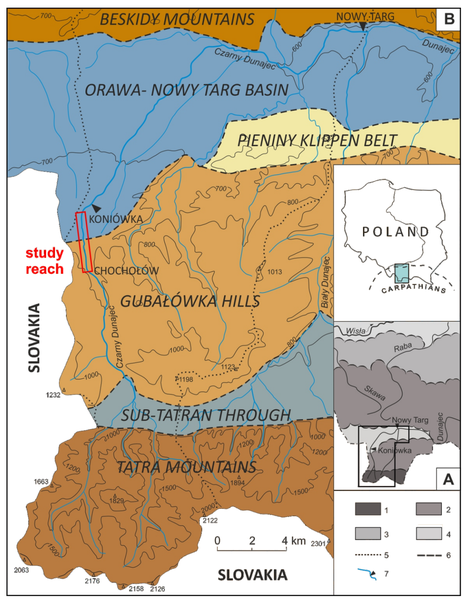
Historical changes in the extent of the flooded area of a mountain river induced by human impacts

Évolutions historiques de l'étendue des zones inondées des rivières de montagne induites par l'impact humain



(A) Location of the study reach of Czarny Dunajec River in relation to physiogeographic regions of southern Poland: 1 — high mountains; 2 — mountains of intermediate and low height; 3 — foothills; 4 — intramontane and submontane depressions; 5 — boundary of the catchment; 6 — boundaries of physiogeographic units; 7— flow-gauging station. (B) Drainage network of the catchment and detailed setting of the investigated river reach

This study focuses on the Czarny Dunajec River in the Polish Carpathians, which has undergone significant channel modifications, including narrowing and extensive illegal gravel extraction. It plays a crucial role in assessing how past human interventions have affected ecological conditions on the floodplains and contributed to headward erosion upstream and increased flooding risk in the downstream river reach.

Study objectives:

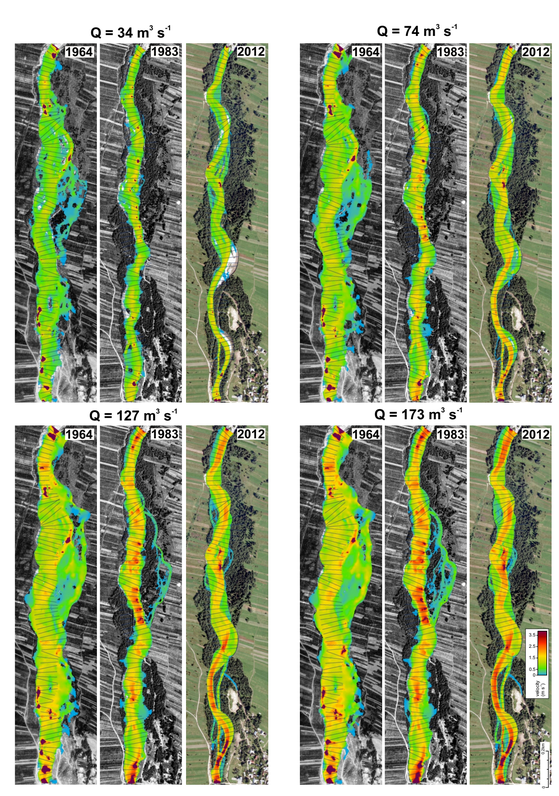
(i) To explore how the hydrodynamics, in terms of flow velocity and unit stream power for a given flood discharge, changed with progressing channel incision along a 2.5 km river reach.

(ii) To verify how these changes were reflected in the modification of the extent of the flooded area during two study periods: 1964–1983 and 1983–2012.

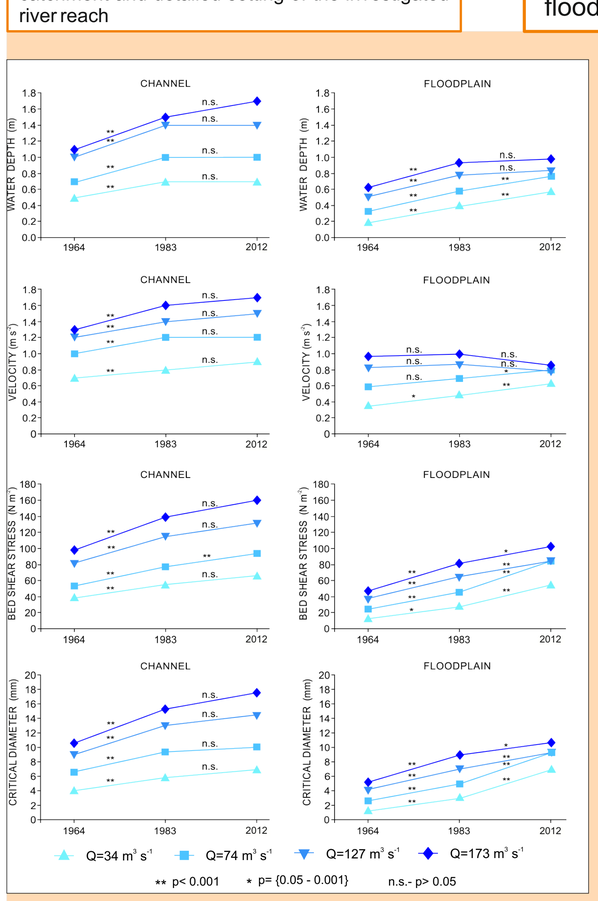
Methods:

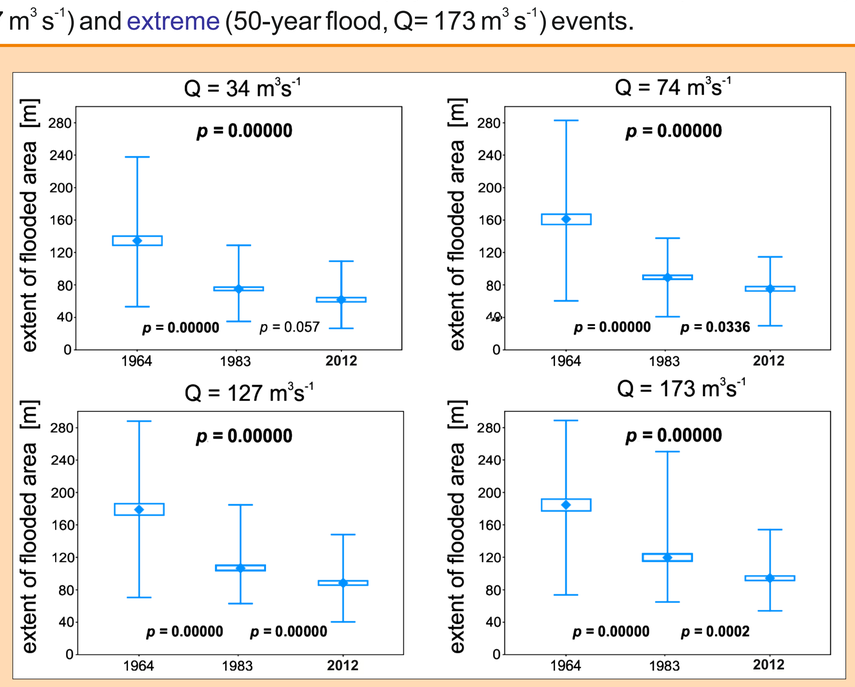
The study utilizes archival aerial photos to reconstruct historical Digital Elevation Models to analyse channel changes between 1964 and 2012. Panchromatic and RGB aerial images from 1964, 1977, 1983, and 1994 were processed using photogrammetric methods with ground control points for exterior orientation and DEM accuracy assessment.

Hydrodynamic changes and the flood extent in the Czarny Dunajec River were examined using the 2D Iber hydraulic model for three years (1964, 1983, and 2012) and various flood scenarios: frequent (2-year flood, Q= 34 $m^3 s^{-1}$), ordinary (5-year flood, Q= 74 $m^3 s^{-1}$), extraordinary (20-year flood, Q= 127 $m^3 s^{-1}$) and extreme (50-year flood, Q= 173 $m^3 s^{-1}$) events.



Spatial patterns of flow velocity in the channel and on the floodplain within the study reach during floods of varying magnitudes across three time horizons

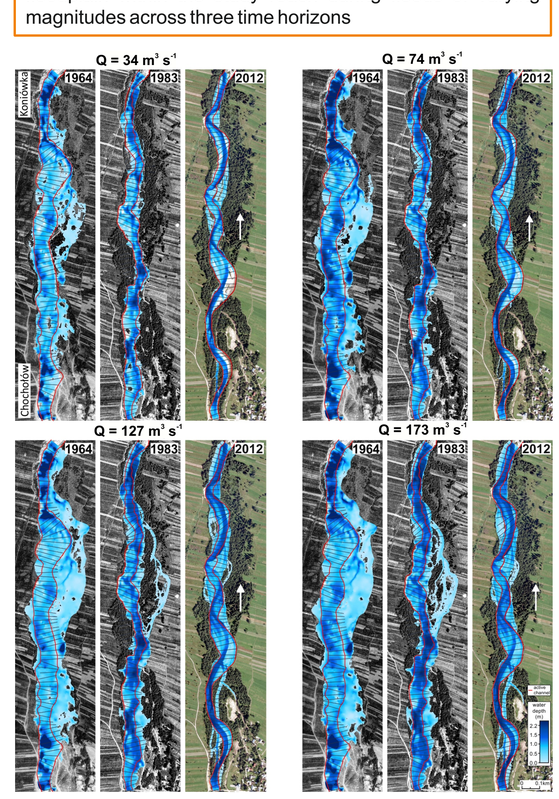




Results:

Extent of flooded area declined across all flood scenarios:
by 35–44% **from 1964 to 1983** and by 12–19% **from 1983 to 2012**

Flushing of channel sediments led to increased channel capacity and more efficient downstream conveyance of floodwaters, limiting overbank inundation across the floodplains of the study area.
These trends point to ongoing hydrodynamic and geomorphological evolution driven by channel narrowing and gravel extraction.



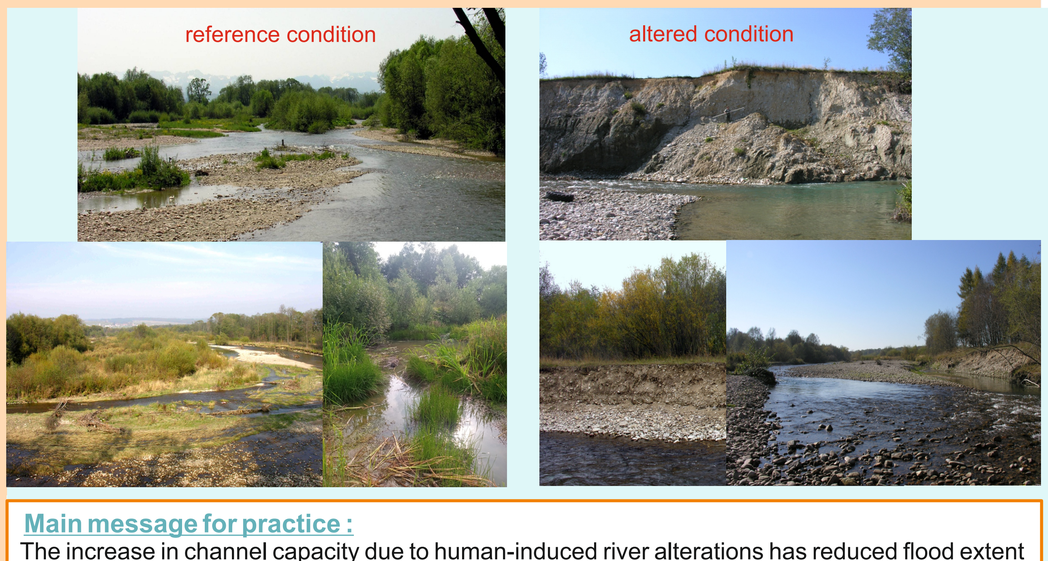
Spatial patterns of water depth in the channel and on the floodplain within the study reach during floods of varying magnitudes across three time horizons

Results:

In the channel - between **1964 and 1983**, changes in hydraulic parameters were **significant**, especially during extraordinary and extreme flood events. Between**1983 and 2012**, changes were **less pronounced**, suggesting slower channel incision.

Higher unit stream power in the earlier period flushed finer sediments and delivered coarser material from upstream, forming a coarse-gravel surface layer by the 1980s. This contributed to channel bed stabilization between 1983 and 2012. Further incision resulted from large floods capable of mobilizing the well-packed coarse sediment.

In the floodplain - the most hydraulic parameters value also increased more in the years **1964-1983** however, the modelled flow velocity for extraordinary and extreme flood events did not change significantly and even decreased in the second study periods, indicating the role of vegetation development in parts of the floodplain in increasing surface roughness.



Main message for practice :
The increase in channel capacity due to human-induced river alterations has reduced flood extent and frequency, and consequently, the floodwater retention potential, contributing to the deterioration of floodplain vegetation.

Main message for practice:
The bridge located in Chochołów, in the upper part of the study reach, is at risk of collapse due to headward erosion caused by progressive channel incision.

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