M-35-127 (USSR. Ukrainian SSR, Vinnytsia, Khmelnytskyi, Chernivtsi regions, Moldavian

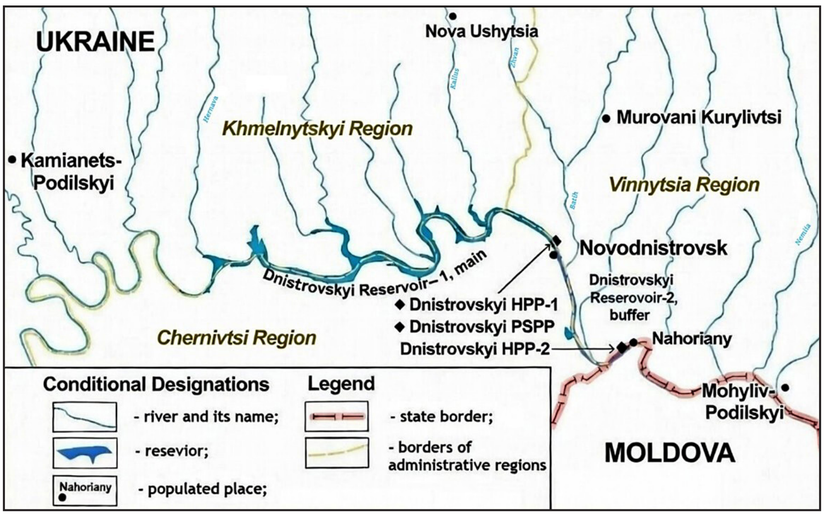

Figure 1. Map of the Dniester reservoirs (main and buffer) [Khilchevskyi et al., 2022]

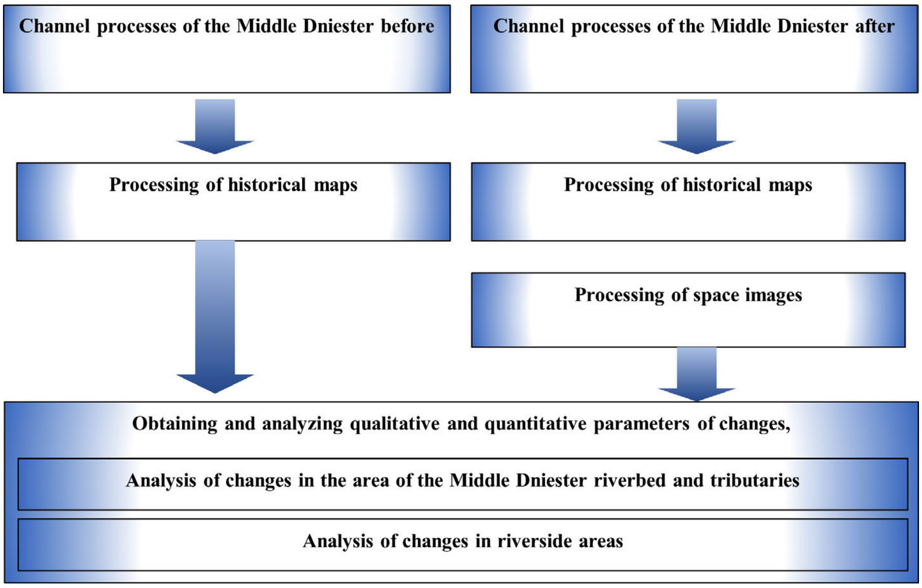

Figure 2. Structural diagram of studies of the impact of hydroelectric power plant construction on riverbed processes in the Middle Dniester

SSR, Sokyryany) Created based on a 1:50000 map using data from a 1949 survey, updated in 1985, terrain as of 1983, printed in 1986.

- Maps obtained from https://freemap.com.ua
- Image from Google Maps https://mt.google.com.

The research task includes determining changes in the water surface of the canyon part of the Dniester riverbed from Novodnistrovsk to the confluence of the Garnava tributary. This canyon part currently serves as the main Dniester reservoir to meet the needs of the Dniester hydroelectric power plants. Changes in river tributaries within the scope of hydroelectric power plants are considered separately.

RESULTS

The consideration of issues related to the construction of hydropower facilities, as a necessary source of modern comfortable human life on Earth, on the one hand, is associated with the calculation of hydropower plant capacities and the construction of reservoirs, and on the other hand with taking into account all nuances of landscape changes. Since each river, due to its specific flow conditions, is studied individually, the results of changes in the channel, its tributaries, as well as landscape transformations for the studied river section will be specific and different from other sections or river systems. The complexity of addressing this topic also lies in the fact that the selection of sites for hydropower plant construction is often associated with river sections that are recreationally attractive for tourism or represent unique landscape areas.

Determination of changes in the water surface of the canyon part

The measurement of water surface areas was carried out using images of the canyon section of the Dniester River within the reservoir. The measurement points were the points of bends and intersections of the riverbed line with landscape elements (Figure 3a-c).

The points for calculating the water surface area were selected at the bends of the riverbed lines, as well as at the intersections of the riverbed lines with characteristic landscape lines (small ravines, channels, paths, etc.). A total of x, y coordinates were measured at the following points: for two-verst maps – 2374 points, with a spacing of 146 m between points; for General Staff maps – 2442 points, with a spacing of 155 m; for the satellite image – 6314 points, with a spacing of 90 m between points. The area of the measured object is determined by the expression:

$$S = \frac{1}{2}\left|\sum_{i=1}^{n}(x_i y_{i+1} - x_{i+1} y_i)\right| \tag{1}$$

where: (x_i, y_i) – coordinates of points.

Measurement results are presented in Table 1. Surface area of the Dniester reservoir from the village of Isakivtsi to the dam in Novodnistrovsk:

- Two versts: 26.89 km^2,
- General Staff: 62.66 km^2,
- Satellite image: 133.19 km^2.

The two-verst maps were constructed using a polyconic projection, which allowed large areas to be mapped with the required accuracy. The maps show settlements, farms and forests in sufficient detail. In Figure 3a, the Dniester riverbed is not flooded, while in Figures 3b and 3c, the water surface has increased due to the construction of a dam and the transformation of the riverbed into a reservoir.

As a result of the construction of hydropower facilities, the water surface area of the Dniester increased by 2.3 times on the General Staff map compared to the corresponding area of the natural flow of the Dniester riverbed shown on the two-verst map, and on the photograph, the corresponding area exceeds the area of the two-verst map by 5 times.

Analysis of changes in the tributaries of the Middle Dniester

The transformation of the riverbed into a reservoir in Figures 3b and 3c caused changes in the lengths of the river's tributaries, as well as the formation of new bends or spills.

Figure 4 shows a diagram of measurements of the lengths of the tributaries of the Studenitsa River, flooded by the reservoir. In the diagram, L1 is the length along the bed of the flooded tributary as of 1980, and L2 is as of 2025. The results of these measurements are presented in Table 2. As a result of flooding of tributaries, bays of various configurations are formed in the form of local planar, elongated shapes (Figure 4).

The changes in the characteristics of the tributaries, visible in Figure 5, are very interesting when we compare the lengths of the tributaries on two-verst maps (natural riverbed) and General Staff maps (after the flooding of the canyon).The length of all tributaries decreased: the length of the Dniester tributary Studenytsia

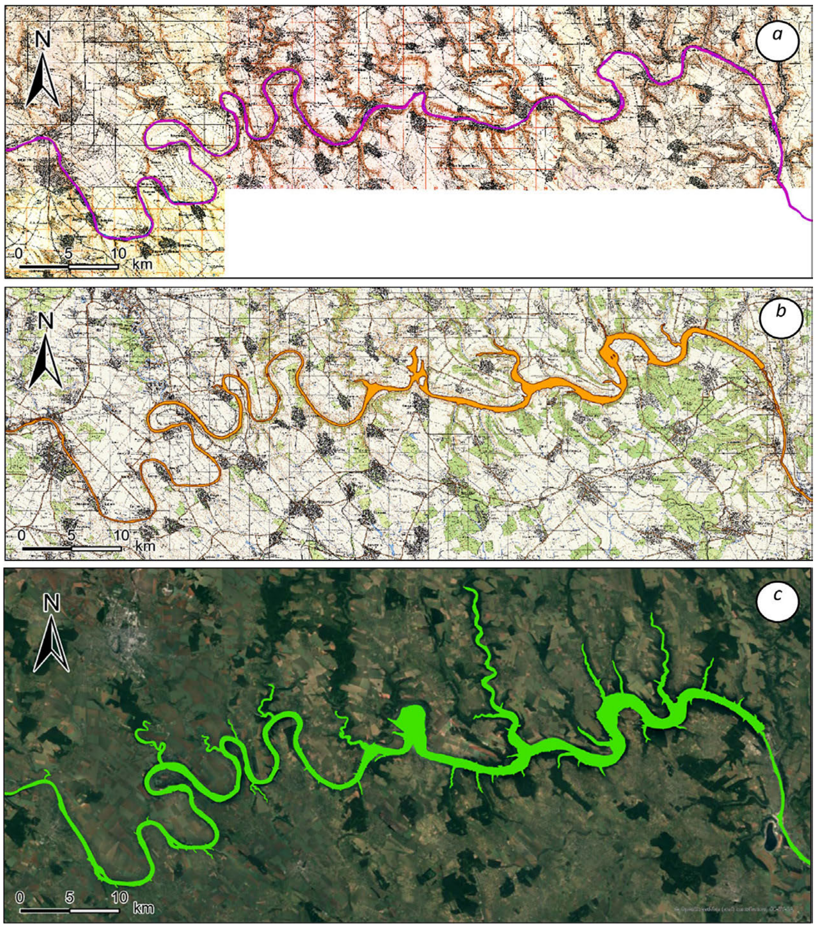

Figure 3. The Dniester River against the background of raster images: a – two-verst maps (1900–1926), b – General Staff maps (1977–1984), c – satellite image (2025)

Table 1. Changes in water surface area

Year	Area, km²	Difference, km²
1900	26.89	
1980	62.66	35.77 (1980–1900)
2025	133.03	107.30 (2025–1900)

on the General Staff map decreased by 4.31 km; the Ushytsia tributary decreased by 18.13 km; the Danylivka tributary decreased by 3.72 km (Table 2), etc. Among all 27 tributaries, not a single one showed an increase in length under the influence of canyon flooding during its transformation into a reservoir. However, after flooding, the formation of new, generally short bays can be observed, as well as flooded near-channel areas.

Analysis of changes in riparian areas

Hydroecological changes in the landscapes of riparian areas are among the most significant, as they are associated with significant changes in the territories due to the forced relocation of settlements and changes in agricultural land management. The main areas of change in the resettlement areas were crop production, livestock farming, and horticulture.

In order to identify and analyze changes related to the relocation of settlements to safe places, the settlements were mapped as shown in Figure 6.

A total of 113 settlements were analyzed, including 13 cottage cooperatives (CC). 91 settlements are marked on the two-verst maps; 81 settlements are marked on the General Staff maps; and 92 settlements are marked on the satellite image. The results of the calculation and comparison of areas are presented in Table 3. A clear, almost two-fold increase in area related to the relocation of settlements between 1980 and 2025 is visible.

In order to understand the difficult process of resettling people to new territories, which was sometimes accompanied by worsening living conditions (poorer land, distance from public transport, conflict situations, etc.), the settlements that underwent changes as a result of the construction of the Dniester Reservoir were divided into groups (Table 4).

Information about flooded villages was obtained from the stand "Completely flooded villages during the filling of the Dniester HPP reservoir in 1981-1987" [https://commons.wikimedia.org/wiki/File:Затоплені_села.jpg] and verified using cartographic data and satellite imagery.

Not all villages that ended up under water were flooded at the same time. Those located directly on the banks of the Dniester were flooded by 1980. Figure 7a shows an example of such a settlement – the town of Studenytsia. Villages located further from the Dniester riverbed on the banks of tributaries were flooded much later. In Figure 7b, the settlement of Chuhor along the

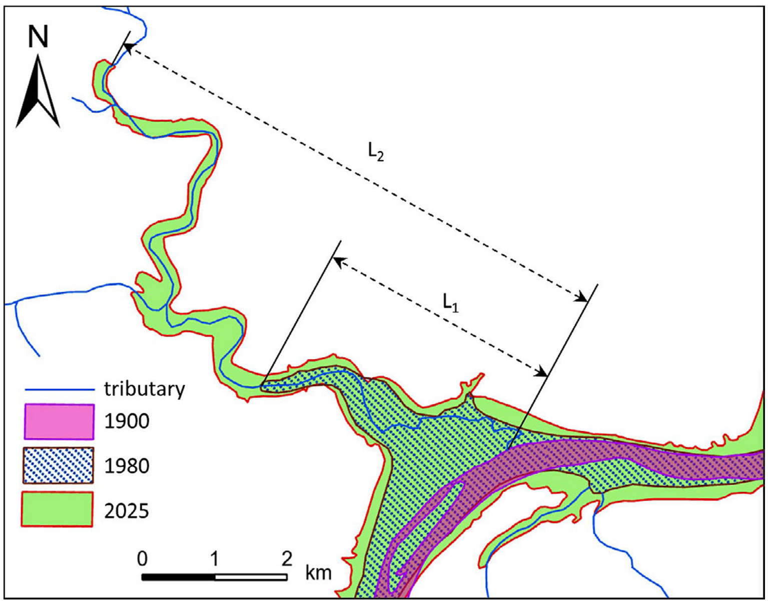

Figure 4. Gradual flooding of tributaries based on the example of the Studenitsa River: L1 – length along the bed of the flooded tributary as of 1980, L2 – as of 202

Table 2. Lengths of flooded tributaries of the Middle Dniester

No.	Tributary name	Length of flooded tributary, km	
		L1 as of 1980	L2 as of 2025
1	Danylivka	4.05	7.77
2	Zharnivka	3.12	5.97
3	Calius	7.87	13.37
4	Materka	1.8	3.58
5	Muksha	2.76	4.41
6	Rudka	2.08	4.26
7	Sara Lunha	1.16	1.29
8	Smotrych	9.13	10.31
9	Studenytsia	5.76	10.07
10	Sursha	2.04	3.11
11	Ternava	5.56	6.22
12	Ushytsia	8.7	26.83
13	tributary 1	0.09	0.67
14	tributary 2	0.6	1.39
15	tributary 3	0.35	0.47
16	tributary 4	1.29	1.67
17	tributary 5	1.38	1.93
18	tributary 6	2.06	2.58
19	tributary 7	2.23	3.45
20	tributary 8	1.42	3.17
21	tributary 9	1.71	2.88
22	tributary 10	0.44	0.92
23	tributary 11	0.79	1.15
24	tributary 12	2.79	3.99
25	tributary 13	1.62	2.48
26	tributary 14	0.86	1.37
27	tributary 15	0.73	1.47

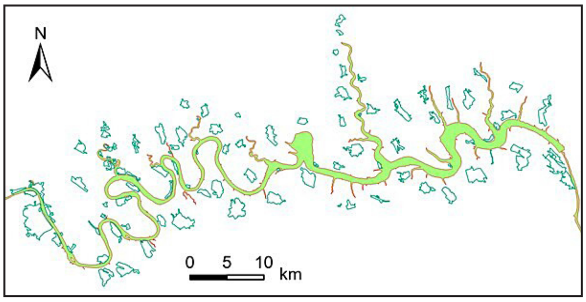

Figure 6. Scheme of the location of settlement boundaries in the study area as of 2025

Ushytsia tributary is still visible on the 1980 map, but it is no longer visible on the satellite image.

Ten settlements within the Dniester Reservoir and its tributaries were partially flooded. The territory of these settlements, which ended up above the current water level of the reservoir, has been preserved, and people continue to live there. People were forced to leave the flooded territory. An example of such settlements is shown in Figure 8.

Two settlements, Darabany (Figure 9) and Polyvaniv Yar, are not flooded but have ceased to exist. In 1987, the residents of the village of Darabany were resettled to the neighboring village of Anadoly. Five settlements were relocated to other areas (Figure 10).

The increase in population caused by resettlement from flooded areas and other demographic factors has resulted in an increase in the area of settlements (Table 3) and significant changes in

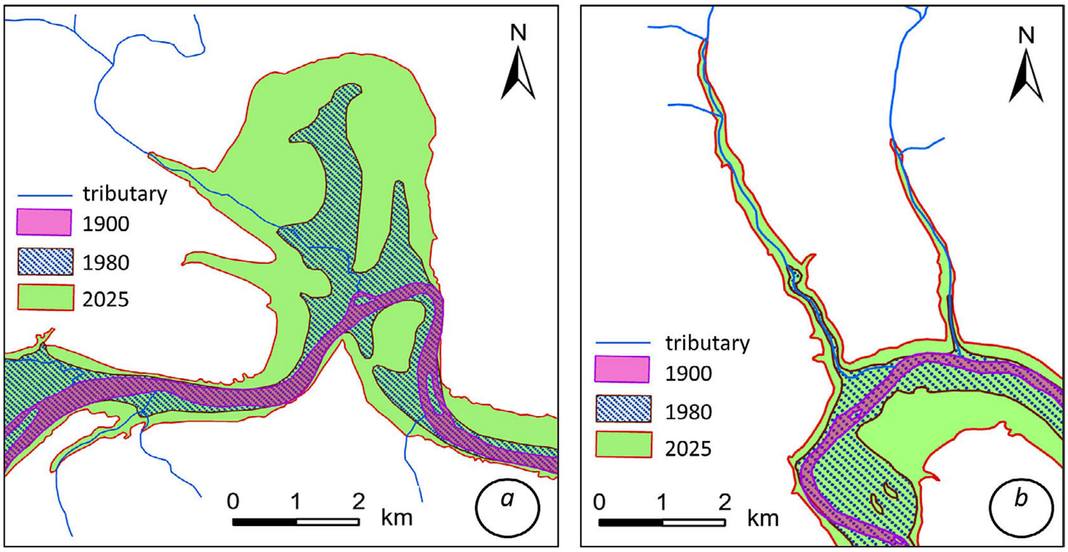

Figure 5. Formation of bays on the tributaries of the Dniester: a – Bakot Bay of the Dniester Reservoir on the territory of the Ruska River tributary (fan-shaped expansion); b – bays on the territory of the Danilivka and Petriv Batig River tributaries (elongated shape)

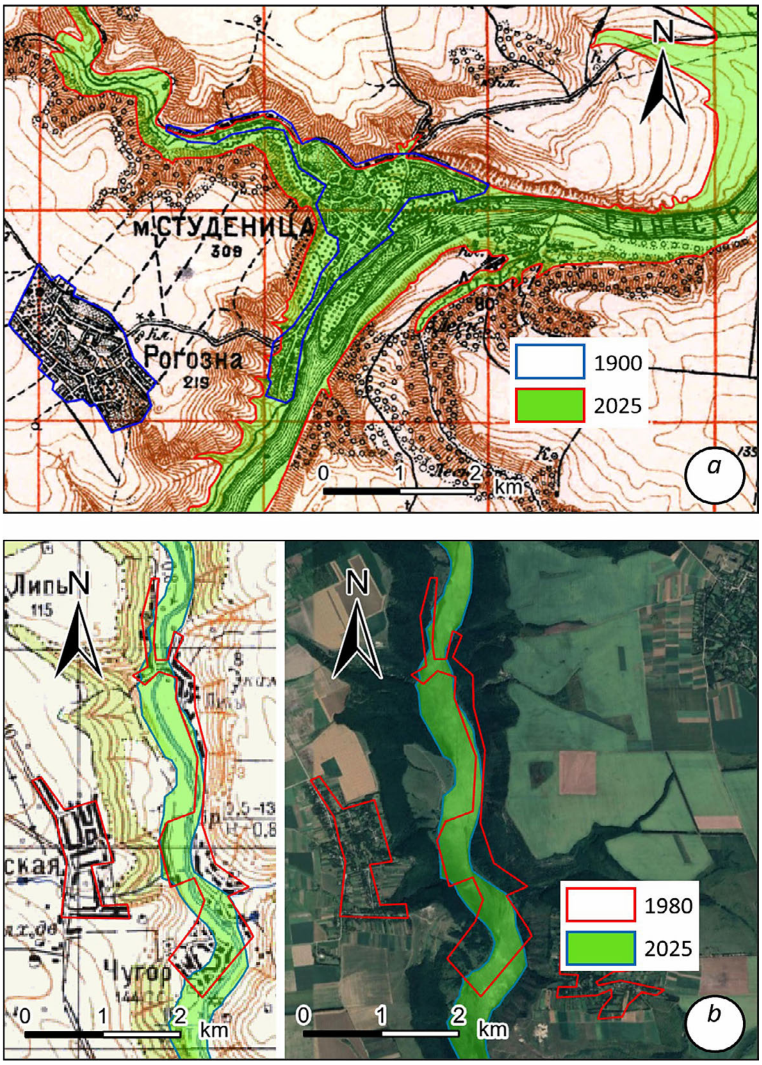

Figure 7. Flooded settlements: a – Studenytsia against the background of a two-verst map; b – Chuhor against the background of a General Staff map and a satellite image

Table 3. Results of calculation and comparison of areas of settlements

Arrangement	Total area, km²	Area increase, km²		
		1900–1980	1980–2025	1900–2025
On two-verst maps	105.66	6.18	12.22	18.40
On General Staff maps	111.84			
On satellite images	124.06			

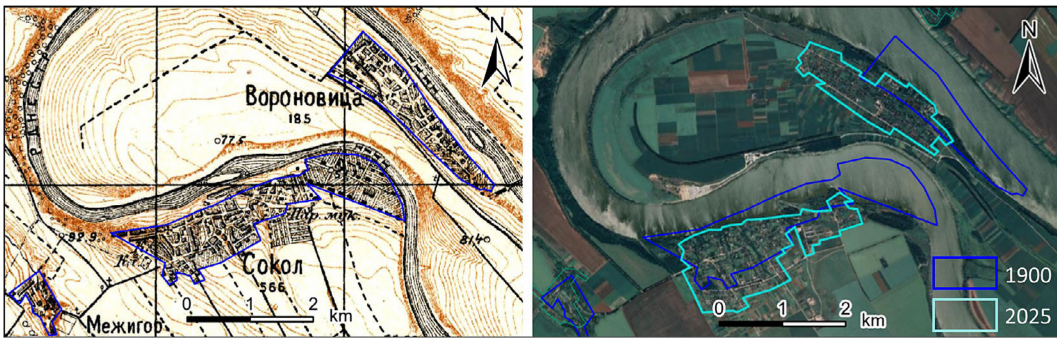

Figure 8. Partially flooded settlements of Voronovytsia and Sokil against the background of a two-verst map and a satellite image

the landscape due to intensive agriculture. An example of such changes is shown in Figure 11.

In addition to the relocated settlements, new ones have been established. For example, the city of Novodnistrovsk (Figure 12) was founded in 1973 and is one of the youngest cities in the Chernivtsi region. The large coastal area of the Dniester Reservoir has become the location of numerous recreation complexes and cottage cooperatives in the modern period (Figure 13). In particular, thirteen such cooperatives were identified in the study area.

Table 4. Number of settlements that underwent changes as a result of the construction of the Dniester Reservoir

Group	Number
Flooded	19
Flooded before 1980	16
Flooded after 1980	3
Partially flooded	10
Liquidated after 1980	2
Transferred	5
New, including DC	22
New after 1980, including DC	14

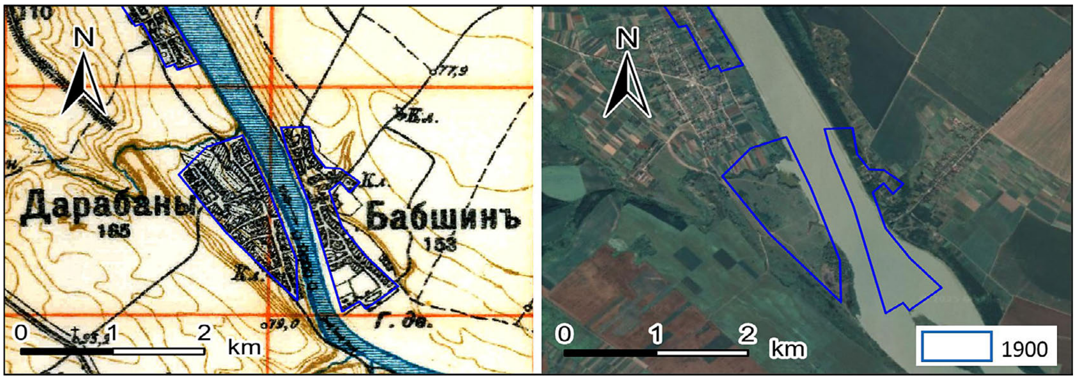

Figure 9. The liquidated settlement of Darabany against the background of a two-verst map and a satellite image

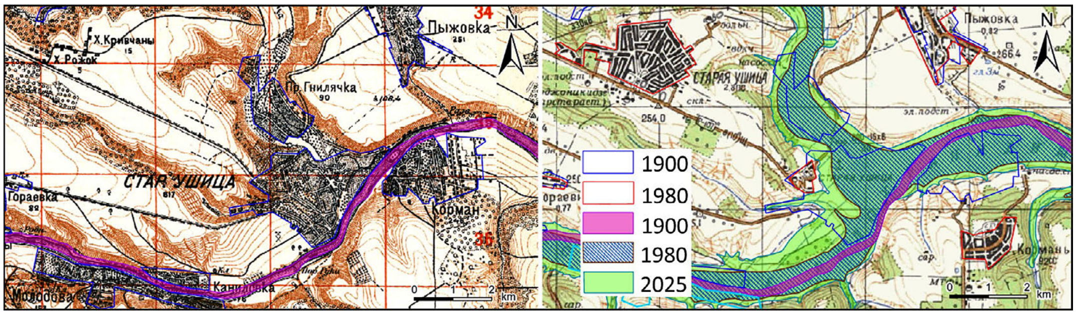

Figure 10. The relocated settlements of Stara Ushytsia and Korman against the background of a two-verst map and a map of the General Staff

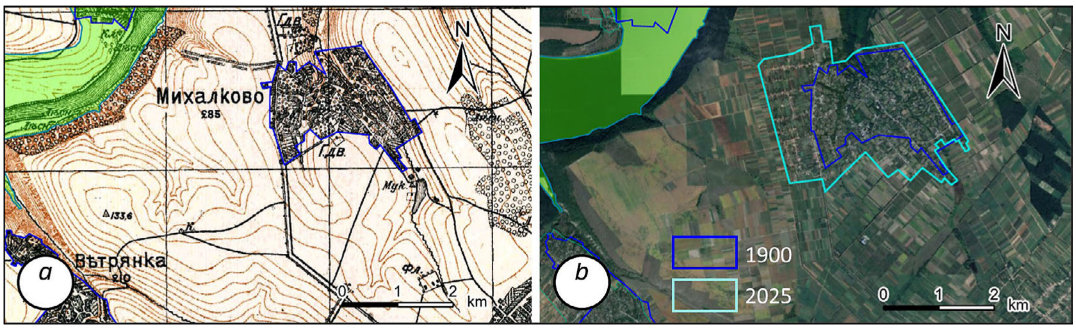

Figure 11. Changes in the settlement of Mykhalkovo and the surrounding landscape: a – two-verst map; b – satellite image

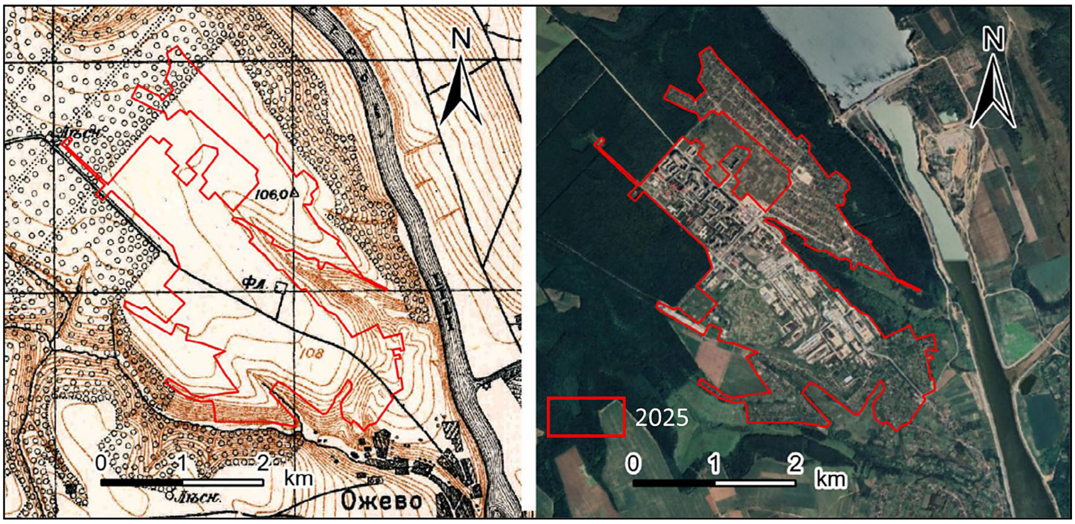

Figure 12. The boundary of the city of Novodnistrovsk against the background of a two-verst map and a satellite image

DISCUSSION

Research results indicate various causes of changes in the river channel processes, depending on the landscape conditions of its flow, in particular geological structures, and the river's importance for human life. Other changes in channel processes are related to river hydropower, which has both positive and negative aspects and requires a coordinated and well-studied position from various experts [Burshtynska et al., 2019; Kiraga, 2021; Tomczyk and Wiatkowski, 2021].

Particular concern arises regarding the construction of six hydropower plants on the Dniester within the Dniester Canyon, as proposed in the Hydropower Development Program [Cabinet…, 2016; Tomczyk and Wiatkowski, 2020; WWF…, 2018]. Among the main socio-environmental risks of operating the planned cascade of hydropower plants in the Dniester Canyon, serious environmental consequences and social challenges, in particular the resettlement of people, are highlighted. As research shows, displacement can have both positive and negative impacts on the displaced population [Egré and Senécal, 2003; Hay et al., 2019; Huang et al., 2018]. However, the greatest losses are associated with the destruction of unique natural landscapes. The construction of six hydroelectric power plants on the Dniester within the Dniester Canyon between the villages of Ustyia (Chernivtsi region) and Vistria (Ternopil region), as announced in the Hydropower Development Programme on the Ukraine, cannot leave anyone indifferent. The ignoring obvious facts that make such construction not only impractical, but also potentially posing significant environmental and social threats [Small…, 2020; Stefanyshyn and Vlasyuk, 2019a; Zhou et al., 2025]. Many research results around the world confirm the unfavorable impact of dam reservoirs on the environment [Calder et al., 2016; McCartney, 2009; Randell, 2022]. To achieve the projected hydropower parameters of the Upper Dniester cascade, reservoir construction would require the inundation of lands within the "Dniester Canyon" National Nature Park [Hetman, 2016; Stefanyshyn, 2017]. There is also a potential threat of large-scale flooding requiring resettlement and evacuation, or at least periodic inundation during peak operation with daily regulation – considered the most environmentally harmful operational regime for river ecosystems [Yao et al., 2022; Zhou et al., 2023]. The assessment of peak operation regimes as harmful to river ecosystems [Cabinet…, 2016; Law…, 2012; National…, 2019] is also reflected in the Water Framework Directive [Landau and Stashuk, 2018]. However, unlike widely accepted international practice, which recognizes peak operation regimes of hydropower plants as detrimental to river ecosystems, such considerations are not always fully integrated into national planning in the Ukraine.

The scale of planned small hydropower development in the Carpathians is also alarming. In Zakarpattia region alone, 330 small HPPs are planned; in Ivano-Frankivsk region, estimates range from 50 to 150; and up to several dozen more are planned in Lviv and Chernivtsi regions

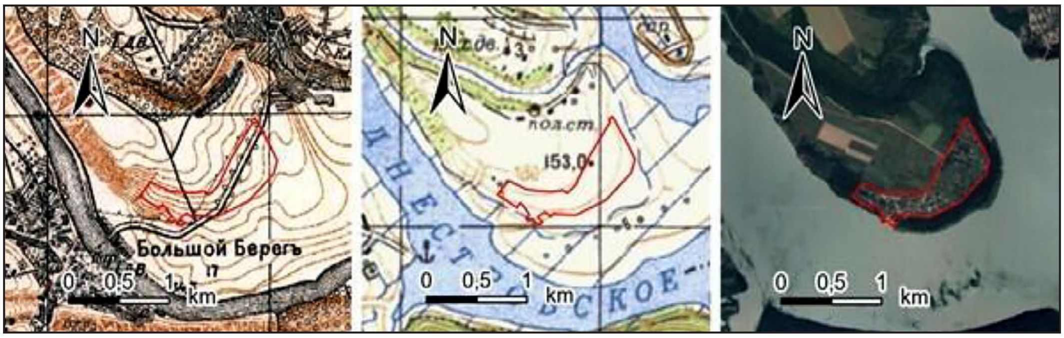

Figure 13. The boundary of one of the cottage cooperatives against the background of a two-verst map, a General Staff map, and a satellite image

[Let's…, 2012; Stefanyshyn, 2018b; Stefanyshyn and Vlasiuk, 2019a]. Research shows that Ukraine has great opportunities to develop hydropower [Bryl et al., 2019; Halych et al., 2023; Stefanyshyn, 2024]. However, the implementation of such plans would effectively lead to the degradation of most Carpathian rivers, the collapse of rafting tourism, and the loss of ecological and recreational value of the region. The area of flooded land could be significant, resulting in the loss of agricultural land and forests. However, the greatest losses are associated with the neglect of environmental issues and the destruction of unique natural landscapes, such as the Dniester Canyon.

The idea of building hydroelectric power plants on the Dniester River has received a lot of attention in civil society circles. Activists point out that the implementation of the Verkhnodnistrovskyi HPP cascade project could lead to the flooding of settlements located near the Dniester, archaeological and architectural monuments; dams would make the development of water tourism impossible; some species of animals and plants would be destroyed, and their natural habitats would be disrupted. Changes in the landscape could lead to the disappearance of the natural habitats of rare species. Many studies have paid special attention to the geodiversity of the geomorphological regions of the Upper and Middle Dniester and the methods of determining the river deformation processes [Burshtynska et al., 2023; Burshtynska et al., 2024; Kravchuk et al., 2016].

According to Ridush's team reasearchers [Bondar et al., 2019; Ridush et al., 2021], the construction of the HPP also threatens world-class archaeological sites: "If the water level in Doroshivtsi rises by 12 metres, many monuments will be lost forever, not only to the history of Ukraine, but to the whole of Europe. After all, they have not yet been fully explored". Therefore, the Ternopil and Ivano-Frankivsk regional councils, public and environmental organisations of Ukraine and Moldova have expressed their support for opponents of the hydroelectric power plant. Taking into account the fact that in the Ivano-Frankivsk region, various rocks of the Mesozoic era are exposed, represented mainly by yellowish-white organogenoclastic and oolitic limestones, contain imprints of several species of fossil marine algae and diverse fossil fauna [Ivchenko, 2004], flooding such a geographically, geomorphologically, and environmentally unique area appears not only unacceptable, but also unlawful, given the losses for scientific research. Attention is also drawn to controversial proposals that border on a lack of understanding of the losses associated with the flooding of protected areas, which serve as habitats for Red Book fish species, unique birds, and rare plant communities – particularly within the Dniester Canyon [Stefanyshyn, 2017].

Environmentalists express a strongly negative view of hydropower development, which is associated not with the performance indicators of different types of hydropower plants, but with changes in the region's environmental conditions and their adverse impacts on the environment [Small…, 2020; Stefanyshyn, 2017, Stefanyshyn et al., 2022]. Specialists engaged in nature protection also treat this type of energy with caution, emphasizing the main causes of the destructive impact of hydropower on ecosystems [Stefanyshyn, 2018b, WWF…, 2018]. Such impacts include:

- degradation of river biodiversity;
- increasing water scarcity;
- destruction of natural habitats of flora and fauna;
- obstruction of fish migration, leading to population decline;
- flooding of large areas

Recent evidence and knowledge suggest that we are entering a new era of hydropower management. It is argued that understanding past policy models and regulatory approaches is essential for developing more sustainable hydropower management systems that meet current and future social and environmental needs. Drawing on these lessons learned, new, more sustainable management systems can be shaped in unprecedented ways [Lindström and Ruud, 2017].

It should be noted that the main reasons for the negative phenomena in Ukraine include the lack of legal regulations in the country that would support the development of hydropower, taking into account the rational use of natural resources and not causing excessive damage to the environment [Kurbatova et al., 2022; Stefanyshyn, 2018a; Stefanyshyn and Vlasyuk, 2019b].

CONCLUSIONS

1. The use of archival cartographic materials and current data obtained using modern remote sensing methods provides an overview of long-term changes occurring in river valleys as a result of water damming. It also enables forecasting areas potentially flooded by the construction of further hydroelectric power plants and the associated environmental and social problems.
2. The results of research into the impact of hydropower on landscape changes in both the Middle Dniester itself and the riparian areas showed changes in the river's water surface area, changes in both the geometry and hydrology of the Dniester's tributaries, as well as changes in the riparian area caused by flooding and the relocation of settlements to safer areas, which in turn became a catalyst for changes in the area due to the intensification of economic activity.
3. After the flooding of the Dniester and its transformation into the main reservoir, the water surface area, compared to the depiction of the Dniester on the two-verst maps, where the river has a natural character, increased on the General Staff map by 2–3 times compared to the corresponding area of the natural flow of the Dniester riverbed shown on the two-verst map, and on the satellite image, the corresponding area is 5 times larger than the area on the two-verst map.
4. Studies of changes in the Dniester's tributaries after flooding indicate a tendency toward a decrease in the length of the tributaries. A total of 27 tributaries were studied, and in most cases, the length of the tributary compared to its length on two-verst maps decreased by 2–3 m. However, on some tributaries, the length of the tributaries decreased, for example, for the Ushytsia tributary by 18 km; Calius – 5.5 km; Studenytsia – 4.3 km.
5. The results of research show that the construction of dam reservoirs for energy purposes is associated with the flooding of vast areas of river valleys and the degradation of the local environment. It also results in the loss of settlement areas, valuable agricultural lands, and archaeological and cultural heritage sites.

REFERENCES

1. Annys, S., Ghebreyohannes, T., Nyssen, J. (2020). Impact of hydropower dam operation and management on downstream hydrogeomorphology in semi-arid environments (Tekeze, Northern Ethiopia). *Water, 12*(8), 2237. https://doi.org/10.3390/w12082237
2. Bondar, K., Ridush, B., Baryshnikova, M., Popiuk, Y. (2019). On palaeomagnetic dating of fluvial deposits in the section of Neporotove gravel quarry on the Middle Dniester. *Journal of Geology, Geography and Geoecology, 28*(2), 241–249. https://doi.org/10.15421/111925
3. Brandt, S. A. (2000). Classification of geomorphological effects downstream of dams. *Catena, 40*(4), 375–401. https://doi.org/10.1016/S0341-8162(00)00093-X
4. Bryl, A. O., Vasko, P. F., Moroz, A. V. (2019). Technical potential of hydropower resources of small rivers of Ukraine with regard to environmental restrictions. *Hydropower Engineering of Ukraine, 3–4*, 47–51. https://uhe.gov.ua/sites/default/files/2019-12/13.pdf (in Ukrainian).
5. Burshtynska, K., Babushka, A. V., Bubniak, I. M., Babiy, L. V., Tretyak, S. K. (2019). Influence of geological structures on the nature of riverbed displacements for the rivers of the Dnister basin upper part. *Geodynamics, 27*(2), 24–38. https://doi.org/10.23939/jgd2019.02.024
6. Burshtynska, K., Hrytskiv, N., Zayats, I., Babiy, L., Fijalkovska, A., Bakuła, K. (2024). Monitoring of channel deformations of the Lower Dniester using topographic maps and satellite imagery with the implementation of GIS technologies. *Water, 16*(15), 2148. https://doi.org/10.3390/w16152148
7. Burshtynska, K., Kokhan, S., Pfeifer, N., Halochkin, M., Zayats, I. (2023). Hydrological modeling for determining flooded land from unmanned aerial

vehicle images: Case study at the Dniester River. *Remote Sensing*, *15*(4), 1071. https://doi.org/10.3390/rs15041071

8. Cabinet of Ministers of Ukraine. (2016). Hydropower development program for the period until 2026 (Order No. 552-r, July 13, 2016). https://zakon.rada.gov.ua/laws/show/552-2016 (in Ukrainian).
9. Calder, R. S. D., Schartup, A. T., Li, M., Valberg, A. P., Balcom, P. H., Sunderland, E. M. (2016). Future impacts of hydroelectric power development on methylmercury exposures of Canadian Indigenous communities. *Environmental Science & Technology, 50*, 13115–13122. https://doi.org/10.1021/acs.est.6b04447
10. Directive 2000/60/EC of the European Parliament and of the Council 'establishing a framework for Community action in the field of water policy' of 23 October 2000. https://zakononline.ua/documents/show/211117___211182 (in Ukrainian).
11. Egré, D., Senécal, P. (2003). Social impact assessments of large dams throughout the world: Lessons learned over two decades. *Impact Assessment and Project Appraisal, 21*(3), 215–224. https://doi.org/10.3152/147154603781766310
12. Fry, J. J., Schleiss, A. J., Morris, M. (2022). Hydropower as a catalyst for the energy transition within the European Green Deal Part II: The complex environment for hydropower, biodiversity challenges and the main innovation and research directions. *E3S Web of Conferences, 346*, Article 04016. https://doi.org/10.1051/e3sconf/202234604016
13. Grill, G., Lehner, B., Thieme, M., Geenen, B., Tickner, D., Antonelli, F., Babu, S., Cheng, L., Crochetiere, H., Ehalt Macedo, H., Filgueiras, R., Goichot, M., Higgins, J., Hogan, Z., Lip, B., McClain, M. E., Meng, J., Mulligan, M., Nilsson, C., Zarfl, C. (2019). Mapping the world's free-flowing rivers. *Nature, 569*(7755), 215–221. https://doi.org/10.1038/s41586-019-1111-9
14. Halych, O., Bilkova, E., Nowak, P., Riabenko, O. (2023). Analysis of hydropotential and prospects for small hydropower development in Ukraine. *Environmental and Climate Technologies, 27*(1), 763–774. https://doi.org/10.2478/rtuect-2023-0056
15. Hamidifar, H., Nones, M. (2023). Hydro-morphodynamic responses of rivers to the construction of hydropower dams: A case study – The Kor River, Iran. *Hydrological Sciences Journal, 68*(11), 1567–1577. https://doi.org/10.1080/02626667.2023.2230197
16. Hay, M., Skinner, J., Norton, A. (2019). *Dam-induced displacement and resettlement: A literature review* (FutureDAMS Working Paper No. 004). The University of Manchester. https://doi.org/10.2139/ssrn.3538211
17. He, F., Zarfl, C., Tockner, K., Olden, J. D., Campos, Z., Muniz, F., Svenning, J.-C., Jähnig, S. C. (2024). Hydropower impacts on riverine biodiversity. *Nature Reviews Earth & Environment, 5*, 755–772. https://doi.org/10.1038/s43017-024-00596-0
18. Hetman, V. (2016). *Dnistrovskyi kanion u natsionalnomu pryrodnomu parku* [Dniester Canyon in the national nature park]. *Visnyk Kyivskoho Natsionalnoho Universytetu Imeni Tarasa Shevchenka. Heohrafiia, 64*(1), 23–29. https://doi.org/10.17721/1728-2721.2016.64.4 (in Ukrainian).
19. Hite, E. B. (2025). Making sense of unsustainable realities: Hydropower and the Sustainable Development Goals. *Water, 17*(13), 1857. https://doi.org/10.3390/w17131857
20. Huang, M. T., Zhai, P. M. (2021). Achieving Paris Agreement temperature goals requires carbon neutrality by middle century with far-reaching transitions in the whole society. *Advances in Climate Change Research, 12*, 281–286. https://doi.org/10.1016/j.accre.2021.03.004
21. Huang, Y., Lin, W., Li, S., Ning, Y. (2018). Social impacts of dam-induced displacement and resettlement: A comparative case study in China. *Sustainability, 10*(11), 4018. https://doi.org/10.3390/su10114018
22. Intergovernmental Panel on Climate Change. (2018). Global warming of 1.5 °C: An IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways. https://www.ipcc.ch/sr15/
23. International Energy Agency. (2024). Analysis and forecast to 2030. *Renewables* https://iea.blob.core.windows.net/assets/17033b62-07a5-4144-8dd0-651cdb6caa24/Renewables2024.pdf
24. Ivchenko, A. (2004). The most important geosites of the Ukrainian Carpathians. *Polish Geological Institute Special Papers, 13*, 149–154. In: Proceedings of the Conference "Geological Heritage Concept, Conservation and Protection Policy in Central Europe".
25. Ji, H., Chen, S., Jiang, C., Fan, Y., Fu, Y., Li, P., Liu, F. (2022). Damming-induced hydrogeomorphic transition in downstream channel and delta: A case study of the Yellow River (China). *Water, 14*(13), 2079. https://doi.org/10.3390/w14132079
26. Khilchevskyi, V., Grebin, V., Zabokrytska, M., Dubniak, S., Bolbot, H. (2022). Large and small reservoirs of Ukraine. *Journal of Water and Land Development, 52*(I–III), 101–107. https://doi.org/10.24425/jwld.2022.140379
27. Khodnevych, Y. V., Stefanyshyn, D. V., Korbutyak, V. M. (2017). Simulation modeling of conditions for the occurrence of local riverbed erosion. *Ecological Safety and Nature Management, 3–4*, 112–123. http://nbuv.gov.ua/UJRN/ebpk_2017_3-4_15 (in Ukrainian)

28. Kiraga, M. J. (2021). Hydroelectric power plants and river morphodynamic processes. *Journal of Ecological Engineering, 22*(7), 163–178. https://doi.org/10.12911/22998993/139068
29. Kondolf, G. M. (1997). Hungry water: Effects of dams and gravel mining on river channels. *Environmental Management, 21*(4), 533–551. https://doi.org/10.1007/s002679900048
30. Kondolf, G. M., Gao, Y., Annandale, G. W., Morris, G. L., Jiang, E., Zhang, J., Cao, Y., Carling, P., Fu, K., Guo, Q., Hotchkiss, R., Peteuil, C., Sumi, T., Wang, H. W., Wang, Z., Wei, Z., Wu, B., Wu, C., Yang, C. T. (2014). Sustainable sediment management in reservoirs and regulated rivers: Experiences from five continents. *Earth's Future, 2*(5), 256–280. https://doi.org/10.1002/2013EF000184
31. Korpak, J. (2007). The influence of river training on mountain channel changes (Polish Carpathian Mountains). *Geomorphology, 92*(3–4), 166–181. https://doi.org/10.1016/j.geomorph.2006.07.037
32. Kowalczyk-Juśko, A., Mazur, A., Grzywna, A., Listosz, A., Rybicki, R., Pytka, A., Dorozhynskyy, O., Jóźwiakowski, K., Gizińska-Górna, M. (2017). Evaluation of the possibilities of using water-damming devices on the Tyśmienica River to build small hydropower plants. *Journal of Water and Land Development, 35*, 113–119. https://doi.org/10.1515/jwld-2017-0074
33. Kravchuk, Y., Zinko, Y., Hnatiuk, R., Moskalyuk, K. (2016). Assessment of the geodiversity of geomorphological regions of the Upper and Middle Dniester. In *Problems of geomorphology and paleogeography of the Ukrainian Carpathians and adjacent territories* (Vol. 1, pp. 275–290). (in Ukrainian)
34. Kurbatova, T., Sotnyk, I., Kubatko, O., Gorbachova, L., Khrystiuk, B. (2022). Small hydropower development in Ukraine under global climate change patterns: Is state economic support sufficient? *International Journal of Environment and Sustainable Development, 21*(4), 456–473. https://doi.org/10.1504/IJESD.2022.126079
35. Landau, Y. O., Stashuk, I. V. (2018). The importance of hydropower in the development of Ukraine's energy system in accordance with NEC-2035 and environmental challenges. *Hydropower of Ukraine*, 3–6. https://uhe.gov.ua/sites/default/files/2018-08/3-6.pdf (in Ukrainian)
36. Law of Ukraine "On Alternative Energy Sources." (2012). Official web portal of the Ukrainian Parliament. https://zakon.rada.gov.ua/laws/show/555-15#Text. (in Ukrainian)
37. Let's save the Carpathians from hydroelectric power plants! (Campaign against hydroelectric power plants in the Carpathians) (2012). https://wwf.ua/?203780/Save-Carpathians (in Ukrainian)
38. Lindström, A., Ruud, A. (2017). Who's hydropower? From conflictual management into an era of reconciling environmental concerns; A retake of hydropower governance towards win-win solutions? *Sustainability, 9*(7), 1262. https://doi.org/10.3390/su9071262
39. Liro, M., Ruiz-Villanueva, V., Mikuś, P., Wyżga, B., Castellet, E. B. (2020). Changes in the hydrodynamics of a mountain river induced by dam reservoir backwater. *Science of the Total Environment, 744*, Article 140555. https://doi.org/10.1016/j.scitotenv.2020.140555
40. Liu, J., Zhang, W., Shen, Y., Wang, X. (2024). Dramatic sediment load changes and sedimentation characteristics upstream of the Three Gorges Dam due to the large reservoirs construction. *Frontiers of Earth Science, 18*(3), 565–578. https://doi.org/10.1007/s11707-022-1081-3
41. Mazur, A., Grzywna, A., Kowalczyk-Juśko, A., Cybulski, J. (2016). Evaluation of options for erecting small hydroelectric power plants on the River Bystrzyca Północna. *Journal of Ecological Engineering, 17*(5), 254–260. https://doi.org/10.12911/22998993/66256
42. McCartney, M. (2009). Living with dams: Managing the environmental impacts. *Water Policy, 11*(Suppl. 1), 121–139. https://doi.org/10.2166/wp.2009.108
43. Morris, G. L. (2020). Classification of management alternatives to combat reservoir sedimentation. *Water, 12*(3), 861. https://doi.org/10.3390/w12030861
44. Moschynskyi, V. S., Ryabenko, O. A., Galich, O. O., Porovskyi, S. M., Sviderska, A. V., Jacobsen, A. (2018). Using Norwegian experience for the development of hydropower in Ukraine. *Hydropower in Ukraine, 1–2*, 72–75. (in Ukrainian)
45. Musonda, J., Ma, L., Liu, T. Y., Shahzad, M., Ali, A. (2025). Megaprojects' environmental impact mitigation by sustainable construction mediated by sustainable practices and regulations. *Cleaner and Responsible Consumption, 1*, Article 100281. https://doi.org/10.1016/j.clrc.2025.100281
46. National Power Company Ukrenergo. (2019). *New horizons: Non-financial report*. https://ua.energy/wp-content/uploads/2020/09/NeFIN_ZVIT_17.09.20 (in Ukrainian)
47. Nile, B. K., Al Saadi, R. J. M., Abdulameer, L., Al-Maimuri, N. M. L., Al Dujaili, A. N. (2025). Climate change impacts on river hydraulics: A global synthesis of hydrological shifts, ecological consequences, and adaptive strategies. *Water Conservation Science and Engineering, 10*, Article 48. https://doi.org/10.1007/s41101-025-00375-y
48. Papadaki, C., Dimitriou, E. (2021). River flow alterations caused by intense anthropogenic uses and future climate variability implications in the Balkans. *Hydrology, 8*(1), Article 7. https://doi.org/10.3390/hydrology8010007

49. Petts, G. E., Gurnell, A. M. (2005). Dams and geomorphology: Research progress and future directions. *Geomorphology, 71*(1–2), 27–47. https://doi.org/10.1016/j.geomorph.2004.02.015
50. Quaranta, E. (2023). The future of sustainable hydropower in the EU: Challenges, projections and opportunities. *International Journal on Hydropower and Dams, 30*(5), 45–51. https://www.researchgate.net/publication/374865867_The_future_of_sustainable_hydropower_in_the_EU_challenges_projections_and_opportunities
51. Randell, H. (2022). The challenges of dam-induced displacement: Reducing risks and rethinking hydropower. *One Earth, 5*(8), 849–851. https://doi.org/10.1016/j.oneear.2022.07.002
52. Ridush, B., Stefaniak, K., Ratajczak-Skrzatek, U., Kovalchuk, O., Kotowski, A., Marciszak, A., & Polishko, O. (2021). Quaternary megafauna from the Dnieper alluvium near Kaniv (central Ukraine): Implications for biostratigraphy. *Quaternary International, 605–606*, 241–253. https://doi.org/10.1016/j.quaint.2020.11.010
53. Ring, K. (1956). On the extraction of stone and aggregate from mountain rivers and streams. *Water Management, 16*(2), 54–55.
54. Sharma, S. R. (2025). Impacts of climate variability on hydrological extremes: Droughts and floods in a changing climate. *Journal of Information Systems Engineering and Management, 10*(36s), 149–167. https://doi.org/10.52783/jisem.v10i36s.6364
55. Small hydropower plants: ambiguous consequences for the Carpathian region. News and analysis about Germany, Ukraine, Europe, and the world DW. (2020) https://bit.ly/37RynCf.
56. Stefanyshyn, D. V. (2017). On the prospects for the development of domestic hydropower in the context of plans to build a cascade of hydroelectric power plants in the Dniester Canyon. In *Environmental Safety and Natural Resource Use: Collection of Scientific Works, 23*(1–2), 5–19. ITGIP NASU & KNUBA. (in Ukrainian)
57. Stefanyshyn, D. (2018a). On peculiarities of hydropower development in the world and in Ukraine. *Environmental Safety and Natural Resources: Collection of Scientific Works, 25*(1), 12–23. KNUBA & ITGIP NASU. https://es-journal.in.ua/article/view/154906
58. Stefanyshyn, D. V. (2018b). Problems and prospects of hydroaccumulation in the context of rational nature management and greening of hydropower in Ukraine. *Mathematical Modeling in Economics, 3*(12), 101–113. http://dspace.nbuv.gov.ua/handle/123456789/162047 (in Ukrainian)
59. Stefanyshyn, D. V. (2024). Prospects for small hydropower in Ukraine in the context of feasibility and environmental impact: Summarising after the *World Small Hydropower Development Report 2022*. *Modeling, Control and Information Technologies, 7*. https://doi.org/10.31713/MCIT.2024.017
60. Stefanyshyn, D., Kuchenko, B., Kravchenko, O. (2022). Hydropower in Ukraine in the context of global trends. *Policy paper*. Ecology, Law, People. https://epl.org.ua/wp-content/uploads/2022/01/AD-pro-gidroenergetyku-final-3.pdf
61. Stefanyshyn, D. V., Vlasiuk, Y. S. (2019a). Some critical remarks on the practical implementation of the Law of Ukraine "On Environmental Impact Assessment" in small hydropower. *Hydropower of Ukraine, 3–4*, 22–30. (in Ukrainian)
62. Stefanyshyn, D., Vlasiuk, Y. S. (2019b). Some critical comments on the quality of environmental impact assessment reports for small hydropower plants in Ukraine. *Environmental Safety and Natural Resources, 32*(4), 43–59. https://doi.org/10.32347/2411-4049.2019.4.43-59
63. Tomczyk, P., Wiatkowski, M. (2020). Challenges in the development of hydropower in selected European countries. *Water, 12*(12), 3542. https://doi.org/10.3390/w12123542
64. Tomczyk, P., Wiatkowski, M. (2021). Impact of a small hydropower plant on water quality dynamics in a diversion and natural river channel. *Journal of Environmental Quality, 50*(5), 1156–1170. https://doi.org/10.1002/jeq2.20274
65. Williams, G. P., Wolman, M. G. (1984). Downstream effects of dams on alluvial rivers (U.S. Geological Survey Professional Paper No. 1286). U.S. Government Printing Office. https://doi.org/10.3133/pp1286
66. WWF Position on Small Hydropower Development in Ukraine. (2018). http://wwf.ua/materials/official/?uNewsID=323990 20. (in Ukrainian)
67. Yao, J., Gao, J., Yu, X., Zhang, Q. (2022). Impacts of a proposed water control project on the inundation regime in China's largest freshwater lake (Poyang Lake): Quantification and ecological implications. *Journal of Hydrology: Regional Studies, 40*, Article 101024. https://doi.org/10.1016/j.ejrh.2022.101024
68. Yao, Y., Cui, W., Wang, W., Ma, F.-M., Chen, B.-Y. (2020). Impacts of dam construction on river channel evolution: A case of Minjiang River in Southeastern China. *Proceedings of the International Association of Hydrological Sciences, 383*, 341–346. https://doi.org/10.5194/piahs-383-341-2020
69. Zhou, P. Y., Ma, Q., Xue, H. C., Peng, P. Y., Xie, C. H., Xie, L. Y., Zhang, X. J. (2023). Effect of daily regulation on navigation conditions in deep reservoirs. *Journal of Applied Fluid Mechanics, 16*(12), 2483–2493. https://doi.org/10.47176/jafm.16.12.1949
70. Zhou, X., Wu, S., Ding, C., Wen, Z. (2025). How does hydropower station construction reshape the geomorphology of downstream mid-channel bars? *Geomorphology, 479*, Article 109729. https://doi.org/10.1016/j.geomorph.2025.109729