Chapter 12
Coping with Droughts

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Abstract Drought represents a serious threat to agriculture, water supply and environment. Nevertheless, only recently Italy has started to adopt an effective response to drought risk, shifting from a crisis management (reactive) approach towards a risk management (proactive) strategy. In this chapter, the drought features within the hydrological cycle and the principles suggested at international level for disaster reduction and the guidelines issued by the European Union on drought and water scarcity are described. Then, a summary of the main strategic and operational drought mitigation measures is presented together with the description of the role of drought monitoring. Afterwards, a recall of the Italian legislative framework to cope with droughts and to prevent or mitigate water shortage in supply systems is presented, accompanied by a short description of the most severe drought events occurred in Italy in the last century, which allows to draw a few lessons for the future. Some indications on the methods to assess drought-related water shortage risk in water supply systems in Italy are finally provided.

12.1 Introduction

Several drought events occurred in Italy have caused relevant damages to many of its socio-economic sectors and environment. Nevertheless, it is only in recent years that Italy has started to pay particular attention to drought issues. Crisis management has been the prevailing approach to respond to drought in the past, and in fact, since the 1990s, the National Civil Protection Agency has been the main actor in charge for drought response. As a consequence, there has been a lack of interest towards the implementation of measures aimed at preventing drought impacts, especially on water supply systems. In fact, only recently a risk management approach has been adopted, fostered by European recommendations, such as the

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Drought Management Plan Report (EC 2007) and the *Report on Water Scarcity and Droughts in the European Union* (EC 2011).

In the first part of this chapter, the evolution of the approaches to drought management is addressed (Sect. 12.2), and the criteria for risk management suggested by the International Strategy for Disaster Reduction, as well as the specific recommendations for drought risk management issued by the European Union (Sect. 12.3), are presented. An analysis of the main typologies of measures that can be adopted for drought prevention and mitigation is carried out (Sect. 12.4) and the role of drought monitoring is discussed (Sect. 12.5). In the second part, the Italian legislative framework regarding drought prevention and mitigation is recalled (Sect. 12.6), the most severe drought events that occurred in Italy in the last century are described (Sect. 12.7), and a few lessons learnt from recent droughts in Italy are discussed (Sect. 12.8). Objectives and methodologies to assess the risk of water shortage due to drought in supply systems are presented, and Italian experiences are described (12.9). Finally, a few concluding remarks are drawn.

12.2 Principles of Drought Management

Drought is defined as a temporary condition of a severe reduction of water availability compared to normal values, lasting a significant amount of time and affecting a large region (Rossi et al. 1992). Although drought is a natural phenomenon, as it stems from the variability of meteorological conditions – in particular, precipitation – it can be considered a disaster. Thus, similar to other disasters, the severity of its impacts on society depends on the vulnerability of water supply systems and of economic and social sectors, as well as on the preparedness to implement appropriate mitigation measures (Mishra and Singh 2010). Drought phenomena exhibit different features in the various components of the natural hydrological cycle, which in turn cause different impacts on the water resource systems (Fig. 12.1). In particular an initial reduction of precipitation with respect to normal conditions (*meteorological drought*) affects different processes within the hydrological cycle, thus determining soil moisture deficit (*agricultural drought*), as well as streamflow and groundwater deficits (*hydrological drought*).

According to the strategies for natural disasters mitigation, *drought risk* refers to the expected loss (in economic and/or social terms) caused by a drought event. It is evaluated as function of drought hazard, exposure and vulnerability. *Drought hazard* is taken into account through the probability of drought occurrence, whereas the *vulnerability* describes the degree of loss for a given element exposed to drought risk.

The risk of water shortage in water supply systems differs from natural drought risk because *water shortage* results from an imbalance between water supply and demand, caused by a meteorological/hydrological phenomenon. Moreover, anthropogenic factors – such as demand pattern development, supply infrastructures and management strategies and especially types of measures adopted for coping with drought – could exacerbate or reduce water shortage.

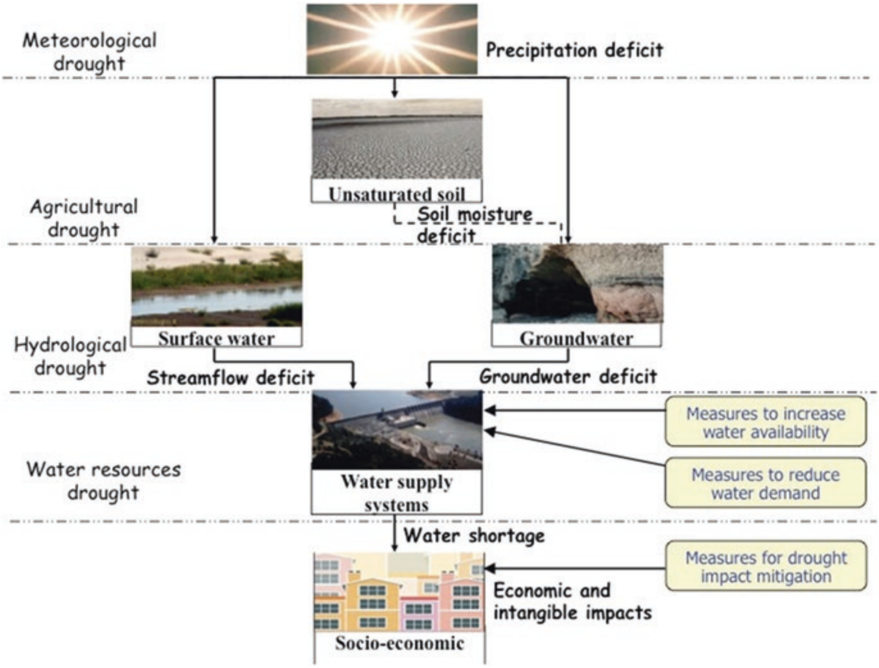

Fig. 12.1 Evolution of drought within the hydrological cycle and water shortage in water supply systems. (Source: Rossi 2017)

As a consequence, drought management presents some differences with respect to managing other natural disasters: (1) prevention actions may be effectively planned since drought effects evolve slowly along a large time span; (2) strategic measures for improving drought preparedness are generally more complex, since the spectrum of potential long-term actions is very large; and (3) operational measures, to be implemented at drought inception, require an adaptive response, due to the dynamic feature of phenomenon. In particular the operational measures should take into account the uncertainty in drought evolution, which can yield a duration and a severity different than those considered in the planning stage (Rossi 2017).

As mentioned in the introduction, drought risk has been traditionally managed by a *crisis management* approach. Although this approach still represents the most common response to drought at local, national and international levels, there is an increasing awareness about its weaknesses. In fact, since it is based on last-minute decisions, it generally leads to expensive actions, with unbearable environmental and social impacts. Thus, a shift towards a *risk management* approach, based on measures planned in advance, has been progressively advocated (Yevjevich et al. 1983; Wilhite 1987; Rossi et al. 1992; Wilhite 2000). Today, such a shift is emphasized in policy instruments adopted in drought-prone countries such as Australia (Botterill and Wilhite 2005), South Africa and USA (Wilhite et al. 2005). It is also suggested by international or European recommendations (UNISDR 2014; EC

2007, 2011), as well as advocated by research projects on drought (see, e.g. MEDROPLAN 2007). Nonetheless, for several countries, including Italy, it is not yet adequately transferred into the legislative and institutional framework on water resources management.

12.3 Drought Risk Management: International and European Recommendations

Risk management is the approach suggested and adopted by the United Nations International Strategy for Disaster Reduction (UNISDR). In particular, the general procedure, established at the World Conference on Disaster Reduction within the “Hyogo Framework for Action 2005–2015”, has identified the following priorities to build resilience of nations and communities to drought (UNISDR 2014): (1) policy and governance; (2) drought risk identification and early warning; (3) awareness and education; (4) reducing underlying factors of drought risk; and (5) mitigation and preparedness, as well as cross-cutting issues. The most recent UNISDR recommendations have been included in the Sendai Framework for Disaster Risk 2015–2030 (UNISDR 2015), highlighting four priorities for action: (1) understanding disaster risk, (2) strengthening disaster risk governance, (3) investing in disaster risk reduction for resilience and (4) enhancing disaster preparedness for effective response and to “Build Back Better” in recovery, rehabilitation and reconstruction. The guiding principles emphasize the primary responsibility of states to prevent and reduce disaster risk, the empowerment of local authorities and communities through resources, incentives and decision-making responsibilities, the coherence between disaster risk reduction actions and sustainable development principles, and the consideration of local specific features of disaster risk.

Several countries, affected by frequent severe droughts, have developed national drought policies in recent decades. In many cases, the planning legislation to cope with drought refers to principles and criteria developed either by the UN Convention for Combating Desertification (UN Secretariat General 1994) or from the UN International Strategy for Disaster Reduction (UNISDR 2009). Also some laws refer to the Integrated Water Resources Management (IWRM) paradigm, introduced in the UN Conference on Water in the Mar del Plata (1977), and emphasized during several international water events, such as World Water Forums. Nonetheless differences in drought policies implementations are strongly affected by the national legal framework and by the structure of the institutions which share water resources governance. A comparison of drought policies implemented in Australia, South Africa and USA by Wilhite et al. (2005) points out that, despite the differences, common strategies are used to address the goal of reducing societal vulnerability to drought. These common strategies include monitoring and early warning of droughts, assessment of drought risk and adoption of a mixture of preparedness measures.

Until recent years, European water policies paid little attention to drought issues in terms of technical and financial instruments and legislative acts. The Water Framework Directive 2000/60 (WFD) promoted a complex water resources planning process at basin level, aimed at preserving or improving water quality for ecosystem and human use protection. However, the WFD treated drought only marginally, in spite of mentioning drought as one of its objectives. Indeed, drought events are considered only as one of the exceptional cases that allow a derogation of good ecological status requirements of the affected water bodies. In order to overcome these weaknesses in EU water policy, the EU Water Scarcity and Drought Expert Network developed a guidance document on drought preparedness and mitigation (EC 2007) with the proposal of drafting a "Drought Management Plan" (DMP), as an Annex to the "River Basin Management Plan" (RBMP). Such a DMP should be prepared by the same body responsible for basin planning, i.e. the River Basin (or District) Authority. In spite of the fact that the DMP is not mandatory for member states, it aims at extending goals and criteria of WFD (in a similar way to the EU Flood Directive 2007/60) to improve drought management and in particular to reduce the vulnerability of the water supply systems, as well as to mitigate drought impacts. Its specific objectives are (1) to ensure sufficient water availability to cover essential human needs to safeguard population's health and life, (2) to avoid or minimize negative drought impacts on water bodies and (3) to minimize negative effects on economic activities (see Rossi 2009).

On the basis of the successive work of the EU Water Scarcity and Drought Expert Network, the Report from the Commission to the European Parliament and the Council on these issues (EC 2011) has suggested to revise the related European policy including some specific topics listed in Table 12.1.

At EU level, discussions are ongoing on how member states should incorporate climate change issues into the implementation of EU water policy, in order to mini-

Table 12.1 Recommendations to revise European policy on water scarcity and drought

Improving water efficiency
Introducing water-saving devices and practices in buildings and improving water-efficient construction.
Reducing water leakages in supply distribution systems.
Improving efficiency in agricultural use of water .
Achieving better planning and preparedness to deal with droughts
Integrating actions against water scarcity and drought into other sectorial policies (agriculture, households, industry).
Assessing the adequacy of the River Basin Management Plans on water scarcity and drought issues.
Further developing the prototype of an observatory and early warning system on drought.
Defining a more comprehensive list of indicators on water scarcity and drought and of vulnerability of water resources.
Developing adequate implementation instruments of financing, water pricing, water allocation research and education
Encouraging EU funding of natural risks through Cohesion Policy, Regional Policy, Solidarity Fund and Economic Recovery Plan and reforming Common Agricultural Policy.
Making the national rules more restrictive to authorize water abstractions.
Developing new research projects on vulnerability and increased drought risk.
Introducing new educational programmes and awareness-raising campaigns .

Source: Rossi and Cancelliere (2013)

mize vulnerability to future climate and to fight possible emergencies by means of specific response actions. According to the White Paper on *Adapting to climate change* (CEC 2009), one of the strategies proposed to increase resilience to climate change consisted in the improvement of the management of water resources through the enhancement of water efficiency in agriculture, households and buildings. Also, the expected revision of the WFD and of the water scarcity and droughts strategy includes options to increase drought resilience. Furthermore, revisions of the River Basin Management Plans (due in 2021) could take advantage from the incorporation of climate change effects within basin planning, through analysis of the pressures on water bodies, definition of the phenomena to be monitored and verification of the resilience of the action program to climate change. Among European countries, Spain has probably developed one of the most advanced legislation systems for drought management, capitalizing on the existing central role of River Basin Authorities in water management. In particular, according to the National Hydrological Plan Act (2001), Drought Management Plans have been adopted by the River Basin Authorities for all districts, and a national drought indicator system has been established (Estrela and Vargas 2012). More recently, the newest Drought Management Plan, approved in 2018, introduced two national indicator systems: (1) the drought indicator system and (2) the water scarcity indicator system. The first system is aimed at the detection of prolonged drought in rivers and the definition of the actions to be taken for limiting temporary water quality deterioration. The second system aims at the timely detection of reduced availability of water resources, in cases where there is a risk of water shortage. The final aim of this system is then to define the measures to delay or avoid the most severe phases of water shortage, by distinguishing for a specific sub-basin the scenarios (i.e. normal, pre-alert, alert and emergency) using a set of hydrological variables (streamflow and groundwater level) and reservoir storage indicators.

12.4 Drought Mitigation Measures

In literature, several classifications of drought mitigation measures are available. A consolidated classification of drought mitigation measures distinguishes three main categories of measures, oriented at (*i*) increasing water supply, (*ii*) reducing water demands and (*iii*) minimizing drought impacts (Yevjevich et al. 1983). Other traditional classifications are based on the type of approach to drought management, either reactive or proactive, or relate on the timing of their implementation (Rossi 2000). In particular, *long-term measures* include the measures aimed at improving drought preparedness through a set of structural and non-structural adjustments to an existing water supply system. *Short-term measures*, defined within a contingency plan, are designed to mitigate ongoing drought events, through actions oriented to improve water supply by using additional water resources or to reduce water demand (Dziegielewski 2000).

In Table 12.2, a list of long-term and short-term mitigation measures is proposed, distinguishing the main categories of actions above-mentioned and the different sectors of application (urban, agricultural, industrial and recreational).

Table 12.2 Long-term and short-term drought mitigation measures

Category	Long-term actions	Affected sectors			
Demand reduction	Economic incentives for water saving	U	A	I	R
	Agronomic techniques for reducing water consumption		A		
	Dry crops instead of irrigated crops		A		
	Dual distribution network for urban use	U			
	Water recycling in industries			I	
Water supply increase	Conveyance networks for bi-directional exchanges	U	A	I	
	Reuse of treated wastewater		A	I	R
	Inter-basin and within-basin water transfers	U	A	I	R
	Construction of new reservoirs or increase of storage volume of existing reservoirs	U	A	I	
	Construction of farm ponds		A		
	Desalination of brackish or saline waters	U	A		R
	Control of seepage and evaporation losses	U	A	I	
Impacts minimization	Education activities for improving drought preparedness and/or permanent water saving	U	A	I	
	Reallocation of water resources based on water quality requirements	U	A	I	R
	Development of early warning systems	U	A	I	R
	Implementation of a Drought Contingency Plan	U	A	I	R
	Insurance programs		A	I	

Category	Short-term actions	Affected sectors			
Demand reduction	Public information campaign for water saving	U	A	I	R
	Restriction in some urban water uses (i.e. car washing, gardening, etc.)	U			
	Restriction of irrigation of annual crops		A		
	Pricing	U	A	I	R
	Mandatory rationing	U	A	I	R
Water supply increase	Improvement of existing water systems efficiency (leak detection programs, new operating rules, etc.)	U	A	I	
	Use of additional sources of low quality or high exploitation cost	U	A	I	R
	Overexploitation of aquifers or use of groundwater reserves	U	A	I	
	Increased diversion by relaxing ecological or recreational use constraints	U	A	I	R
Impacts minimization	Temporary reallocation of water resources	U	A	I	R
	Public aids to compensate income losses	U	A	I	
	Tax reduction or delay of payment deadline	U	A	I	
	Public aids for crops insurance		A		

Source: Rossi (2017)
U urban, *A* agricultural, *I* industrial, *R* recreational

Regardless of the adopted classification, after a set of potential mitigation measures are identified, selection of the best combination should be based on a comparison and ranking of the performance of each measure in mitigating negative impacts of drought as well as of the main economic, environmental and social consequences of the adopted measures. To this end, multi-criteria approaches have been proposed since the pioneering work by Duckstein (1983). The NAIADE model has been applied to different complex water systems, in order to rank the alternative combinations of long-term and short-term measures for reducing shortage risk in a water supply system (see Munda et al. 1998; Rossi et al. 2005).

12.5 Role of Drought Monitoring

Several methods have been developed for drought identification and the estimation of its severity, as well as for the subsequent assessment of drought vulnerability referred to a specific area and/or a water supply system. An objective procedure to identify the onset and the end of a drought and to evaluate its characteristics (duration and severity) was proposed by the pioneering work of Yevjevich (1967), based on the *run method* to be applied at the time series of the variable of interest. The run method has been largely used for probabilistic characterization of drought by means of univariate, bivariate and spatial-temporal analyses (Bonaccorso et al. 2003; Cancelliere and Salas 2010; Mishra and Singh 2011).

Assessment of ongoing drought conditions and water shortages in water supply systems is a crucial step for drought management. To this end, a set of indices measuring the anomaly from a "normal" condition in terms of one or more meteorological or hydrological variables can be employed. In literature, several indices for drought monitoring have been proposed, which differ for the selected variable, the time scale of analysis, the definition of "normal" conditions, the way of computing the anomaly (e.g. difference, ratio, etc.) and the standardization method.

Several reviews and classifications of drought indices have been made in the last decades. Examples can be found in MEDROPLAN (2007) and on websites of drought monitoring and information services such as National Drought Information Center (NDIC 2011). Generally, drought indices are categorized in meteorological, hydrological, agricultural, remote-sensing-based drought indices. Some indices also attempt to combine different data related to different variables (e.g. precipitation, soil, water content, etc.) and/or to merge the information from several indices into an indicator that takes into account also the status of water reserves.

A drought monitoring system has a key role to assess drought risk and to define preparedness and mitigation measures. The indices to be used in a drought monitoring system must satisfy several requisites in order to provide an effective early perception of the severity of the phenomenon and its impacts. A few requisites have been identified in Rossi (2017). In particular, the indices should be appropriate for:

1. Representing the complex interrelation between meteorological and hydrological components of a significant reduction of water availability.
2. Making use of real-time easy available hydrometeorological data.
3. Being able to describe drought conditions even in a drought's early stage.
4. Providing comparability of drought events both in time and space.
5. Describing in some way drought impact.
6. Assessing the severity of the current drought so to induce decision-makers to effectively activate drought mitigation actions.

Regardless of the selected indices, effective drought early warning must rely on a network of meteorological and hydrological stations, including remote sensing devices, an advanced DSS running on adequate computer facilities (adequate computational power and ease of use).

12.6 Legislation Framework to Cope with Drought in Italy

In spite of several drought events which hit several Italian regions with dramatic impacts, drought management has been marginally covered by Italian legislation until recent years. The Law 183/1989, regulating soil conservation and water supply, listed the long-term measures to improve drought preparedness among the measures to be included in the river basin plan by the authority of basin. However, this provision did not find application in most of the river basin plans. Actually, the actions to mitigate the drought effects have been carried out by the civil protection system according to Law 225/1992. Most of the measures were emergency actions, generally implemented by local commissioners that operated according to a deliberation drafted after an occurring drought was recognized as a natural disaster to be faced through emergency measures.

An attempt to introduce drought mitigation concepts with reference to municipal water supply was established by the Prime Minister Decree 47/1996, which, with reference to the Law 36/1994, required to introduce the assessment of water deficiency risk in municipal supply systems and the proposal for water crisis prevention within the Plan of Optimal Territorial Unit for Integrated Water Service. Unfortunately, most of the plans did not consider drought risk, likely due to a lack of specific indications about the methods for risk assessment in the guidelines for the drafting Optimal Territorial Unit plans.

Another attempt to implement a preventive approach to drought risk was done by the Legislative Decree 152/1999 and the Deliberation 21/12/1999 of the Interministerial Committee for the Economic Planning (CIPE), which required the identification of areas vulnerable to drought and desertification, as well as the program of action in the framework of the international convention against drought and desertification. However, no guidelines on technical standards or operational steps to identify areas vulnerable to drought areas were issued.

As a consequence, for several years, only a reactive response to drought has been adopted in Italy. In particular, two main action lines have been implemented: (1) emergency actions by the Department of Civil Protection and (2) subsidies to farmers for covering the agricultural damages caused by drought, under the provisions of national acts on natural disasters. The implementation process of emergency measures in Italy includes the following phases:

1. Emergency declaration by national government due to drought, by request of local authorities through the regional government.
2. Appointment of a Commissioner for Water Emergency by the Prime Minister.
3. Establishment of the Office of the Commissioner for Water Emergency at regional level.
4. Approval of a list of water emergency measures, including the funding of new hydraulic works, the authorization of water exchanges between users and the simplification of administrative procedures for the design and the realization of the planned works.

Furthermore, local authorities can be authorized to implement specific actions such as rationing of supply or transfer of private sources to public use.

With reference to the subsidies issued to farmers for covering drought damages in agriculture, they are the result of a joint action by national and regional governments. Usually, Regional Department of Agriculture and Forest request a drought declaration to the national Ministry of Agriculture and Forestry Policies based on evidenced impacts on different crops in the territory of some provinces or municipalities. After the Decree of the Ministry, the regional department publishes the rules to be followed for subsidies, which can consist of financial contributions for revenue losses and of loans with reduced interest rate. Funding is provided through a specific national fund for natural disasters.

A significant shift from emergency management approach to preventive approach occurred in Italy as a consequence of the Guidance Document on drought preparedness and mitigation, drafted by the EU Water Scarcity and Drought Expert Network (EC 2007). The Agency for Environmental Protection and Technical Services (APAT) and the Institute for Environmental Protection and Research (ISPRA) since its establishment in 2008 (see Chap. 4) contributed to the preparation of a Guidance Document and have developed several activities to improve drought management.

The most recent initiative aimed at drought and water scarcity monitoring and the regulation of water resources management during drought events is the establishment of the Observatories on water resource uses within Hydrographic Districts (ISPRA 2018). The Observatories, in operation since February 2016 on a voluntary basis, include, besides the District Authorities, representatives from various ministries (Environment and Protection of Land and Sea, MATTM; Agricultural Food and Forestry Policies, MPAAF; Infrastructures and Transport, MIT), as well as from regions within the district, the Department of Civil Protection (DPC), ISPRA, the Institute of Statistics (ISTAT), the Council for Research in Agriculture and Economy (CREA), the National Research Council (CNR), the Association of Land Reclamation Consortia (ANBI), the Lake Regulation Consortia and companies for water and electric services. A Technical Committee for coordinating the Observatories, established in October 2016 at MATTM, has prepared guidelines for selecting proper indicators to monitor drought and water scarcity.

12.7 Severe Drought Events in Italy in the Last Century

Italy has experienced several drought events, both in its northern regions, characterized by humid climate and abundant water resources, and in semiarid southern regions where the higher variability of the hydrometeorological conditions and the reduced amount of water resources combined with an increase of water demand lay the basis of more frequent water shortage conditions. In what follows, some of the most severe documented droughts that occurred in the last 100 years are briefly described.

12.7.1 Drought of 1921

A very severe drought affecting most of the Italian regions, with significant agricultural impacts, occurred in the last trimester (October–December) of 1921, following similar dry periods occurred in summer over other European countries (Great Britain, France, Switzerland) (Eredia 1922). The Po River Basin and Liguria Region were affected by the maximum deficit: total precipitation in the trimester at Piacenza was 7 mm (precipitation deficit of −98% of the long-term average), at Milan 8 mm (−97%) and at Genoa 95 mm (−81%). Minor deficits were reported for the islands: precipitation at Cagliari in Sardinia 241 mm (−41%) and in Catania in Sicily 289 mm (−40%).

12.7.2 Drought of 1938

Another severe drought occurred in the first 4 months (from January to April) of the 1938 in North and Central Italy, Sardinia included. The available analysis (Marchetti 1938) includes both precipitation deficit and low-flow deficit in several rivers. The most severe precipitation deficits were recorded at Trento in Trentino-Alto Adige (−93%), Genoa in Liguria (−93%), Belluno in Veneto (−91%) and Turin in Piedmont (−91%), while minor deficits occurred in Central Italy (Rome, −39%) and Sardinia (Cagliari, –43%). The amount of precipitation from January to April 1938 was the minimum since 1866 at Turin (21.5 mm) and Trento (17.6 mm). In other stations precipitation was very close to the minima recorded in very long series such as Padua (203 years from 1713 to 1915) and Milan (158 years from 1764 to 1922). Also severe streamflow deficits in the first 4 months of 1938 occurred in several rivers, particularly in the Northern and Central Apennines (Trebbia −72%, Magra −70%, Reno −60%), as well as in Sardinia (Flumendosa −65%). Minor deficits were registered in the Veneto rivers (Isonzo −62%, Po −44%), while streamflow deficits in Southern Italy river were even lower (Ofanto in Apulia −36%, Simeto in Sicily −31%).

12.7.3 Drought of Years 1988–1990

A severe 3-year drought occurred in the 1988–1990 period, affecting almost the entire national territory, and with the most severe deficits observed during the wet season, which led to severe impacts on water supply. A survey of such a drought was promoted by the Department of Civil Protection, which organized two round tables at Rome at the National Research Council (on February 1989 and February 1990) and established a commission, with the aim to monitor and to analyse the drought process, so to identify the best drought mitigation measures. The commission included representatives of the involved ministries, hydrometeorological services and water supply management companies. The commission produced a detailed report on this drought event (Rossi and Margaritora 1994). In Table 12.3 the long-term average (annual and seasonal) precipitation values and the estimated related deficits per year and geographic area are shown. Annual precipitation deficits over the whole Italian territory were −21% in 1988, −24% in 1989 and −16% in 1990. Deficits in the period from September to March were more significant: −44% in the 1988–1989 and −43% in the 1989–1990 period.

Precipitation deficit generally determined great water deficit in rivers, in Alpine lakes, and caused groundwater deficits in aquifers. Table 12.4 shows annual deficits and mean deficits on 1988–1990 period related to streamflow observed in selected rivers. The mean 1988–1990 deficits range from −12% (Adige in Veneto) to −74%

Table 12.3 Precipitation deficit during the 1988–1990 drought event in Italy

	Area	Annual values				Seasonal values (Sept–March)			
		Avg. prec	Deficit (%)			Avg. prec	Deficit (%)		
	(10^3 km^2)	(mm)	1988	1989	1990	(mm)	1988–1989	1989–1990	1988–1990
Northern Italy	106.8	1116	13	18	12	567	38	42	40
Central Italy	79.5	977	27	16	18	716	53	39	46
Southern Italy	65.2	1106	20	30	20	733	40	50	45
Insular Italy	49.8	723	25	30	12	612	44	39	41
Italy	301.3	1012	21	24	16	645	44	43	43

Source: De Vito and Rusconi (1994)

Table 12.4 Runoff deficit (shortfall) in some significant Italian rivers

River	Catchment area (km²)	Avg. runoff (mm)	Annual deficit (%)			Mean 1988–1990 deficit	
			1988	1989	1990	(mm)	(%)
Brenta	1567	1143.1	12	2	42	199	19
Adige	11,954	536.3	4	2	29	708	12
Sieve	831	576.8	38	64	41	814	48
Ombrone	2657	316.9	37	67	66	540	57
Fiora	818	269.8	25	53	51	375	43
Pescara	3125	573.2	33	34	39	597	35
Tevere	16,545	443.7	23	39	47	480	36
Biferno	1290	281.1	60	32	52	388	48
Cervaro	657	134.4	43	89	89	297	74
Ofanto	2716	160.2	2	67	59	232	43
Oreto	76	375.6	33	67	11	407	37
Tirso	587	214.9	48	70	75	406	64

Source: De Vito and Rusconi (1994)

(Cervaro in Apulia). Lake Como and Lake Maggiore reached almost their minimum level on record in both 1989 and 1990, and many aquifers displayed an unusual drop in water table levels. Also the increase in average temperature, recorded in several stations, contributed to reduce snowfall and snow coverage in the Alps and in part of the Apennines.

Because of the severe water deficits, extreme impacts on water supply and economic activities occurred. Southern regions and major islands, particularly hit by unexpected water shortage, had to rely on tank trucks to supply drinking water, as a last option. Irrigation agriculture was also badly struck by the drought. For example, in several districts of Sicily and Sardinia in 1989, a very severe decrease of irrigated surface was observed (see Table 12.5). Also, hydroelectric production exhibited a significant reduction, and persistent low flows caused heavy damages on aquatic ecosystems.

The 1988–1990 drought found the communities unprepared to cope with the impacts on water supply, as no mitigation measures were planned in advance. Only emergency actions were adopted with funds provided by the national government, especially through the Department of Civil Protection. The total cost was estimated to be of 1133 billion of Italian liras for both short-term and long-term measures (Cittadino and Landrini 1994).

12.7.4 Drought of 2017 in Various Italian Rivers

According to the data published by the ISTAT for World Water Day 2018 (ISTAT 2018), and to the analyses carried out for different parts of the country (AA.VV 2017), the drought that hit the main Italian rivers (Po, Adige, Arno and Tiber) in

Table 12.5 Reduction of irrigated surface in some regions of Southern Italy during the 1988–1989 drought

Region	Irrigation districts	Irrigable surface (ha)	Irrigated surface (ha)		Comments
			1988	1989	
Abruzzo	Right and Left Pescara	13,300	11,050	8300	Reduced supply
Campania	Sannio, Right and Left Sele	36,280	33,945	29,675	Reduced supply
Apulia	Tavoliere, Tara, Arneo	115,540	55,143	41,860	Reduced or no delivery
Basilicata	Bradano, Val d'Agri	59,300	31,400	18,680	
Calabria	Catanzaro, Lao Abatamarco, Sibari and Crati	53,180	14,570	23,150	Irregular delivery
Sicily	Catania plain, Caltagirone, Lentini, Scicli, Acate, Gela Salso, Belice Carboj, Delia Nivolelli, Birgi	100,500	28,850	28,375	Reduced supply to selected crops or no delivery
Sardinia	Southern Sardinia, Oristano, Central Sardinia, Liscia, Nurra	96,580	31,670	10,670	

Source: Leone (1994)

2017 has been severe, due to the scarce precipitation of the autumn 2016 and of the entire 2017, characterized also by high temperatures.

The analysis carried out by ISTAT, by using the SPI (Standardized Precipitation Index) at 12 months over the river basins, shows much dry or extreme dry conditions from May to December for all rivers (where "much dry" refers to $-1.50 \leq \text{SPI} \leq -1.99$ and "extreme dry" to $\text{SPI} \leq -2.00$). A moderate dry condition ($-1.00 \leq \text{SPI} \leq -1.50$) was registered in the Adige basin since February and in the Tiber basin from April.

The annual streamflow deficit, computed with reference to the average value of the 1981–2010 period, presents significant values: −41% for Po river at Pontelagoscuro (with monthly peak of −61% in October); −33% for Adige river at Boara Pisani; −27% for Arno at S.Giovanni alla Vena (with monthly peak of −88% in October, while positive deviation occurred in the months of February, March and September); and −39.% for Tiber at Ripetta (with maximum deficit of −55.% in November). The drought which hit the Lazio region in 2017 had severe effects on the water supply of Rome, especially after the emergency withdrawals from Bracciano Lake were stopped for environmental reasons.

12.7.5 Droughts in the Po River Basin in the Last 20 Years

Several drought events occurred in the Po river basin in the last 20 years, generally due to anticyclone conditions in the Mediterranean leading to low precipitation and high temperatures over the Italian peninsula. The most severe events occurred in 2003–2008, 2011–2012 and 2016–2018, which caused heavy reduction of water withdrawals from Po river and its tributaries for the different uses, as well as severe impacts on the water quality in the lower reach of the river.

The severity of the droughts in the Po river is estimated by using the available series of monthly flow observed at the Pontelagoscuro gauge (basin surface 70,091 km^2) (Pecora 2019), whose mean flows computed on the 1923–2018 periods and minimum monthly flows on the same period are shown in Fig. 12.2. Figure 12.3 shows the monthly flow deficit or surplus, computed with reference to long-term means (1923–2018) for each month, as well as the 12 months Standardized Flow Index (SFI) (12) referring to the same means. Each graph covers a 3-year period of the most severe droughts of last 20 years comparing their characteristics with those of the two previous worst drought events (1943–1945 and 1988–1990).

During 2003, low flows occurred from February to November with mean monthly deficits greater than 50% from May to October and with a maximum deficit of 70% in June. The mean monthly flow in June, July and August was lower than 600 m^3/s, which is considered a warning threshold for the upstream flow of brackish water from Adriatic Sea in the Po delta mouth, although the extreme critical low flow below which water quality is not acceptable for withdrawals is 450 m^3/s. Despite in December 2003 and during the first months of 2004 the monthly flows exceeded the mean flows, the value of SFI (12) continue to indicate a "moderate dry condition" ($-1.00 \leq$ SFI ≤ -1.50) or a "much dry" condition ($-1.50 \leq$ SFI ≤ -1.99).

The 2005–2008 drought was very long and severe. According to the recorded monthly deficits, it lasted for 41 months (flows below average flows from January 2005 to May 2008, with the exception of September 2006). Based on the time-distribution of SFR (12), duration is estimated 39 months, with peaks of "extreme dry" (SFI ≤ -2.00). The monthly flows in June and July 2006 were lower than all previous historical minima. The 2011–2012 drought was not too severe, while the 2016–2018 drought covered 23 months (on the basis of monthly deficits) or 26 months (on the basis of SFI(12) amounts).

However the comparison with the previous past droughts shows that the droughts that occurred in the Po river during the last 20 years have been more severe than the

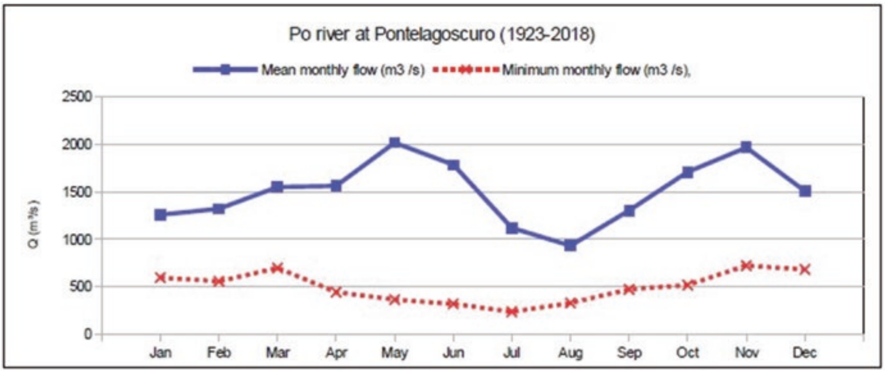

Fig. 12.2 Mean and minimum monthly flow in the 1923–2018 period in Po river at Pontelagoscuro

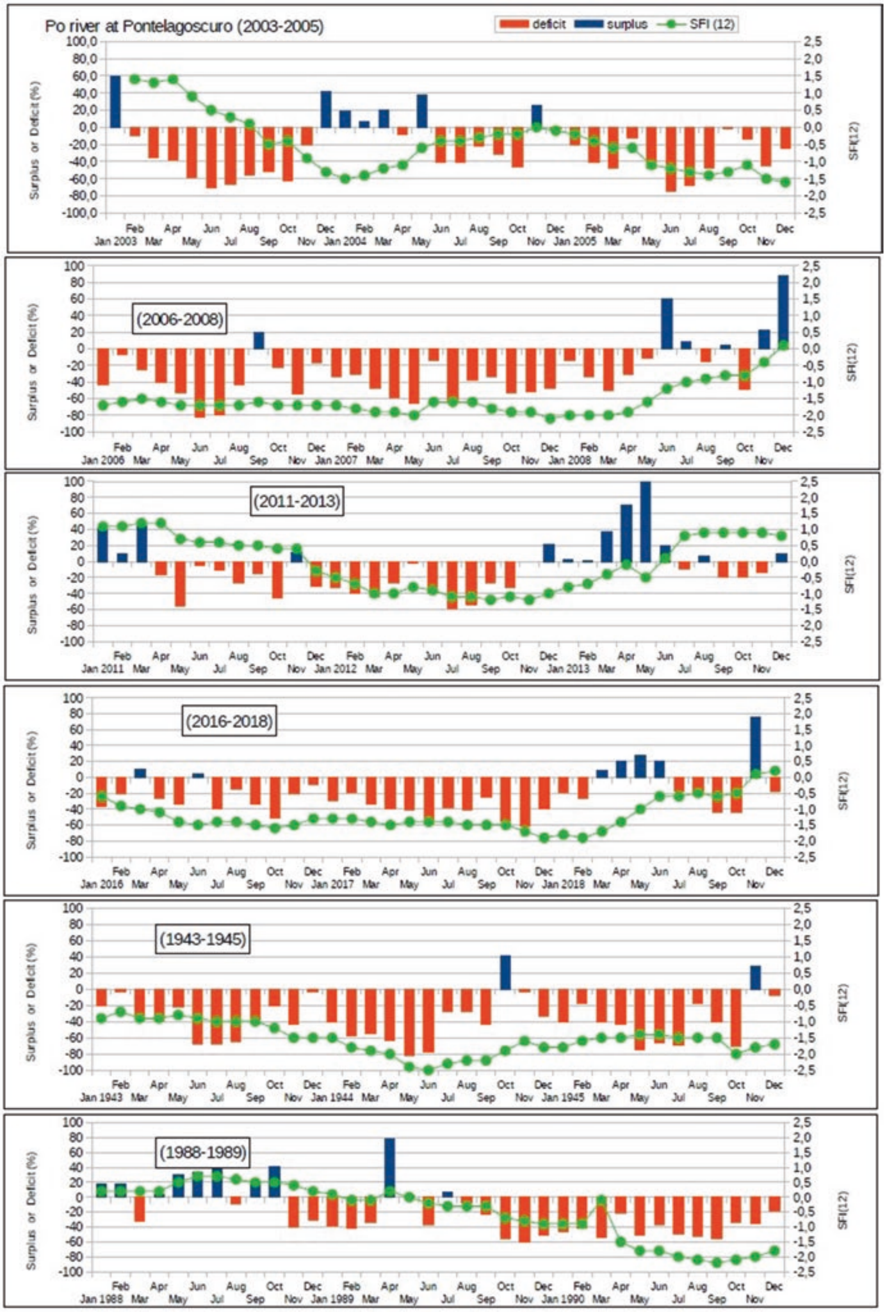

Fig. 12.3 The most severe droughts in Po river at Pontelagoscuro

1989–1990 drought, but not as much as the 1943–1945 drought. In fact, two moderate droughts occurred in the 1988–1990 period: length of 5 months (from November 1988 to March 1989) and length of 17 months (August 1989–December 1990). Instead, during the 1943–1945 period, a drought of 34 months occurred (from January 1943 to October 1945 with the exception of October 1944).

Obviously, the effects of the more recent droughts were more severe due to the increase of water demands for different uses in the basin. Also the consequences of extreme low flows (lower than 450 m^3/s) in the valley reach of Po caused more severe impacts due to the presence of withdrawals for municipal use (Aqueduct of Ferrara and Aqueduct of the Po delta), which cannot derive water with high salt content. Thus the occurrence of events with flows lower than 450 m^3/s during the years 2003 and 2005 (five events per year with duration of 6 and 8 days) caused more damaging impacts than those ones of the years 1944 and 1945 (six and five events per year with duration of 8 and 12 days).

12.7.6 Italian Droughts Versus European Droughts

By using investigations on the most severe droughts occurred in Europe, a comparison of Italian droughts with those observed in other European countries can be helpful. Since the beginning of the twenty-first century, a large part of Europe has experienced a series of exceptionally severe drought events, affecting a wide range of socio-economic sectors. Most of these events have been the results of heat waves in combination with a lack of precipitation during the summer months (2003, 2010, 2013, 2015 and 2018).

Several studies have investigated drought events over Europe (Bonaccorso et al. 2013; Gudmundsson and Seneviratne 2015; Spinoni et al. 2015). In general, a different drought regime is observed in the Mediterranean than the rest of Europe, with the only exception of drought in 1949 which is evident both in Southern and Central Europe. Bonaccorso et al. (2013) conclude that besides Euro-Mediterranean regions, North Western and Central Eastern regions appear more drought-prone than the rest of Europe, in terms of low values of return periods. Other studies on drought hazard frequency and intensity seem to find increasing trends in Southern and Western Europe (Gudmundsson and Seneviratne 2015; Spinoni et al. 2015).

Spinoni et al. (2015) identified the most severe drought events in Europe between 1950 and 2012, by means of three indicators: Standardized Precipitation Index (SPI) (McKee et al. 1993), Standardized Precipitation Evapotranspiration Index (SPEI) (Vicente-Serrano et al. 2010) and Reconnaissance Drought Index (RDI) (Tsakiris et al. 2007). These indicators, computed using the E-OBS gridded data (0.25°x 0.25°), have been averaged into a combined indicator X at 3 months and 12 months scale for 13 European regions. The values of the X12 series from 1950 to 2012 for Italy are shown in Fig. 12.2, where drought events are marked in red. A drought event starts when the indicator falls below a threshold (computed as the mean minus the standard deviation) for at least three consecutive months and ends when it turns above the mean of the series (Fig. 12.4).

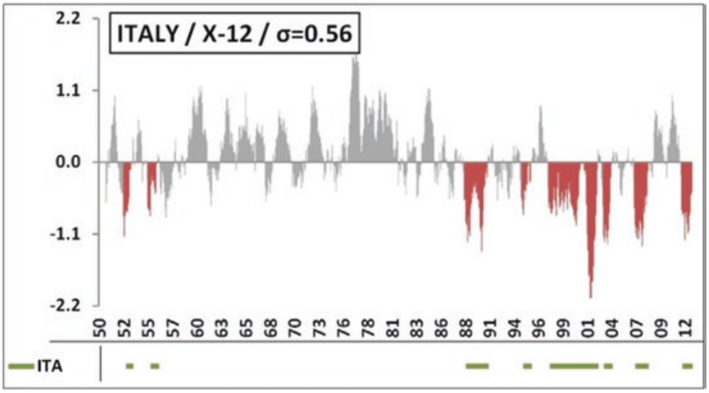

Fig. 12.4 Drought events identified through the indicator X12 (computed as average of SPI, SPEI and RDI) in 1950–2012 period in Italy. (Source: Spinoni et al. 2015)

Table 12.6 Characteristics of droughts in some European/Mediterranean countries in the period 1950–2012

Region	Countries	No drought events in:			Average duration (months)			Average severity		
		1951–1970	1971–1990	1991–2000	1951–1970	1971–1990	1991–2010	1951–1970	1971–1990	1991–2010
Italy	Italy	2	1	4	11.0	30.0	26.3	1.3	5.7	6.9
Aegean	Cyprus, Greece and Turkey	3	4	3	10.7	18.3	27.7	1.7	1.8	5.3
Balkans	Yugoslavia, Albania	5	3	4	9.0	8.3	16.3	2.7	3.6	4.2
Central Europe	Austria, Germany and Switzerland	3	2	3	16.7	25.0	13.7	6.0	8.0	2.6
France Benelux	France, Belgium the Netherlands and Luxembourg	1	2	3	13.0	26.0	33.0	2.6	7.8	7.0
Iberian	Spain, Portugal	2	3	5	14.5	9.7	18.6	2.5	1.3	5.5

Source: Spinoni et al. (2015)

Table 12.6 shows the main characteristics of the identified droughts in Italy and in the Mediterranean European regions for the periods 1950–1970, 1971–1990 and 1991–2010: number of events, duration and average severity (computed as the sum of dimensionless differences between indicator values and threshold).

This study confirms that the most severe events occurred in between 1991 and 2010. The features of Italian droughts are similar to the events that affected other parts of Europe. Droughts heavier for duration and severity occurred in France and Benelux in the 1991–2000 period.

12.8 Lessons Learnt from Recent Droughts in Italy

Following the severe droughts, several monitoring systems have been set up in Italian regions. The monitoring systems aim at providing the necessary information to implement adequate mitigation measures useful for the agencies responsible for water government and water supply system operation. For example, drought monitoring bulletins have been developed in Sicily (Rossi and Cancelliere 2002; www.osservatorioacque.it), in Emilia-Romagna (www.arpae.it), ISPRA (www.isprambiente.gov.it/pre_meteo/siccitas/), and Sardinia (www.sar.sardegna.it/servizi/agro/monit_siccita.asp).

In the recent guidelines issued by the Technical Committee for coordinating the Districts Observatories (ISPRA 2018), already mentioned in Sect. 12.6, the set of suggested drought indicators include Standardized Precipitation Index (SPI), Standardized Runoff Index (SRI), Standardized Snow Pack Index (SSPI), Standardized Precipitation Evapotranspiration Index (SPEI), Spring Anomaly Index (SAI) and Fraction of Absorbed Photosynthetically Active Solar Radiation (FAPAR). In addition, to monitor water stress it is suggested to adopt the Water Exploitation Index Plus (WEI+), defined as the ratio between water consumption (WC) (computed as withdrawal minus outflow in water body) and renewable water resource:

$$WEI+=\frac{WC}{RWR}=\frac{\text{Withdrawal}-\text{Outflow}}{RWR} \quad (12.1)$$

The main activities carried out in each Italian district for drought monitoring and for defining alert triggering levels for the activation of the Water Emergency Plan are summarized in Table 12.7.

The activities of the Authority of the Po River Basin are particularly significant among the notable examples of the ongoing shift towards a proactive approach for coping with drought in Italy.

The severity of the water crisis which hit the Po plain during spring and summer of 2003 pushed the National Civil Protection Department and the Po River Basin Authority to establish a Technical Committee and an Agreement among the bodies responsible of the water resources management. The aims were the following: to mitigate the effects of drought, to guarantee withdrawal and to avoid impacts on cooling needs for thermoelectric production as well as on water quality due to the upstream flow of brackish water. The Agreement included, besides the National Civil Protection Department and the Po Basin Authority, the Dam Directorate of the Minister of Infrastructures and Transports, the regions within the Po basin, the manager of the national electric energy network (today TERNA), the bodies which provide the regulation of Pre-alpine lakes (Garda, Como, Maggiore, Iseo, Idro), the

Table 12.7 Features of drought monitoring and thresholds for emergency measures in the Italian districts

Hydrographic district	Drought monitoring	Drought-related documents	Decision-making process for emergency measures
Po river	Early warning system (from 2010) based on SPI, SFI, SWSI and "run method"	Plan of the water balance	Four phases (normal status, and ordinary, moderate, high criticality with increasing detail and more severe emergency measures)
Eastern Alps	Current hydrometeorological network operated by Province of Trento, by ARPA in Veneto and regional bodies and civil protection in Friuli-Venezia Giulia (where flow reduction curve is observed by the Regional Hydrographic unity) The District Observatory is planning to set up two monitoring systems (surveillance and operative)	Water balance in Trento, monthly water resource report in Veneto (with warning system, snow water equivalent, storage volume and aquifers levels in Piave river basin)	
North Apennines	Drought indicators: SPI (1–24 months), WEI+ (June–September), DMVf and DMVf (June–September); reservoir storage; triggering levels in aquifers	Water Management Plan	
Central Apennines		Water Management Plan	
Southern Apennines	No specific drought indicators. DMV and WEI+ estimated in the Water Management Plan	Water Management Plan merging specific plans of river basins or regions	
Sardinia	Drought bulletin including SPI (3–24 months) and storage volumes in reservoirs		Contacts between region and management bodies for defining long-term and short-term measures
Sicily	Drought bulletin including SPI (3–24 months) and storage volume in reservoirs. The previous bulletin since 2003 included also rainfall deficit and Palmer index.		

Association of Land Reclamation Consortia (ANBI) and the companies of electric energy production. The Technical Committee facilitated the exchange of information to improve water resources monitoring, which included storage levels in the reservoirs managed by hydroelectric companies, lake volumes and releases, withdrawals from rivers for irrigation, industrial and municipal uses and the minimum flow for acceptable water quality in the Po river.

During the 2005 drought, a new Cooperation Agreement was established with the objectives of improving analysis and control of water balance and preventing exceptional low flows and water shortage for all water users of the Po river. Among the activities developed at the Drought Steering Committee, one of the most important consisted in real-time monitoring and assessment of drought evolution scenarios. This activity contributed to reduce the conflicts between different water uses. For instance, opposing interest exists between Land Reclamation Consortia or regional authorities and Lake Regulation Consortia. This happens because the former are interested to ensure the satisfaction of irrigation requirements through water release from lakes and hydroelectric reservoirs, while the latter are interested in preserving high water levels for environmental and recreational purposes in the lakes.

The publication in July 2015 of a Water Balance Plan contributed to reinforce the cooperation among the several institutions responsible for water resources management and the main stakeholders, as well as to minimize the impacts of water shortages. The key element of this Plan is the assessment of available water reserves during spring and summer, in order to optimize the allocation across different sources and water uses, as well as to reduce water shortage risk during months with higher water demands. For example, Table 12.8 lists, for the most severe recent droughts, the available storage in Pre-alpine lakes, in hydroelectric reservoirs and in terms of snow water equivalent (SWE) at the beginning of August of each year.

In addition, an early warning system was developed with the objective of optimizing the use of water resources and avoiding water quality deterioration. It comprises four possible criticality phases:

Table 12.8 Estimated water reserves for supplying the Po plain demands during the recent severe droughts (at the beginning of August) (Pecora 2019)

	Stored volumes (hm^3)			
Year	In lakes	In reservoirs	Snow water equivalent	Total
2003	195	722	127	1044
2005	147	632	131	910
2006	262	637	16	915
2007	352	694	49	1095
2011	892	790	164	1846
2015	445	657	63	1165
2017	497	740	85	1322
2018	573	668	116	1357

– *Normal*: monitoring of meteo-climatic conditions and of the state of the available resources according to the provisions of the Water Balance Plan.
– *Pre-alert* (vigilance): reinforcement of monitoring and definition of measures aimed at water saving with particular reference to irrigation uses.
– *Alert* (danger): improved monitoring, daily updating of the state of water reserves, assessment of impacts of drought on sensitive uses (municipal needs, touristic requirements and water quality in protected areas of the Po delta); start-up of the measures foreseen by the Drought Directive, established by the Authority of the Po River Basin.
– *Emergency*: several measures take place, under the responsibility of the civil protection system, in order to satisfy priority emergency requests, to reduce threats to population and to minimize environmental impacts.

12.9 Water Shortage Risk Assessment

Assessment of water shortage risk due to droughts can be carried out with reference to two distinct objectives, namely: (1) increasing the robustness of the system within the strategic planning stage through appropriate prevention strategies and (2) improving the performance of water supply during droughts within the operation stage. When dealing with strategic planning, risk assessment should be *unconditional*, i.e. not referred to a particular state or condition of the system, and aimed at selecting the best long-term measures (Bonaccorso et al. 2007). In the case of the operation of water supply systems under drought conditions, the risk assessment has to be *conditional*, i.e. taking into account the current state/condition of the system. In this case the main problem is defining the status of the system with respect to predefined operational levels (e.g. normal, alert, alarm) in order to decide *when* and *how* to activate predefined sets of mitigation measures (e.g. rationing policies and/or use of additional water resources) able to prevent future severe shortages (MEDROPLAN 2007).

Since risk represents a probabilistic measure of economical or intangible damages consequent to a disaster, when dealing with water supply systems, water shortages are generally assumed as proxy of damages, and drought risk is generally assessed in terms of the probabilistic features of water shortages due to droughts. To this end, Monte Carlo simulation of the system, where the probabilistic features of droughts are implicitly taken into account through the stochastic generation of hydrological inputs and where the vulnerability of the system is considered in the simulation stage, may constitute a more efficient tool to assess water shortage risk, as compared to other approaches based on the concept of design droughts (Cancelliere et al. 1998). As shown in Fig. 12.5, such procedure can still be framed within the more traditional risk assessment based on combination of hazard and vulnerability.

Monte Carlo simulation can also find application for the selection of different alternative mitigation measures in combination with multi-criteria techniques (Rossi et al. 2008). For example, such procedure has been applied in Italy with reference to

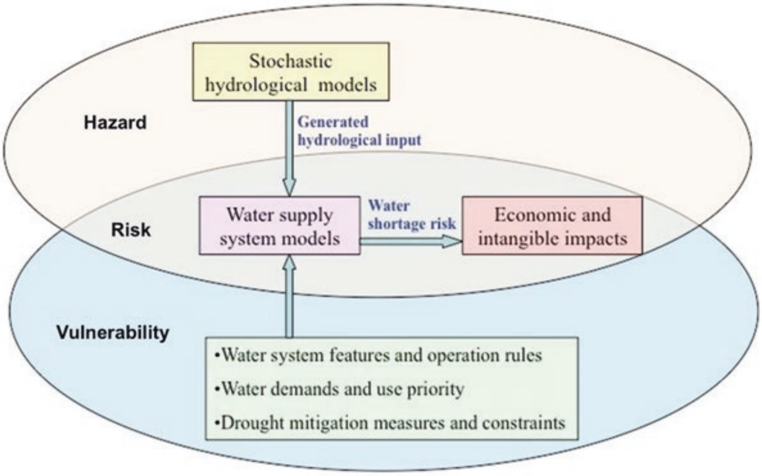

Fig. 12.5 Assessment of water shortage risk due to drought in a water supply system through Monte Carlo simulation. (Source: Rossi 2017)

Palermo water supply in Sicily (Munda et al. 1998), Simeto water system in Sicily (Rossi et al. 2005) and Flumendosa-Campidano water system in Sardinia (Rossi et al. 2006).

Many papers have been devoted to evaluate the risk of water shortage with the aim of defining operating policy or storage allocation in a single reservoir and/or complex water supply system in response to drought. Some studies in Italy addressed the use of early warning system information within drought management of water supply systems, for example, with reference to the Simeto water system in Sicily (Cancelliere et al. 2009), Acate system in Sicily (Nicolosi et al. 2009) and Basilicata-Apulia water system (Nicolosi et al. 2008). In some cases, the probability of shortages within a short-term time horizon has been assessed to support the selection of different mitigation measures, for instance, with reference to the Acate water system in Sicily (Rossi et al. 2011).

Early warning systems could also benefit from the use of forecasting methods based on past observations of the drought indicators or hydrometeorological variables, also including exogenous forcing mechanisms in the forecasting scheme. Indeed, the links between precipitation and large-scale circulation patterns such as El Niño-Southern Oscillation (ENSO), Sea Surface Temperature (SST) and Geopotential Height (GpH) observed in some regions in the last decades have sparked interest about the possibility to use such indices to improve mid-long-term precipitation forecasting, which in turn can be used to make seasonal drought predictions. The relation of large-scale circulation patterns with rainfall remains very much region-dependent. Several studies have established links between NAO and climate in Europe and the Mediterranean basin. Some studies have investigated whether encompassing the influence of NAO into models structure improves drought forecasting (Cutore et al. 2009; Chen et al. 2013; Santos et al. 2014; Bonaccorso et al. 2015).

12.10 Concluding Remarks

Based on the Italian legislative and institutional framework as well as on the recent experiences in coping with drought events, some concluding remarks on the possible issues related to the implementation of an effective drought proactive approach in Italy can be drawn.

First, effective drought management in water supply systems represents a complex challenge due to several specific weaknesses and gaps affecting drought preparedness and mitigation planning, organization and implementation. Besides, still the differences between *water scarcity* (i.e. a permanent unbalance between available water resources and demands) and *drought* (i.e. a natural temporary negative deviation from normal precipitation amount for a significant duration and extension, which leads to a temporary water shortage in a supply system) are not fully clear to many stakeholders and the population in general. In order to overcome these issues, specific drought preparedness and mitigation planning activities should be adopted within the general framework of water resources and water quality protection planning.

In addition, the need of an appropriate institutional structure for coping with drought risk is not fully recognized in Italy. Indeed, there is a lack of coordination between River Basin Authorities and the civil protection. The former plans to water shortage prevention, while the latter is in charge for drought risk mitigation and recovery. Therefore, it appears necessary to entrust the bodies responsible for each water supply system (similar to what has been done in Spain) to define in advance the measures needed to face water shortage risk, with a specific focus on primary needs such municipal water use. Furthermore, general criteria for declaring drought as a natural disaster should be developed at the national level, while emergency management organizations should intervene at local level within a predefined emergency plan. Also advanced drought early warning systems, which are being developed in different Italian districts, can improve drought management, at the condition that standard criteria, drought indicators and triggering thresholds for a timely implementation of contrasting measures are available.

Beyond the interesting outcomes of several research projects on drought, which recently have fostered a renewed interest towards this hazard also in Italy, future research to improve resilience to drought should be oriented to address the following aspects (Rossi 2017):

- Better modeling of drought occurrence and characteristics, both in terms of their stochastic nature and their links with global atmospheric circulation patterns, especially when the analysis aims at taking into account climatic changes.
- Thorough analysis of past experiences in drought monitoring and mitigation as well as a greater knowledge exchange on the measures adopted in different contexts, in order to implement best practices in drought management.
- Advanced assessment of economic, environmental and societal impacts of droughts and mitigation measures, preferably based on multi-criterion tools.

- Development of appropriate models and integrated packages of techniques, which can be easily understood and applied by decision-makers. This may foster the inclusion of the most advanced scientific tools in drought preparedness planning (e.g. stochastic hydrology for drought characterization; economics and environmental sciences for a comprehensive impact evaluation; social sciences for selecting the way to reduce users conflicts).
- Development of advanced tools for an "adaptive" drought management in water supply systems, based on drought early warning systems, drought monitoring and forecasting systems and advanced DSS that use modern technologies.

In conclusion, Italy is still struggling to adopt a comprehensive drought risk management approach. However, fostering good practices at the European level can certainly contribute at improving the situation, as shown by the recent promising efforts at the national and the river basin district scales.

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