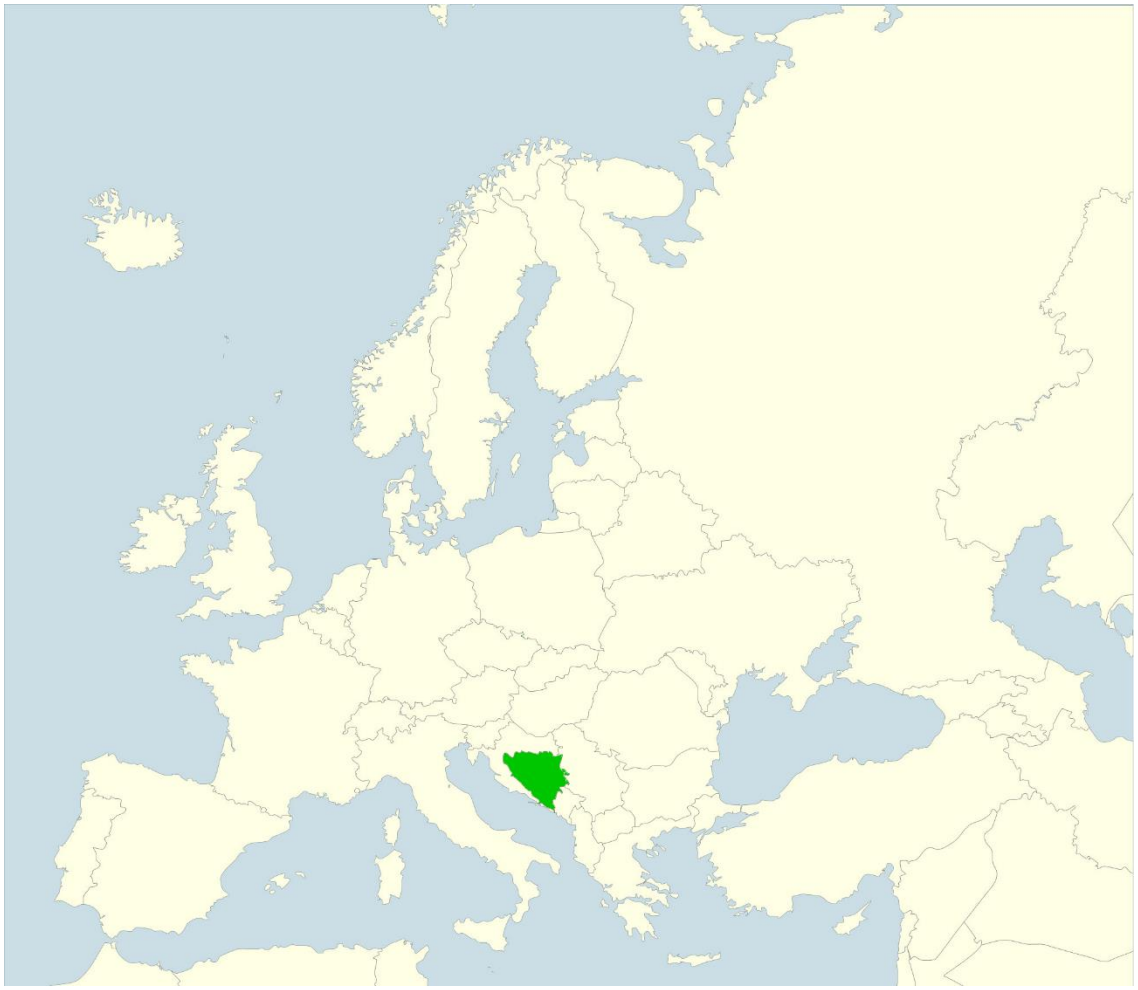
European Countryside | volume 18 | No. 1 | p. 52-89 | DOI: 10.2478/euco-2026-0004

RETHINKING FLOOD RESILIENCE IN THE CONTEXT OF FLOOD-PRONE RURAL AREAS IN EUROPE





Nerma Omičević[1]

[1] Faculty of Engineering and Natural Sciences, International University of Sarajevo, Bosnia and Herzegovina, ORCID: 0000-0001-9364-2763, e-mail: nomicevic@ius.edu.ba

Received 17 July 2025, Evaluated 28 December 2025, Revised 16 January 2026, Accepted 23 January 2026

Abstract: Floods, as one of the hydrological disasters, have been recorded as the most common within the natural disaster occurrences since 1990. Floods can be induced by natural forces, by heavy or continuous rain that exceeds the assimilative capacity of the soil or the river flow capacity, but they can also be triggered by human activities, deforestation, constructions on unstable slopes and constructions of embankments, which can result in activation of landslide processes on the slopes. Floods affect agricultural areas, areas with forestry, but also urban areas. This research explores flood resilience strategies through the comparative analysis of selected flood events in Europe, which occurred from 2005 until 2025, with the focus on the recent floods in 2024 that affected the rural areas of the southern part of Switzerland and the southern part of Bosnia and Herzegovina. The research is conducted based on documentary evidence about floods, which is compared from an urban planning perspective, including historical data and the recorded floods since the 20th century. The main aim is to explore how planned flood resilience strategies have been applied and the effectiveness of their implementation during the last 20 years of repeated flood impacts, in order to rethink the concept of flood resilience. The research points out the importance of approaching the existing resilience framework from a holistic perspective and understanding that climate adaptation requires flexible and transformative land-use policies in both urban and rural areas, as well as a diversified application of resilience strategies.

Keywords: floods, resilience, Switzerland, Bosnia and Herzegovina, rural settlements

Highlights

- Overview of flood events in Europe (2005–2025).
- Focus on floods in Switzerland and Bosnia and Herzegovina in 2024.
- Comparative analysis of resilience strategies and capacities (2005–2025).
- Exploring how flood resilience has been achieved during the past 20 years.
- The importance of land-use policies and the diversification of resilience strategies.

1. Introduction

Extreme weather events and climate variability over the past two decades have shown that the climate is changing and affecting the rise of sea level, increase of temperatures, withdrawal of glaciers, soil and forest deterioration and the loss of biological diversity and desertification (Akay, 2019, p. 3). These effects are one of the underlying reasons for the occurrence of natural disasters. The United Nations International Strategy for Disaster Reduction defines disaster as a "serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources" (UNSDR, 2009, p. 9). Disasters can be divided into two main categories: natural disasters caused by natural forces and man-made disasters. Natural disasters can be further divided into four main categories: hydrological disasters, that include floods, landslides and mudflows and avalanches; meteorological disasters, that include storms, typhoons, cyclones, hurricanes, winter storms, tornadoes and tropical storms; geophysical disasters, that include earthquakes, volcanic eruptions and tsunamis; and climatological disasters, that include droughts, extreme temperatures and wildfires (Omićević & Bojanić Obad Šćitaroci, 2020, p. 14).

Based on the records by EM-DAT, during the period from 1980 until 1999, 4212 natural disasters occurred, while during the period from 2000 until 2019, this number increased to 7348 natural disasters worldwide. The increase in disaster events is mainly due to the rise of meteorological, climatological and hydrological disasters. Out of these climate releated disasters, floods are considered the most frequent natural disaster worldwide. During the period from 2000 until 2019, floods accounted for 44% of the total number of

natural disasters with 3254 reported events, which is significantly less than in the period from 1980 until 1999, with 1389 records (UNDRR, 2020, p. 6). These data indicate that the continued flood impact is expected to increase even more due to the climate change impact of extreme rainfalls and increased population density in flood-prone areas, but also as the result of environmental degradation, through deforestation, constructions on unstable slopes and constructions of embankments and other human activities, which can result in activation of landslide processes on the slopes. (Ruiz-Villanueva and Molnar, 2020; Omićević and Bojanić Obad Šćitaroci, 2020). Climate change has significantly increased the frequency of weather events, through long-term shifts in temperatures and weather, mostly caused by burning fossil fuels, which increases the heat-trapping gas levels in the Earth|'s atmosphere, resulting in rising global temperature, rising sea level and ice melting (Azadgar et al., 2024, p. 1). Several studies confirmed that the changes in climate conditions are projected to worsen the flood risk worldwide, through intense precipitation[2] events, rising temperatures, upward shifting snowline and amplification of coastal flooding (Fang et al., 2025; Chapagain et al., 2025; Savić, 2025; Paprotny et al., 2025; McClymont et al., 2020; Azadgar et al., 2024; Laidlaw and Percival, 2023). However, it is important to emphasise that these changes are not the only causes of long-term variations in flood occurrence, as the socio-economic impact influences the hydrological response of a catchment and changes in the land use, including deforestation, afforestation, crops, urbanisation, etc. (Paprotny et al., 2025).

Floods are defined as "the overflowing of the normal confines of a stream or other body of water or the accumulation of water over areas that are not normally submerged" (OECD, 2016, p. 18). Due to their different origins, floods can be classified into three main categories: coastal floods, fluvial floods or river floods and pluvial floods or flash floods. Each of these flood types poses different impacts and requires different mitigation strategies. The long term observed changes in the climate conditions suggest that the strongest increase will be evident in flash floods in terms of fatalities and economic impact, but also in river floods, in terms of the affected population (Paprotny et al., 2025). The study of Fang et al. (2025) indicates that the frequency of floods tends to decline in snow-dependent regions due to global warming and shorter snow seasons with less snowfall. Particularly in the Alpine regions, the flood occurrence is expected to decrease by 17% under the 3°C warming level compared to the period 1971-2000 (Fang et al., 2025, p. 3).

The research on flood risk management has been a continuous process over the past decades. There are many discussions, urban planning strategies and different response measures to address the increasing flood impacts. Most of the studies of flood risk mitigation are focused on the concept of resilience, through the use of different resilience strategies, but mostly related to urban resilience (World Bank, 2021; Rajasekar, 2022; Azadgar, 2024; Aloscious, 2025; Haider and Cleaver, 2023). However, the implementation of these resilience strategies is challenging and their link with resilience capacities and methods for assessing their implementation remains unclear.

This research explores flood resilience strategies through the comparative analysis of selected flood events in Europe, which occurred from 2005 until 2025, with the focus on the recent floods and landslides in 2024 that affected the rural areas of the southern part of Switzerland and the southern part of Bosnia and Herzegovina. The main aim is to explore how flood resilience has been achieved based on identifying the resilience strategies and resilience capacities that have been planned and implemented during the past 20 years, and by assessing the effectiveness of their implementation.

For the research context, the focus will be on the occurrence of pluvial or flash floods and fluvial or river floods in rural areas. Pluvial floods occur when exessive rainfalls create an overflowing water body, in the form of surface water floods or flash floods. Flash floods are triggered by high torrential rainfall, which occur whitin a short amount of time and within a nearby elevated terrain (Zurich, 2025). As such, they can be very destructive by enhancing the occurrence of debris flows with large amounts of solid matter such as soil, sand, gravel and rock (OECD, 2016, p. 18). Fluvial floods or river floods occur when the water level in a river, lake or stream overflows into dry land, adjacent to the channel (Zurich, 2025).

[2] Precipitation is liquid or solid water falling from clouds to the Earth's surface or formed on different bodies as a result of atmospheric water vapour condensation.

The term *rural* refers to "areas of open country and small settlements" (Dasgupta et al., 2014, p. 618). Rural areas include different forms of settlements and infrastructures, and as such, experience specific vulnerability towards climate change impacts. This is mainly due to their dependence on the weather and the natural resources. Over centuries, people in rural areas have learned to adjust to climate variability, relying on historical averages of rainfall and temperature, but with the climate change impact, the range and scale of climate variability are considerably increasing, posing a considerable threat to crop yields and production (IFAD, 2009). Almost half of the world's population, 3.3 billion people, live in rural areas, and 90% of those people live in developing countries (OECD, 2016, p. 18). As a result, the focus on addressing these vulnerabilities in rural areas has grown, and findings highlight the urgent need for effective and long-term resilience strategies involving community actions and designing interventions that can adapt to the changes (Gyawali et al., 2021). The contribution of this research lies in its holistic approach to the flood resilience framework, achieved by identifying resilience strategies, resilience capacities, and resilience indicators within the flood-prone rural context.

The research begins with the theoretical background by defining the concept of resilience and exploring its role in flood mitigation (Section 2). For the purpose of collecting the statistical data and information on flood disasters, the list of the used databases was elaborated in Section 2, as a basis to provide an overview of the selected flood events in Europe and the comparative analysis of the selected case study examples (Section 3). The research summarises the findings of the analysed examples and concludes by assessing the effectiveness of resilience achievement with an outline of future research directions (Section 4).

2. Theoretical and data background

2.1 The Concept of Flood Resilience

The word resilience comes from the Latin word *resilire*, "the idea of resisting and rebounding" (Leroy et al., 2016, p. 2). The concept of resilience was initially introduced in physics to define the extent to which a component is required to return to its initial state after undergoing a certain form of alteration (Leroy et al., 2016, p. 2). In 1973, Holling used the term resilience in his works in ecology and defined it as the "ability of a system to maintain its integrity under disturbance" (De Bruijn, 2003, p. 3). The term was soon widely used in other disciplines, such as social science, psychology, medicine and disaster management. Its widespread adoption among disciplines created a lack of clarity regarding a definite application of its concept (Laidlaw and Percival, 2024; McClymont et al, 2020; Qamar, 2024).

Within the context of disaster framework and climate change adaptation, resilience refers to "the ability of a system and its components to anticipate, absorb and accommodate or recover from the effects of a hazardous event in a timely and efficient manner, through ensuring preservation, restoration and improvement of its essential basic structures and functions" (UNDRR, 2017a). Based on the comprehensive reviews of articles presented in the research of Laidlaw and Percival (2024) and McClymont et al. (2020), efforts have been made to develop a multidisciplinary framework for flood resilience, but there is still no consensus on the flood resilience definition. Although the term has been divided between several fields, it can be reviewed and grouped into *community resilience*, *socio-economic resilience* and *systems resilience* (Laidlaw and Percival, 2024, p. 10781) or *engineering resilience, systems resilience*, and *resilience in complex-adaptive systems* (McClymont et al., 2020, p. 1153).

Across 425 journal articles and conference papers reviewed in the study by McClymont et al. (2020), a debate exists related to conceptualising resilience as resistance vs resilience, flood control vs flood adaptation, and structural vs functional approaches. Some studies argue that resistance measures are an inherent part of resilience, because they contribute to the mitigation process, while other studies view resistance as a separate concept, associated with flood control strategies (McClymont et al., 2020, p. 1158). Studies where resistance is perceived as an undermining concept of resilience are applied at larger spatial scales. They indicate that the flood resistance approach has a negative effect on the long-term development of flood resilience, emphasising the need to shift from resistance as a traditional

paradigm of flood protection to a long-term resilience approach, by taking into account the social and ecological dimensions of resilience (Zevenberger et al., 2020; Dewa et al., 2022; Meng and Yue, 2024).

The concept of resilience in social sciences was seen as a socially and culturally embedded construct. Although social resilience is a multidimensional concept, the majority of definitions in relevant literature are disaster-focused and related to the capacity/ability of communities to face and overcome a crisis (Qamar, 2024, p. 136). The socio-ecological approach to resilience is grounded on several aspects, which include that there is no optimal or best solution; that it's important to learn from the outcomes to be able to adapt, but also to transform if needed; to take into account all possible interventions which can mitigate flood risk; and to facilitate collective participation in the planning and learning process (Zevenberger et al., 2020, p. 6).

Based on the need for a comprehensive and holistic resilience framework, flood resilience in this study is being conceptualised from an urban planning perspective through a three-pillar conceptual framework – **resilience capacities, resilience strategies and resilience indicators** as presented in Figure 1.

In flood risk management, resilience capacities refer to **the capacity of a system to resist/mitigate** when exposed, **to absorb/recover** from a flood event and **the capacity to transform** the existing approach. (McClymont et al., 2020, p. 1159; Zevenberger et al., 2020, p. 2). A strong commonality between resilience studies is the transformability aspect, which indicates that resilience should be perceived as more than just mitigation and adaptation, and that these aspects are not the outcome of resilience, but rather to understand floods as an opportunity for change. Past flood events can contribute to mitigating future flood impact, but they can also become a resource to increase livelihoods (McClymont et al., 2020, p. 1159).

The capacity of mitigation is defined as “the act of reducing a hazardous event or adverse impact” (UNDRR, 2017b) and, as such, addresses the cause of the flood impact. Possible mitigation measures include early warning systems to provide timely and relevant information about possible impact and providing disaster risk policy frameworks (Jeans et al., 2017). The capacity of adaptation is defined as” the process of changing to adjust to different climate change effects and impact” (IPCC, 2014, p. 5) and addresses the flood impact. Characterised with flexibility, possible adaptation measures include community participation in the resilience process, disaster awareness, new social innovations, new agricultural practices and sustainable use of natural resources (Jeans et al., 2017). In addition to adaptation and mitigation, which seek to preserve the existing system, resilience enables the capacity for transformation as well. The capacity to transform allows the creation of a new system when adaptation measures cannot reduce the system’s exposure to vulnerability. Transformative measures refer to the reorganisation and potential transformation of unstable systems and the capacity to create a fundamentally new system when ecological, economic, or social conditions make the existing system unsustainable. They address the underlying failures of the existing development, which can cause or increase the risk. (Jeans et al., 2017; Walker et al., 2004).

All three resilience capacities, mitigation, adaptation and transformation are important, but their implementation relies on the analysis of the existing vulnerability and possible risk assessment. This means that in flood-prone rural areas, resilience measures can be applied to reduce the impact of flooding or to relocate land use (OECD, 2020). Based on the resilience capacity framework, social resilience also includes coping, adaptive and transformative capacities which societies have to develop to enable resilience, acknowledging the importance of community involvement in the resilience process (UN-HABITAT, n.d.). In disaster management, capacity is defined as “the combination of all the strengths, attributes and resources available within an organisation, community or society to manage and reduce disaster risks and strengthen resilience” (UNDRR, 2017). Based on this definition, resilience capacities refer to the functional ability of a system to cope with flood impact, while resilience strategies refer to interventions on how these abilities are achieved in practice.

Flood resilience strategies are focused on the implementation of structural and non-structural measures, which can be applied in the form of **green infrastructure** through nature-based solutions, **policy regulations** through planning interventions and **grey infrastructure** in the form of technological and

infrastructural interventions. Nature-based Solutions (NBS) are non-structural interventions that "protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (Rajasekar et al., 2022, p. 4). These interventions include wetland restoration, directing stormwater runoff to vegetated areas, increasing soil infiltration and the integration or reuse of overland areas with green spaces to accommodate flood waters and alternative purposes. Examples of successfully implemented NBS include the Yanweizhou Park in Jinhua, China. Due to its monsoon climate, the city suffers from annual flooding, but for a long time, concrete flood walls were built as the only flood protection strategy. The city adopted a resilient wetland management system to conserve the wetlands for flood control by creating a natural ecosystem and building flood resilience. The Yanweizhou Park is grounded in the concept based on flood adaptation and integration of the flooding process with the landscape. This included the plantation of native trees, channelling excess flood water to the wetland, creating bio-swales that increased the recharge of groundwater, floodable pedestrian paths and a pedestrian bridge elevated above the 200-year flood level and designed to be adaptive to river currents (Landscape Architecture Built, 2025; Rajasekar et al., 2022, p. 16).

Policy regulations include the implementation of building codes and zoning restrictions in flood-prone areas with lower population density. Along with regulations, strategic planning interventions are also an important aspect of implementing resilience measures. The flood mitigation plan project in the city of Kochi, India, demonstrates a successful planning intervention by creating a new urban model for flood management and strengthening ecological infrastructure and drainage networks. The floods in Kochi frequently inundate farmlands and cause direct losses, damage to property and natural resources. Comprising a network of 44 rivers and many ponds and streams, the city's vulnerability to flood impact increased due to the changes in the climate conditions. The new model is based on rejuvenating the existing canal system, which includes cleaning the vegetation that blocked the canals and the deposited concrete debris, demolishing and reconstructing the culverts that blocked the canals, and widening the width of the canals. The city has been envisioned as a *sponge city* for better water conservation and to improve the city's ecological balance. To build community resilience, numerous urban forests have been planted in flood-prone areas to reduce extreme heat (Aloscious et al., 2025; Rajasekar et al., 2022, p. 36).

Grey infrastructure is reflected through the technological aspect, which is based on computational flood models and integrating the models with Geographical Information System (GIS) to identify spatial vulnerabilities, and the infrastructure aspect, which refers to the engineered solutions of structural flood measures and includes the construction of embankments, dykes and levees With the main aim to become a flood-proof city by 2025, the city of Rotterdam, Netherlands adopted resilient measures to increase the water absorption rate and capture the rainwater by building underground water storage spaces across the city, green roofs and green facades, reducing pavements and increasing vegetation in streets and neighbourhoods, and building several outer-dykes and inner-dykes to provide multi-layered flood protection from sea-level rise. The city's climate change adaptation plan is not focused solely on grey infrastructure solutions, but combines them with blue-green infrastructure solutions. This has been proven to regulate water flow and mitigate runoff and has a positive effect on evapotranspiration, which reduces heat stress in the city (Oppla, 2025; Rajasekar et al., 2022, p. 72).

The flood risk management in rural areas is mostly reflected through the implementation of self-specific flood adaptive practices, by seeking safety and moving to higher grounds, storing water and food supplies, planting forestry along the flood plains to create a buffer zone for flood mitigation (Palazzo, 2025; Liu et al., 2025; Gyawali et al., 2021). These can be further categorised into three different flood adaptation strategies in the rural context: Localisation – avoiding flood-prone rural areas and selecting elevated rural land; Attenuation – accepting occasional flooding in transitional zones and taking advantage of fertile soil; and Safe to flood strategy – intentionally placing agricultural land in flood-prone areas to transform risk into opportunity (Pallazo, 2025, p. 15).

However, the most essential role plays the community connectedness and social support. To strengthen the resilience in flood-prone rural areas, rural communities emphasise the importance of the social

dimension of resilience – the livelihood resilience, which refers to the ability to preserve their well-being in the time of a disaster. The results from the study of Dewa et al. (2022) revealed that sense of place, health and the communites well being are important aspects in the resilience process, which can help to understand why people living in flood-prone rural areas choose to continue staying despite the possible risks (Dewa et al., 2022; Liu et al., 2025; Gyawali et al., 2021).

To assess the effectiveness of resilience achievements – encompassing resilience capacities and resilience strategies, this research will use six indicators, developed for a resilient system in the disaster risk domain: **Risk avoidance** as the planning phase to reduce the flood impact; **Robustness** as the ability to absorb and withstand floods through built structures; **Redundancy** as a functional diversity by providing evacuation routes and possibilities; **Resourcefulness** as the ability to mobilize in case of flood impact, by converting facilities into flood shelters; **Rapidity** as the ability to enable quck access to the neccerary sources of financing to support recovery; and **Recovery** as the ability to evolve and to adapt to new circumstances (Zurich Flood Resilience Alliance, 2019; Zevenberger et al., 2020, p. 3; Kim et al., 2025, p. 3).

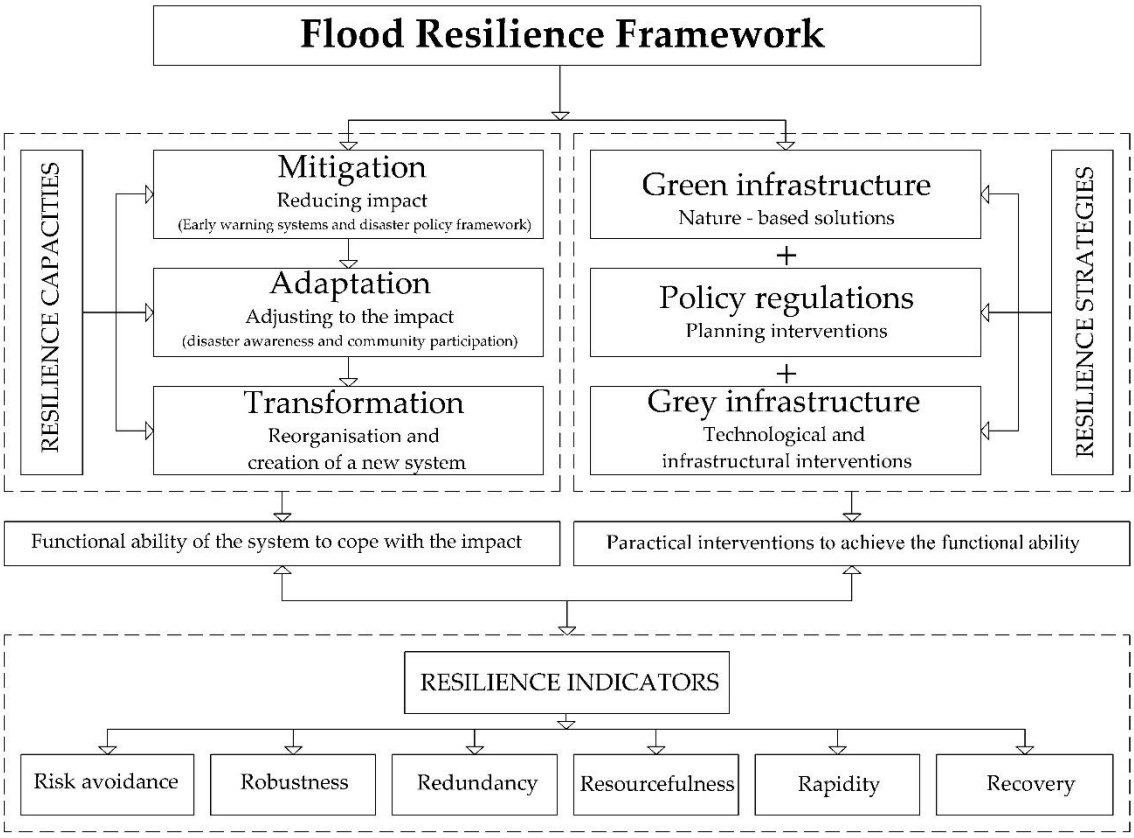


Fig 1. Conceptual framework of the flood resilience framework. Source: author

2.1 Sources of statistical data

For the research analysis, the information and statistical data on flood disasters were used and collected from three databases: the Centre for Research on the Epidemiology of Disasters (CRED), CRED's Emergency Events Database (EM-DAT) and the UN Office for Disaster Risk Reduction (UNDRR). The overview of the numerical data on flood disasters in Table 1 (Appendix I), Table 2, Table 3 and Table 5 was extracted from the Emergency Events Database (EM-DAT), which contains the world's most comprehensive data on the occurrence and effects of more than 24,000 technological and natural hazard-related disasters from 1900 to the present day. The documentation on terminology and classification of research terms was used from the Centre for Research on the Epidemiology of Disasters (CRED) and the UN Office for Disaster Risk Reduction (UNDRR). CRED is one of the leading agencies for the study of public health during mass emergencies, including natural and man-made disasters. UNDRR serves as

the focal point in the United Nations System for the coordination of disaster risk reduction, which supports the implementation of the Sendai Framework for Disaster Risk Reduction 2015–2030.

3. Flood Disaster Events in Europe (2005–2025)

3.1 Criteria for selection and analysis of selected case studies

For providing the basis of conducting the comparative analysis, the research firstly gives an overview of all flood disaster events, which occurred in Europe from 2005 until 2025 (Table 1 in Appendix I). The data was collected based on the selection of hydrological disasters with flood types that included floods in general, pluvial or river floods and fluvial or flash floods. The comprehensive overview of the data in Table 1 has been further extracted and summarised in Table 2 to show the number of flood occurrences per type which occurred from 2005 until 2025. The data shows how river floods had the highest number of occurrences from 2005 until 2015, while from 2015 until 2025, general floods were the most common flood type in Europe. The year 2005 had the highest number of flood disaster occurrences, in total 39, and the highest number of river flood impacts with 35 occurrences, while the lowest number of flood events was recorded in 2022, with a total of 5 occurrences, as seen in Figure 2. The term floods in general is specified in the EM-DAT database as a "general term for the overflow of water from a stream channel onto normally dry land in the floodplain (riverine flooding), higher-than-normal levels along the coast – coastal flooding and in lakes or reservoirs as well as ponding of water at or near the point where the rain fell – flash floods" (CRED/Louvain, 2025).

Tab 2. Numerical overview of flood occurrences in Europe per flood type (2005–2025). Source: Table data extracted from the EM-DAT database on February 3, 2025. Summary, data editing and table overview prepared by the author

Year	Flash flood	Flood (General)	River flood	Total
2005	2	2	35	39
2006	1	1	28	30
2007	3	1	15	19
2008	/	1	8	9
2009	/	/	15	15
2010	6	/	26	32
2011	2	/	5	7
2012	2	/	13	15
2013	3	/	13	16
2014	8	/	20	28
2015	10	3	7	20
2016	4	13	2	19
2017	4	2	2	8
2018	4	9	/	13
2019	1	15	1	17
2020	4	10	1	15
2021	5	23	/	28
2022	1	4	/	5
2023	/	16	1	17
2024	/	8	/	8
Total	**60**	**108**	**192**	**360**

The focus of the research is the recent flood and landslide events which occurred in 2024, which affected the rural areas of the southern part of Switzerland and the southern part of Bosnia and Herzegovina. The criteria for choosing these examples are based on the classification of flood disasters and the period

of their repeated occurrences, from 2005 until 2025, positioned in a mountain valley, within the European countryside context. The analytical overview of the selected examples is carried out by comparing the period from 2005 to 2025, characterized by recurrent flood impacts with the recent floods events that occurred in 2024, based on the use of resilience strategies (grey infrastructure, green infrastructure, planning regulations) and resilience capacities (mitigation, adaptation and transformation) and evaluated through key resilience indicators (risk avoidance, robustness, redundancy, resourcefulness, rapidity and recovery) to reveal the effectiveness of the implemented resilience measures during the last 20 years of repeated flood impacts.

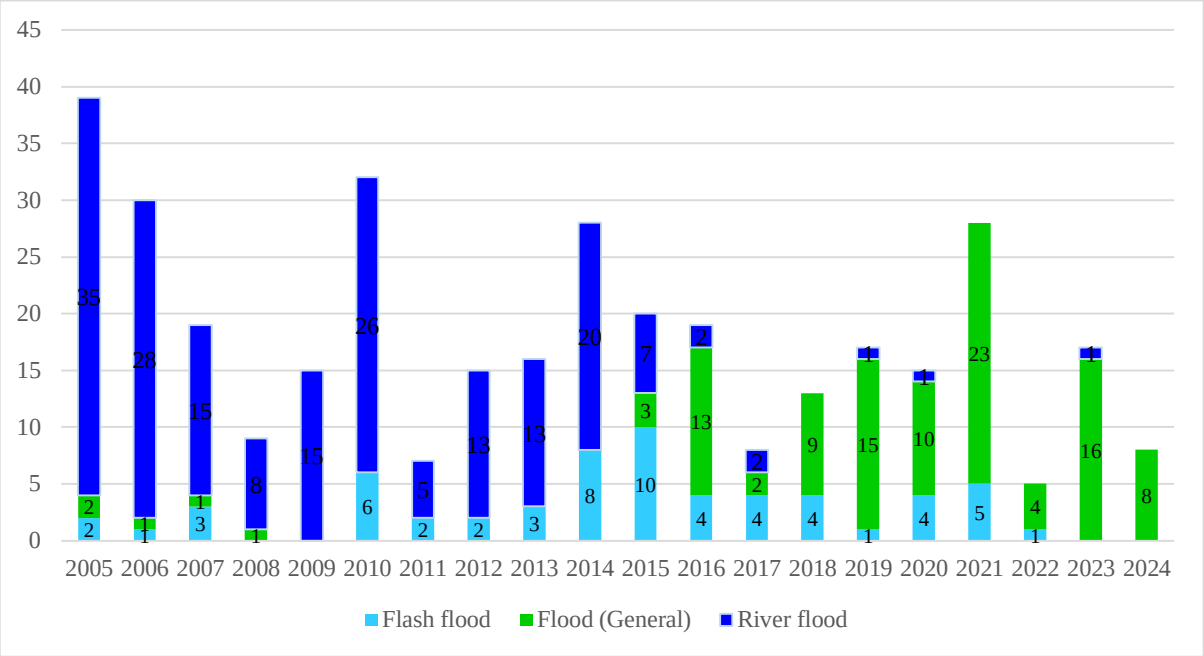


Fig 2. Number of flood occurrences in Europe per flood type, 2005–2025. Source: author

3.2 Floods in Switzerland (2024)

Period of recurrent flood impacts (2005–2025)

Switzerland is a country with a high vulnerability risk of flood impact. During the past 20 years, there have been numerous flood events causing severe population and property impact. With over 1422 km² of lake areas and 65,300 km of watercourses with little capacity for accommodating flood peaks, Switzerland is under an increasing risk of floods (UNDRR, 2022). For this reason, the country possesses one of the largest hydrological data series in Europe. The Swiss Federal Research Institute WSL has, since 1972, systematically collected and analysed data related to floods, debris flows, landslides and, since 2002, also rockfall (Ruiz-Villanueva and Molnar, 2020, p. 30). Rural communities living around mountain valleys and floodplains are mostly affected by flooding and prone to flash floods. The floods which occurred in August 2005 were the most severe flood event that has impacted the country. After several days of torrential rainfall, within a matter of hours, streams and rivers were overflooded, and many slopes became unstable, resulting in the activation of 5000 recorded landslides and debris flows (FOEN, 2008, p. 6). The people were evacuated to the higher ground levels, and strong retaining walls for debris flows were built in the river areas. During the post-flood recovery process, a flood risk mitigation plan was established with the aim of reducing the flood risk by defining land-use planning policies. These involved:“ reducing the flood hazard, by increasing the drainage system, storage of runoff, enhancing the river capacity and dams and flood embankments; reducing the flood volume and exposure, by flood plain regulations, redevelopment of land-use policies and housing and building codes; and preserving the natural resources of floodplains, by enlarging the river space to enable space for extreme floods, soil pollution regulation and increasing the flood awareness through the development of flood hazard maps for every flood prone area” (Omićević and Bojanić, 2020, p. 30).

Hazard maps serve as a basis for regional and land use planning and disaster prevention by indicating dangerous areas and aligning land use with the natural conditions to decrease potential damage (Kunz and Hurni, 2008). In Switzerland, the application of hazard maps in populated areas has been obligatory since 1991(Kunz & Hurni, 2008; Rindsfuser et al., 2025) and as of 2021, for 97% of the populated area, hazard maps are completed and produced on a municipal and canton level (Rindsfuser et al., 2025, p. 3). Since Switzerland is prone to different types of natural disasters, the hazard maps are focused on floods, mass movements and snow avalanches (Kunz & Hurni, 2008, p. 134). The understanding and use of the hazard maps can be found on the website of the National Platform for Natural Hazards (PLANAT), while an overview of all hazards is available on the Natural Hazards Portal or the MeteoSwiss app. The data on the natural disasters that occur throughout Switzerland are being collected in the web-based StorMe database operated by the Swiss Federal Office for the Environment (FOEN), allowing government agencies and cantons to record, process and analyse the data. (FOEN, 2020). With the aim of preserving the collective flood memory, the Mobiliar Lab for Natural Risks at Bern University has set up a website as a “collective aide-memoire”. The website contains photos from floods throughout Switzerland with specified location and time period, dating back to 1572 (FOEN, 2020, p. 10). This helps to increase awareness of the flood risks while demonstrating the flood impacts. In case of a natural disaster event, the authorities issue a warning on the Alertswiss app run by the Federal Office for Civil Protecion and monitoring data and information can also be accessed on the GIN shared natural hazards information platform (FOEN, 2020, p. 22).

The importance of monitoring the disaster process and possible threats has been particularly evident in the Saas Valley in Valais. The landscape is dominated by steep mountains and extreme temperature changes under continuous risk of rockfalls and rock avalanches. In response, 3800 metres of rockfall nets have been installed in recent years (FOEN, 2020, p. 23). With the risk of ice breaking off the Trift glacier above Saas-Grund, a monitoring system was set up in October 2014 with radar equipment, GPS points and a camera. The measurements in September 2017 indicated that the ice would soon break off again, so the crisis team evacuated over 200 people (FOEN, 2020, p. 24). The monitoring process of the slope movement is carried out by FOEN by using images from the Interferometric Synthetic Aperture Radar (InSAR), which are produced by the Sentinel satellites of the European Space Agency (FOEN, 2020, p. 25). The summer floods in 2007 led to the overflow of the River Sorne and the flooding of the entire Morépont district. In the event of a disaster, the authorities built two embankments to decrease further extension of the impact and, in the aftermath, focused immediately on how to prevent future flooding, but also to improve people’s quality of life. This was achieved through the implementation of natural measures in the Delémont Marée Basse project. These measures included the revitalisation of the River Sorne by creating more space for the river, which also increased the river flow and created habitats for animals and bird species. The river is now 40m wide, twice the width it used to be, with open spaces connected to the river and dry meadows. Besides the enviromental and social characteristics, the project also included the concept of discharging water onto the railway line that runs between Delémont and Basel in case the capacities of the natural flood defences exceed (FOEN, 2020, p. 29). In order to mitigate surface runoff in case of debris flow, a surface runoff risk map for Switzerland has been available since 2018. It shows the natural topography of the areas at risk of runoff and illustrates where the water will flow. These surface runoff risk maps, together with the hazard maps, are being used in the construction projects by planning controlled runoff natural corridors (FOEN, 2020, p. 31).

The data summarised in Table 3 shows how extra-tropical storms were the main flood type occurrence from 2005 until 2021, followed by river floods, but due to the increase in climate change effects, more frequent types of hydrological disaster after 2021 were avalanches and storms. Out of all hydrological and meteorological disasters which occurred from 2005 until 2025 in Switzerland, extra – tropical storms were the most common disaster type, while the lowest number of occurrences had floods in general, as presented in Figure 3.

Tab 3. Overview of flood disaster events in Switzerland (2005–2025). Source: Table data extracted from the EM-DAT database on February 3, 2025. Summary, data editing and table overview prepared by the author

Year	Location (Village/City, Province)	Hydrological disaster subtype and Meteorological disaster subtype	Flood causes	Flood effects
2005	Brienz (Bern province); Bern, Luzern, Schwyz, Uri, Obwalden provinces	River flood	Heavy rains	n.d.
2006	Bern, Graubünden, Ticino, Uri, Valais provinces	Storm (General)		n.d.
	Martigny city (Valais province),	River flood	Heavy rain	n.d.
2007	Aargau, Appenzell Ausserrhoden, Appenzell Innerrhoden, Basel-landschaft, Basel-stadt, Bern, Fribourg, Genève, Glarus, Graubünden, Jura, Luzern, Neuchâtel, Nidwalden, Obwalden, Sankt Gallen, Schaffhausen, Schwyz, Solothurn, Thurgau, Ticino, Uri, Valais, Vaud, Zug, Zürich provinces	Extra-tropical storm	n.d.	n.d.
	Bern, Graubünden, Ticino, Uri, Valais provinces	River flood	Heavy rain	n.d.
2010	Aargau, Appenzell Ausserrhoden, Appenzell Innerrhoden, Basel-landschaft, Basel-stadt, Bern, Fribourg, Genève, Glarus, Graubünden, Jura, Luzern, Neuchâtel, Nidwalden, Obwalden, Sankt Gallen, Schaffhausen, Schwyz, Solothurn, Thurgau, Ticino, Uri, Valais, Vaud, Zug, Zürich provinces	Extra-tropical storm		
2011	Juras Bernois, Alpes Bernoises area (Bern province), Bas-Valais area (Valais province)	Extra-tropical storm	n.d.	Transport accident
2013	Aargau, Appenzell Ausserrhoden, Appenzell Innerrhoden, Basel-landschaft, Basel-stadt, Bern, Fribourg, Genève, Glarus, Graubünden, Jura, Luzern, Neuchâtel, Nidwalden, Obwalden, Sankt Gallen, Schaffhausen, Schwyz, Solothurn, Thurgau, Ticino, Uri, Valais, Vaud, Zug, Zürich provinces	Extra-tropical storm		
2020	n.d,	Storm (General)	n.d.	Flood, Slide (land, mud, snow, rock)
2021	Swiss Alps. Part of the canton of Valais was placed under the avalanche danger level 5.	Avalanche (wet)	n.d.	Snow/ice
	Basel, Zurich, Lucerne, Schwyz and Uri Cantons	Flood (General)	Torrential rainfall caused by a slow-moving area of low pressure	n.d.
2023	n.d.	Avalanche (wet)	n.d.	n.d.
2024	Valais, Vale Mesolcina	Extra-tropical storm	n.d.	n.d.

*Note(s): Data in Table 2 includes hydrological disasters of the type of avalanche, due to the geographical context and meteorological disasters, due to the storm impact on inducing floods.
n.d. - No data available.

Changes in the flood frequency and intensity in Switzerland are the result of the complex impact of climatic changes in elevation of snowfall, extreme precipitation and river morphology and non-climatic factors – changes in land use, flood protection and infrastructure (Molnar et al., 2020, p. 50). According to several studies, one of the possible causes of increased flood frequency observed in northern Switzerland since 1970 is the increase in air temperature, leading to strong precipitation events (Ruiz-

Villanueva et al., 2020, p. 33). The results from the study of Molnar et al. (2020) indicated the tendency for an increase in the flood magnitude in Switzerland in the future, characterised by large spatial variability and extreme uncertainty in projected changes during flood events.

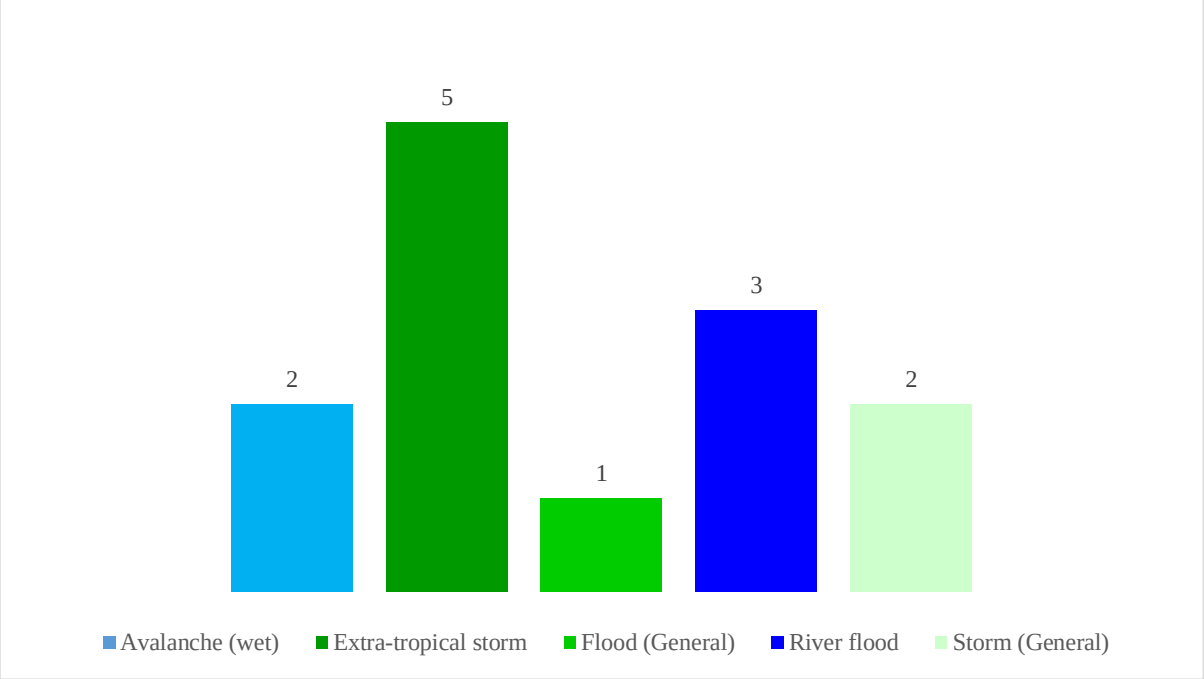


Fig 3. Hydrological and Meteorological Disaster Subtype Occurrences in Switzerland, 2005–2025. Source: author

Floods in Valle Mesolcina, 2024

During the summer of 2024, intense flash floods occurred frequently in Switzerland. In June 21st, 2024, in the Alpine region and the Jura Mountains, extensive rain fell within a short amount of time, reaching 125mm of rainfall within 24 hours in the Grisons (Graubünden) Mountain valley of Valle Melsocina. According to Reuters, "it was not the level of rain that caused the problems, but the concentration of rain that fell in such a short period of time, a concentration that happens once in every 30 years" (Reuters, 2025). Several rivers burst their banks, and a total of 100 hectares of land and 8 km of roads were flooded. This led to landslide occurrence in the Mesolcina Valley, destroying part of the highway and covering agricultural fields and villages with 290,000 cubic metres of debris material and mud (SWI, 2025). Expanding urbanisation and intensified agriculture saturated the land soil and reduced the absorption of the land surface, indicating that the existing flood defence systems require a new model that can keep up with the increasing climate change conditions (SWI, 2025). To address the current challenges, Switzerland's water protection legislation is focused on preserving the natural water bodies and restoring impaired sections through rehabilitation projects. These comprehensive rehabilitation projects aim to restore 4,000 km of Swiss degraded watercourses and lakeshores by 2090, through the re-establishment of their natural functions, which would contribute to the ecological, social and economic aspects and strengthen flood protection (FOEN, 2025). The overview of the flood resilience process in Switzerland (2005–2025) is presented in Table 4.

Tab 4. Overview of the flood resilience process in Switzerland (2005–2025). Source: Table overview prepared by the author

DISASTER CATEGORY/SUBCATEGORY	Natural/ Meteorological disasters
DISASTER SUBTYPE/CATEGORY	Tropical Storm
CASE STUDY (country, region/city, month, year of disaster event)	Switzerland, Valle Mesolcina, June 2024;
	The Buffalora area in Valle Meslocina experienced floods and debris flow in June 2024. **Image Source: Federal Office of Topography swisstopo – Rapid Mapping - Swisstopo / map.geo.admin.ch / Rapid mapping – Date of publication: 02.07.2024**

FLOOD RESILIENCE STRATEGIES (2005-2025)	
Grey infrastructure	Construction of retaining walls in the river areas
Green infrastructure	Natural flood defence through river revitalisation
Policy regulations	**The flood risk mitigation plan** was established with the aim of reducing the flood risk by defining land-use planning policies. These involved:" reducing the flood hazard, by increasing the drainage system, storage of runoff, enhancing the river capacity and dams and flood embankments; reducing the flood volume and exposure, by flood plain regulations, redevelopment of land-use policies and housing and building codes; and preserving the natural resources of floodplains, by enlarging the river space to enable space for extreme floods, soil pollution regulation and increasing the flood awareness through the devlopment of flood hazard maps for every flood prone area.
	Hazard maps serve as a basis for regional and land use planning and disaster prevention by indicating dangerous areas and aligning land use with the natural conditions to decrease potential damage. The understanding and use of the hazard maps can be found on the website of **the National Platform for Natural Hazards (PLANAT),** while an overview of all hazards is available on **the Natural Hazards Portal or the MeteoSwiss app.**
	Web-based StorMe database – a collection of data on the natural disasters that occur throughout Switzerland.
	The Mobiliar Lab for Natural Risks at Bern University has set up a website as a "collective aide-memoire" - With the aim of preserving the collective flood memory. The website contains photos from floods throughout Switzerland with specified location and time period, dating back to 1572.
	Alertswiss app – authorities issue a warning in case of a natural disaster event. The app is run by the Federal Office for Civil Protection.
	GIN shared a natural hazards information platform – monitoring data and information access.
	Surface runoff risk map - shows the natural topography of the areas at risk of runoff and illustrates where the water will flow. These surface runoff risk maps, together with the hazard maps, are being used in the construction projects by planning controlled runoff natural corridors.
	FOEN monitoring process of the slope movement - using images from the Interferometric Synthetic Aperture Radar (InSAR), which are produced by the Sentinel satellites of the European Space Agency
FLOOD RESILIENCE CAPACITIES	
Flood Mitigation and Adaptation Plan	Restoration of 4,000 km of Swiss degraded watercourses and re-establishment of their natural functions by 2090 Contribution to the ecological, social and economic aspects and to strengthen the flood protection system Rehabilitation projects - to preserve the natural water bodies and to restore impaired sections
Land Use Transformation	/

3.3 Floods in Bosnia and Herzegovina (2024)

Period of recurrent flood impacts (2005–2025)

Bosnia and Herzegovina was exposed to repeated threats of flood impact during the period from 2005 to 2025 (Table 5). Most affected areas were the rural settlements near river basins or mountain valleys, which are highly vulnerable to the devastating flood impacts and consequences. During the floods which occurred in December 2010, particularly agricultural land in the Drina River area and eastern Herzegovina were flooded. The floods which occurred in May 2014 uncovered the country's vulnerability towards the threat of climate change and the lack of capacity to address its negative impact. After several days of heavy rainfall, the rivers Bosna, Sava, and Drina overflooded within a short time, and numerous landslides occurred, revealing serious defects in the country's existing flood protection system (UNDP BiH, 2021). To primarily protect farmland, the most commonly used flood protection measure was the construction of river embankments and water evacuation facilities. After the floods, the focus was to rehabilitate the existing flood protection system through the reconstruction of the defensive embankments along the rivers and 19 existing pumping stations. These defence strategies were outlined in the technical documentation of several projects: Drina Flood Protection Project, 2014 (World Bank Group, 2025); Bosnia and Herzegovina Flood Risk Management, 2014 (UNDRR, 2014); and Technology transfer for climate resilient flood management in Vrbas River Basin, 2015 (UNDP Climate, 2025). The construction works were often carried out along one of the shorter sections of only one riverbank, by increasing the depth of the existing riverbeds and lining the banks with the aim of increasing the water flow capacity (UNDP, 2021, p. 39). It is evident that these types of flood defence measures are not sufficient to assess the existing vulnerability, indicating the urgent need for active implementation strategies. With the focus on river floods in the mentioned projects, the data in Table 5 shows how river floods were the main flood type occurrence from 2005 until 2014, but the most frequent type of floods after 2014 were floods in general, with flash floods and storms, as presented in Figure 4.

The changes in the climate conditions in Bosnia and Herzegovina are particularly affecting the agricultural sector through increased air temperatures and long-term heat waves, causing droughts and leading to reduced rainfall during the summer period and reduced snow cover retention during the winter period. Severe damage to crop land is additionally caused by intense late frosts in the spring period. The study of Trbić et al. (2021) indicated that these increasing climatic variabilities will intensify in the future. Additionally, the country is facing challenges in implementing flood control plans, inadequate emergency strategies and a lack of awareness of proper flood protection and climate change adaptation.

Tab 5. Overview of flood disaster events in Bosnia and Herzegovina (2005–2025). Source: Table data extracted from the EM-DAT database on February 3, 2025. Data summary, editing and table overview prepared by the author

Year	Location (Village/City, Municipality)	Hydrological disaster subtype and Meteorological disaster subtype	Flood causes	Flood effects
2005	Kneževo municipality, Piskavica village	Blizzard/Winter storm	n.d.	Cold wave
	Bihać, Velika Kladuša municipalities, Bosanska Krupa, Sanski Most, Prijedor, Bosanski Novi	River flood	Heavy rains	Rain
2009	Rastoci, Otok, Rupe, Pridvorci villages (Trebinje municipality), Velicani, Dracevo, Drijenjani, Galicici, Sedlari, Grmljani, Zavala villages (Popovo Polje municipality), Ravno, Velja Meda, Turkovici, Pecina, Trucina, Trebinja, Cvaljina villages (Ravno municipality), Glumina, Gornji Zelenikovac, Donji Zelenikovac, Dobri Do, Hrasno villages (Neum municipality), Svitava village Kardaglije, Jablanica, Dobro poljie, Mekisn Bukva, Medakovo, Trepca, Novo Selo, Tesanjka, Tesanj villages (Tesanj municipality)	River flood	Heavy rains	n.d.

Year	Location (Village/City, Municipality)	Hydrological disaster subtype and Meteorological disaster subtype	Flood causes	Flood effects
2010	Gradacac, Doboj Istok, Gracacina, Srebrenik, Celic, Tuzla, Kalesija, Lukavac, Zivicine, Kladanj municipalities, Tesanj, Doboj Jug municipalities, Kozarska Dubica municipality, Rahic, Satorovici, Bijela, Bukvik, Brka village, Celinac municipality, Derventa municipality, Kotor Varos municipality, Prijedor municipality, Prnjavor municipality, Doboj municipality, Modrica municipality, Teslic municipality	River flood	Torrential rains	n.d.
	Tomislavgrad, Drvar municipalities, Sarajevo, Tmovo, Ilidza municipalities, Foca-Ustikolina, Pale-Praca municipalities, Domaljevac-Samac municipality, Ravno, Capljinska, Citluk, Caplijna, Stolac, Mostar municipalities, Novi Grad municipality, Bijeljina, Visegrad, Zvornik, Tuzla, Gorazde, Trebinje, Bileca, Nevesinje, Foca, Orašje, Maglaj, Bosanska Krupa	River flood	n.d.	Slide (land, mud, snow, rock)
2014	Delibasino city	River flood	n.d.	n.d.
	Sanski Most municipality, Srpski Sanski Most municipality, Banja Luka municipality, Celinac municipality, Kotor Varos municipality, Zenica, Zepce, Maglaj, Vares, Kakanj, Visoko, Olovo, Doboj-Jug, Breza, Doboj-Jug municipalities, Tuzla, Celic, Srebrenik, Gracanica, Gradacac, Kladanj, Lukavac, Sapna, Brcko, Doboj-Istok municipalities, Bijeljina municipality, Brcko municipality, Petrovo municipality, Doboj municipality, Modrica municipality, Samac municipality, Domaljevac-Samac municipality, Zvornik municipality, Bratunac municipality, Srebrenica municipality, Stari Grad Sarajevo municipality, Sekovici municipality	River flood	Heavy rains	Slide (land, mud, snow, rock)
	Banja Luka municipality, Tuzla municipality, Bijeljina municipality, Zepce municipality	River flood	Torrential rain	n.d.
	Cazin municipality	Flash flood	n.d.	n.d.
2015	Knezica village, Kozarska Dubica town and municipality, Novi Grad, Kostajnica, Gradiska, Bihac	Flash flood	n.d.	n.d.
2019	Lukavac, Banovici, Tešanj, Doboj Jug, Sanski Most, Bosanska Krupa, Prijedor, Cazin, Usora, Kljuc, Teslic	Flood (General)	n.d.	n.d.
	Tuzla	Flood (General)	Heavy rains	Slide (land, mud, snow, rock)
2020	Tuzla Canton	Flood (General)	n.d.	Slide (land, mud, snow, rock)
2021	Ilidza, Trnovo, East Ilidza, Stari Grad, Konjic, Jablanica, Novi Grad, Kiseljak, Goražde, Pale, Foča, Sokolac, Gacko, Foča Novo Sarajevo, Zenica, Doboj	Flash flood	Heavy rain and river overflow	Slide (land, mud, snow, rock)
2022	Novi Grad, Gradiška, Sanski Most, , Bihać and Bosanska Krupa municipalities	Flood (General)		Slide (land, mud, snow, rock)
2023	Novi Grad, Prijedor, Kostajnica, Bihac, Bužim, Sanski Most, Cazin, Velika Kladuša, Kljuc, Bosanska Krupa, Kozarska Dubica and Srbac.	Flood (General)	Heavy rains	n.d.
	Brčko District	Storm (General)	n.d.	Flood
2024	Donja Jablanica, Konjic, Buturović polje, Fojnica, Kiseljak and Kreševo	Flood (General)	Heavy rains	Slide (land, mud, snow, rock)

*Note(s): Data in Table 4 includes hydrological disasters and meteorological disasters, due to the storm's impact on inducing floods
n.d. – No data available.

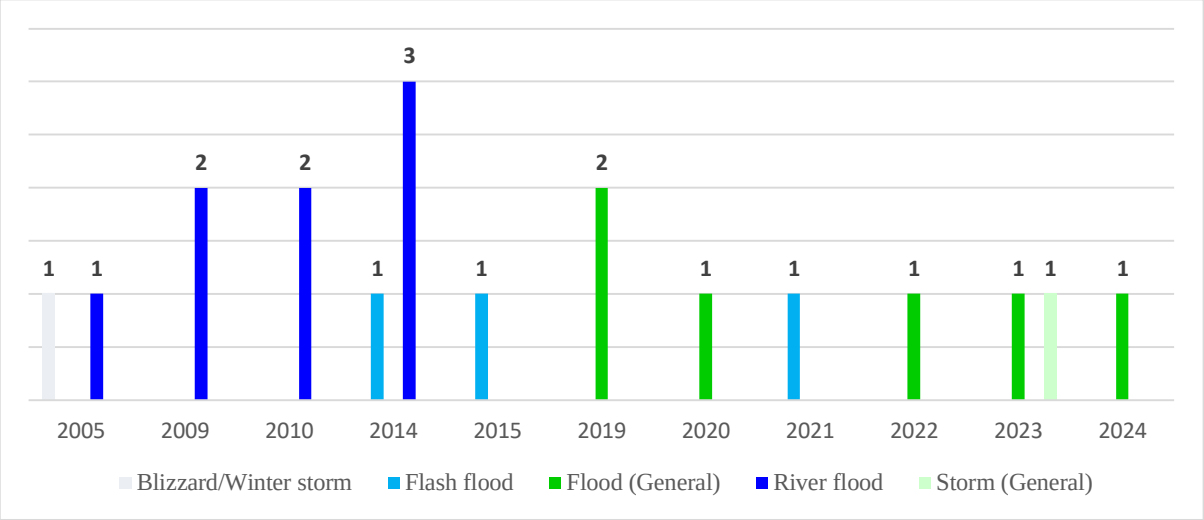


Fig 4. Hydrological and Meteorological disaster subtype occurrences in BiH, 2005–2025. Source: author

Floods in Donja Jablanica (2024)

The latest flood event followed by landslides, mudslides and rockfall, occurred in October 2024, in the area of Jablanica, Konjic, Kiseljak, Kreševo, Fojnica and Mostar municipalities, causing the death of 27 people. Out of 27,716 people living in the flood-affected areas, 322 required the need for evacuation (IOM, 2024). The most destructive flood events occurred in the early morning hours on October 4, in the village of Donja Jablanica, where unprecedented rainfall triggered a rock fall from a nearby quarry and activated landslides and mudslides, which caused the destruction of homes, roads and bridges and resulted in the death of 17 people. Over 1,000 households were affected, and 322 people required evacuation (IOM, 2025). The recovery process included immediate assistance by providing temporary accommodation and humanitarian aid for the displaced people and the mud and debris removal, as seen in Figure 5.

In January 2025, the European Union announced the launch of a flood and landslide recovery project for the affected areas of BiH to "provide permanent housing solutions, restore critical public services and infrastructure and support economic recovery for those impacted by the disaster with the focus on the agricultural producers (micro, small and medium enterprises) in reviving their economic activities" (IOM, 2025, p. 2). Despite their loss and the existing vulnerability of future flood impact, the people in Donja Jablanica are determined to rebuild their lives and their homes in the same flood-affected region. The overview of the flood adaptation process in Bosnia and Herzegovina (2005–2025) is presented in Table 6.



Fig 5. Debris removal in the aftermath of the floods and landslides in Donja Jablanica on October 20, 2024. Source: author

Tab 6. Overview of the flood resilience process in Bosnia and Herzegovina (2005–2025). Source: Table overview prepared by the author

DISASTER CATEGORY/SUBCATEGORY	Natural/ Hydrological disasters
DISASTER SUBTYPE/CATEGORY	Floods
CASE STUDY (country, region/city, month, year of disaster event)	Bosnia and Herzegovina, Donja Jablanica; Konjic; Buturović polje; Fojnica; Kiseljak and Kreševo, October, 2024
	The area of Donja Jablanica with floods and debris flow in October 2024 Image copyright: Federal Civil Protection Administration, BiH –for the purpose of press release for the media. Date of publication: 12.11.2024 https://tuzlainfo.ba/index.php/bosna-i-hercegovina/item/255130-istraga-o-katastrofi-u-donjoj-jablanici-ko-je-odgovoran-za-tragicne-poplave-i-kliziste/#goog_rewarded
FLOOD RESILIENCE STRATEGIES (2005-2025)	
Grey infrastructure	Construction of defence embankments and water evacuation facilities. The construction works were often carried out along one of the shorter sections of only one riverbank by increasing the depth of the existing riverbeds and lining the banks.
Green infrastructure	/
Policy regulations	**Drina Flood Protection Project (2014)** – to provide increased protection from flood events for the communities in the project areas and agricultural interests.
	Bosnia and Herzegovina Flood Risk Management (2014) - to prepare and implement urgent and long-term flood protection measures and facilities, dedicated to: rehabilitation of river dykes, channels, riverbanks, small bridges; replacement and upgrade of pumping stations; preventive measures, including erosion protection and flood risk mapping.
	Technology transfer for climate resilient flood management in Vrbas River Basin (2015) – to develop: Flood Risk Management plan (FRM) for Vrbas river basin (VRB); Flood risks and flood hazard maps for the VRB; Flood forecasting system; Emergency response plans; Training on climate-induced FRM; Implementation of non-structural interventions in municipalities of the VRB; Training to local communities in climate resilient FRM; Preparation and implementation of municipal-level flood response; Implementation of agro-forestation scheme; Index-based flood insurance and credit deference schemes as a means of compensating for flood damages for agriculture.
FLOOD RESILIENCE CAPACITIES	
Flood Mitigation and Adaptation Plan	Assessing the vulnerability of the existing flood protection system Need for active adaptation measures Technology transfer for agricultural flood EU Support to Floods Recovery in BiH Project (2024) – aims to provide permanent housing solutions and support economic recovery for those affected by floods and landslides through the construction and rehabilitation of housing units and the restoration of critical public services and infrastructure. Additionally, the project will assist agricultural producers and micro, small, and medium enterprises (MSMEs) in reviving their economic activities. Rebuilding of the pre-flood housing settlements and infrastructure
Land Use Transformation	/

4. Discussion and concludive remarks

The analytical overview of the selected flood disaster process in Switzerland and Bosnia and Herzegovina from 2005 until 2025, was carried out based on the use of resilience strategies (grey infrastructure, green infrastructure, planning regulations) and resilience capacities (mitigation, adaptation and transformation), by assessing how these measures have been applied during the last 20 years of repeated flood impacts to understand how flood resilience can be observed from a different perspective.

The effectiveness of these measures as an indicator of flood resilience achievement in both countries from 2005 to 2025 was evaluated using six resilience indicators – Risk avoidance, Robustness, Redundancy, Resourcefulness, Rapidity and Recovery and presented in Table 7. Based on the observed theoretical background, the concept of flood resilience emerged from a traditional paradigm of spontaneous adaptation to floods and structural flood protection, toward the application of resilience strategies through grey infrastructure, green infrastructure and policy regulations. Grey infrastructure in both case studies is being implemented through the construction of defence embankments and retaining walls. The only difference is that in Switzerland, these resilience strategies are implemented as a short-term solution to sustain further expansion of the flood impact, as opposed to the implementation in Bosnia and Herzegovina, where these are implemented as the only long-term solutions. In terms of green infrastructure, Bosnia and Herzegovina has no data on implementation, both in planning and practice, while Switzerland is actively working on implementing natural defence systems through the revitalisation of river flows and its adaptation to the increasing climate change. The application of grey and green infrastructure in both countries contributes to the Robustness aspect to absorb and withstand the impact. Both case studies have been actively participating in preparing reports on enhancing flood planning regulations, flood management and flood protection projects and contributing to the Recovery aspect to be able to adapt to new possible risks. However, Bosnia and Herzegovina is still mainly focused on the post disaster process in terms of recovery and rebuilding, while Switzerland has been extensively working on the enhancement of the Risk avoidance aspect as the pre-disaster planning phase, through the implementation of hazard maps, surface runoff risk maps, collection of data on hazards which is accessible to the public and a continuous monitoring process of the slope movement. Evacuating people to higher ground in Switzerland and the ability of self-organising evacuation routes in Bosnia and Herzegovina during the flood impact contribute to the Redundancy aspect of Resilience.

Both countries show specific strengths and weaknesses in terms of achieving resilience through the mitigation and adaptation capacities, but the transformability remains absent. When the adaptation and mitigation capacities exceed their limits, then the flood resilience requires a transformative role in terms of its capacities and relocation of land use in terms of resilience strategies. This is specifically evident in the recent example of disaster events which occurred in the Blatten village in Switzerland. On May 19, 2025, 300 residents were warned and evacuated from the village, since experts, while monitoring the movement on the slopes, spotted a radical change on the local mountain *the Kleines Nesthorn*. The mountain was known for its unstable rock layers. Due to a series of rock avalanches on the Brich glacier below the mountain, in May 28, the glacier collapsed, causing a massive landslide which covered the entire village with three million cubic metres of rock (UNDRR, 2025; SWI, 2025). Despite the extensive material damage, this example shows how the flood monitoring process saved the lives of 300 people. Although there is an ongoing discussion between the authorities who believe that the Blatten village can be rebuilt, experts believe that this is highly unlikely and extremely dangerous to remove the piles of debris and to build again on such unstable land. In the meantime, the new Blatten village is planned to be built in the two nearby hamlets *Eisten* and *Weissenried* and settled by 2030 but leaving the final decision of rebuilding or relocating to the citizens of Blatten (PlanetSKI, 2025). Providing timely evacuation for the 300 residents of the Blatten village, along with temporary accommodation and humanitarian aid for the 322 displaced people from Donja Jablanica, contributes to the aspect of Resourcefulness. It also enhances the aspect of Rapidity through rapid response planning for the new Blatten village and prompt community support in debris and mud removal in Donja Jablanica, alongside the reconstruction of defensive river embankments. In both case studies, the livelihood capacity of the people living in flood-prone rural areas is demonstrated through their decision to either rebuild or relocate. Residents in Donja Jablanica are determined to restore their homes and livelihoods, while in Blatten, residents have been left with the option to decide. As these complex questions will continue to arise, it is evident that the existing resilience framework requires a new perspective in the areas experiencing recurrent flooding and risk of other disaster impacts. In Switzerland, pre-disaster planning measures and continuous flood monitoring successfully saved the lives of 300 residents, while in Donja Jablanica, 17 people lost their lives due to the lack of timely warnings. The effectiveness of the implemented resilience measures in both countries between 2005 and 2025 highlights that an effective flood monitoring process and the use of flood warning systems during the pre-disaster phase are crucial for ensuring prompt evacuation and preserving lives.

Tab 7. Overview of flood resilience achievement in Switzerland and Bosnia and Herzegovina (2005–2025). Source: author

FLOOD RESILIENCE INDICATORS	Effectiveness of flood resilience achievement in Switzerland (2005-2025)	Effectiveness of flood resilience achievement in Bosnia and Herzegovina (2005–2025)
Risk avoidance	**The Swiss Federal Research Institute WSL** systematically collects and analyses data related to floods, debris flows, landslides and rockfall. **Hazard maps** serve as a basis for regional and land use planning and disaster prevention. **StorMe database** – collects data on the natural disasters that occur throughout Switzerland. **The Alertswiss app** for disaster warning. **GIN shared a natural hazards information platform** for monitoring data and information. **The Interferometric Synthetic Aperture Radar (InSAR)** uses images for monitoring slope movement. **The surface runoff risk map** illustrates where the water will flow.	In development; however, no exact data are currently available.
Robustness	Strong retaining walls were built in the river areas to prevent debris flows. Embankments and revitalisation of the River Sorne by creating more space for the river and enlarging its width.	The construction of river embankments and water evacuation facilities
Redundancy	Evacuation to the higher ground levels during the flood impact.	Self-organising evacuation routes, where feasible.
Resourcefulness	300 residents of the Baltten village were warned and evacuated in time before the disaster occurred.	Providing temporary accommodation and humanitarian aid for the 322 displaced people.
Rapidity	The new Blatten village is planned to be built in the two nearby hamlets, Eisten and Weissenried and settled by 2030.	The reconstruction of the defensive embankments along the rivers and 19 existing pumping stations Mud and debris removal.
Recovery	**Flood risk mitigation plan:** Reducing the flood hazard by increasing the drainage system, storage of runoff, enhancing the river capacity and dams and flood embankments. Reducing the flood volume and exposure, by flood plain regulations, redevelopment of land-use policies and housing and building codes. Preserving the natural resources of floodplains, by enlarging the river space to enable space for extreme floods, soil pollution regulation. Increasing the flood awareness through the development of flood hazard maps for every flood prone area. **Comprehensive rehabilitation projects:** To restore 4,000 km of Swiss degraded watercourses and lakeshores by 2090, through the re-establishment of their natural functions. **Livelihood capacity:** Although the new Blatten village is planned to be built and settled by 2030, the final decision of rebuilding or relocating is left to the citizens of Blatten.	**Recovery projects:** Drina Flood Protection Project, 2014. Bosnia and Herzegovina Flood Risk Management, 2014. Technology transfer for climate-resilient flood management in the Vrbas River Basin. The European Union announces the launch of a flood and landslide recovery project for the affected areas of BiH in 2025. **Livelihood capacity:** The people in Donja Jablanica are determined to rebuild their lives and their homes in the same flood-affected region.

Due to an uncertain future with the ever-changing shifts in disaster occurrences and based on the results of the last 20 years of implemented flood resilience strategies, the research results point out the importance of approaching the existing resilience framework from a holistic perspective and understanding that climate adaptation requires flexible and transformative land-use policies in both urban and rural areas as well as a diversified application of resilience strategies. Based on the examples of good practice in building resilience from the theoretical background, relying solely on one resilience strategy may not be sufficient to cope with the predicted increasing flood impact (Section 1). More diverse implementation of resilience strategies contributes to higher mitigation and adaptation capacities, but it

does not necessarily increase resilience. This depends on the feasibility of the resilience strategies and their appropriate implementation by taking into consideration the country's existing vulnerability and the physical and geographical factors (Hegger et al., 2016). It also relies on the active engagement of rural communities in the planning process, which requires more technical support and financial resoures, which can enhance their self-organisational capacities. Cities are already designing multifunctional spaces that enhance climate and social resilience, while rural communities have to start developing transformative land use areas which can preserve the rural environment but also integrate sustainable agricultural development that can enhance flood resilience. The transformation of land use can be used as a concept of achieving balance in the current ongoing dilemma of rebuilding or relocation, but also as an additional step in the entire process of achieving flood resilience in rural areas and the overall preservation of our natural resources.

Academic references

[1] Akay, A. (2019). *The effects of natural disasters caused by climate change*. Ankara: Republic of Turkyie, Ministry of Environment and Urbanisation.

[2] Aloscious, A. A., Artuso, M. & Torabi Moghadam, S. (2025). Nature-Based Solutions for Flood Mitigation: The Case Study of Kochi. *Sustainability*, 17(5), 1983. DOI: 10.3390/su17051983.

[3] Azadgar, A., Nyka, L., Salata, S. (2024). Advancing Urban Flood Resilience: A Systematic Review of Urban Flood Risk Mitigation Model, Research Trends, and Future Directions. *Land* 13(12), 2138. DOI: 10.3390/land13122138.

[4] Chapagain, D., Hochrainen-Stigler, S., Velev, S., Keating, A. & Mechler, R. (2025). Realized resilience after community flood events: A global empirical study. *International Journal of Disaster Risk Reduction,* 118. DOI: 10.1016/j.ijdrr.2025.105246.

[5] Dasgupta, P., Morton, J. F., Dodman, D., Karapinar, B., Meza, F., Rivera-Ferre, M. G., Sarr, A. T., Vincent, K. E. (2014). Rural areas. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C. B., Barros, V. R., Dokken, D. J., Mach, K. J., Mastrandrea, M. D., Bilir, T. E., Chatterjee, M., Ebi, K. L., Estrada, Y. O., Genova, R. C., Girma, B., Kissel, E. S., Levy, A. N., MacCracken, S., Mastrandrea, P. R. and White, L. L. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 613–657.

[6] De Bruijn, K. M. (2003). Resilience strategies for flood risk management under uncertainties. In *Proceedings of the IWRA World Water 2003 Congress: Water Resources Management in the 21st Century, Madrid*. Paris: IWRA.

[7] Dewa, O., Makoka, D. & Ayo-Yusuf, O. A. (2022). Measuring community flood resilience and associated factors in rural Malawi. *Journal of Flood Risk Management*, 16(1), 1–21. DOI: 10.1111/jfr3.12874.

[8] Fang, B., Bevacqua, E., Kumar, R. & Zscheischler, J. (2025). Diverging trends in large floods across Europe in a warming climate. *Communications Earth & Environment*. 6, 717. DOI: 10.1038/s43247-025-02734-y.

[9] Gyawali, N., Devkota, D., Chaudhary, P., Chhetri, A. & Devkota, N. R. (2021). Rural Strategies for Flood Resilience: Analysis of Community Actions in Narayani River Basin, Nepal. *International Journal of Agricultural Extension and Rural Development Studies,* 8(5), 1–16. DOI: 10.37745/ijaerds.15.

[10] Haider, L. J. & Cleaver, F. (2023). Capacities for resilience: persisting, adapting and transforming through bricolage. *Ecosystems and People,* 19(1), 2240434. DOI: 10.1080/26395916.2023.2240434.

[11] Hegger, D. L. T., Driessen, P. P. J., Wiering, M., Van Rijswick, Z., H. F. M., Kundzewicz, W., Matczak, P., Crabbé, A., Raadgever, G. T., Bakker, M. H. N., Priest, S. J. & Larrue, C., Ek, K. (2016). Toward more

flood resilience: Is a diversification of flood risk management strategies the way forward? *Ecology and Society*, 21(4), 52. DOI: 10.5751/ES-08854-210452.

[12] Jeans, H., Castillo, G. E. & Thomas, S. (2017). *The Future is a Choice. Absorb, adapt, transform. Resilience Capacities.* Oxford: OxFam International.

[13] Kim, T., Yi, S., Kim, J. H. & Byun, J. (2025). Disaster resilience analysis framework for lifeline networks: Integrating reliability, redundancy, and recoverability. *International Journal of Disaster Risk Reduction,* 123, 105436. DOI: 10.1016/j.ijdrr.2025.105436.

[14] Kunz, M. & Hurni, L. (2008). Hazard Maps in Switzerland. State of the Art and Potential Improvements. In Hurni, L. & Kriz, K., eds., *Mountain Mapping and Visualisation* (pp. 113–138). Zurich: ETH.

[15] Laidlaw, S. & Percival, S. (2024). Flood resilience: a review of evolving definitions. *Natural Hazards,* 120, 10773-10884. DOI: 10.1007/s11069-024-06627-9.

[16] Leroy, J., Amdal, J., Vuillet, M., Cariolet, J. M., Diab, Y. & Becue, Y. (2016). Vulnerability and social resilience: comparison of two neighborhoods in New Orleans after Hurricane Katrina. *E3S Web of Conferences, 7*(2), 1–10. DOI: 10.1051/e3sconf/20160708002.

[17] Liu, W., Ni, Y., Feldman, M. & Xu, D. (2025). Livelihood Resilience and Disaster Preparedness Among Farmers in Flood Risk Areas of Rural China. *Water*, 17(16), 2454. DOI: 10.3390/w17162454.

[18] McClymont, K., Morrison, D., Beevers, L. & Carmen, E. (2020). Flood resilience: a systematic review. *Journal of Environmental Planning and Management,* 63(7), 1151–1176. DOI: 10.1080/09640568.2019.1641474.

[19] Meng, J. & Yue, Z. (2024). Urban and Rural Flood Adaptation and Its Planning Application in Floodplains. *Journal of Resources and Ecology,* 15(6), 1488–1501. DOI: 10.5814/j.issn.1674-764x.2024.06.008.

[20] Molnar, P., Chang, Y. Y., Peleg, N., Moraga, S., Zappa, M., Brunner, M. I., Seibert, J., Freudiger, D., Martius, O. & Mülchi, R. (2020). Future changes in floods. In Ruiz-Villanueva, V. & Molnar, P., eds., *Past, current, and future changes in floods in Switzerland* (pp. 51–58). Bern: Federal Office for the Environment. DOI: 10.3929/ethz-b-000458556.

[21] Omićević, N. & Bojanić Obad Šćitaroci, B. (2023). *The Urban Rehabilitation of Post-disaster Scapes.* Springer Singapore. DOI: 10.1007/978-981-19-9505-7.

[22] Palazzo, E. (2025). Sponge Landscapes: Flood Adaptation Landscape Type Framework for Resilient Agriculture. *Land*, 14(10), 2023. DOI: 10.3390/land14102023.

[23] Paprotny, D., Tilloy, A., Treu, S., Buch, A., Vousdoukas, M., Feyen, L., Kreibich, H., Merz, B., Frieler, K. & Mengel, M. (2025). Attribution of flood impacts shows strong benefits of adaptation in Europe since 1950. *Sciences Advances,* 11(33). DOI: 10.1126/sciadv.adt7068.

[24] Qamar, A. A. (2024). Social Resilience: A Critical Synopsis of Definitions. *Corvinus Journal of Sociology and Social Policy,* 15, 129–147. DOI: 10.14267/CJSSP.2024.1.6.

[25] Rajasekar, U., Shankar, V., Thool, P., Dutta, M. & Bhaisare, M. (2022). *A catalogue of best practices for building flood resilience*. Delhi: National Institute of Urban Affairs.

[26] Rindsfuser, N., Mosimann, M., Keiler, M. & Zischg, A. P. (2025). Flood risk monitoring in Switzerland: Proof of concept. *International Journal of Disaster Risk Reduction* 119, 105337. DOI: 10.1016/j.ijdrr.2025.105337.

[27] Ruiz-Villanueva, V., Molnar, P., Schmocker-Fackel, P., Andres, N., Zappa, M. (2020), Recent floods: changes in floods since the 19th Century. In Ruiz-Villanueva, V. & Molnar, P., eds., *Past, current, and future changes in floods in Switzerland* (pp. 29–37). Bern: Federal Office for the Environment. DOI: 10.3929/ethz-b-000458556.

[28] Ruiz-Villanueva, V. & Molnar, P., eds., *Past, current, and future changes in floods in Switzerland* (pp. 51–58). Bern: Federal Office for the Environment. DOI: 10.3929/ethz-b-000458556.

[29] Savić, D. (2025). Urban Flood Risk and Resilience: How Can We Protect Our Cities from Flooding? *Hydrology*. *12*(4), 78. DOI: 10.3390/hydrology12040078.

[30] Trbic, G., Popov, T., Djurdjevic, V., Milunovic, I., Dejanovic, T., Gnjato, S. & Ivanisevic, M. (2022). Climate Change in Bosnia and Herzegovina According to Climate Scenario RCP8.5 and Possible Impact on Fruit Production. *Atmosphere*, 13(1), 1. DOI: 10.3390/atmos13010001.

[31] Walker, B., Holling, C. S., Carpenter, S. R. & Kinzig, A. (2004). Resilience, adaptability and transformability in social–ecological systems. *Ecology and Society,* 9(2), 5. DOI: 10.5751/ES-00650-090205.

[32] Zevenbergen, C., Gersonius, B. & Radhakrishan, M. (2020). Flood resilience. *Philosophical Transactions A* 378(2168), 20190212. DOI: 10.1098/rsta.2019.0212.

Other sources

[33] CRED/UCLouvain, (2025). Hydrological Hazards. Available online: https://doc.emdat.be/docs/data-structure-and-content/glossary/hydrological-hazards/. Accessed 16 July, 2025.

[34] Federal Office for the Environment (2020). Natural Hazards. The Environment. Natural resources in Switzerland. Available online: https://www.bafu.admin.ch/en/publication?id=UCNqABEsnLJb.

[35] Federal Office for the Environment (2025). Evaluating the outcome of restoration projects – Collaborative learning for the future. Available online: https://www.bafu.admin.ch/dam/en/sd-web/04PKyPu0s7fm/Outcome_restoration_Collaborative_learning_20250131.pdf.

[36] Federal Office for the Environment (2008). The Floods of 2005 in Switzerland. The Federal Department for the Environment, Transport, Energy and Communications (DETEC). Bern, Switzerland. Available online: https://www.preventionweb.net/files/10580_index1.pdf?startDownload=true.

[37] IFAD (2009). *Climate Change: Building the Resilience of Poor Rural Communities*. International Fund for Agricultural Development, Rome, Italy. Available online: https://reliefweb.int/report/world/climate-change-building-resilience-poor-rural-communities. Last accessed: December 20, 2025.

[38] IOM (2024). *2024 Flood and Landslide Disaster Response. Focus on displacement in Bosnia and Herzegovina*. International Organization for Migration (IOM) Bosnia and Herzegovina. Available online: https://bih.iom.int/sites/g/files/tmzbdl1076/files/documents/2024-12/2024-flood-and-landslide-response-situation-report-26-december_final-eng.pdf.

[39] IOM (2025). *2024–2025 Flood and Landslide Disaster Response. Focus on displacement in Bosnia and Herzegovina*. International Organization for Migration (IOM) Bosnia and Herzegovina. Available online: https://bih.iom.int/sites/g/files/tmzbdl1076/files/documents/2025-01/eng-iom-bih-2024-2025-flood-and-landslide-response-situation-report-9-23-january-2025.pdf.

[40] IPCC (2014). Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C. B., V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea, and L .L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1–32. Available online: https://www.ipcc.ch/site/assets/uploads/2018/03/ar5_wgII_spm_en-1.pdf.

[41] Landscape Architecture Built (2025). Yanweizhou Park. Aritcle published online: https://landscapearchitecturebuilt.com/yanweizhou-park-2/. Accessed on December 20, 2025.

[42] OECD (2016). *Financial Management of Flood Risk*, Paris: OECD Publishing. DOI: 10.1787/9789264257689-en.

[43] OECD (2020). *Strengthening Agricultural Resilience in the Face of Multiple Risks*, Paris: OECD Publishing. DOI: 10.1787/2250453e-en.

[44] Oppla (2025). Rotterdam – NbS for building a waterproof city. Available online: Rotterdam – NbS for building a waterproof city | Oppla. Accessed on December 20, 2025.

[45] PlanetSKI (2025). One month after Blatten Landslide What is the Future of the Swiss Village? Available online: https://planetski.eu/2025/06/27/one-month-after-blatten-landslide-what-is-the-future-of-the-swiss-village/. Accessed on July 10, 2025.

[46] Reuters (2024). Heavy rains trigger floods and landslides in Switzerland. Available online: https://www.reuters.com/world/europe/heavy-rains-trigger-floods-landslides-switzerland-2024-06-22/. Accessed June 12, 2025.

[47] SWI (2024). How Switzerland is trying to defeat extreme weather events. Available online: https://www.swissinfo.ch/eng/alpine-environment/body-recovered-from-graub%C3%BCnden-river-following-floods/82067515. Accessed June 12, 2025.

[48] SWI (2025). Flood risk threatens Swiss valley after 'millennium event' glacier collapse. Available online: https://www.swissinfo.ch/eng/various/flood-risk-threatens-swiss-valley-after-glacier-collapse/89433920. Accessed June 12, 2025.

[49] UNDP BiH (2021). Bosnia and Herzegovina National Adaptation Plan – NAP with proposed measures. Available online: https://www.undp.org/bosnia-herzegovina/publications/national-adaptation-plan-nap-bosnia-and-herzegovina.

[50] UNDRR (2014). Bosnia and Herzegovina Floods 2014 Recovery Needs Assessment. World Bank Group. Available online: https://www.preventionweb.net/quick/69706_UNISDR (2009). *2009 UNISDR terminology on disaster risk reduction*. UNISDR-20-2009-Geneva. Available online: https://www.preventionweb.net/files/7817_UNISDRTerminologyEnglish.pdf.

[51] UN-HABITAT, Social Resilience Guide. 2012–2025 United Nations Human Settlements Programme. Available online: Urban Resilience Enhancer: Social Resilience | UN-Habitat.

[52] United Nations Office for Disaster Risk Reduction, UNDRR. (2020). *The human cost of disasters: an overview of the last 20 years (2000-2019).* Centre for Research on the Epidemiology of Disasters (CRED). Available online: https://www.preventionweb.net/files/74124_humancostofdisasters20002019reportu.pdf.

[53] UNDP Climate (2025). Technology Transfer for Climate Resilient Flood Management in Bosnia and Herzegovina's Vrbas River Basin. Available online: https://www.adaptation-undp.org/projects/technology-transfer-climate-resilient-flood-management-bosnia-and-herzegovinas-vrbas-river. Last accessed: December 20, 2025.

[54] United Nations Office for Disaster Risk Reduction, UNDRR (2017). The Sendai Framework Terminology on Disaster Risk Reduction. "Capacity". Accessed 23 December 2025. https://www.undrr.org/terminology/capacity.

[55] United Nations Office for Disaster Risk Reduction, UNDRR, (2017a). The Sendai Framework Terminology on Disaster Risk Reduction. "Resilience". Available online: https://www.undrr.org/terminology/resilience. Accessed July 10, 2025.

[56] United Nations Office for Disaster Risk Reduction, UNDRR, (2017b). The Sendai Framework Terminology on Disaster Risk Reduction. "Mitigation". https://www.undrr.org/terminology/mitigation. Accessed 16 July 2025.

[57] United Nations Office for Disaster Risk Reduction, UNDRR (2022). The underestimated risk of flooding in Switzerland. Available online: https://www.preventionweb.net/quick/70035. Accessed 12 May 2025.

[58] United Nations Office for Disaster Risk Reduction, UNDRR (2025). Glacier collapse destroys Swiss village of Blatten – More melting giants to follow? Available online: https://www.preventionweb.net/news/glacier-collapse-destroys-swiss-village-blatten-more-melting-giants-follow. Author(s): Christian Fischer. Accessed on July 10, 2025.

[59] World Bank Group (2025). Bosnia and Herzegovina – Drina Flood Protection Project environmental assessment (Vol. 1). Environmental management plan for sub-project Gorazde. Bosnia and Herzegovina. Available online: https://documents1.worldbank.org/curated/en/701671468199473676/pdf/E44300V10ECA0E00Box382138B00PUBLIC0.pdf.

[60] World Bank (2021). *A Catalogue of Nature-based Solutions for Urban Resilience. Washington, D.C*. World Bank Group. DOI: 10.1596/36507.

[61] Zurich (2025). Three common flood types explained. Available online: https://www.zurich.com/knowledge/topics/flood-and-water-damage/three-common-types-of-flood. Accessed May 20, 2025.

[62] Zurich Flood Resilience Alliance (2019). The Flood Resilience Measurement for Communities (FRMC). Available online: https://www.ifrc.org/sites/default/files/2021-07/Flood-resilience-measurement-communities-brochure.pdf. Accessed on January 10, 2026.

APPENDIX I

Tab 1. Overview of flood disaster events in Europe (2005–2025). Source: Table data extracted from the EM-DAT database on February 3, 2025. Summary, data editing and table overview prepared by the author

Year	Country	Flood type (Flood – general/Fluvial – riverine flood/Pluvial – flash flood)	Total number of deaths	Flood causes	Flood effects
2005	Czechia	River flood	1	Heavy rains and melting snow	/
	Hungary	River flood		Heavy rains and melting snow	/
	Poland	River flood	2	Heavy rains and melting snow	/
	Romania	River flood	2	Heavy rains, melting snow	Slide (land, mud, snow, rock)
	Slovakia	River flood	1	Heavy rains and melting snow	/
	Ukraine	Flood (General)		/	/
	Romania	River flood	2	Heavy rains	Broken Dam/Burst bank Slide (land, mud, snow, rock)
	Serbia Montenegro	River flood	2	Heavy rains	Broken Dam/Burst bank
	Russian Federation	River flood	3	Heavy rains and ice	Broken Dam/Burst bank
	Russian Federation	Flood (General)		/	/
	Bulgaria	River flood	6	Heavy rain	Rain
	Russian Federation	River flood		Heavy rains	Broken Dam/Burst bank Slide (land, mud, snow, rock)
	Russian Federation	River flood		Heavy rains	Broken Dam/Burst bank
	Finland	River flood		Large amount of snow during winter and late onset of spring thaw	/
	Romania	River flood	8	Heavy rains	Broken Dam/Burst bank Rain
	Bulgaria	River flood	17	Heavy rains	Broken Dam/Burst bank Slide (land, mud, snow, rock)
	Austria	River flood		Heavy rains	/
	Germany	River flood		Heavy rains	/
	Romania	River flood	24	Heavy rains	/
	Lithuania	River flood		Heavy rains	/
	North Macedonia	River flood		Heavy rains	/
	Austria	River flood	4	Heavy rains	/
	Switzerland	River flood	6	Heavy rains	/
	Germany	River flood	1	Heavy rains	/

	Russian Federation	River flood	19	Heavy rains	/
	Bulgaria	River flood	7	/	/
	Hungary	River flood		Heavy rains	/
	Romania	River flood	33	Heavy rains	/
	Slovenia	River flood		/	/
	Belgium	Flash flood		Thunderstorm	Slide (land, mud, snow, rock)
	France	Flash flood	1	Violent thunderstorms	Slide (land, mud, snow, rock)
	Republic of Moldova	River flood		Heavy rains and storms	/
	Bulgaria	River flood	2	Heavy rains	/
	Romania	River flood	10	Heavy rains	/
	France	River flood	2	Heavy rains	/
	Bosnia and Herzegovina	River flood		Heavy rains	Rain
	Albania	River flood	3	Heavy rains	/
	Bulgaria	River flood	7	Heavy rains	Slide (land, mud, snow, rock)
	Croatia	River flood		Heavy rains	/
2006	Serbia Montenegro	River flood		Rain and snowmelt	Broken Dam/Burst bank
	Romania	River flood		Heavy rains	/
	Austria	River flood		Rains and snowmelt	Broken Dam/Burst bank
	Bulgaria	River flood		/	/
	Czechia	River flood	6	Rains and snowmelt	Broken Dam/Burst bank
	Germany	River flood		Rains and snowmelt	Broken Dam/Burst bank
	Croatia	River flood		Snowmelt and heavy rain	/
	Hungary	River flood		Snowmelt and strong rains	/
	Romania	River flood	6	Snowmelt	Rain
	Serbia Montenegro	River flood		Snowmelt and heavy rains	Slide (land, mud, snow, rock)
	Slovakia	River flood	1	Heavy rains and snowmelt	/
	Bulgaria	River flood		/	/
	Romania	River flood		Rains and snowmelt	Broken Dam/Burst bank
	Ukraine	River flood		/	Broken Dam/Burst bank
	Russian Federation	River flood		Snowmelt	/
	Poland	River flood		Heavy rain	/
	Slovakia	River flood		Heavy rain and unseasonable snow	/
	Russian Federation	River flood		Rain and snowmelt, excessive dumping of water	Broken Dam/Burst bank
	Romania	Flash flood	14	Torrential rain	Slide (land, mud, snow, rock)
	Romania	River flood	1	/	Rain
	Ukraine	River flood	2	Heavy rain	Broken Dam/Burst bank
	Romania	River flood	30	Heavy rains	/

	Czechia	Flood (General)			/
	Russian Federation	River flood		Heavy rain	/
	Switzerland	River flood		Heavy rain	/
	North Macedonia	River flood		Heavy rains	Slide (land, mud, snow, rock)
	Greece	River flood	1	Heavy rain	Rain Slide (land, mud, snow, rock)
	Greece	River flood		Heavy rain	Slide (land, mud, snow, rock)
	Spain	River flood		Heavy rain	/
	Portugal	River flood		Heavy rains	Slide (land, mud, snow, rock)
2007	Romania	Flash flood		Torrential rain	Slide (land, mud, snow, rock)
	Spain	River flood	1	Heavy rain and snowmelt	/
	Bulgaria	River flood	2	Heavy rain	/
	Spain	River flood	1	Heavy rain	/
	Russian Federation	River flood		Snowmelt, Ice jam/break-up	/
	United Kingdom of Great Britain and Northern Ireland	River flood	1	Heavy rain, thunderstorms	Broken Dam/Burst bank
	United Kingdom of Great Britain and Northern Ireland	River flood	6	Heavy rain	/
	United Kingdom of Great Britain and Northern Ireland	River flood	7	Hevay rains	Rain
	Bulgaria	River flood	8	Heavy rains	/
	Romania	Flood (General)	3	/	Rain
	Switzerland	River flood	1	Heavy rain	/
	Germany	River flood	1	Heavy rain	/
	Romania	River flood	2	/	Rain
	Romania	River flood	7	Heavy rains	/
	Spain	River flood	3	Heavy rains	/
	Bulgaria	River flood	2	Heavy rain	/
	Greece	River flood	2	Heavy Rain	/
	Montenegro	Flash flood		Heavy rain and melting snow	Broken Dam/Burst bank
	Serbia	Flash flood		Heavy rain and melting snow	/
2008	United Kingdom of Great Britain and Northern Ireland	River flood		Heavy rain	/
	Portugal	River flood	2	Heavy rains	Slide (land, mud, snow, rock)

	Italy	River flood	4	/	Slide (land, mud, snow, rock)
	Republic of Moldova	River flood	3	/	Rain
	Romania	River flood	5	Heavy rains	/
	Ukraine	River flood	38	Heavy rains and thunderstorms	Rain
	United Kingdom of Great Britain and Northern Ireland	River flood	8	Torrential rain	Rain
	Italy	Flood (General)	2	/	Slide (land, mud, snow, rock)
	Italy	River flood	3	Heavy rain	Rain
2009	Romania	River flood	11	Snowmelt	/
	Bosnia and Herzegovina	River flood		Heavy rains	/
	Austria	River flood	1	Heavy rains	Slide (land, mud, snow, rock)
	Czechia	River flood	13	Heavy rain	/
	Germany	River flood		Heavy rains	/
	Poland	River flood	1	Heavy rains	/
	Romania	River flood		/	Lightening
	Bosnia and Herzegovina	River flood		Heavy rain	/
	Austria	River flood		Heavy rains	/
	Italy	River flood	35	Heavy rains	Slide (land, mud, snow, rock)
	United Kingdom of Great Britain and Northern Ireland	River flood	3	Heavy rains	/
	Ireland	River flood		Heavy rains	/
	Serbia	River flood		Heavy rains	Slide (land, mud, snow, rock)
	Montenegro	River flood		Heavy and constant rain	/
	Albania	River flood		Heavy rains, melting snow	/
2010	Portugal	River flood	43	Torrential rain	Rain Slide (land, mud, snow, rock)
	Serbia	Flash flood		Heavy rains, Rapid snow melting	/
	Russian Federation	River flood		Sharp increase in temperatures triggering melting snow	/
	Czechia	River flood	1	Heavy rains	Slide (land, mud, snow, rock)
	Croatia	River flood		Heavy rains	/
	Hungary	River flood	1	Heavy rains	/
	Poland	River flood	16	Heavy rains	Broken Dam/Burst bank
	Serbia	River flood	2	Heavy rains	/
	Slovakia	River flood	1	/	/
	Czechia	River flood	3	/	/
	Slovakia	River flood	3	Heavy rains	/

	France	Flash flood	25	Torrential rain	Slide (land, mud, snow, rock)
	Romania	River flood	26	Heavy rains	/
	Bosnia and Herzegovina	River flood		Torrential rains	/
	Ukraine	River flood	6	Heavy rains	/
	Republic of Moldova	River flood	1	Heavy rains	/
	Czechia	Flash flood	7	/	Flood
	Germany	Flash flood	3	/	Flood
	Lithuania	Flash flood	4	/	Lightening
	Poland	Flash flood	3	/	Broken Dam/Burst bank
	Russian Federation	River flood	23	Torrential rains	/
	Italy	River flood		Heavy rains	/
	Montenegro	River flood		Heavy rains	/
	Belgium	River flood	3	Heavy rains	Slide (land, mud, snow, rock)
	Albania	River flood		/	/
	Bulgaria	River flood		/	/
	Bosnia and Herzegovina	River flood	3	/	Slide (land, mud, snow, rock)
	Greece	River flood	1	/	/
	Croatia	River flood		Heavy rains	/
	Montenegro	River flood		/	/
	Serbia	River flood		/	/
	Spain	River flood	2	/	Rain
2011	Russian Federation	River flood		Heavy rains	/
	Russian Federation	River flood		Heavy rains	Broken Dam/Burst bank
	Italy	Flash flood	10	Torrential rain	Slide (land, mud, snow, rock)
	Italy	Flash flood	6	Heavy rains	/
	France	River flood	6	Heavy rains	/
	Ireland	River flood	2	Heavy rain	/
	Spain	River flood	1	Heavy rains	/
2012	Bulgaria	River flood	5	Heavy rains and melting snow	Broken Dam/Burst bank
	Greece	River flood	1	Torrential rain	/
	Russian Federation	River flood		Temperature, melting snow and spring rains	/
	Russian Federation	Flash flood	172	/	/
	Russian Federation	River flood		/	/
	Russian Federation	River flood	7	Torrential rains	/
	United Kingdom of Great Britain and Northern Ireland	River flood	3	Heavy rains, hurricane Nadine	/
	Spain	River flood	10	/	/
	Italy	River flood	4	Torrential rain	/

	United Kingdom of Great Britain and Northern Ireland	River flood		Heavy rains	/
	United Kingdom of Great Britain and Northern Ireland	River flood		One month worth-of-rainfall	/
	United Kingdom of Great Britain and Northern Ireland	Flash flood	1	/	/
	Croatia	River flood		/	/
	Slovenia	River flood		Heavy rains	/
	United Kingdom of Great Britain and Northern Ireland	River flood	4	Torrential rains	/
2013	North Macedonia	River flood	1	Heavy rains	/
	Serbia	River flood		Heavy rains	/
	Austria	River flood	4	Heavy rains	Slide (land, mud, snow, rock)
	Czechia	River flood	15	Heavy rains	Slide (land, mud, snow, rock)
	Germany	River flood	4	/	/
	Hungary	River flood		/	/
	Slovakia	River flood	1	/	/
	Spain	Flash flood		/	/
	France	Flash flood	2	/	/
	Russian Federation	River flood		Heavy rains	/
	Russian Federation	River flood	4	Torrential rains	/
	Romania	River flood	9	Torrential rains	/
	Serbia	Flash flood		Heavy rains	/
	Ukraine	River flood	2	/	/
	Italy	River flood	18	Cyclone Cleopatra	/
	United Kingdom of Great Britain and Northern Ireland	River flood	2	Heavy rains	/
2014	Italy	Flash flood	2	Heavy rains	Slide (land, mud, snow, rock)
	France	River flood	4	Heavy rains	/
	United Kingdom of Great Britain and Northern Ireland	River flood		Heavy rains	/
	Italy	River flood	4	/	Slide (land, mud, snow, rock)
	Bulgaria	River flood		Heavy rains and melting snow	/
	Bosnia and Herzegovina	River flood		/	/

	Romania	River flood		Heavy rains and melting snow	/
	Serbia	River flood		Heavy rains and melting snow	Slide (land, mud, snow, rock)
	Bosnia and Herzegovina	River flood	25	Heavy rains	Slide (land, mud, snow, rock)
	Croatia	River flood	3	/	/
	Serbia	River flood	51	Heavy rains	Slide (land, mud, snow, rock)
	Russian Federation	River flood	6	Torrential rains	/
	Bulgaria	River flood	15	Torrential rains	Hailstorm
	Italy	Flash flood	3	Torrential rain	/
	Bulgaria	River flood	2	Heavy rains	Broken Dam/Burst bank
	Romania	River flood	4	Heavy rains	/
	Bosnia and Herzegovina	River flood	1	Torrential rain	/
	Serbia	River flood	1	Torrential rains	/
	Hungary	River flood		Heavy and unseasonal rain	/
	Bosnia and Herzegovina	Flash flood		/	/
	Croatia	Flash flood		Heavy rains	/
	Serbia	Flash flood	4	Massive rainfalls	Slide (land, mud, snow, rock)
	Slovenia	River flood	3	Torrential rains	Slide (land, mud, snow, rock)
	Bulgaria	River flood	3	Severe thunderstorm and heavy rainfall	/
	Greece	Flash flood		Depression 'Gonzalo'	Storm
	Italy	Flash flood	1	Torrential rain	Slide (land, mud, snow, rock)
	France	River flood	5	Heavy rains	/
	France	Flash flood	5	Heavy rains	Lightening
2015	Albania	River flood		Heavy rains	Slide (land, mud, snow, rock)
	North Macedonia	River flood		Heavy rains	/
	Albania	River flood		/	/
	Bulgaria	River flood	5	Heavy rains and strong winds	/
	Greece	River flood		/	/
	Romania	Flood (General)	1	Heavy rains	/
	Russian Federation	River flood	1	/	/
	North Macedonia	Flash flood	7	Torrential rain	Slide (land, mud, snow, rock)|Storm
	Greece	Flood (General)	3	Heavy rain	/
	Spain	Flash flood	4	/	/
	France	Flash flood	20	Torrential rain	/
	Bosnia and Herzegovina	Flash flood		/	/

	Croatia	Flash flood		/	/
	Italy	Flash flood	4	Heavy rains	Slide (land, mud, snow, rock)
	Spain	Flash flood	4	/	/
	Italy	Flash flood	2	/	/
	Portugal	Flash flood	1	/	/
	Albania	Flood (General)	1	Heavy rain	/
	United Kingdom of Great Britain and Northern Ireland	River flood		Heavy rains, Storms Eva ad Franck	/
	Italy	Flash flood		Heavy rains	/
2016	Serbia	Flash flood		Torrential rains	/
	Russian Federation	Flood (General)		Snowmelt, Ice jams and rising temperatures	/
	Austria	Flood (General)		Heavy rains	/
	Belgium	Flood (General)	1	Thunderstorms	/
	Germany	Flood (General)	7	Heavy rains	
	France	Flood (General)	5	Heavy rains	Lightening
	Poland	Flood (General)	2	/	Lightening
	Romania	Flood (General)	2	Heavy rains	/
	Russian Federation	Flood (General)		Torrential rains	Slide (land, mud, snow, rock), Storm
	North Macedonia	Flash flood	22	/	Slide (land, mud, snow, rock), Storm
	Russian Federation	Flood (General)		Heavy rains	Lightening
	Greece	Flood (General)	4	Torrential rains	/
	Albania	Flood (General)	2	Heavy rains	/
	Romania	River flood	1	Heavy rains	/
	Ukraine	Flood (General)	3	Heavy rains	Storm
	Serbia	Flash flood		Heavy rains	/
	Italy	River flood	2	Heavy rains	/
	Hungary	Flood (General)			Hail
	Spain	Flash flood	5	Heavy rains	/
2017	Russian Federation	Flash flood			/
	Germany	River flood		Low pressure Alfred	/
	France	Flash flood	1	Torrential rains	/
	Greece	Flash flood	23	Torrential rains	Slide (land, mud, snow, rock)
	United Kingdom of Great Britain	Flood (General)		Heavy rains	/

	and Northern Ireland				
	Ireland	Flood (General)		Heavy rains	/
	Albania	Flash flood	1	Heavy rains	Slide (land, mud, snow, rock)
	Italy	River flood		Snowmelt, Rain	/
2018	France	Flood (General)		Heavy rains	/
	Albania	Flood (General)		Heavy rains, melting snow	Broken Dam/Burst bank Slide (land, mud, snow, rock)
	Croatia	Flash flood		Heavy rains, snow melt	Slide (land, mud, snow, rock)
	Belarus	Flood (General)		/	/
	Russian Federation	Flood (General)	2	Melting snow	/
	Romania	Flood (General)		Heavy Rain and Snowmelt	Slide (land, mud, snow, rock)
	Bulgaria	Flood (General)		Torrential rain	/
	Serbia	Flash flood		/	Lightening
	Romania	Flash flood		/	/
	Italy	Flash flood	10	/	/
	Spain	Flood (General)	13	/	/
	France	Flood (General)	14	Torrential rains	/
	Russian Federation	Flood (General)	8	/	Storm
2019	Spain	River flood	4	Heavy rains	Slide (land, mud, snow, rock)
	Bosnia and Herzegovina	Flood (General)	1	/	/
	Croatia	Flood (General)	1	/	/
	Italy	Flood (General)		Heavy rains	/
	Romania	Flood (General)	4	/	Hailstorm
	Serbia	Flood (General)		/	/
	Bosnia and Herzegovina	Flood (General)		Heavy rains	Slide (land, mud, snow, rock)
	Russian Federation	Flood (General)	31	Heavy rains	/
	Spain	Flash flood	1	Heavy rains	Storm
	Spain	Flood (General)	7	/	Storm
	Russian Federation	Flood (General)		Heavy rains	/
	Russian Federation	Flood (General)		/	/

	Russian Federation	Flood (General)	28	/	Broken Dam/Burst bank Collapse
	Spain	Flood (General)	5	Heavy rains	Slide (land, mud, snow, rock)
	France	Flood (General)	3	/	/
	United Kingdom of Great Britain and Northern Ireland	Flood (General)	1	/	/
	France	Flood (General)	5	/	Slide (land, mud, snow, rock)
2020	United Kingdom of Great Britain and Northern Ireland	River flood		Heavy rains	/
	France	Flood (General)		Heavy rains	/
	France	Flash flood		Heavy rains	/
	Poland	Flood (General)		/	/
	Ukraine	Flood (General)	3	Heavy rains	/
	Bosnia and Herzegovina	Flood (General)		/	Slide (land, mud, snow, rock)
	Serbia	Flood (General)		/	Slide (land, mud, snow, rock)
	Romania	Flood (General)	3	Heavy rains	/
	Greece	Flood (General)	8	Heavy rains	/
	Slovakia	Flood (General)	1	/	/
	France	Flash flood	2	Heavy rains	/
	Greece	Flash flood		/	/
	Italy	Flash flood	3	Heavy rains	Slide (land, mud, snow, rock)
	Italy	Flood (General)	2	Heavy rain	Snow/ice Storm
	Italy	Flood (General)		Heavy rains	/
2021	Albania	Flood (General)		Heavy rains	/
	Bulgaria	Flood (General)		Heavy rains	/
	Serbia	Flood (General)		Heavy rains	/
	France	Flood (General)		Heavy rains	/
	Slovakia	Flash flood	1	Heavy rains	Broken Dam/Burst bank
	France	Flash flood	1	Heavy rains	Lightening
	Romania	Flood (General)	1	Heavy rains	/
	Russian Federation	Flood (General)	8	Heavy rains	Storm

Austria	Flood (General)	1	Torrential rainfall caused by a slow-moving area of low pressure – named “Bernd”	Slide (land, mud, snow, rock)
Belgium	Flood (General)	39	Torrential rainfall caused by a slow-moving area of low pressure – named “Bernd”	/
Switzerland	Flood (General)		Torrential rainfall caused by a slow-moving area of low pressure – named “Bernd”	/
Czechia	Flood (General)		Torrential rainfall caused by a slow-moving area of low pressure – named “Bernd”	Hail
Germany	Flood (General)	226	Torrential rainfall caused by a slow-moving area of low pressure – named “Bernd”	Slide (land, mud, snow, rock)
France	Flood (General)		Torrential rainfall caused by a slow-moving area of low pressure – named “Bernd”	Slide (land, mud, snow, rock)
Italy	Flood (General)	1	/	Hailstorm
Luxembourg	Flood (General)		Torrential rainfall caused by a slow-moving area of low pressure – named “Bernd”	Slide (land, mud, snow, rock)
Netherlands (Kingdom of the)	Flood (General)		Torrential rainfall caused by a slow-moving area of low pressure – named “Bernd”	/
Poland	Flood (General)		Torrential rainfall caused by a slow-moving area of low pressure – named “Bernd”	Storm
Russian Federation	Flood (General)		Heavy rains	/
Spain	Flash flood	2	Related to a phenomenon locally referred to as "DANA" or a cold drop	Lightening
Russian Federation	Flood (General)		Heavy rains	/
Sweden	Flash flood		Heavy rains	/
France	Flood (General)		Heavy rains	Lightening

	Slovenia	Flood (General)		Heavy rains	/
	Bosnia and Herzegovina	Flash flood		Heavy rain and river overflow	Slide (land, mud, snow, rock)
	France	Flood (General)	1	Heavy rains	/
	Spain	Flood (General)	1	Cut-off low pressure area (locally referred to as DANA)	Slide (land, mud, snow, rock) Snow/ice
	France	Flood (General)		Heavy rains	Slide (land, mud, snow, rock)
2022	Russian Federation	Flood (General)	1	Heavy rains	/
	Bulgaria	Flash flood		Heavy rains	/
	Italy	Flood (General)	12	Heavy rains	Slide (land, mud, snow, rock) Storm
	Bosnia and Herzegovina	Flood (General)	1	/	Slide (land, mud, snow, rock)
	Croatia	Flood (General)		/	/
2023	Serbia	River flood	2	Heavy rainfall and river overflow	/
	Belarus	Flood (General)		Heavy rainfall and snowmelt	/
	Latvia	Flood (General)		Heavy rainfall and snowmelt	/
	Ukraine	Flood (General)		/	Storm
	Italy	Flood (General)	2	Heavy rains	Slide (land, mud, snow, rock)
	Czechia	Flood (General)		/	/
	Italy	Flood (General)	15	Storm Minerva	Slide (land, mud, snow, rock)
	Croatia	Flood (General)		Heavy rains	/
	Bosnia and Herzegovina	Flood (General)		Heavy rains	/
	Serbia	Flood (General)		Heavy rains	Slide (land, mud, snow, rock)
	Slovenia	Flood (General)		/	Slide (land, mud, snow, rock)
	Spain	Flood (General)	3	Heavy rains	/
	Bulgaria	Flood (General)	4	/	/
	Greece	Flood (General)	17	Storm 'Daniel'	Lightening Slide (land, mud, snow, rock)
	Belgium	Flood (General)		Heavy rains	/
	France	Flood (General)		Heavy rains	/
	France	Flood (General)	1	Heavy rains	Storm

2024	Greece	Flood (General)		/	Hail
	France	Flood (General)	1	/	Storm
	Russian Federation	Flood (General)	3	Rapid snow melting, heavy rains	Broken Dam/Burst bank
	Germany	Flood (General)	12	Heavy rains	Slide (land, mud, snow, rock)
	Bosnia and Herzegovina	Flood (General)	27	Heavy rains	Slide (land, mud, snow, rock)
	France	Flood (General)		Heavy rains	/
	Spain	Flood (General)	232	High-altitude isolated depression (DANA in Spanish)	Lightning Storm
	Spain	Flood (General)		Heavy rains	/