ASSESSMENT OF THE CURRENT (1991-2020) AND FUTURE (up to 2041-2060) WATER RESOURCES IN THE DNIESTER RIVER BASIN BASED ON THE NEW CLIMATE SCENARIOS, THE RECENT LOW-WATER EPISODES, AND WATER-USE TRENDS

Report summary

Introduction

The Dniester River connects Moldova and Ukraine, providing water to over ten million people. However, since 2011, there has been a persistent trend of repeated low-water periods caused by both climate change and the increased water withdrawal within the basin. This study aims at assessing the state of water resources in the Dniester River basin; analysing climate trends there; and projecting future changes of the river flow based on the current climate scenarios.

Analysing climatic and hydrological changes is crucial for ensuring the sustainable use of water in the Dniester basin. In recent decades, climate change has led to significant changes in the river flow, affecting the availability of water for the various economic sectors and ecological systems. This study examines key trends, projected changes, and the possible ways to adapt to these new conditions.

The report was prepared by a joint Moldo-Ukrainian expert group one the request and with contribution from the National Administration "Apele Moldovei" and State Agency of Water Resources of Ukraine and with the support of the United Nations Economic Commission for Europe and the Secretariat of the Water Convention.[1]

[1] Moldova: Gherman Bejenaru, Anatol Zavadschi – National Administration "Apele Moldovei"; Vitaliy Mardar – State Hydrometeorological Service of the Republic of Moldova.

Ukraine: Vira Balabukh, Oleg Skrynyk, Vladyslav Sydenko – Ukrainian Hydrometeorological Institute under the State Emergency Service and the National Academy of Sciences of Ukraine; Vasyl Hrebin, Maryna Hoptsii – Taras Shevchenko Kyiv National University.

Overall coordination: Hanna Plotnykova, Secretariat of the Water Convention, UNECE.

Translation of the report summary into English: Olena Maliuta.

Editing of the report summary in English: Nickolai Denisov, Zoï Environment Network.

Table of Contents

1. Sources and methodology of the study

The study is based on the long-term data series of hydrometeorological observations, as well as on the statistical analysis of climate indicators and the modelling of their future changes. As the basis, the study has used climate change scenarios SSP2-4.5 (moderate warming) and SSP5-8.5 (strong warming) from the Sixth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC). Climate projections are based on the CMIP6 ensemble of climate models adjusted through quantile delta mapping.

For hydrological analysis the study has used the data obtained from hydrological stations in Moldova and Ukraine. An important part of the study, a geographic information system has been used to identify spatial patterns of climate change and water run-off within the basin. The data were processed using modern statistical methods, including regression analysis and the modelling of time-series.

2. Climate trends in 1991-2020

The hydrological regime of the Dniester River basin is formed under the climate conditions which have undergone significant changes in the recent decades. The changes in temperature and precipitation directly affect river flow as well as water evaporation, infiltration and surface runoff. This chapter of the report is dedicated to the analysis of the 1991-2020 temperature and moisture dynamics in the basin in order to identify key trends and drivers affecting its water balance.

2.1 Temperature trends

Air temperature is one of the most important climate factors determining evaporation, the freezing of water bodies, and the intensity of snowmelt. In the Dniester basin, steady warming was observed between 1991 and 2020. The average annual temperature increased by 0.7-1.2°C compared to the period of 1961-1990, with the most intense increase during the summer months.

2.1.1 Seasonal temperature changes

- **Winter**: shortened winter season; increased number of days with positive temperature; shortened season when water bodies are covered with ice.

- **Spring**: earlier onset of spring warming which leads to an accelerated snowmelt and affects flood patterns and runoff distribution.
- **Summer**: increased average daily temperatures accompanied by increased evaporation, decreased soil moisture, and a higher likelihood of drought.
- **Autumn**: a shift in statistical averages leads to a longer warm season thus affecting plant growth and vegetation processes in the basin's ecosystems.

2.1.2 Impact of the warming on the river flow

Higher air temperature leads to an increased evaporation from the water surface and soil, thus reducing the amount of available water. In the Dniester basin, the observed increase in the number of days with extremely high temperatures is accompanied by droughts and a reduced river flow during low-water periods.

2.2 Precipitation

Precipitation is the main source of water in the basin, determining its overall amount. The analysis of precipitation between 1991 and 2020 has shown that its temporal and spatial patterns have changed.

2.2.1 General precipitation trends

- The average annual precipitation decreased in the Dniester basin, especially during summer and autumn.
- The higher intensity of precipitation in winter has been accompanied by the increased runoff of melt- and rainwater which can lead to seasonal floods.
- The increasingly uneven temporal distribution of precipitation has led to a growing number of such extreme events as floods and droughts.

2.2.2 Spatial distribution of precipitation

- A slight increase in winter precipitation was recorded in the northern part of the basin due to the intensified cyclonic activity.
- Precipitation has decreased by 10-20% in the central and southern parts of the basin, in combination with rising temperature leading to the increased aridity and moisture deficit.

2.3 Evaporation and moisture balance

Evaporation plays a key role in the water balance of the region, determining the losses of water and its availability for ecosystems and the economy.

2.3.1 Evaporation trends

- Between 1991 and 2020, the average annual evaporation in the Dniester basin increased by 15-25%.
- Due to a higher temperature and fewer clouds, the highest evaporation is observed in summer.
- River basins experienced a stronger loss of moisture, causing reduced river runoff and lower water levels in water reservoirs.

2.3.2 Impact on soil moisture

- Increased evaporation reduces soil moisture, which in turn affects crop productivity and the functioning of ecosystems.
- Lack of moisture degrades the soil, reduces the land's water retention capacity, and increases the need for irrigation.

2.4 Conclusions

The analysis of the temperature and moisture trends in the Dniester River basin during 1991-2020 shows clear climatic changes:

- a steady rise in temperature, especially in summer and winter;
- seasonal changes in precipitation leading to reduced water availability in summer and an increased intensity of winter floods;
- increased evaporation which reduces the availability of water for rivers and ecosystems and intensifies droughts.

Integrated strategies are required for adapting water management in the Dniester basin to climate change. These should include measures to control the flow, optimise the use of water, and introduce modern methods for preserving moisture in soil.

3. Climate and flow projections up to 2041-2060

3.1 Annual, seasonal, monthly mean, maximum and minimum air temperature

A steady upward trend is projected for the temperature in the Dniester basin in 2041-2060: compared with the current climatic period (1991-2020), the average annual air temperature is expected to increase by 1.5°C, and in large parts of the basin by up to 1.6-1.8°C, under the moderate climate-change scenario (SSP2-4.5), and by 2.0-2.4°C under the strong warming scenario (SSP5-8.5). The strongest temperature growth is projected under the SSP5-8.5 scenario.

Key changes:

- **the mean annual temperature** will increase by an average of 2.0-2.7°C under the SSP5-8.5 scenario;
- **the mean maximum temperature in summer** will increase by 2.6-2.8°C under the strong warming scenario, the frequency of extremely hot days will increase too;
- **the mean minimum temperature in winter** will increase by 2.0-2.6°C, the duration of the season with ice cover on rivers will respectively decrease;
- **with the strongest growth of temperature** in summer and autumn, evaporation and the frequency of droughts will increase.

3.2 Annual, seasonal, monthly precipitation

Winter precipitation will increase and summer precipitation will decrease in the Dniester basin.

Key projected changes:

- **the mean annual precipitation** will decrease not significantly;
- **summer precipitation** may decrease by 35% and more, leading to increased water deficit during the warm part of the year;
- **winter precipitation** will increase by 20-30%, enhancing the likelihood of winter floods;
- **seasonal anomalies** will include increased precipitation in the form of heavy rain, which will intensify soil erosion and make water inflow more uneven.

3.3 Annual, seasonal, monthly river flow

Projections suggest a significant reduction of the river flow in the Dniester basin in summer and its possible increase in winter.

Key projected changes:

- **total annual river flow** is likely to decrease by 10% upstream to 30% or more downstream. These projections do not significantly differ between the SSP2-4.5 and SSP5-8.5 scenarios;
- **summer flow** may decrease by 10-15% upstream and up to 25-35% downstream, creating shortages for agriculture and other water consumers;
- **winter flow** is expected to decrease by 7% upstream and up to 25-35% downstream under the scenario SSP2-4.5. Under the scenario SSP5-8.5 the flow may reduce even more dramatically, by up to 30-40% downstream;
- **hydrological extremes** will include more frequent and severe floods in winter and longer dry periods in summer.

Changes in temperature, precipitation and river flow require the following adaptation measures:

- optimising the management of water resources, in particular the operation of reservoirs;
- implementing methods for water conservation in agriculture;
- increasing the efficiency of irrigation systems;
- strengthening the monitoring of climate change, and adapting cross-border cooperation between Moldova and Ukraine on the management of the Dniester River basin.

The projected changes require urgent measures to adapt to new climatic conditions and to mitigate their negative impacts on the population and economy of the basin.

4. Dniester River flow in 1991-2020

The flow in the Dniester River is determined by the amount of water provided by the precipitation, groundwater, and surface runoff. Due to the climatic and anthropogenic drivers, significant changes have been observed in the Dniester hydrological regime over the past 30 years.

Key trends:

- **the total flow** decreased by 10-25% compared to the period of 1961-1990;
- **the mean annual flow** in the lower Dniester decreased by an average of 15-30%, in particular in dry years;
- **the distribution of flow** became more uneven: the low-water period in summer became longer, while winter floods became more pronounced;
- **reservoirs played a significant role** in regulating the flow, especially under climate change.

According to the hydrological observations, the Dniester River flow has changed significantly over the past decades:

- **the mean annual flow decreased** in the entire basin, especially in its southern part;
- **spring floods** have become less pronounced due to the reduced snow cover and increased air temperature;
- **low-water periods have become longer** in summer and autumn, leading to a shortage of water for economic use;
- **flash floods have become more common** in winter due to the intensified precipitation and snowmelt.

Climate change has a significant impact on the water resources of the Dniester River basin:

- **the increasing temperature** leads to a higher evaporation, thereby reducing the amount of the available water;
- **the decreasing summer precipitation** increases moisture deficit in soil, reducing the amount of water reaching the rivers;
- **the intensified winter precipitation** results in sharp fluctuations of the run-off and the increased frequency of floods;
- **the reduced depth and duration of the snow cover** adversely affect spring floods.

In addition to climate factors, human activity has a significant impact on the flow of the Dniester:

- **regulation by hydraulic structures** – dams and reservoirs change the natural regime of the river;
- **increased abstraction of water** for agriculture, industry, and the municipal sector;
- **pollution** with wastewater and solid waste, leading to the deterioration of water quality;
- **disruption of the water balance** as a result of the uncontrolled use of groundwater.

The analysis of the current changes in the Dniester River flow calls for the urgent adaptation and sustainable management of its water resources. Recommended measures include:

- **developing a comprehensive system for monitoring** the runoff, precipitation and other hydrometeorological indicators;
- **increasing the efficiency of water conservation** and introducing modern irrigation techniques;
- **optimising reservoir operation** to stabilise seasonal flow fluctuations;
- **reducing pollution of water bodies** and improving wastewater treatment;
- **strengthening cross-border cooperation** between Moldova and Ukraine for joint water management.

Stabilising the Dniester River flow in a changing climate requires a comprehensive approach which including research, strategic planning, and coordination at the international level.

5. Seasonal flow fluctuations

Affected by the climatic factors and human activity, the seasonal fluctuations of the Dniester River flow have undergone significant changes. Traditional spring floods have become less pronounced, while the duration and intensity of summer low-water periods has increased.

Key trends:

- **spring flow** has decreased due to the reduced snow cover and earlier snowmelt;
- **summer low-water periods** have become longer due to a higher air temperature and increased evaporation;
- **minimal flow in the autumn** has become lower due to the decreased precipitation in September-October;
- **winter flow** has increased due to the growing rainfall and winter thaws.

A comparative analysis of the Dniester River's seasonal flow in 1991-2020 versus 1961-1990 shows that:

- winter flow increased by 10-15% due to more precipitation falling as rain;
- spring floods became less pronounced and shorter in duration;
- summer flow decreased by an average of 20-40%, leading to water supply challenges;
- in the autumn, low flow was observed more often and lasts longer than before.

Global climate change has a serious impact on the seasonal distribution of the river flow:

- **the reduced snow cover** leads to lower spring floods;
- **a higher temperature** increases evaporation, thus reducing the flow during the warm season;
- **the changing precipitation** patterns, less snow and more rain increase the flow in winter;
- **more frequent extreme events** (droughts and heavy rains) lead to sharp fluctuations of water levels throughout the year.

In addition to climate factors, seasonal fluctuations in river runoff are affected by human activity:

- **reservoirs and dams** smooth out natural seasonal fluctuations in runoff, reducing the adverse impact of floods and maintaining a minimum water level during the dry season;
- **the withdrawal of water for agriculture and industry** reduces its availability in summer;
- **land-use changes** (urbanisation, land melioration) affects the natural water cycle by changing the intensity of the run-off and of water infiltration into the soil.

The analysis of seasonal changes of the Dniester River flow indicates the need for the following adaptation measures:

- **improving monitoring and forecasting** of the seasonal flow for effective water management;
- **expanding water storage systems** to compensate for water deficit during the dry season;
- **optimising the operation of the hydroengineering infrastructure** taking into account the changing climate;
- **implementing water-saving methods** in industry and agriculture to reduce the demand for river flow in summer;
- **developing a strategy for adaptation** to changing conditions, including transboundary cooperation for flow regulation.

Further studies of seasonal flow fluctuations are required to help adapt water management strategies to the current and future climate conditions.

6. Water-use trends

Water use in the Dniester River basin is characterised by the increasing water abstraction for agriculture, industry and the municipal sector.

6.1 The Moldovan part of the basin

The Moldovan part of the Dniester basin experiences a serious pressure on water resources due to the climate change, increasing water consumption, and pollution. The main water users are agriculture and the municipal sector, with industrial consumption being of lesser importance.

Key trends:

- **increasing water abstraction** – between 1991 and 2020, the amount of water used for irrigation increased, and currently makes 13.5 million m^3 per year on the right bank and 32.8 million m^3 per year on the left bank of the Dniester.
- **outdated irrigation methods** – up to **70%** of irrigation systems use outdated technologies resulting in **30-40%** water losses;
- **insufficient use of water-saving technologies** – drip irrigation is used only in **10-15%** of the irrigated area, although its implementation would reduce water consumption by **30-50%**;
- **seasonal peaks**: during summer, water consumption for irrigation increases **2-3 times** leading to temporary water shortages in the lower reaches of the Dniester;
- **water pollution** – at about **50%** of water intakes the water is polluted with agricultural chemicals (pesticides and fertilizers).

Challenges and problems:

- high water losses due to outdated infrastructure;
- limited financial capacity of farmers to implement water-saving technologies;
- low degree of wastewater treatment in smaller towns and rural areas.

Recommended measures:

- retrofitting irrigation systems with the emphasis on water conservation.
- tightening control over the use of agricultural chemicals near water bodies;
- strengthening the instruments of transboundary cooperation for water management between Moldova and Ukraine.

6.2 The Ukrainian part of the basin

Due to both the climatic and socio-economic developments, water use in the Ukrainian part of the Dniester River basin has undergone significant changes during the recent decades. The main water-consuming sectors are agriculture, industry, municipal services and power generation.

Key trends:

- **increasing water consumption in agriculture** – over the past 30 years, water abstraction for irrigation has increased, especially in dry years, and currently makes 17.5 million m^3 per year. The southern part of the basin, including Vinnytsia and Odesa regions, has seen the strongest increase;
- **decreasing industrial water use** – since 2000, the amount of water used in industry has decreased by **15-20%** due to the introduction of recycling technologies. In particular, water consumption was reduced in metallurgy, chemical and food industries;
- **increased municipal consumption** – as a result of growing population and expanding infrastructure, in cities such as Ivano-Frankivsk, Lviv and Chernivtsi water consumption has increased by **10-15%**;
- **stronger pressure on water resources due to pollution** – nutrients (nitrogen and phosphorus) in wastewater have caused the deterioration of water quality in **60% of the basin's water bodies**. The main sources of pollution are agricultural runoff and untreated municipal wastewater.

Challenges and problems:

- low efficiency of water supply systems: **up to 40%** of water is lost in worn-out pipes;

- lowering groundwater levels due to increased water abstraction, especially in the southern part of the basin;
- risks of summer droughts leading to seasonal water shortages.

Recommended measures:

- improving the monitoring of water quality and wastewater discharges;
- reconstructing water supply systems to reduce water losses;
- introducing more efficient irrigation methods (drip, sprinkler irrigation);
- river revitalization aimed at restoring disrupted natural processes and functions of river ecosystems;
- on small rivers of the basin, dismantling dams and other artificial structures that impede the natural flow, cause silting, overgrowing, the deterioration of water quality and increased water loss due to additional evaporation.

The analysis of the situation in the Moldovan and Ukrainian parts of the basin shows that the main challenges for the Dniester remain the excessive water consumption in agriculture, low efficiency of water supply infrastructure, and pollution. Addressing them requires an integrated approach that includes technical innovation, state regulation, and international cooperation.

Conclusions

The study confirms a significant impact of climate change on the hydrological regime of the Dniester River. The anticipated rise in temperature, a lower summer precipitation, and a decreased river flow pose threats to water supply for the basin population and ecosystems.

Adaptation to these changes requires:

- measures to increase water efficiency;
- the development of water saving technologies; and
- strengthening cross-border cooperation between Moldova and Ukraine.

The changes in the water resources of the Dniester basin call for their integrated management and adaptation to new climate conditions.