



Reference period matters, so do altitude and geography: understanding trends in rainfall extremes across the Italian landscape

Paola Mazzoglio¹, Gianluca Lelli², Alessio Domeneghetti³, and Serena Ceola⁴

¹Department of Environment, Land and Infrastructure Engineering, Politecnico di Torino, Torino, Italy

(paola.mazzoglio@polito.it)

²Department of Civil, Chemical, Environmental, and Materials Engineering, Alma Mater Studiorum Università di Bologna, Bologna, Italy (gianluca.elli2@unibo.it)

³Department of Civil, Chemical, Environmental, and Materials Engineering, Alma Mater Studiorum Università di Bologna, Bologna, Italy (alessio.domeneghetti@unibo.it)

⁴Department of Civil, Chemical, Environmental, and Materials Engineering, Alma Mater Studiorum Università di Bologna, Bologna, Italy (serena.ceola@unibo.it)

Extreme rainfall and its temporal evolution critically influence flood hazard, slope stability, and infrastructure resilience. Yet in Italy, where complex topography and diverse climates shape precipitation, studies of rainfall extremes have produced conflicting outcomes, with neighboring sites often showing opposite trends. Much of this inconsistency stems from differences in data length, baseline period selection, and orographic context.

This study builds upon and extends the recent national-scale analysis by Mazzoglio et al. (2025), which, for the first time, quantified trends in rainfall extremes across Italy for the 1960–2022 period. Using the Improved Italian - Rainfall Extreme Dataset (I²-RED), which compiles data of thousands of rain gauges, we apply distributed quantile regression to annual maximum precipitation for short (1 h) and long (24 h) durations. Trends are expressed as percentage variations per decade and evaluated over multiple baseline windows (1960–2022, 1970–2022, 1980–2022, and 1990–2022) to test the sensitivity of results to the observational timeframe. Elevation effects are assessed by stratifying rain-gauge samples into low- and high-altitude groups and by comparing the regression slopes obtained for each.

Results reveal that short-duration extremes exhibit widespread and coherent positive trends, while 24-hour events show more heterogeneous and regionally variable patterns. Shortening the analysis period strengthens the positive signal, indicating that the intensification of sub-daily rainfall is largely a recent phenomenon. The most pronounced increases occur at higher elevations, especially in the Alps and Apennines. By contrast, lowlands and coastal areas show weaker or negligible changes. The geographic segmentation further demonstrates that spatial patterns of change align closely with major Italian physiographic structures, highlighting the combined roles of orography and regional geography in shaping rainfall evolution.

These findings suggest that trends in rainfall extremes in Italy cannot be interpreted through a single national lens: both methodological choices (baseline period and rainfall duration) and environmental factors (topography and geography) fundamentally shape the detected signals. The combined sensitivity to time window and elevation highlights the importance of accounting for Italy's physiographic diversity when assessing hydrological risk and designing climate-resilient infrastructure.

Reference

Mazzoglio P., Viglione A., Ganora D., Claps P. (2025). Mapping the uneven temporal changes in ordinary and extraordinary rainfall extremes in Italy. *Journal of Hydrology: Regional Studies*, 58, 102287. <https://doi.org/10.1016/j.ejrh.2025.102287>