Chapter 11
Flood Risk Reduction

Giuseppe Rossi and Bartolomeo Rejtano

Abstract Italy is particularly vulnerable to water-related disasters (flooding, landslides, drought) and to other related phenomena, such as soil and coast erosion, which affect land and human activities. Traditional strategies to face water-related hazards were based on structural measures, aiming at land reclamation by drainage networks, at soil conservation by agricultural and forestry practices and at flooding defence by hydraulic works such as structures against overflow and inundation (river banks, diversions) or for flood routing. The land transformation due to the growth of urbanized areas and infrastructures and the likely effect of climate change have increased the flood risk, while the structural measures began to be considered insufficient and costly and to be criticized for environmental reasons. Thus, non-structural measures such as constraints on land use, early warning systems and better information to increase public awareness and behavioural responses to floods have been emphasized. In this chapter, basic concepts of flooding risk and measures for its reduction are discussed. The most severe flooding disasters which occurred after the unification of the country (1861) and the development of policy about the flood risk reduction are analyzed. Then, a synthesis of flood hazard and risk assessments in Italian regions is presented. Finally, an attempt is made to identify priorities and trends to improve flood disaster resilience.

11.1 Introduction

Mitigation of flooding risk can be considered one of the most relevant challenges to be faced by a community in order to improve its resilience to water-related disasters. A severe flood is the result of several factors including (i) severity of precipitation, (ii) soil and vegetation coverage, (iii) geomorphological characteristics and land-use of watershed and (iv) extent and morphology of the flood expansion zone.

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Nevertheless, the possibility that a flood becomes a disaster is strictly connected to various anthropogenic factors, such as the increased industrial and agricultural activities and the urban settling and development of infrastructures in the flood prone areas, the loss of a significant part of the floodplain as an expansion zone and the construction of hydraulic structures (dams and dikes), whose failure can increase the damage under exceptional circumstances. Besides, the impacts of climate change on rainfall intensity and on seasonal distribution of precipitation are other important factors. Furthermore community disaster preparation plays a very important role, particularly with respect to the risk of mortality, by means of early warning systems and by improving the population behaviour in response to threatening events.

Italy is particularly vulnerable to all water-related disasters and has been forced to adopt an adaptive approach to face the dramatic increase of frequency and damages of these disasters. In particular, the specific characteristic of a combined flooding and landslide, which seems a unique feature of the territory of many Italian regions in contrast to other European countries, explains the adoption of a more comprehensive view in Italian legislation in order to face both risks. Such a comprehensive approach has been the basis of Law 183/1989 and of the following regulations. While the European Flood Directive 2007/60/EC is focused only on flood risk, in Italy the activities aiming at understanding and managing the risks continue to concern both flood and landslide phenomena.

This is a positive feature of the Italian legislative framework, which in the last decades has been characterized by a closer attention to non-structural measures and to the role of a civil protection organization. However, the delays in the preparation and implementation of the planning tools, the limited financial resources available for works and the cumbersome bureaucracy have influenced negatively the flood risk mitigation policies based on structural measures. The application of non-structural measures has presented other difficulties, such as the constraints established by the flooding risk plans which often are not compliant with the land planning. Moreover, there is inadequate coordination in the decision-making process which aims at avoiding casualties and extensive damage, by meteorological/hydrological forecasting, early warning systems and real-time local decisions during severe events. Finally, there is a lack of public participation in the decision-making processes ranging from the strategy planning to the design of structural measures and to the operation of warning system

In the next sections of this chapter, the basic concepts and different types of flood risk are presented (Sect. 11.2), and an analysis of the severe flooding disasters that occurred in Italy since the unification in 1861 is carried out (Sect. 11.3). Section 11.4 outlines the major steps of the development of flood mitigation policy. The results of the recent assessment and mapping of flood hazard and flood risk are presented in Sect. 11.5. Then the expected trends in flood risk reduction are analysed in Sect. 11.6, and finally, in Sect. 11.7, the key approach to improve flood management is pointed out.

11.2 Basic Concepts and Types of Flood Risk

Flood risk management has been considered in Italian legislation within the more general frame of soil defence. A very comprehensive approach had already been adopted since the Royal Decree 215/1933, which established the rules for hydraulic reclamation by considering it as a part of an integrated land conservation strategy aiming at removal of the obstacles to an agricultural and socio-economic development of the land reclamation district by means of a general reclamation plan. Such a plan had to consider the needed measures for meeting the irrigation demand, improving rural roads and electric networks. It was parallel to other international experiences of integrated development of that period, such as the Tennessee Valley in the USA during the F.D. Roosevelt presidency.

The concept of soil defence has been proposed by the Inter-ministerial Commission for the study of hydraulic regulation and soil defence (Commissione Interministeriale 1970) established by the Ministry of Public Works and the Ministry of Agriculture and Forest soon after the dramatic floods occurred in November 1966 in Florence and in Veneto. “Soil defence” was defined as:

> the set of all activities for preserving and safeguarding the soil, its capability of production and the infrastructures from extraordinary assaults by intense rainwater, floods and sea water.

The Law 183/1989 approached the water and soil problems in a unitary way. It introduced the provision of a comprehensive river basin plan and gave a broader definition of “soil defence”, as:

> the set of activities related to the knowledge, legal rules and land management aiming at conserving, defending and enhancing soil and appropriate use of water resources, including water quality protection.

Such a broad approach has been criticized for being too ambitious and it has been considered as one of the reasons for the delay that occurred in the implementation of planning provisions (as already discussed in Chap. 3). The Legislative Decree (DLgs) 152/2006 extended further the concept of soil defence, defining the “soil defence” and “hydrogeological instability” as follows:

> Soil defense is the set of actions and activities regarding the protection and safeguard of land, rivers, canals, lakes, lagoons, coastal areas, groundwater, with the goal of reducing hydraulic risk, eliminating the geologic instability, optimizing the use and management of water resources and enhancing the connected environment and landscape and the fight against desertification.

> Hydrogeological instability is the condition of areas, where natural or anthropogenic processes determine a risk condition to the land.

The more recent definitions, regarding “flood” and “risk of flooding”, stated in the DLgs 49/2010, coincide with those of the Directive 2007/60/EC, which states:

> Flood means the temporary covering by water of land not normally covered by water. This shall include floods from rivers, mountain torrents, Mediterranean ephemeral water courses, and floods from the sea in coastal areas, and may exclude floods from sewerage systems.

> Flood risk means the combination of the probability of a flood event and of the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event.

In order to provide homogeneity and reference about types of flooding, the E.C. *Guidance for reporting under the Flood Directive* (E.C. 2013) distinguishes different sources, mechanisms and characteristics of flooding as follows:

Source: Fluvial, pluvial, groundwater, seawater, artificial water-bearing infrastructures (or failure of such infrastructures)

Mechanism: Natural exceedance, i.e. water exceeding the capacity of the carrying channel, defence exceedance, i.e. flood waters overtopping flood defences, failure (breaching or collapse) of natural or artificial defence or infrastructure, blockage or restriction of a conveyance channel or bridges or sewage due to, e.g. landslide or ice jam

Characteristic: Flash flood, snow-melt flood, medium- or slow-onset flood, debris flow, high velocity or deep flood

In order to consider the prevailing types of floods occurring in Italy, the following simplified list of flooding categories is adopted in this chapter:

River flooding
Urban flooding due to river outbreak
Flooding originating from dam break and/or landslide
Flooding connected with debris flow or mud-slide.

A lot of flooding events occur each year in different regions of the country, but only a limited number causes deaths, missing persons, homeless and injured people and/or damage so serious as to be defined a flood disaster. Today, the awareness of an increased risk of flood disasters in many Italian regions is spread largely not only among the technicians and the politicians but also in the public opinion, due to the attention paid by TV and social media to natural disasters. Obviously, the increase in flooding risk is driven by different factors. First of all, the hydrological response of catchment to meteorological events (very heavy rainfall, worsened in some cases by snow melting) is becoming more severe. This derives mainly from the increase of impervious areas of the catchment, in turn due to the land consumption deriving from urban sprawl, construction of roads, occupation of floodplain by illegal buildings and upstream training works.

Also, the transformation of agricultural land, particularly the abandonment of agricultural practices, reduces soil infiltration and concentration time of the drainage basin, thus increasing peak flow and runoff volume.

Structural defence measures and river regulation infrastructures have become inadequate, e.g. since the floodplain areas have been modified, the dikes are poorly maintained, the sizing of the channel obtained by covering urban reaches of torrents is affected by mistakes in the design flood, etc.

Moreover, according to most of the scientific community, climate change must be considered as a contributing factor that increase the disaster risk, causing more frequent and higher intensity storms.

Besides the above physical causes, a more general but not less important factor should be mentioned, which has, perhaps, a greatest impact on the severity of disasters. This consists in the inadequacy of policy choices in the few last decades, which, in spite of advanced knowledge of the prevention and mitigation measures and of improvement of civil protection role for monitoring and acting during the events, has not improved significantly the resilience of several urban areas and of most of the basins to the flooding hazard. Finally the not adequate behaviour of people during the most severe events is another significant reason of many casualties.

11.3 Main Flood Disasters in Italy After the State Unification

Several historical documents keep alive the memory of water-related disasters that occurred in the past centuries in the Italian peninsula since the time of the Roman Empire to the various Italian states that existed before the unification. Examples of some of the most severe events include flooding of the Arno River at Pisa during 9 storms on September–November 1167, flooding of the Arno River at Florence on 4 November 1333 (which destroyed the Ponte Vecchio), flooding of Polesine (from the Po River) and Verona (from the Adige River) on Autumn 1348, flooding of Palermo on 27 September 1557 (about 7000 deaths), flooding of Pisa on 19 May 1680 due to the overflow of the Arno River, flooding along the Po River in 1705 (up to 15,000 killed people), disaster in the eastern Ionic coast of Sicily (Messina province) on February 1763.

Reports of these disasters generally do not provide enough information on the meteorological and/or hydrologic features of the events and on the number of fatalities (deaths and missing persons) and extent of the damage. Detailed research to gather technical details was started by the SGA (Storia Geofisica Ambiente) company of Bologna, funded by ENEA (Ente Nazionale Energia Atomica) in 1987 for the period 1000–1985, but unfortunately, it has not been completed.

Hence in the present section, the survey is limited to the events that occurred after the Italian kingdom was established (1861) as a unitary state. The most severe flood disasters after Italian unification, which are significant either for rainfall intensity (and for consequent flood discharge) or for serious human consequences and damages, are described in Table 11.6 of the Appendix to the present chapter. For each event, the prevailing category of flooding is indicated, according to the four types identified in the previous section and specified as follows.

River Flooding (RF)

This is the most severe type of flooding, deriving from long and intense storms striking most of the river catchments. It is characterized by the flooding of large part of floodplain and/or the urban area crossed by the river. It is due either to the insufficiency of the cross section of the river to contain exceptional flood runoff or to the rupture or overtopping of the dikes.

Urban Flooding due to River Outbreak such as Flash Flood (UFF)
This is generally due to the inadequacy of the cross section of urban reaches of a river to drain a flash flood (especially if the watercourse has been used as a road or has been covered to build a road, a square or a parking lot) or due to a discharge in the sewer network exceeding the design flow.

Flooding Originating from Dam or Landslide (FDL)
It includes both the disasters caused by a dam break (Gleno, Molara, Stava) and disasters due to the flooding consequent to landslide events (Tavernerio, Vajont, Valtellina). The first type of disasters, although destructive, had a positive impact for establishing more rigorous technical rules to improve design, construction and operation of dams.

Flooding Connected with Debris Flow or Mud-Slide (FDFMS)
This category includes the floods which caused most damages from the debris flows and/or mud-slides triggered by severe storm events.

The following information, if available, is given for each disaster: flood category, date, affected area, i.e. province and region hit strongly, main river basins, hydro-meteorological features, number of fatalities and number of evacuees and homeless, short description of the event and, whenever possible, a comment on the effects of the disaster on policy and/or technical provisions adopted to face the risk of new severe events.

According to the terms adopted by the Research Institute for Hydrogeological Protection (IRPI CNR), "fatalities" include the number of deaths and missing persons caused by a harmful flood event; "evacuees" indicates the number of people forced to abandon their homes temporarily; "homeless" indicates the number of people that lost their homes; "harmful" event indicates an event with human consequences, i.e. "casualties" (including fatalities and injured people), homeless people and evacuees.

The main sources of information are the reports prepared by the IRPI, beginning from the AVI (Vulnerated Italian Areas) Project, carried out within the activity of the group for Hydrogeological Disasters of the National Research Council (Guzzetti et al. 1994), till the Information System on Hydrogeological Disasters (CNR 1999–2019). Part of these data is now available in the website POLARIS (Salvati et al. 2016). Other sources of information, including books, scientific journals, technical reports and papers presented in congresses, have been examined in order to deepen the hydro-meteorological features, such as Piccoli (1972), Botta (1977), AII (2010), Accademia dei Lincei (2013) and Rosso (2017).

Since the original sources of information have different reliability, the data listed in the table are affected by high uncertainty, particularly with reference to the human consequences and to the damages, due also to the difficulty of distinguishing the effects of direct floods from the effects of landslides triggered by the same storms causing the floods.

According to the analysis carried out by IRPI (Salvati et al. 2015), the total amount of fatalities (deaths and missing persons) in the period between 1861 and 2013 is at least of 3268 people and the number of evacuees and homeless about 691,000 persons, as detailed in the Table 11.1. However, these estimates do not

Table 11.1 Human consequences of harmful flood events in Italy from 1861 to 2013

Period	1861–1910	1911–1960	1961–2013	1861–2013
Number of death	665	1782	735	3182
No. of missing person	–	18	68	86
No. of injured people	12	989	903	1904
No. of evacuees and homeless	123,918	275,743	291,012	690,677

Source: Salvati et al. (2015)

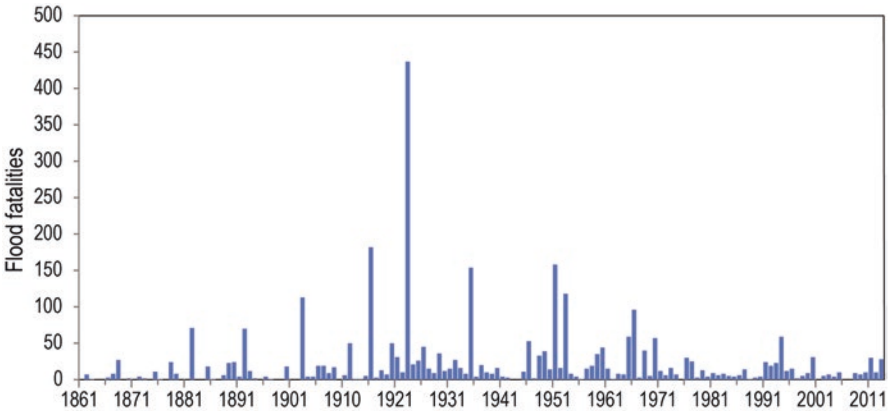

Fig. 11.1 Flood fatalities in the 1861–2013 period. (Source: http://polaris.irpi.cnr.it/)

consider the fatalities due to the floods that occurred in consequence of landslide (e.g. the Vajont disaster).

For the same period, Fig. 11.1 shows the number of flood fatalities per year. It is possible to ascertain that floods events with deaths and missing persons occurred almost every year of the period 1861–2013, though presenting a great variability. Also, excluding the Gleno dam collapse on December 1923, the worse years occurred between the 1950s and 1960s. The figure highlights the decreasing trend in the number of fatalities, which is evident in the recent decades.

In Italy, quantitative estimates of geohydrological risk to the population are estimated and made available by IRPI in the "Polaris" website (http://polaris.irpi.cnr.it/) (Salvati et al. 2016).

The risk posed by geohydrological hazard to the population is assessed commonly by means of mortality rates. Mortality rate is measured as the number of fatalities due to a specific hazard per 100,000 people in a period of 1 year. Based on data on landslide and flood fatalities, the annual flood and landslide mortality rates for all Italian regions are updated and published annually by IRPI. Table 11.2 shows, for each region, the number of fatalities and the average mortality rate in the period 1968–2017 due to landslides and floods (in separate columns) and the total number of damaging events, including both the disasters for the same period.

Table 11.2 Number of fatalities and of mortality rates, caused by landslides and floods in the Italian regions in the 50 year period 1968–2017 and number of damaging events in both types of disasters

Region	Landslides		Floods		Landslides and floods
	No. fatalities	Mortality rate[a]	No. fatalities	Mortality rate[a]	No. of damaging events[b]
Piedmont	130	0.060	138	0.064	140
Aosta Valley	24	0.406	6	0.102	35
Lombardy	116	0.026	31	0.007	231
Trentino-Alto Adige	324	0.732	11	0.025	159
Veneto	30	0.013	7	0.003	100
Friuli-Venezia Giulia	13	0.021	8	0.013	44
Liguria	38	0.044	96	0.101	119
Emilia-Romagna	49	0.025	19	0.009	97
Tuscany	56	0.032	50	0.028	157
Umbria	12	0.030	7	0.017	57
Marche	6	0.008	14	0.019	59
Lazio	18	0.007	16	0.006	123
Abruzzo	10	0.016	4	0.006	72
Molise	0	0.000	1	0.006	28
Campania	274	0.098	21	0.008	198
Apulia	3	0.001	37	0.019	54
Basilicata	14	0.046	11	0.036	63
Calabria	28	0.028	32	0.031	145
Sicily	66	0.027	92	0.037	160
Sardinia	7	0.009	40	0.050	90
Italy	1218	0.040	641	0.020	2131

Source: www.irpi.cnr.it

[a]Average no. of fatalities per year on 100,000 inhabitants; [b]Events with fatalities, evacuees and homeless

The damaging events listed in Table 11.2 can be considered as the ensemble of floods and/or landslides that occurred in a given geographical area (e.g. a catchment, a municipality, a province, a region) in a period, ranging from hours to weeks, triggered by the same meteorological conditions. It is very common that the same intense or prolonged rainfall generates widespread landslides and floods, human impacts and severe and widespread economic damage. In these cases, it is very difficult to assign the damage to a single landslide or flood phenomenon.

As an example, we can mention the Mediterranean cyclonic vortex originating from the Balearic Islands that on 1 October 2009 generated an intense storm cell dumping intense rainfall along the Ionian Coast of Sicily, southeast of the city of Messina, with a cumulated rainfall exceeding locally 220 mm in 7 h (Napolitano

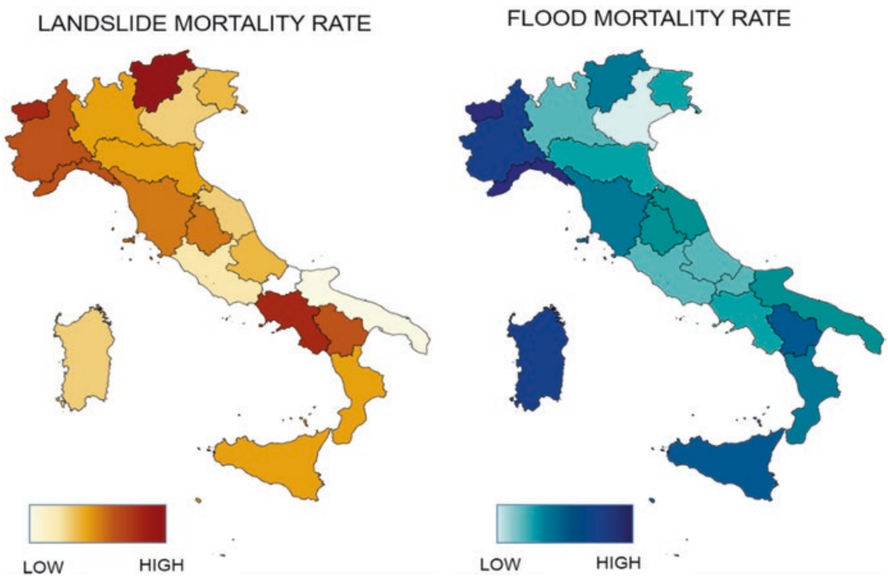

Fig. 11.2 Average landslide and flood mortality rate in the period 1968–2017 in Italian regions. (Source: http://polaris.irpi.cnr.it/report/last-report/)

et al. 2018). The intense rainfall caused flash floods and widespread – mostly shallow – landslides and debris flows that affected public and private buildings and roads, in urban and rural areas. Landslides and floods caused 31 deaths and 7 missing persons. After the event, a total of 193.6 million euros were allocated by the national and the regional governments for the necessary recovery and risk mitigation actions.

Maps in Fig. 11.2 portray the average flood and landslide mortality rates for the period 1968–2017 for all Italian regions. The figure shows that the highest mortality was recorded in the northwestern Italian regions (Aosta valley, Piedmont and Liguria).

In this 50-year period, geohydrological events (floods and landslides) caused a cumulative number of 1858 fatalities in Italy (1796 deaths and 62 missing persons) and forced a more than 316,270 people to abandon their houses. Landslides were responsible for 1218 fatalities (65.5%) and floods for 641 (34.5%). Landslides killed more people than floods did. It could be a direct consequence of (i) the higher destructiveness of landslides compared to floods, (ii) the related larger vulnerability of the population to landslides than to floods and (iii) the generalized lack of effective landslide early warning systems (Salvati et al. 2017).

However, floods and landslides are not the only natural hazards that caused harm to people. Geophysical hazards (mainly earthquakes) are also frequent and mostly destructive in Italy. Table 11.3 lists the average mortalities calculated for the most impacting natural hazards in Italy for the period 1968–2017 and for the period 1861–2017.

Table 11.3 Average mortality rates for different natural hazards in Italy in the period 1968–2017 and 1861–2017

	Average mortality rate*	
	1968–2017	1861–2017
Flood	0.022	0.048
Landslide	0.043	0.082
Earthquake	0.166	2.240
Volcanic activity	0.000	0.005

*No. of fatalities per year on 100,000 inhabitants (Source: www.polaris.irpi.cnr.it)

The available data shows that the amounts of the average mortality for all hazards computed for the last 50 years are significantly less than those of the whole 157 years period. In particular the difference is very high for mortality due to earthquake events, since the long period includes a few exceptional disasters with a very high number of fatalities, such as earthquake of Messina, 1908 (more than 80,000 deaths), of Avezzano, 1915 (more than 35,000), etc. In any case, the values referring to flood and landslide hazards in the recent period 1968–2017 are about one half of those ones referring to the long period. Besides, for both periods the mortality due to flood hazard is almost one half of that one due to landslide hazard.

11.4 A Summarized History of the Flood Mitigation Policy

Although the evolution of law on flood mitigation has been presented in detail already in Chap. 3 (Sect. 3.3.5) and a survey on flood disasters has been presented in previous Sect. 11.3, significant connections among disasters and development of law and consequent actions deserve to be recognized, in order to provide a better understanding of the recent history of the flood mitigation approach in Italy. Only a few significant steps will be recalled now, essentially those which happened within the memory of the present generation and were significant for their role, independently from magnitude, in order to give evidence to their generated impulses and shortcomings, so as to a few fore and back steps.

We will start recalling the flood of November 1951 in the Polesine area, generated from the Po River, mainly through several ruptures of levees (Fig. 11.3). The magnitude and impact of that immense catastrophe were such to impress and affect the whole nation. The Po River adjustments and the River Regulation Plan of 1952 established by Law 154/1952 have to be considered as an effect of that event. However its follow-up was limited, in time, in financing and in constructions, and floods continued to hurt the country.

The 1966 flooding from Arno in the city of Florence was another event which struck the public feeling, not only in Italy but worldwide, since, beside victims and economic losses, it affected an art patrimony of universal importance (Fig. 11.4).

This event gave impulse to the cultural and political process which at a later time led to a legislative recognition of the river basin size of the problem, in connection

Fig. 11.3 Views of the Po River flooding in November 1951

Fig. 11.4 Views of Florence during and after the flood of November 1966

with other types of water problems, and to legislation on river basin planning. This process went through the work of the De Marchi Commission and of the "Conferenza Nazionale delle Acque" (National Water Conference). It took many years of controversial political and engineering debates until Law 183/1989 was finally shaped and approved, thus introducing the concept of a comprehensive river basin planning approach into legislation.

That law, as it was discussed already in Chap. 3, established to plan at basin scale all activities concerning water use, defence from water and soil conservation and indicated the institutional and organizational scheme for the development of plans (with different sort of authorities for national, inter-regional and regional basins), including indication of preliminary studies to be carried out in order to support the planning phase. Although river basin planning as a practice had been already initiated in other countries, the Italian law must be recognized as an outstanding piece of legislation in its field; the legislative tradition which dates back to ancient Rome was producing still its fruits! However the gap between theoretical formulation and practical implementation was not easy to overcome, while in other countries, whose legislation and administration derived from Anglo-Saxons principles or empiric principles, things were running faster in practice.

The development of river basin plans was very inhomogeneous in the country. Mostly, National River Basin Authorities were more successful in their operation. In this sense, the Po River Basin Authority is an example. It took advantage of being born aside of the existing authority for regulation of the Po River (Magistrato del Po), beside of being located in the northern part of the country, where administrative organization was well rooted already. On the other side, mostly with respect to smaller and regional basins, and mostly in the southern regions of the country where collaborative and organizational activities face some political and social resistance, the establishment of river basin authorities and the development of river basin plans failed, while floods continued to hit heavily.

In order to overcome these difficulties, the national Law 493/1993, in a context aiming to accelerate public investments and to simplify many administrative procedures, established that river basin plans could be drafted and approved also for single subbasins and/or for specific sub-matters, such as the defence from floods, a sort of sub-plans. This provision was not intended to change the logic of river basin planning but only to allow an escape possibility to make things moving and to provide at least partial solution to urgencies. However, in a sense, it was a back step with respect to the comprehensive and basin-scale approach.

Nevertheless, this provision of Law 493/1993 did not produce the expected size of effects. And in the meanwhile, flooding events continued to occur and to require public financial commitment for repairs and refund of damages. At about the same time, a National Civil Protection Service was established by Law 225/1992, intended to face urgencies. Since a few years the government had already established the GNDCI, a national group for the defence from hydrogeological risks. It was entrusted to the National Research Council and to the academy in order to develop methodologies and strategies to face the water-related risks: floods, landslides, droughts and groundwater pollution.

In 1998, a combined flood and soil instability phenomenon hit the Sarno area. The event was not so severe as the Polesine and Florence events, but the times were mature to impose issuing a governmental decree to make the flood defence and the landslide defence plans as mandatory obligations for river basin authorities or for regions, according to the case (DL 180/1998). The decree established a deadline for the adoption of the plans for mitigation of hydrogeological risk and the obligation to establish safeguard measures, plus the provision of urgent action programs being entrusted to civil protection. That decree was soon approved by the parliament as Law 267/1998. It is indicated as the Sarno Law, from the name of the site where the disrupting event had occurred.

Also, times were mature to take advantage of the methodologies which had been envisaged by the GNDCI group about hydrological evaluations and flood risk mapping. So, soon after, in the same year, the government, by the decree issued on 29 September 1998, established detailed regulations and steps for the hydrogeological planning activity, with different specifications for the case of flooding and landslide risks. A step-by-step procedure was established with specific subsequent deadlines for each of the major steps: simplified "identification" of flood-prone areas, detailed mapping of hazard and risk in the selected areas, enacting of immediate safeguard measures, i.e. constraints, for the most risky areas and planning of long-term measures, with the option of revising the mapping and the safeguard measures once mitigation measures had been implemented.

Three orders of magnitude of flooding probability and consequent mapping were indicated: "high probability" areas (for return period Tr of about 20–50 years), "medium probability" areas (for Tr of about 100–200 years) and "low probability" areas (for Tr of about 300–500 years). Then, the mapping of four classes of risk was prescribed, ranging from "moderate" to "very high", in order to account also for activities, possible damages and human presence over the land. Stringent and immediate constraints on land use modifications were specified in general for areas and/or sites which would be mapped within "very-high-risk" and "high-risk" categories. Also, a mandatory scheduling of revisions and updating of the mapping and of the action plan was indicated, thus establishing a dynamic planning scheme.

We like to refer to the set of provisions of the Sarno Law and of the subsequent regulations of the 29 August 1998 decree as "the Italian methodology". It was a pioneer approach, since the European Directive on Flood Mitigation was still to come.

Another step in legislation was fostered by the harmful flood occurred in Soverato (Calabria) in September 2000. In fact, soon after, the governmental Decree 279/2000 (approved by the parliament as Law 365/2000) anticipated the deadline for the adoption of the sectorial plans, extended the validity of extraordinary mitigation plans in time, and in space, thus including all the riparian areas and the areas with flooding probability higher than once in 200 years in the safeguarding measures zone. Also it included provisions and additional resources for meteo- and hydrological monitoring and early warning systems and for the civil protection.

At a later time, in 2006, formally, the legislation about river basin planning was abrogated, but at the same time, it was reintroduced, substantially unmodified in the principles and methodology, into the Legislative Decree 152/2006, a broad comprehensive code which included the whole matters of water and environment. The only modification deserving to be pointed out is the adjustment of the administrative organization of the basin planning. In fact, according to European Directive 2000/60/EC, the Legislative Decree 152/2006 modified the administrative organization of the basin planning, thus substituting the several River Basin Authorities (national, interregional and regional) with only seven River Districts Authorities (plus the experimental district of Serchio basin) which had to group minor basins together.

In the following year, the European Directive 2007/60 EC on the management of flood risk was issued. It was more limited with respect to the Italian legislation, since it was dealing only with the flood risk, but its provisions and steps were reproduced from the Italian approach, although it established its own new deadlines. The Flood Risk Mitigation Plan, as introduced by the European Directive, was in the substance almost the same thing as the flooding part of the plan for hydrogeological asset of the Italian legislation.

However, Italy had to comply formally with the European Directive and had to transpose it into the national legislation, which Italy did with the DLgs 49/2010. It introduced the Flood Risk Management Plan to be developed for all districts. Since Italy had been working already on the same matter, Italian transposition law anticipated all deadlines with respect to the indication of the European Directive.

As the actual starting of the District Authorities was delayed, the responsibility of drawing up the planning tools established by the two European Directives has been ascribed to the National River Basin Authorities, by coordinating the regions within the districts. Since some duties of the Flood Directive had been carried out on the basis of previous laws (in particular the evaluation of flooding risk and landslide risk and the subsequent drafting of the Hydrogeological Asset Plan), Italy flew over the preliminary estimate of the flood risk and proceeded directly to map the flood hazard and risk and to develop the Flood Risk Management Plans.

While the National River Basin Authorities developed the planning tools in order to satisfy the European Directives, the national government initiated efforts to improve the actions concerning the flood risk mitigation, in particular to accelerate the use of financial resources for defence from floods (Law 116/2014), in order to ensure a better coordination between the Ministry for Environment, regional governments and local authorities and to improve the quality of the projects of the structural measures by specific guidelines.

The catalyst for these efforts has been the mission structure "Safe Italy" established by DPCM 27 May 2014, founded upon the idea that a body at national level could play a key role in pressing and coordinating the local responsibilities about flood defence. In this context other measures have been taken, e.g. the establishment of the plans for urban areas at high risk (DPCM 15/9/2015) and the issuing of an Act (Law 221/2015) which defines specific rules for the demolition of unauthorized buildings in high-risk areas and introduces rules at municipal level to reduce the vulnerability of buildings, including also a program for the management of sediments in river basins. Also, although in 2018 the new national government cancelled the mission structure, attention to the flooding defence has been confirmed with a recent program of investments of 11 billion of euros in 3 years (February 2019).

11.5 Mapping and Assessment of Flood Hazard and Flood Risk

The assessment of flood hazard and risk, carried out in the planning tools prepared by the River Basin Authorities and by regions in the context of the Hydrogeological Asset Plan and of the Flood Risk Management Plan, has been synthetized by ISPRA for the Ministry of Environment over all regions of the country (ISPRA 2018). In particular, according to the indications of DLgs 49/2010, the scenarios considered for flood hazard areas included floods with high probability P3 (with return period T = 20–50 years, where T is computed in terms of non-exceedance probability P, i.e. T = 1/(1−P); floods with a medium probability P2 (return period 100–200 years); and floods with a low probability P1. Generally, the hazard maps indicate the extension of the areas affected by flooding, without details on water depths and flow velocity.

The areas with high flood hazard P3 in the whole of the Italian territory were estimated to be 12,405.3 km^2 (4.1% of the entire surface of the country), the areas with average hazard P2 were 25,397.6 km^2 (8.4%), and the areas with low hazard P1 were 32,960,9 km^2 (10.9%). The distribution of these areas among the different regions is indicated in Table 11.4.

Figure 11.5 shows the different probability percentages for the regions affected by flood hazard. The highest percentages regard Emilia-Romagna, Toscana, Lombardy, Piedmont and Veneto. The relevant extension of area with flood medium probability in Emilia Romagna derives also from the presence of a dense network of land reclamation channels. Figure 11.6 shows the areas affected by floods with medium probability P2 over the whole national territory.

Another interesting analysis, carried out by ISPRA by using also the landslide hazard data of the Hydrogeological Asset Plans, besides the data on the Flood Risk Management Plan, shows the areas of municipalities which are vulnerable to both flooding and landslide disasters (Fig. 11.7).

A number of 1602 municipalities out of the total of 7983 municipalities (20.1%) present a high or very-high landslide hazard, 1739 (21.8%) show a medium hydraulic hazard and a relevant number (3934, i.e. 49.3%) both hazards (see Fig. 11.8). The amount of surface area of municipalities under landslide hazard is 25,410 km^2 (8.4% of total area of Italy), the amount of areas with medium hydraulic hazard is 25,398 Km^2 (8.4%).

With respect to the flood risk maps required by the EU Flood Directive, the DLgs 49/2010 establishes that the potential adverse consequences associated with the flood scenarios (limited in a first stage to the medium probability range) be expressed in terms of the (i) approximate number of inhabitants potentially affected; (ii) stra-

Table 11.4 Areas affected by flood hazard in the Italian regions

Region	Total area (km^2)	Area with high hazard P3		Area with medium hazard P2		Area with low hazard P1	
		km^2	%	km^2	%	km^2	%
Piedmont	25,387	1148	4.5	2066	8.1	3272	12.9
Aosta Valley	3261	157	4.8	239	7.3	299	9.2
Lombardy	23,863	1860	8.0	2406	10.1	4599	19.3
Trentino-Alto Adige	13,605	52	0.4	79	0.6	114	0.8
Veneto	18,407	1231	6.7	1713	9.3	4635	25.2
Friuli-Venezia Giulia	7862	229	2.9	610	7.8	700	8.9
Liguria	5416	111	2.1	153	2.8	189	3.5
Emilia-Romagna	22,452	2485	11.1	10,252	45.7	7980	35.5
Toscana	22,987	1380	6.0	2791	12.1	4845	21.1
Umbria	8464	232	2.7	337	4.0	479	5.7
Marche	9401	12	0.1	241	2.6	35	0.4
Lazio	17,232	430	2.5	572	3.3	647	3.8
Abruzzo	10,832	97	0.9	150	1.4	179	1.7
Molise	4460	85	1.9	139	3.1	161	3.6
Campania	13,671	512	3.7	670	5.1	843	6.2
Apulia	19,541	651	3.3	885	4.5	1060	5.4
Basilicata	10,073	216	2.1	277	2.7	295	2.9
Calabria	15,222	563	3.7	577	3.8	601	3.9
Sicily	25,832	245	1.0	353	1.4	452	1.6
Sardinia	24,100	706	2.9	857	3.6	1602	6.6
Total	302,066	12,405	4.1	25,398	8.4	32,961	10.9

Source: ISPRA (2018)

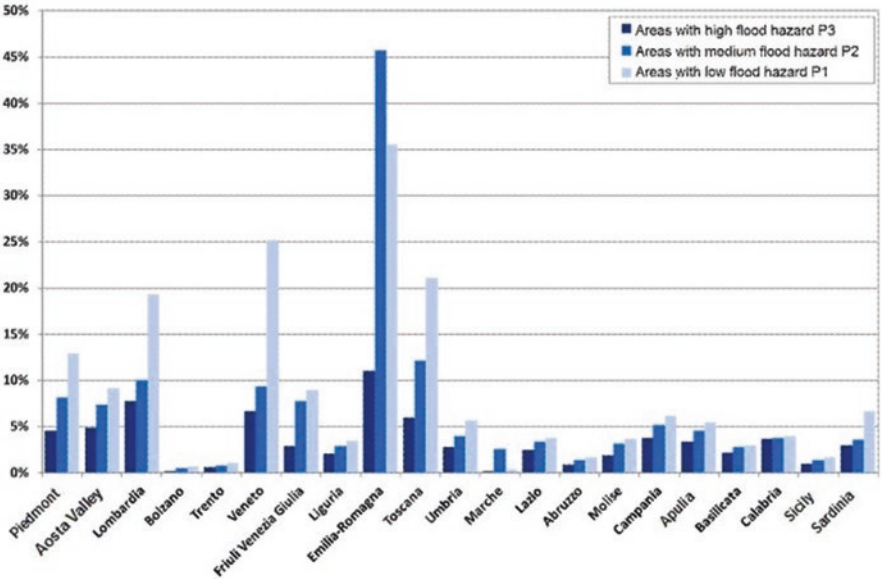

Fig. 11.5 Percentages of regional areas affected by the flood hazard of different probability. (Source: ISPRA 2018)

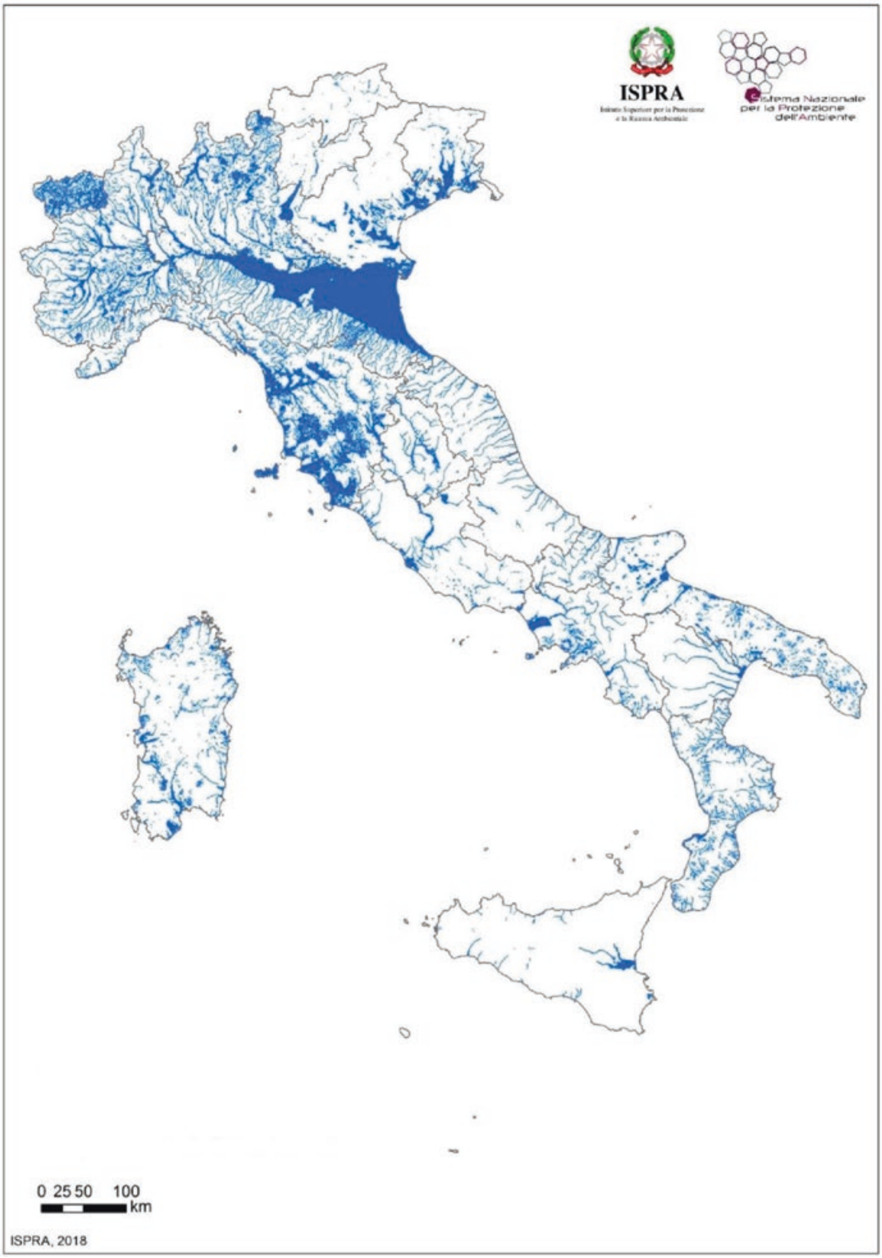

Fig. 11.6 Areas affected by medium flood hazard P2 (return periods 100–200 years). (Source: ISPRA 2018)

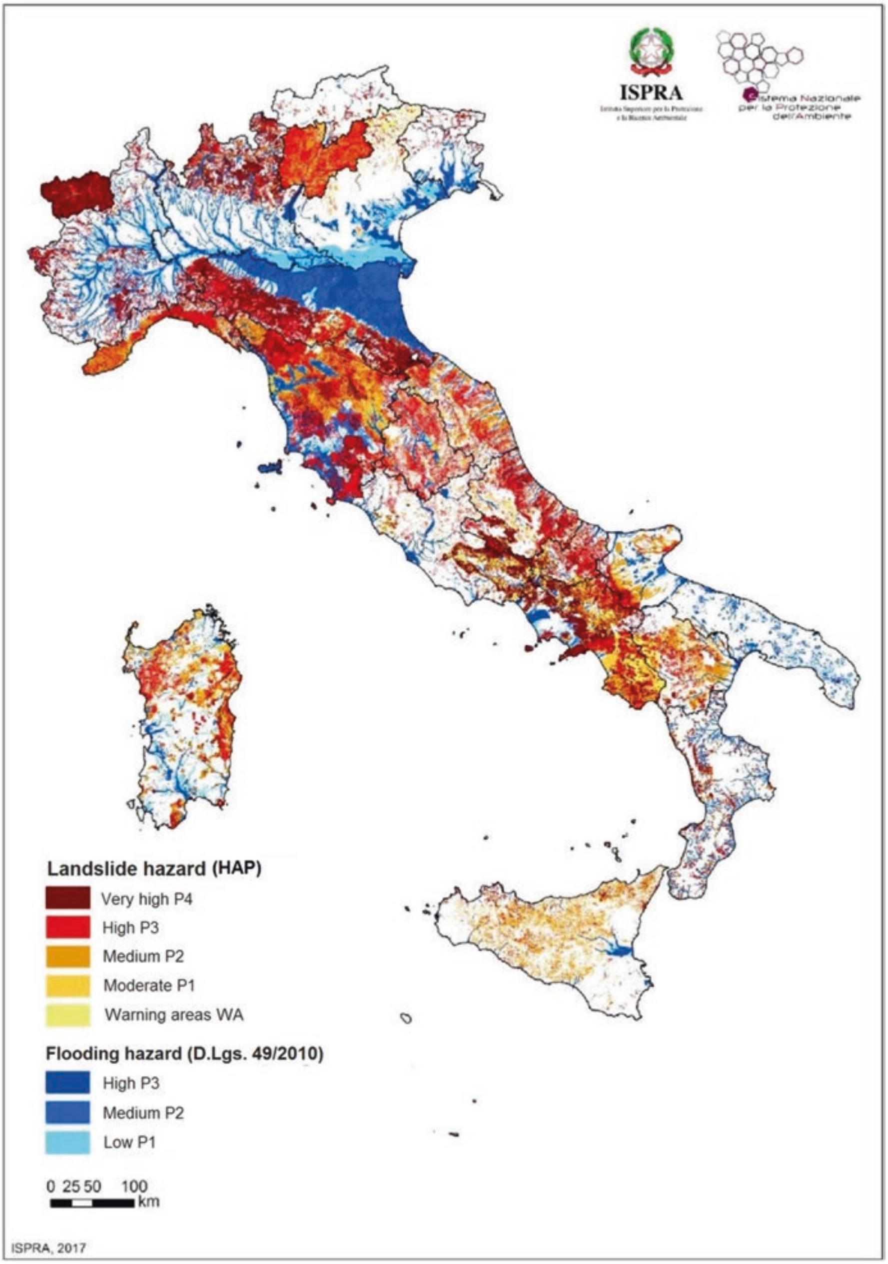

Fig. 11.7 Areas affected by landslide hazard (from Hydrogeological Asset Plan) and by flooding hazard (from Flood Risk Management Plan). (Source: ISPRA 2018)

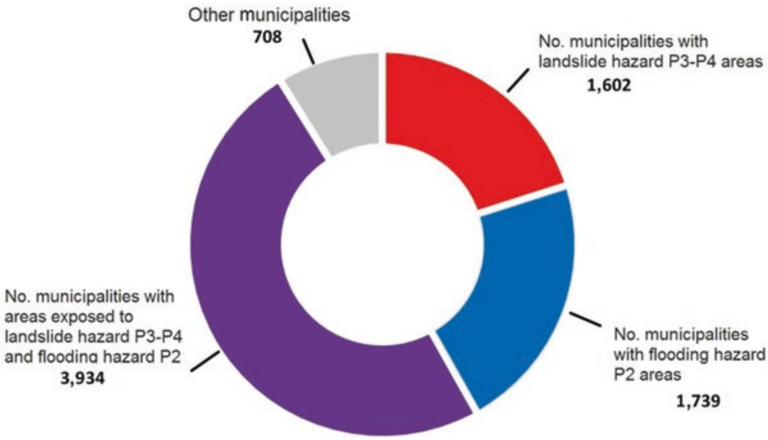

Fig. 11.8 Number of municipalities with areas affected by landside hazard and/or flooding hazard. (Source: ISPRA 2018)

tegic infrastructures and structures (motorway, rail-way, hospitals, schools, etc.); (iii) environmental, historic and cultural values of relevant interest; (iv) economic activities; and (v) installations concerning pollution prevention and control which might cause accidental pollution in case of flooding and protected areas (for withdrawal of water devoted to human consumption, for protection of aquatic species and habitat, etc.).

The mapping of the risk indicators, according to the synthesis by ISPRA (2018), provided many interesting results. The number of residential inhabitants affected by flood hazard has been estimated in 2,062,475 (3.5%) for high probability (T = 20−50 years), 6,183,364 (10.4%) for medium probability (T = 100−200 years) and 9,341,533 (15.7%) for low probability (T greater than 200 years). Figure 11.9 shows the number of residential inhabitants affected by the medium scenario in the Italian regions.

The number of buildings located in areas affected by flood hazard has been estimated in 487,895 (3.4%) for high probability P3, 1,351,578 (9.3%) for medium probability P2 and 2,051,126 (14.1%) for low probability. The number of industrial firms affected by flood hazard has been estimated at 197,266 (4.1%) for high probability, 596,254 (12.4%) for medium probability and 884,581 (18.4) for low probability. The related number of employed people has been evaluated at more of 2.2 million for the medium scenario.

The cultural heritage sites affected by flood hazard have been estimated in 13,865 (6.8 %) for high probability, in 31,137 (15.3%) for medium probability and in 39,426 (19.4 %) for low probability. Figure 11.10 shows the cultural heritage sites affected by the flood in the scenario of medium probability. The analysis carried out at local level has identified that the municipalities with the highest percentage for cultural heritage at risk (for medium flood scenario) are Venice, Ferrara, Florence, Genoa, Ravenna and Pisa. When considering the low probability scenario, Rome

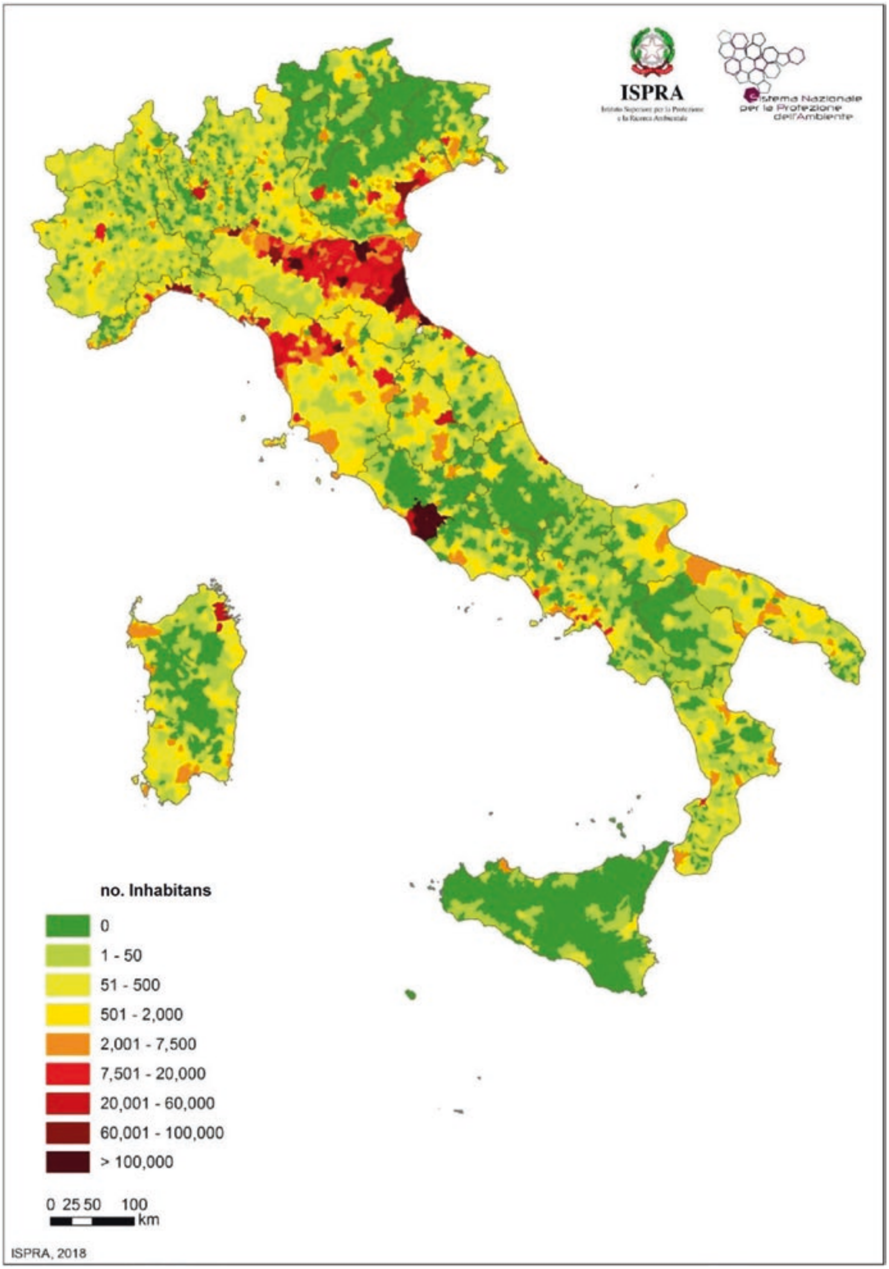

Fig. 11.9 Number of residential inhabitants potentially affected by medium flood hazard. (Source: ISPRA 2018)

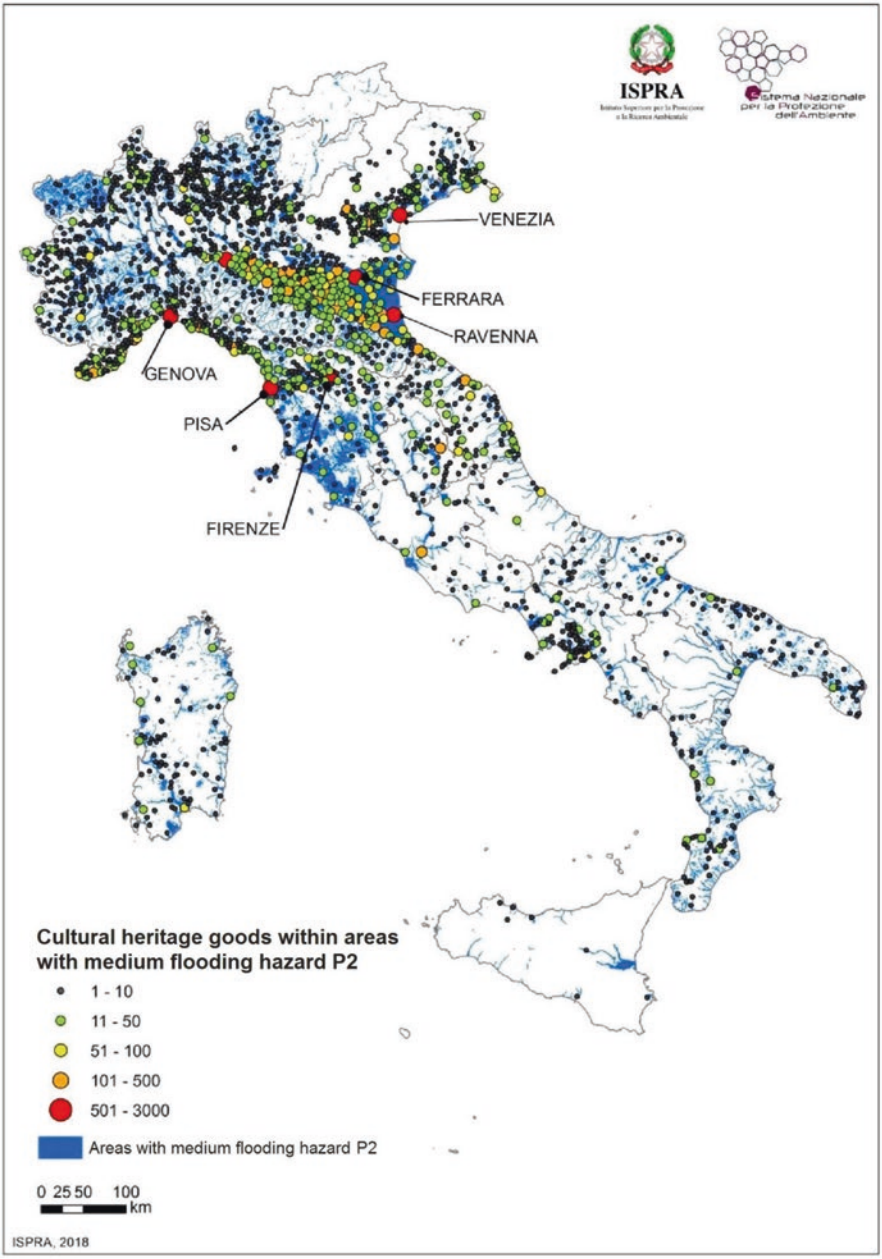

Fig. 11.10 Cultural heritage sites affected by medium flood hazard. (Source: ISPRA 2018)

must also be included. In particular the patrimony of architectonic, archaeological and monument sites at risk (medium scenario) in Florence has been estimated in 1259 (most of them have suffered the flooding event of 4 November 1966).

11.6 Expected Trends of Flood Risk Mitigation

Along many decades, defence from flood risk has been limited to the construction of hydraulic works. In particular, more ancient efforts, since the nineteenth century, were oriented to reduce damage in the valleys of the major rivers, completing or reinforcing the dikes along the watercourses (starting with the Po River) and recovering the marshes in coastal areas by means of land reclamation networks (e.g. valley of Reno, Pontine marshes, etc.). Only a few floodways were built (e.g. the Adige-Garda Lake). Also, the number of reservoirs devoted to flood routing is very limited (in total only seven) in the whole national territory.

Several hydraulic works were planned and built after the flooding disasters. The first example after the unification of Italy (1861) was the construction of the walls along the Tiber River in Rome after the flooding of 28 December 1870. The first planning tool referring to the whole country, namely, the River Regulation Plan (Law 184/1952), followed the Polesine disaster on Po River (14–18 November 1951).

Most of the financial resources to fund the works necessary to increase the safety of several cities were assigned after dramatic events which resulted in victims and severe damage (e.g. Trento and Florence, 4 November 1966). Later, the Law 183/1989 introduced the river basin plan as a comprehensive planning tool, thus giving a key role to the River Basin Authorities, similar in some aspects to the role of the *Agencies des basins* in France and *Water Authorities* in Great Britain.

If the Law 183/1989 emphasized the structural measures, the decrees established after the Sarno (1998) and Soverato (2000) disasters focused on the role of civil protection in order to reduce the timing for the implementation of actions aiming at safeguarding the more vulnerable areas. As a result, preparedness and recovery measures have increased, while inadequate funding and procedural delays in approving the projects of hydraulic structures and in entrusting contracts for public works have limited the construction of new structural measures.

While the positive results of civil protection actions are acknowledged, in particular for the development of warning systems based on the multi-functional centres and for emergency and recovery actions, the assessment of the flooding prevention and soil protection policies generally shows poor results in improving resilience to the flood risk in a major part of the territory. The reasons are the delays in the implementation of the District Authorities' role, the lack of coordination between the constraints imposed on the hazard and risk areas by the Hydrogeological Asset Plans and the choices of the urban and land planning, as well as the small and uncertain flow of funds for actions designed at prevention and protection.

What are the necessary modifications in the selection of measures aiming at achieving a more effective reduction of flood risk in the future?

Referring to the *Guidance for reporting under the Floods Directive* (E.C. 2013), it is convenient to adopt a classification of flood management measures into the following stages: prevention, protection by structural and non-structural measures, preparedness including the emergency response, recovery and review. This classification coincides substantially with that one suggested by the Chart of the Sendai Framework for Disaster Risk Reduction, established by the United Nations Office for Disaster Risk Reduction (UNISDR 2015). It includes many measures for each stage, as listed in Table 11.5.

Table 11.5 Measures to be adopted in the various stages of flood risk management (Source: E.C. 2013)

Stage/Measure	Description
Prevention	
Avoidance	Land use planning policies and regulation aimed at preventing the location of new additional "receptors" in flood-prone areas
Removal or relocation	Measures to remove or relocate "receptors" from flood-prone areas
Reduction	Measures to reduce the adverse consequences of flooding on building, public networks, etc.
Other prevention	Other measures, e.g. flood vulnerability assessment, maintenance programs, etc.
Protection	
Runoff and catchment management	Measures to reduce the flow into natural or artificial drainage systems (e.g. enhancement of infiltration, overland flow interceptors or storage, etc.) including in-channel, floodplain, etc.
Water flow regulation	Construction, modification or removal of water retaining structures (e.g. dams or online storage areas or flow regulation rules)
Channel, floodplain and coastal works	Construction, modification or removal of structures or alteration of channel, sediment dynamic management, dikes, etc.
Surface water management	Interventions to reduce surface water flooding, e.g. enhancing urban drainage systems
Other protection	Other measures, e.g. maintenance programs
Preparedness	
Flood forecasting and warning	Measures to establish or enhance forecasting or warning system
Emergency response planning	Measures to establish or enhance flood event institutional emergency response planning/contingency planning
Public awareness and preparedness	Measures to establish or enhance the public awareness for flood events or for reducing adverse consequences
Recovery and review	
Individual and societal recovery	Clean-up and restoration of building, infrastructures; health supporting actions (e.g. managing stress); disaster financial assistance; temporary or permanent relocation
Environmental recovery	Clean-up and restoration, e.g. mould protection, securing hazardous materials containers, etc.
Other recovery and review	Lessons learnt from flood events; insurance policies

The list proposed for the implementation of the European Flood Directive takes into account the recent directions of European policy concerning a high level of environmental protection in accordance with the principle of sustainable development and concerning the flexibility to be left to the local and regional authorities, according to the principles of proportionality and subsidiarity.

Priorities to increase the resilience of the Italian territory to the flooding risk include the following:

– It is necessary to achieve a more clear allocation of responsibilities among the district authorities (in terms of prevention measures), the regions, the civil protection and the local authorities (responsible for emergency measures) and to reinforce the key role of the District Authorities particularly for an authoritative coordination of the duties of regions within the district.
– The revision of the general river basin planning process should eliminate the current anomaly of two different plans aiming at coping with flood disasters: the Hydrogeological Asset Plan, established by the Law 267/1998 and the Flood Risk Management Plan. Today the presence of the two plans is maintained, since the second plan, according to the European Directive, does not include landslide risk;
– More homogeneous criteria should be adopted in the definition of the planning measures for flood risk mitigation among the districts operating in different parts of the country, and also more homogeneous criteria should be applied in the design of structural measures (according to the guidelines developed within the Safe Italy initiative) and in the choice of measures for emergency.
– Structural measures remain a key element of an effective flood defence policy, and the flood routing purpose should be achieved, if possible, in the reservoirs devoted to other purposes (e.g. agricultural supply, hydropower, ecosystem protection) by improving operation rules; a periodic maintenance is required on the old structures, and in some cases a re-assessment of the design flood should be carried out in order to take into account the new information provided by the available updated hydro-meteorological series as well as the consequences of expected climate change.
– An effort should be dedicated to consider the mapping of flood hazard not solely with regard to the probability of the hydrological event but also with respect to the reliability of existing structural measures. This is especially important, at the light of the insufficiency of monitoring and maintenance of existing structures such as levees, whose probability of failure may be higher than the probability of being overtopped by the river flow.
– More specific rules are required to implement the principle of hydraulic and hydrologic invariance, i.e. the provisions aiming to avoid the increase of the peak flow and flood volume notwithstanding the growth of impervious urban areas; also a larger use of flood-proofing measures, to be implemented by involvement

of private subjects, can contribute to reduce the vulnerability to the flooding hazard.
- In spite of the positive results obtained by the Multi-functional Civil Protection Centres in implementing the early warning system, a more effective management of emergency is required to better coordinate the meteorological/hydrological forecasting, the alert/alarm procedures and the operative actions under the municipal responsibility; in particular, a more accurate implementation of the emergency plan is required in the case of flash flood in urban areas, where the alert cannot be linked to the water depth in an above river cross section (as in streamflow forecasting of large rivers), but must be connected to the data of the short-duration high intense rainfall and weather radar information.

Besides the specific actions cited above, a few general changes of policy direction are necessary, such as the following:

- Particular attention should be paid to improve the functioning of the technical bodies of public administration by means of a careful revision of past reforms which led to the fragmentation of some national services (e.g. the Hydrographic Service) and transferred the Civil Engineering Offices (Genio Civile) to the regions with negative consequences on the homogeneity of the procedures.
- Sustainable land use should be achieved limiting the excessive transformation of agricultural land into urban areas and infrastructures; in some cases the reduction of the areas exposed to flood risk requires the demolition of unauthorized buildings in high-risk areas.
- It is necessary to establish once more a stronger link between the institutions which have responsibility for water governance and advise and the research institutions (universities, research centres) in order to improve the transfer of research results from the scientific communities to the bodies with operational duties and in order to direct some research efforts toward practical needs.
- Education and training activities in the water fields should be promoted by adopting a multidisciplinary approach but keeping most of contents (hydraulics, hydrology, geology, geo-mechanic, etc.), which have assured a high professional preparation for the development of water policies during the last centuries in Italy.
- A better awareness among the population about the correct behaviour to adopt during severe flooding events can contribute to reduce significantly mortality and economic damage. This objective requires that specific activities, devoted to informing the population on actions to take in case of floods, should be specifically financed and carried out, especially in schools, universities, etc., as well as through social media.
- It is not possible to postpone the initiatives aiming to guarantee the public participation in decision-making processes in the water field, through an effective transparency of the plans and programs and a real involvement of all stakeholders and citizens.

11.7 Key Approach to Improve Flood Management

Nowadays, an improved flood management is generally claimed as a guiding strategy to mitigate flood risk. This requires the contribution of a large range of disciplines to achieve a multidisciplinary approach and a coordinated effort at different levels of legislation and governance. Among the several shifts in the approach paradigms, invoked in Italy during last decades, a large consensus has been obtained on the following changes: (1) from the emergency management to the risk management, (2) from a simple structural approach to a combined structural and non-structural actions approach and (3) from a top-down method to a shared responsibility between central government and subnational, regional and local authorities, according with the subsidiarity principle.

In spite of the differences between the Italian legislation framework on soil defence – aiming at facing both flooding and landslide risks – and the European Directive 2007/60/EC, which covers only the risk of flooding, both are inspired by the same principles: river basin is the territorial unit for planning; the risk concept includes the dimensions of hazard, exposure of persons and assets and vulnerability; and the choice of the solutions requires a careful understanding of the risk to be pursued by mapping of the different components of the risk and a well-calibrated combination of prevention, preparedness, recovery and rehabilitation measures.

Besides the specific measures referring to each stage of the flood risk reduction process, many general improvements are required in order to improve the institutional framework of water governance (political and technical branches of public administration) and the land use planning policies which should be able to reduce the land consumption and to remove the hazardous presence of buildings from flood-prone areas. The role of research and training, the increase of the awareness of people on correct behaviours to be adopted in advance and during the high-risk events and the public participation to the decision-making processes in water management are recognized at many levels as the key element to face the very complex goal of managing the flood disaster risk.

Appendix

Table 11.6 Main flooding disasters that occurred in Italy in the 1861–2017 period

Flood categories	Date	Affected area	Main river basins	Hydro-meteorological features	No. of fatalities/ evacuees and homeless	Short description	Effects on defence policy
RF	26 December 1870	Rome city (Lazio region)	Tiber	Height of 17.22 m. and 3300 m^3/s discharge in Tiber River at Ripetta	2/~6000	Overflow of Tiber flooded part of the centre of Rome	After the disaster, walls were built along the Tiber reach crossing Rome
UFF	26 September 1902	Modica, Ragusa province (Sicily region)	Scicli torrent	395 mm in 24 h (Giarratana); estimated peak flow 700 m^3/s	112/	Flooding of three tributaries of Scicli torrent (two covered by urban roads) flooded the centre of Modica. Estimated damages 1–2 million of liras	
UFF	17 November 1908	Eastern Sicily region and Southern Calabria region	Riposto torrent	465 mm in 24 h, 150 mm in 25 min. (Riposto, Catania province)	10	Flooding of urban centres of Riposto and Giarre (Catania province)	
FDFMS	24 October 1910	Amalfi Coast and Ischia island (Campania region)			>250 (200 in Cetara, 20 in Maiori)	Severe storm and debris flows	

(continued)

Table 11.6 (continued)

Flood categories	Date	Affected area	Main river basins	Hydro-meteorological features	No. of fatalities/ evacuees and homeless	Short description	Effects on defence policy
FDL	1 December 1923	Valley of Scalve, Bergamo province (Lombardia region)			~500	The break of the Gleno dam in Pian del Gleno (BG), caused about 6 million cubic meters of water to flow out of the reservoir and covered the entire valley, until it ran out in the Iseo Lake about 45 min after the collapse	New rules for dam design
UFF	26 March 1924	Coast of Amalfi, Salerno province, (Campania region))			86/≥100		
UFF	21 February 1931	Palermo city (Sicily region)	Oreto, Papireto and Kemonia rivers	Max rain at Villa Pioppo (520 mm in 3 days, 411 mm in 24 h); peak flow of Oreto 248 m^3/s	12/	Flooding of Palermo centre with max water height of 6 m.	Planning of regulation of river network near Palermo

FDL	13 August 1935	Valley of Orba, Alessandria province (Piedmont region)		400 mm in 8 h	>110/	A heavy rain affected the area on the border between the provinces of Alessandria and Genoa, causing the collapse of a portion of the Sella Zerbino dam (Molare, AL). The consequent flood wave from the reservoir produced fatalities and damages	
RF	4 September and 12–14 September 1948	Asti, Alessandria, Cuneo, Torino and Vercelli provinces (Piedmont region)	Tanaro, Borbore and Belbo	About 250 mm in Borbore catchment; 350 mm in Belbo catchment.	23/≥790	Flooding of the Langhe (vineyards) with damages in the transport system. Estimated damage 20 billion of liras in Asti province	
RF	1 October 1949	Benevento, Avellino, Caserta and Salerno provinces (Campania region)	Calore and Volturno	Max rain 246 mm in a day (S. Croce del Sannio). Peak flow 688 m^3/s (h = 5.28 m) in Calore at Apice. Peak flow 3200 m^3/s (h = 9.86 m) in Volturno at Ponte Annibale	32/1970	Flooding of Benevento and other municipalities. Overflow of Volturno river Estimated damage 7 billion of liras	

(continued)

Table 11.6 (continued)

Flood categories	Date	Affected area	Main river basins	Hydro-meteorological features	No. of fatalities/ evacuees and homeless	Short description	Effects on defence policy
RF	14–19 October 1951	Calabria, Sicily and Sardinia regions	Calabria: many torrents near Reggio Calabria. Sicily: Simeto, Sardinia: Flumendosa, Cetrino	Calabria: max rain 1770 mm in 4 days; 1595 mm in 72 h, 1068 in 48 h, 535 in 24 h (Petrace) Sicily: max rain 529 mm in 24 h, 166 mm in 3 h (Lentini Bonifica); Peak flow of Simeto 3300 m^3/s (1547 km^2) Sardinia 1014 mm in 2 days (1431 mm at Sicca d'Erba), 544 mm in 24 h	68/>8600 (Calabria); 10/>700 (Sicily); 6/≥280 (Sardinia)	Severe storms of very long duration caused main river flooding and landslides Aprico village (Reggio Calabria) was destroyed. Estimated damage in Reggio Calabria province 30 billion of liras	Embankments along Simeto River were designed for defence of the plain of Catania
FDL	8 November 1951	Tavernerio, Como province (Lombardia region)	Cosia torrent	120 mm in 24 h	18/	Heavy rains caused landslides and floods. At Tavernerio a landslide interrupted the flow of the Cosia torrent, leading to the formation of a temporary basin whose waters, at the breaking of the barrier, poured over the inhabited area	

RF	14–18 November 1951	Polesine, Rovigo province (Veneto region)	Po	About 300 mm over the Po river basin. Peak flow 12,800 m^3/s at Piacenza	98/180,000	Break of banks of Po River in Rovigo province caused flooding of about 1170 km^2. 100 houses, 5000 buildings, 13,800 farms and 1130 km^2 of crops were damaged or destroyed. Estimated damages 400 billion of liras	A national plan for river regulation over the country was established (1954)
UFF	21 October 1953	Reggio Calabria, Cosenza, Vibo Valentia, Catanzaro provinces (Calabria region)	Valanidi	82.6 mm in 1 h. Overflow of Valanidi torrent (450 m^3/s)	103/>3800		
UFF	25–26 October 1954	Coastal area of Salerno province (Campania Region)	Bonea and Cavaiola torrents	500 mm in 11 h, 95 mm in 1 h	325/12,000	Overflow of torrents and mud-slides from Cava dei Tirreni mountain hit urban areas of Salerno city and, Vietri and Maiori villages. Estimated damage 45 billion of liras	

(continued)

Table 11.6 (continued)

Flood categories	Date	Affected area	Main river basins	Hydro-meteorological features	No. of fatalities/ evacuees and homeless	Short description	Effects on defence policy
FDL	9 October 1963	Vajont valley, Pordenone province (Friuli-Venezia Giulia region) and Piave valley, Belluno province (Veneto region)	Piave	A flood wave of about 50 million of m^3 overran the Vajont dam (261 m of height)	1917	A landslide (≥ 240 million m^3) from Mount Toc fell into the Vajont reservoir and produced a wave that ran over the dam. The water destroyed some villages in the municipalities of Erto and Casso (Pordenone province), the town of Longarone and other villages in the province of Belluno. Estimated damage € 986 million	The study of landslide features have imposed an in-depth estimate of risk of side instability in the design of a reservoir
RF	4 November 1966	Florence and other towns of Tuscany region	Arno	Max rain 150 mm in 24 h. Peak flow of Arno in Florence 4000 m^3/s. Rainfall during the previous October ≥200 mm	47 (38 in Florence and province)/>46,600	The heavy rains caused landslides and the overflow of the Arno, that flooded large part of the centre of Florence (4.85 m at the church of Santa Croce). Other villages in Tuscany were flooded. Young people (Mud Angels) saved artistic masterpiece and rare books. Estimated damage 300 billion of liras	After the disaster a national committee (presided by De Marchi) was established for flood defence over Italy. A plan to mitigate flood risk in the Arno basin through flood routing works was prepared

RF	2–3 November 1968	Biella, Asti, Vercelli, Novara, Verbano-Cusio-Ossola and Cuneo provinces (Piedmont region)	Tanaro, Bormida, Sesia, Ticino	Max rain 500 mm in 2 days Peak flows: Sesia 3900 m^3/, Toce 2000 m^3/s	86/>370	Main river flooding and landslides hit industrial areas of Biella and lands in Vercelli and Novara. Estimated damage 300 billion of liras.	
RF	4 November 1966	Trentino-Alto Adige, Veneto, Friuli-Venezia Giulia and Lombardia regions	Adige, Piave, Livenza, TagliamentoBrenta-Bachiglione	Exceptional storms (>400 mm in 32 h, max 711 mm) and snow melting caused peak flows in Piave, Livenza, Tagliamento	87/>42,000	Overflow of Adige, Brenta-Bacchiglione, Piave, Livenza and tributaries caused many flooding events. High water at Venice (1.94 m) Estimated damage 15 billion of liras	
UFF	7–8 October 1970	Genoa city and some municipalities of Genoa and Alessandria provinces (Liguria region)	Bisagno, Polcevera, Leiro	690 mm in 48 h, 480 mm in 24 h (Genova Molassana); peak flow of Bisagno 1000 m^3/s; peak flow of Leira 510 m^3/s	51/>1400	Max water height 2.0 m. Estimated damage 45 billion of liras	

(continued)

Table 11.6 (continued)

Flood categories	Date	Affected area	Main river basins	Hydro-meteorological features	No. of fatalities/ evacuees and homeless	Short description	Effects on defence policy
RF	30 December 1972–3January 1973	Calabria region: Reggio Calabria and Catanzaro provinces Sicily region: Messina, Enna, Agrigento provinces	Torrents of Sila and Aspromonte mountains (Mesima, S.Agata, Bonamico and Corace) in Calabria. Torrents near Messina and South Imera and Platani rivers in Sicily	Calabria: max rain 433 mm in a day after previous heavy rains since 20 December 1972. Peak flow 430 m^3/s in Corace torrent Cumulated rain of almost 1500 mm over South Calabria (20 December 1972–3 January 1973) Sicily: Max rain 1000 mm in 4 days at Antillo; 640 mm in 5 days at Elicona. Peak flow 3036 m^3/s in Platani river (1247 km^2)	18/>5700	The torrents of Thyrrenian and Jonian sides of Calabria destroyed several bridges Landslides produced severe damages to building Also severe damages in many provinces of Sicily Estimated damages 900 billion of liras	Law 36/1973 provided 50 billion for people hit by the disasters and promoted the draft of plans for river basin assessment in Calabria and Sicily regions
FDL	19 July 1985	Valley of Stava, Trento province (Trentino-Alto Adige region		Mud flow of 160,000 m^3	268/~100	The break of two ponds for storing mine sediments caused a mud flow that destroyed Stava village. Estimated damage 8.5 billion Liras	A survey of small dams was made (Law 662/1985) and rules to estimate flooding areas below all dams was established

FDL	28 July 1987	Val Pola, Valtellina, Sondrio province (Lombardia region)		600 mm in 3 days (17–19 July 1987)	29 (due to the landslide)/~20,000	A landslide (30 million m^3) produced a dam in the Adda river (lake capacity of about 20 million m^3) with high risk down in the valley due to the break of dam (100 m. high) Estimated damage more of 1000 billion liras	An innovative method was tested for emptying the lake above the landslide dam: three pumping plants and pipes and a channel for controlled overflow (31 August 1987)
RF	5 November 1994	Alessandria, Asti, Biella, Cuneo, Torino, Vercelli and Verbano-Cusio-Ossola provinces (Piedmont region)	Tanaro	300 mm in 24 h	71/>5800	Main river flooding and landslides. The damages were estimated in 15,000–25,000 billion of Lire	
UFF	13 March 1995	Giarre, Mascali, Acireale municipalities, Catania province (Sicily region)	Urban roads	Max rain 376 mm in 12 h, 253 in 3 h, 144 mm in 1 h (Giarre-Jungo)	6/>60 (Other victims: 12 sailors of the sinked Greek ship *Pelhunter*	Flooding of centres of Giarre and Acireale; flooding of Presa (village of Mascali municipality)	
RF	19 June 1996	Lucca and Massa-Carrara provinces (Tuscany region)	Versilia	Max rain 478 mm in 11 h, 390 mm in 6 h, Rain peak 176 mm in 1 h	15/>700	Flooding of Versilia and debris-flows destroyed Cardoso village. Total damages estimated in 146 million Euro	

(continued)

Table 11.6 (continued)

Flood categories	Date	Affected area	Main river basins	Hydro-meteorological features	No. of fatalities/ evacuees and homeless	Short description	Effects on defence policy
FDFMS	5 May 1998	Sarno, Siano, Bracigliano, Salerno province and Quindici, Avellino province, (Campania region)		173 mm in 48 h after a rain of 614 mm in the previous 6 days	159/6000	Mud-slides of volcanic soils placed over saturated carbonate rocks struck the municipalities, located down the mountains. 178 buildings destroyed and 450 damaged	The Sarno Act (Law 267/1998) introduced the Hydrogeological Asset Plan (HAP)
FDFMS	16 December 1999	Cervinara and San Martino Valle Caudina, Avellino province, (Campania region)		325 mm in 48 h	6/1500	Mud-slides of volcanic soils located over saturated carbonate rocks with velocity of 14–15 m/s	
UFF	9 September 2000	Soverato and Jonian coast of Catanzaro and Reggio Calabria provinces (Calabria region)	T. Beltrame	630 mm in 3 days	13 victims/~200 (Soverato)	The flooding of Beltrame killed guests at a camping site	The Soverato Act (law 365/2000) introduced the procedures for Hydrological Asset Plans (HAP)
RF	13–16 October 2000	Aosta valley and Piedmont regions	Dora Baltea and Po	600 mm in 48 h	27/>15,500	Main river flooding and landslides	

FDFMS	1 October 2009	Giampilieri and other villages in Messina municipality, Scaletta Zanclea municipality and Itala municipality (Sicilia region)		225 mm in 9 h after severe rain in the preceding month (max 400 mm)	37/>2000	Several debris flows struck some villages of Messina and other municipalities of the eastern coast of Sicily. Estimated damages € 550 million including motorway, aqueduct etc.	
UFF	25 October 2011	Cinque terre in La Spezia province (Liguria region), Lunigiana in La Spezia and Massa-Carrara province (Tuscania)		Max rain 542 mm in 30 h and 470 mm in 6 h (Brugnato)	14/>1500	Heavy precipitations have threatened the watersheds, causing floods and numerous debris flows and landslides	
UFF	4 November 2011	Genova city and Val Bisagno in Genova province (Liguria region)	Bisagno, Fereggiano, Sturla and Scrivia	Max rain 510 mm in 24 h (Rossiglione) and 469 in 24 h (Vicomorasso)	6/>150	Following heavy rains, widespread phenomena of geohydrological instability occurred, with extensive overflow, numerous flooding and landslides that caused extensive damages	
UFF	18 November 2013	Olbia-Tempio, Nuoro, and Oristano provinces (Sardinia region)	Cedrino and Posada	Max rain 300 mm in 20 h. Peak flow of Posada 3000 m^3/s	18/>1900	Flooding of Torpè village due to overflow from Posada	

(continued)

Table 11.6 (continued)

Flood categories	Date	Affected area	Main river basins	Hydro-meteorological features	No. of fatalities/ evacuees and homeless	Short description	Effects on defence policy
UFF	8–9 October 2014 Genova (Liguria)	Genova city (Liguria region)	Bisagno, Fereggiano, Sturla	Max rain in Geirato (Genova) 754 mm in 5 days, 135 mm in 1 h. At Torriglia 513 mm in 5 days and 373 in 1 day	1/~200	Heavy rains caused the flooding of the watercourses of Genova resulting in serious damages, estimated at € 250 million of public goods and € 100 million of business goods	
RF	15 November 2014	Liguria, Piedmont, Lombardy regions	Polcevera, Bormida, Seveso, Niguarda, Lambro	Max 238 mm in a day at Alessandria	9/>2000	The heavy rains caused landslides in mountainous and hilly areas of Liguria (Genoa province), Piedmont (Biella province) and Lombardy (Varese province) and floods along the Bormida river at Alessandria city, Lambro and Seveso rivers at Milan city	
UFF	9–10 September 2017	Livorno city (Tuscany region)	Ardenza and Maggiore	Max rain 42 mm in 15 min (Quercianella). Total rainfall 260 mm.	8/20	Due to heavy rains the Ardenza and Maggiore torrents overflowed and flooded the south part of Livorno	The flood with 200 years return period adopted for a flood routing facility resulted inadequate

RF River flooding, *UFF* Urban flooding due to flash flood, *FDBL* Flooding due to dam break or to landslide, *FDFMS* Flooding connected with debris flow or mud-slide

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