

FLOOD EXPOSURE OF SLOVAK BIOSPHERE RESERVES

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Abstract

Biosphere reserves represent unique UNESCO model areas that integrate biodiversity conservation with sustainable socio-economic development. Given the expected increase in the frequency of flash floods caused by extreme manifestations of climate change, it is necessary to assess their impact on these areas. The aim of the study was to determine the extent of flooding in Slovak biosphere reserves (Slovak Karst, Poľana, Tatras, Eastern Carpathians) based on flood hazard maps of the Slovak Water Management Enterprise for average return periods of 10, 100 and 1 000 years. The methodological approach was based on delineating reserve boundaries, extracting flood lines, and calculating the inundated area. The results showed significant differences between the reserves. The study highlights the need for more detailed research on flood risks in biosphere reserves and their integration into area management.

Key words: Biosphere reserve, flood, extent

Introduction

UNESCO-designated biosphere reserves (BR) hold a unique position as model areas for sustainable development, as they aim to reconcile biodiversity conservation with the socio-economic vitality and cultural identity of local communities (Brieger et al., 2025). Flash floods are highly destructive due to their sudden onset, and scientists expect their frequency to increase as a result of current extreme rainfall events driven by climate change. Such repeated occurrences of flash floods have significant implications for BR, which host diverse plants, animals, and microorganisms and support local livelihoods (Eze, Siegmund, 2023). Floods regularly cause substantial damages worldwide. Their characteristics are changing—for example, due to climate change—which poses challenges for flood-risk management. The spatial extent of floods is an important indicator of potential impacts, as the consequences of large-scale flooding are particularly difficult to mitigate. Across Europe, we observe an average increase in flood extent of 11.3% over the past 70 years, although this trend is highly spatially variable (Fang et al., 2023).

BR perform three fundamental functions. The conservation function ensures the preservation of genetic, species, and landscape diversity, maintaining ecosystems in a favourable state. The development function supports economic and human development that is socio-culturally and environmentally sustainable, as well as the socio-economic and ecologically sustainable development of the region. The logistic function provides support for education, research, and environmental monitoring (Vitálošová et al., 2025). These functions are implemented through an appropriate delineation of the territory into three zones: (1) one or more legally protected core areas designated for long-term conservation; (2) a clearly defined buffer zone or zones surrounding the core area; and (3) an outer transition area where practices of sustainable natural-resource management are promoted and developed (Hriňová, 2014). The transition zone is the part of the BR that is neither a core area nor a buffer zone. It represents a “transition” toward the surrounding landscape and differs from the boundaries of large-scale protected areas. Its defining feature is direct human intervention and activity in the landscape in accordance with the principles of sustainable development (Vitálošová et al., 2025).

In our research, we focused on calculating the areas of BR within the flood-hazard maps published by the Slovak Water Management Enterprise, considering return periods ranging from 10 to 1000 years.

Area of interest

Four BR have been designated in Slovakia: Slovak Karst (1977), Poľana (1990), the Tatra Transboundary BR (Poland/Slovakia, 1992), and the East Carpathians Transboundary BR (Poland/Slovakia/Ukraine, 1992). They are protected under Act No. 543/2002 Coll. on Nature and Landscape Protection as areas of international importance, and at the same time as areas of national importance Poľana as a Protected Landscape Area, and the others as national parks (Špulerová et al., 2023).

Methods

In our methodology, we followed the methodological procedure of Grežo et al. (2020). The aim of the authors in that study was to demonstrate how data from historical maps could be applied in the process of flood-risk assessment in suburban zones located within flood-prone areas, serving as complementary datasets to national flood maps. We modified and adapted their methodology to our study area. The methodology consists of the following steps: a) delineation of BR based on publicly available data from the State Nature Conservancy of the Slovak Republic (PABR, 2025); b) extraction of flood lines using available data from the Slovak Water Management Enterprise (SWMC, 2025); c) calculation of the area of BR within the flood-hazard extents.

A flood-hazard map is prepared at the most appropriate scale for each geographical area where a potentially significant flood risk exists, or where the occurrence of significant flood risk can be expected. The flood-hazard map depicts the possible inundation of the area by:

- a) a flood with a low probability of occurrence, meaning a flood that may occur on average once every 1,000 years or less often, or one with exceptionally dangerous characteristics;
- b) a flood with a medium probability of occurrence, which may occur on average once every 100 years;
- c) a flood with a high probability of occurrence, which may occur on average once every 10 years (7/2010 Z. z., 2025).

Result

Within the total area of the BR, the flood-hazard maps show that areas inundated at an average return period of once every 10 years amount to 512.67 ha, once every 100 years to 1 536.56 ha, and once every 1 000 years to 1 976.47 ha. Summed across all reserves, this corresponds to 3 451.25 ha in Slovak Karst, 89.04 ha in Poľana, 485.166 ha in the Tatras, and 0.22 ha in the Eastern Carpathians.

Tab. 1: Flooded Area in the Biosphere Reserves of the Slovak Republic

Biosphere reserve	Q10 (ha)	Q100 (ha)	Q1000 (ha)	Together (ha)
Slovak Karst	428.76	1341.73	1680.76	3451.25
Poľana	21.17	31.48	36.40	89.05
Tatry	62.69	163.27	259.21	485.17
Eastern Carpathians	0.05	0.08	0.1	0.23
Together (ha)	512.67	1536.56	1976.47	4025.7

Source: SWME, 2025; PABR, 2025

The Slovak Karst BR has the largest inundated area, totalling 3 451.25 ha, of which 428.76 ha correspond to the Q10 return period, 1 341.73 ha to Q100, and 1 680.76 ha to Q1000. In the Poľana BR, the inundated area for an average return period of once every 10 years is 21.17 ha, for Q100 it is 31.48 ha, and for Q1000 it is 36.40 ha (Map 1).

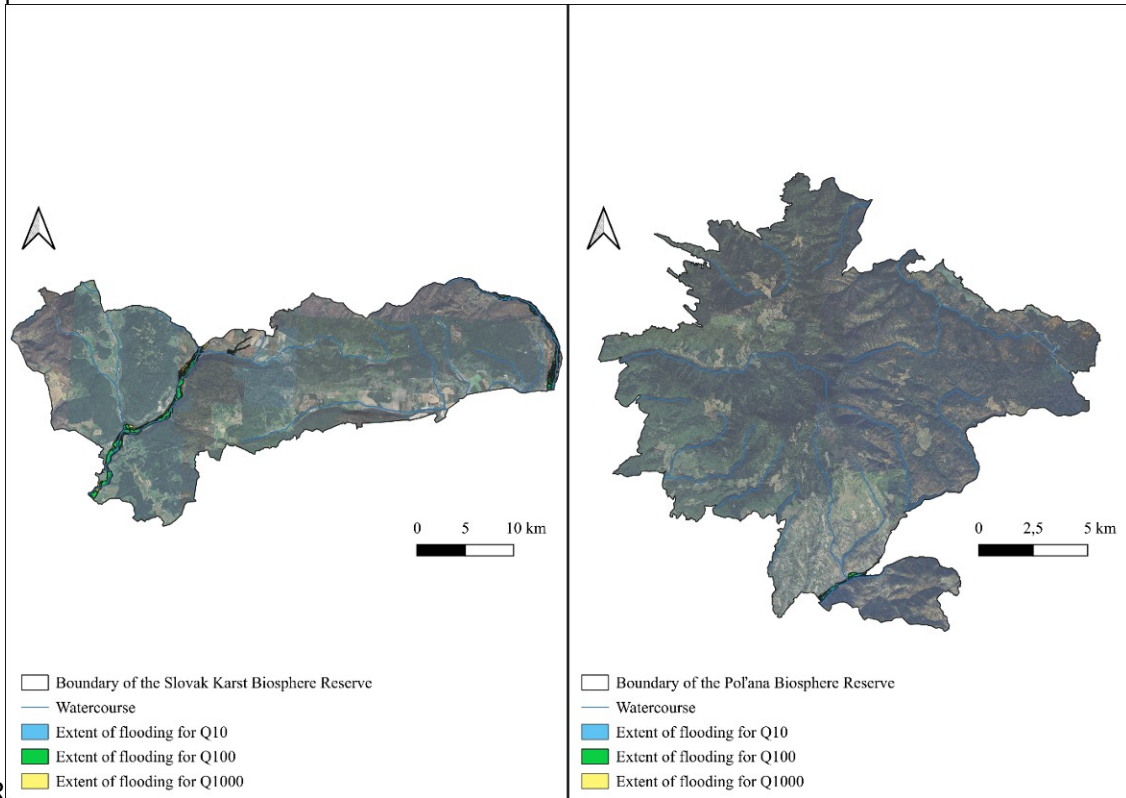
In the Tatras BR, the inundated area for a return period of once every 10 years is 62.69 ha, for Q100 it is 163.27 ha, and for Q1000 it is 259.21 ha. In the Eastern Carpathians BR, the inundated area is 0.05 ha for the 10-year return period, 0.08 ha for Q100, and 0.1 ha for Q1000 (Map 2).

Conclusion

In general, flash floods have destroyed human and animal lives, livelihoods, and infrastructure. In some cases, floods have been followed by displacement of people, alterations to the landscapes of BR, and further disasters. A study by the authors revealed that flash floods in BR have been insufficiently researched. Specifically, no study was found documenting the occurrence of flash floods in Africa (Eze, Siegmund, 2023).

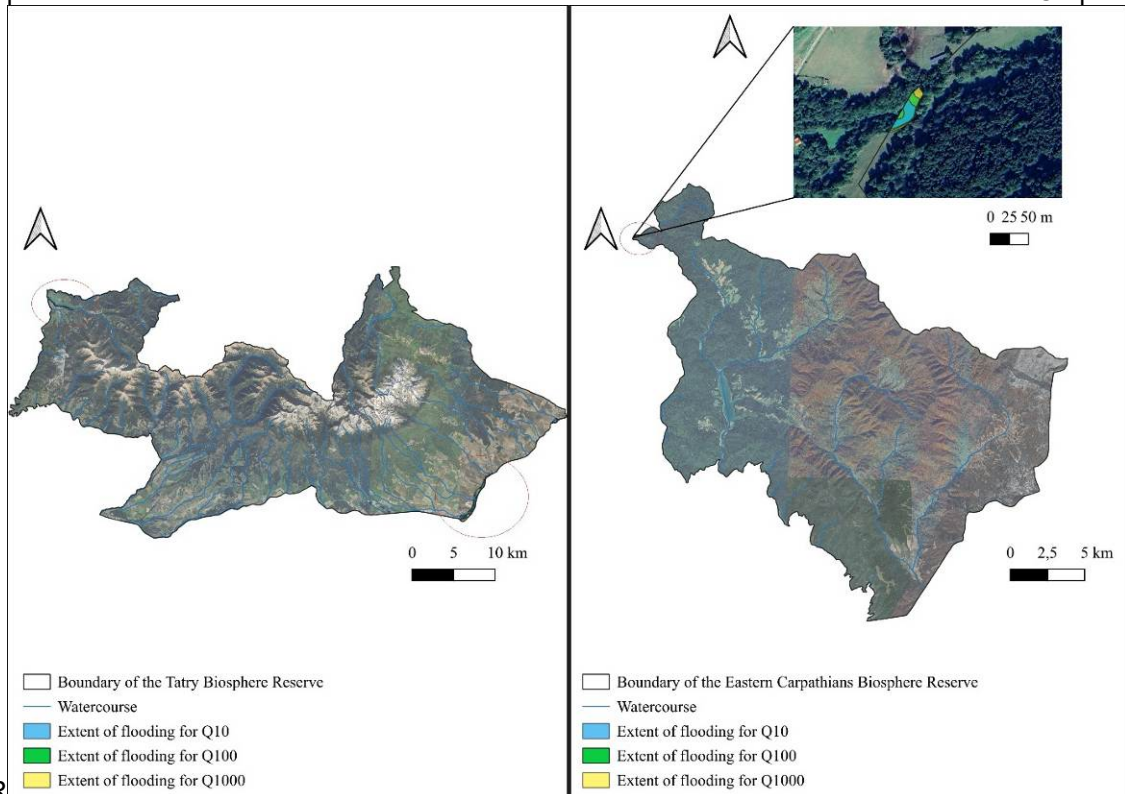
Within the Slovak Republic, several studies focus on flash floods; however, we were unable to identify any research dedicated specifically to the study of flash floods or floods comprehensively addressing BR. The aim of this research was to assess and calculate the inundated area of all BR in Slovakia. Across the four BR, the total area at risk according to flood-hazard maps amounts to 512.67 ha for floods with an average return period of once every 10 years, 1 536.56 ha for the 100-year return period, and 1 976.47 ha for the 1 000-year return period.

Map 1: Extent of Flood-Hazard Areas in the Slovak Karst and Poľana



Zdroj: SWMC, 2025; PABR, 2025

Map 2: Extent of Flood-Hazard Areas in the Tatras and Eastern Carpathians



Source: SWMC, 2025; PABR, 2025

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Souhrn

Tato studie hodnotí potenciální povodňové riziko ve čtyřech biosférických rezervacích (BR) na Slovensku vyhlášených organizací UNESCO – Slovenský kras, Poľana, Tatranská přeshraniční BR a Východokarpatská přeshraniční BR – pomocí map povodňového ohrožení vypracovaných Slovenským vodohospodářským podnikem. BR slouží jako modelové regiony udržitelného rozvoje, protože spojují ochranu biodiverzity se socioekonomickými potřebami. Stále častěji se vyskytující přívalové povodně způsobené změnou klimatu představují pro tato chráněná území významnou hrozbu.

Výzkum aplikoval upravenou metodiku podle Grežo a kol. (2020), která zahrnovala vytyčení hranic rezervací, extrakci povodňových linií a výpočet zaplavených ploch pro období opakování 10, 100 a 1000 let. Výsledky ukázaly, že rozsah povodňového ohrožení se mezi rezervacemi výrazně liší. Největší zaplavenou plochu má Slovenský kras (3 451.25 ha), následují Tatry (485.17 ha), Poľana (89.05 ha) a Východní Karpaty (0.23 ha). Celkem je ohroženo 512.67 ha při 10 leté povodni, 1 536.56 ha při 100 leté povodni a 1 976.47 ha při 1000 leté povodni.

Studie poukazuje na to, že přívalové povodně v BR jsou na globální úrovni i v rámci Slovenska stále nedostatečně prozkoumány. Zjištění zdůrazňují potřebu integrovat hodnocení povodňových rizik do managementu a dlouhodobého plánování BR.

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