FLOODS AND DROUGHTS IN BELARUS AS A RESULT OF CLIMATE WARMING

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**O.P. Meshik, A.A. Volchek, S.I. Parfomuk, M.V. Borushko,
S.V. Sidak, Ju.P. Koljada, A.S. Protasevich**

Brest State Technical University

Abstract. *The article focuses on studying environmental problems in Belarus related to climate warming. Specifically, it examines floods and droughts as extreme hydrological and climatic events. It highlights the issue of abrupt transitions from floods to droughts. The piece presents results from analyzing historical events. It discusses risks that emerged in 2023 when spring flooding shifted to a May drought.*

Keywords. *Flood, Spring Flooding, Drought, Abrupt Transition, Climate Warming, Belarus*

INTRODUCTION

Extreme hydrological and climatic events are highly unpredictable and have a major impact on national economies. Floods are common in most parts of the world, and European rivers are no exception [1, 2]. On top of that, most researchers highlight droughts and abnormal heatwaves as some of the most troublesome natural disasters, affecting water resources, agriculture, forestry, socio-economic stability, ecosystem health, and even linked to organized armed conflicts and migrations [3, 4]. Over the past two decades, researchers at regional and global levels have made significant efforts to identify patterns and principles behind the formation of individual hazards like droughts and floods [5, 6]. However, there aren't enough studies that fully explain the mechanisms driving transitions from one event to the other. Droughts and floods should be studied together to enable the development of integrated and effective management strategies [7, 8].

The abrupt alternation between droughts and floods—defined as a rapid shift from drought to flood over a short period—amplifies the negative effects of either one alone. This can cause even greater damage than a single disaster [9, 10, 11]. Such alternations can occur as transitions from drought to flood or vice versa. It makes sense to apply the Standardized Weighted Average of the Precipitation index (SWAP) method on a daily scale to identify drought-flood sequences.

Despite the previously published scientific findings, there's still a need for a more detailed analysis of transitions from floods to droughts in typical ecologically challenged regions. Belarus's entire territory could be considered one such area.

METHODS AND MATERIALS

The study utilizes climate monitoring data from the Republic of Belarus and analytical methods for data processing. It provides an analysis of the abrupt transition from spring flood to drought in 2023.

RESULTS AND DISCUSSIONS

Global warming, which has been underway since the late 20th century, has a significant impact on the hydrological cycle and, as a result, on the dynamics of river runoff. Changes in river water regimes directly affect the functioning of aquatic ecosystems by altering the magnitude, duration, timing, frequency, and rate of changes in river water discharges. In a steadily changing climate and under constant anthropogenic pressure on water resources, up-to-date hydrological information on the duration of spring floods, maximum runoff rates, and the duration and intensity of transitions from floods to droughts—and vice versa—serves as a crucial economic factor. It helps businesses and authorities choose the right development strategies and take timely protective measures to prevent damage from adverse and dangerous hydrometeorological events.

Among all natural hydrological phenomena, high river levels accompanied by floods cause the greatest danger to Belarus [12]. A flood is understood as "the inundation of land adjacent to a river or lake, which causes material damage, harms public health, or leads to loss of life." In Belarus, floods typically occur during the spring flood period and, in some years, during rain-induced floods in the summer-autumn and winter periods. Over the period of regular observations, three catastrophic floods have affected the country's rivers. One occurred in 1931 on the Western Dvina, the Dnieper, the Berezina, and the Sozh rivers. The second was in 1958 on the Neman and the Shchara rivers. Additionally, the 1845 flood was catastrophic for the Pripyat River basin [13]. During the observation period, the following cases of the greatest exceedance of the maximum level above the floodplain water level were recorded: 1) in the Western Dvina basin, an exceedance of 424 cm occurred in 1951 on the Disna River in Sharkovshchina; 2) in the Neman basin, it reached 394 cm in 1958 in Mosty; 3) in the Dnieper basin, an exceedance of 565 cm occurred in 1931 in Loyev; 4) in the Berezina basin, it reached 281 cm in 1956. The photographs show typical floods in Belarus (Figure 1).

Fig 1. Floods in Belarus's Rivers (photos by Viktor Bosak)

Since 1990, the frequency of droughts during the warm period has significantly increased in Belarus, along with the area they cover, their intensity, and duration [14]. The most severe droughts occurred in 1992, 1999, 2002, 2010, 2015, and 2018. Notably, the drought in May 2023 saw precipitation across the republic at about 19% of the climatic norm, amid air temperatures exceeding the norm by 1-2°C.

In recent years, the frequency and number of droughts, alongside extreme temperatures and forest and peat fires—which have major socio-economic and environmental impacts—have been on the rise. Moreover, an increase in drought frequency is observed even in regions where precipitation is increasing. Clear trends toward climate aridization are evident in Belarus [15]. We can expect that further intensification of climatic dryness, particularly the rise in heatwaves and droughts, will lead to regular significant crop losses, especially if they occur during sensitive plant development phases like the start of the growing season, flowering stages, etc. Currently, soil droughts in Belarus are a limiting factor in intensifying agricultural production and require serious scientific research. Droughts and heatwaves can also cause noticeable deficits in soil moisture, increased air pollution, and more frequent forest fires, affecting land use and soil-vegetation cover, including crops and woodlands, thus triggering negative economic and ecological consequences. As a result, Belarus faces new challenges and threats of emergencies due to climate change.

As noted earlier, scientific interest lies in studying abrupt transitions in the flood-drought system. In this regard, 2023 stands out as particularly illustrative. Let's examine the hydrological and climatic situation of 2023 in more detail.

The 2023 Spring Flood

The autumn of 2022 and the start of winter were quite wet, leading to high water levels by January 2023 and flooding onto floodplains on most rivers.

From the second half of December 2022 through the end of January 2023, amid thaws, pronounced winter floods developed, with river flows in January–February being 2–3 times higher than usual for winter. Warm weather and snow/ice melting from December 31 to January 2 caused a sharp rise in water levels on rivers with ice jams.

By early spring, flows on most rivers remained above normal, and on the Dnieper and the Sozh rivers, they significantly exceeded long-term averages, creating a "reserve" of water for an intense spring flood.

Spring processes kicked off actively in March. Snowmelt, ice breakup, and clearing of riverbeds from ice occurred everywhere. By the second half of March, rivers were practically ice-free.

In March, against a backdrop of elevated temperatures and heavy precipitation, water levels rose universally with daily intensities up to 15 cm, and locally up to 30–33 cm. The formation of

spring flood peaks began in the first two decades of March on most rivers. On the Pripyat River, water level growth was nearly continuous from the winter season onward.

During the spring flood development, up to 70% of the annual runoff from Belarusian rivers passed through channels in just a few spring weeks, with annual maxima observed on many rivers.

These are the main rivers with dangerous water level exceedances: the Western Dvina near Polotsk and Verkhnedvinsk; its tributary, the Ulla near Bocheykovo; the Dnieper near Zhlobin and Loyev; the Berezina near Borisov and Bobruisk; the Sozh near Gomel; the Pripyat near Chernichy and Petrikov. Dangerous marks were also exceeded on some the Pripyat tributaries (the Ptich, the Sluch, the Tsna).

The rivers with levels close to dangerous are the following: the Neman near Stolbtsy; its tributary, the Shchara near Slonim; the Berezina near Berechino; the Pripyat near Mozyr.

On these watersheds, floodplain inundation and coastal development flooding had been recorded before at similar levels, prompting heightened monitoring by emergency services.

Critical levels and dates for specific rivers are listed below:

- The Pronya River (Letiagi village, Slavgorod district, Mogilev region) exceeded the danger mark by 7 cm (rise of 15 cm/day) in January 3, 2023;
- The Ptich River (1st Slobodka village, Petrikov district, Gomel region): January 3, 2023 – 341 cm;
- The Sozh River (Gomel) flooded the embankment in late March to early April 2023 – 635 cm (close to the 2013 maximum);
- The Mukhavets River (near Brest) overflowed its banks in January 20, 2023 (Figure 2).

Fig 2. Spring Flood on the Mukhavets River in 2023

The flood's runoff exceeded the norm by 136–165% in the Dnieper, the Sozh, and the Pripyat basins, though damage was confined to coastal areas. Localized flooding of riparian zones, floodplain meadows, individual yards, and road sections was recorded in several districts of Gomel, Vitebsk, Minsk, and Mogilev regions. The 2023 spring flood escalated into a flood event, leading to inundation of over 100 settlements across about 60 districts in Belarus.

In mid-to-late April, a universal decline in spring flood water levels began, with intensities up to 39–42 cm per day, though water still lingered on the floodplains.

As of April 14–17, 2023, water level rises persisted mainly in the Pripyat basin, while the decline phase dominated on other rivers.

The flood's duration aligned with typical values for the area: around 30–40 days on small and medium rivers, and up to several months on major waterways, especially the Pripyat and the Dnieper.

The 2023 flood in Belarus doesn't fall into the highly destructive category: maximum water levels were close to long-term averages, though they exceeded them in some spots. By May, however, amid a sharp precipitation deficit (only about 19% of the monthly norm fell, making it one of the driest Mays since 1945), levels dropped rapidly, later causing low river flows and navigation challenges. In effect, a fairly abrupt flood-to-drought transition formed, spanning 15-25 days.

The 2023 Drought

In 2023, Belarus endured one of the most severe droughts in recent decades, especially during the spring and summer, attributable to global climate shifts and the La Niña phase.

March 2023 was exceptionally wet (ranking among the wettest months in records since 1945), while April's precipitation was close to normal (around 39 mm, i.e., 102% of the norm). From late April through about June 25, rainfall in most parts of the country fell to no more than 10–30% of the climatic norm, forming the core of the 2023 drought. This resulted in the complete drying out of the top 10-cm soil layer across much of the area.

May 2023 turned out to be the driest since 1945, with an average of just 12 mm of precipitation nationwide, or about 19% of the climatic norm. The previous low (26 mm) occurred in 1971.

Totally for the year, the country saw 724 mm of precipitation (113% of the norm), but distribution was highly uneven: spring totalled 121 mm (86% of the climatic norm), and May only 12 mm (19%). The May deficit was universal, being particularly acute in central and southern regions. The table below details the share of May precipitation relative to the climatic norm for Belarusian regional centers.

Table. *Share of precipitation relative to the climatic norm in May, %*

Brest	Vitebsk	Gomel	Grodno	Mogilev	Minsk
27	16	27	28	22	9

In 2023, Belarus's average annual air temperature stood at around +8.7°C, which is 1.5°C above the climatic norm and ranks among the warmest years on record.

Throughout the year, temperatures ran above normal in nearly every month, including spring and summer. The summer saw numerous "very hot days," which boosted evaporation and worsened the drought.

As a result of the drought, about 141 thousand hectares of crops perished (less than 5% of sown areas), and 368 thousand hectares were damaged (around 15%), primarily grain crops in the southern regions.

Among winter crops, triticale suffered the most (around 10% of areas), while winter barley lost about 4%. Grain yield shortfalls across the republic were estimated at tens of percent in individual farms.

The deep moisture deficit slowed flax stem growth, impaired perennial grass regrowth, worsened ear formation in grains, and created a shortage of green mass for forage.

Damaged crops were widely harvested for feed purposes, while perished areas were reseeded with drought-resistant varieties like millet, foxtail millet, and crucifers. Over 50% of the affected areas were reseeded. Some losses were offset by expanding plantings of heat-tolerant crops.

To secure forage supplies and food security, around 500 thousand tons of grain were purchased (mainly from Russia), with existing reserves of about 900 thousand tons of fodder grain.

The drought led to lower groundwater levels and river low flows. In some settlements, wells dried up, and drinking water quality deteriorated.

Forest and peat fire risks surged significantly, and the condition of wetland and meadow ecosystems worsened, especially in the southern Polesie regions.

Due to low water levels and rising temperatures, operations at certain hydroelectric facilities and water intakes deteriorated, necessitating additional water regime adjustments. In some areas, pressure on water supply and irrigation systems increased, raising costs for water transfers and pump station operations.

The drought's impacts are illustrated in the photographs (Figure 3).

Fig 3. The Drought's Impacts in Belarus

Events similar to those in 2023 occur in Belarus during spring in 60-70% of years in Brest and Gomel regions, and in 20-30% in Vitebsk region.

It's also worth noting that the risk of floods and other hazardous hydrological and climatic phenomena is becoming a limiting factor for natural resource use. In turn, dangerously low water levels lead to issues with drinking water, high fire risks, suspension of navigation, reduced biodiversity, changes in water body basins, disruptions in agricultural and energy sectors.

The agricultural and forestry sectors, which are among the most important and hold a strategic position in the economy, suffer the greatest damage from these extreme events. An adverse consequence of global warming is the increasing aridity of the climate over a significant part of Belarus.

Thus, Belarus faces new challenges and threats of emergencies due to climate change. There is a need to develop strategies and response measures for the evolving situation.

CONCLUSION

The abrupt alternation of floods and droughts amplifies the negative impacts of individual hazardous events and calls for identifying patterns and uncovering the nature of the mechanisms behind the transitional processes being studied. Since floods and droughts can't be entirely eliminated, the top priority is to adapt economic activities as much as possible to potential extreme conditions and minimize ecological risks. In this context, developing computer modeling systems, including those utilizing artificial intelligence, will help tackle challenges in managing water management facilities in typical ecologically troubled regions, which could encompass the whole of Belarus.

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REFERENCES

1. Czaja S., Machowski R., Rzetala M. (2014). Floods in the Upper Part of Vistula and Odra River Basins in the 19th and 20th Centuries. Chemistry-Didactics-Ecology-Metrology, 19, 127-134.
2. Jeneiová K., Kohnová S., Hall J., and Parajka J. (2016). Variability of seasonal floods in the Upper Danube River basin. Journal of Hydrology and Hydromechanics, 4, 357-366.
3. Zscheischler J. et al. (2018). Future climate risk from compound events. Nature Climate Change, 6, 469-477.
4. Mach K. et al. (2019). Climate as a risk factor for armed conflict. Nature, 7764, 193-197.
5. Zhang B., Wang S. & Wang Y. (2019). Copula-based convection-permitting projections of future changes in multivariate drought characteristics. Journal of Geophysical Research: Atmospheres, 124, 7460-7483.
6. Chen H., Wang S. & Wang Y. (2020). Exploring abrupt alternations between wet and dry conditions on the basis of historical observations and convection permitting climate model simulations Journal of Geophysical Research: Atmospheres, 125.
7. Di Baldassarre G., Martinez F., Kalantari Z., & Viglione A. (2017). Drought and flood in the Anthropocene: Feedback mechanisms in reservoir operation. Earth System Dynamics, 8(1), 225–233.
8. Kreibich H., Blauhut V., Aerts J., Bouwer L., Van Lanen H. , Mejia, A., … Van Loon, A. F. (2019). How to improve attribution of changes in drought and flood impacts. Hydrological Sciences Journal, 64(1), 1–18.
9. Handwerger A., Huang M-H., Fielding E., Booth A., and Bürgmann R. (2019). A shift from drought to extreme rainfall drives a stable landslide to catastrophic failure. Scientific Reports, 9, 1-12.
10. He X., and Sheffield J. (2020). Lagged compound occurrence of droughts and pluvials globally over the past seven decades. Geophysical Research Letters, 47, 1-14.
11. Qiao Y., Xu W., Meng C., Liao X., and Qin L. (2022). Increasingly dry/wet abrupt alternation events in a warmer world: Observed evidence from China during 1980–2019. International Journal of Climatology, 42, 6429-6440.
12. Meshyk, A. P. The role of snow cover in forming spring flooding on Belarus rivers / A. P. Meshyk, V. A. Marozava, M. V. Barushka. – Land Reclamation, 2021. – N 4. – P. 35–40.
13. Volchak, A. A. Floods on the territory of Polesie / A. A. Volchak, A. P. Meshyk, M. M. Sheshka [et al.] // Procedia Engineering. – 2016. – № 162. – P. 91–97. https://doi.org/10.1016/j.proeng.2016.11.020
14. Atlas: Weather Hazards in Belarus / A. A. Volchak [and others]. – M. : All-Russian Research Institute for Hydraulic and Land Reclamation, 2017. – 70 p.
15. Логинов, В. Ф. Современные изменения климата Беларуси. / Фундаментальная и прикладная климатология. – 2022. – № 1. – С. 51–74.