Abstract

River flooding poses a major threat to infrastructures, particularly in small watersheds. Small catchment hydrology is highly representative of the Italian landscape and dams are a striking example, as about 70% of the Large Dams in Italy drain watersheds smaller than 100 km^2. The percentage of small basins to be accounted for may significantly increase when considering ungauged basins belonging to the secondary river network and minor crossings, where collapses triggered by small rivers and creeks cause the highest damages.

The reference framework of this dissertation is that of the rainfall-runoff connections, needed for flood hazard assessment in small ungauged basins. The critical factors controlling the event-based flood peak estimation, i.e. those forming the foundation of the rational formula, are investigated using a sensitivity analysis perspective across different climates and landscapes, as a pragmatic pathway to enhance flood hazard estimation.

At first, the variability of the parameters of the rational formula and the hydrograph shape is investigated all over Italy in relation to the classification of flood peak attenuation potentials of Large Dams, emphasizing the interaction between infrastructure geometry and upstream river basin processes. The research highlights the critical influence of the time of concentration on the attenuation potential sensitivity, emphasizing the importance of accurate estimates across diverse basin morphologies. On the other hand, the hydrograph shape and runoff coefficient have less impact on the classification outcome. The analysis of extreme rainfall variability in Italy allows to identify optimal combinations for effective flood mitigation, with Alpine dams showing the best outcomes. These results can help in selecting more strategic reservoirs that deserve in-depth

attenuation studies by means of supervised flood management and can provide crucial support to wide-area flood frequency analyses on anthropized basins.

Given the clear need for robust estimates for the time of concentration, a methodological approach is suggested to either reject or recommend formulas of the characteristic flood response time for ungauged basins. This methodological screening is based on a comparison of the magnitude and basin-scale dependence of the average velocities produced by each formula with values observed in the literature, rather than on a comparison in terms of travel times. The outcomes of this analysis, showing how only 5 out of 35 formulas examined turn out to be robust and consistent with observations, provide useful recommendations for selecting efficient formulas, as well as some guidance for calibrating new empirical ones. Closely tied to flood response times are flood volumes, which estimation in ungauged basins is still a challenging task. In this direction, a methodology for reconstructing the design hydrograph shape of ungauged basins is proposed through a regionalized non-dimensional flood reduction function (FRF) in 87 watersheds North-Western Italy. Indications are given on how the specific hydrograph shape is related to the basin morphology and, in particular, to its average elevation.

Mindful of the need to integrate climate change into flood hazard assessment, the last part of the work specifically deals with mountain basins, often seen as hot spots for climate change. The research focuses on how flood hazard in the Italian Alps may be affected by climatic perturbations and the extent to which this depends on the local elevation features of the watershed. By analysing a wide set of basins, this study offers a broad and regionally representative understanding of the potential flood risk increase due to global warming faced by communities in the Italian Alpine region. The results underscore a pronounced sensitivity to rising temperatures above 1500 m a.s.l., with a potential reduction of the return period of the current 100-year flood of up to 5 times, depending on the basin hypsometric features. Lower-lying regions are found to be more vulnerable to the impacts of intensifying precipitation.

To achieve the objectives of this thesis, a systematic and consistent knowledge of hydrological and catchment-related information all over Italy has been built, i.e. state-of-the-art, country-wide datasets have been produced for Italy, encompassing both gauged basins and basins closed by Large Dams. This data can provide new opportunities to perform both regional and national-scale studies using catchments shapes and attributes extracted using a common framework, subjected to the same quality-control procedure.