Chapter 6
Climate and Water on the Spanish Mediterranean Coast: Challenges for the Future

Jorge Olcina Cantos and María Hernández Hernández

Abstract The study of two basic resources, climate and water on the Spanish Mediterranean coast, has evolved in recent decades in relation with the conceptual changes, changes of focus and of method that have taken place in Spain in relation with both concepts. Furthermore, in the current context of spatial sustainability, new processes have appeared that are marking the actions for planning and management of these two elements of the natural environment. This is the case of climate change and its associated effects, with repercussions, moreover, on the availability of water, where a change of paradigm has been recorded. Contrary to the traditional criterion of unlimited supply, the planning of water resources is now governed by the principles of demand management. An analysis has been made of the evidence of climate change on the Spanish Mediterranean coast and the changes in the regulation of water resources introduced in the last two decades. Lastly, an agenda is proposed with actions to be implemented in this region in the east of the Iberian Peninsula, to allow the conciliation of socioeconomic development and environmental sustainability.

Keywords Mediterranean coast · Climate · Water · Climate change · Water planning · Future challenges

6.1 The Study of Climate and Water in the Last Two Decades: Thematic Changes and Changes of Focus

The study of climate and water on the Spanish Mediterranean coast has progressed, in the last two decades, from conceptual and theoretical approaches to visions of an applied nature since these two elements are essential for the development of

J. Olcina Cantos (✉) · M. Hernández Hernández
University of Alicante, Alicante, Spain
e-mail: jorge.olcina@ua.es; maria.hernandez@ua.es

R. C. Lois-González (ed.), *Geographies of Mediterranean Europe*, Springer Geography, https://doi.org/10.1007/978-3-030-49464-3_6

economic activities in this geographical area. In turn, increasing consideration is given to the risk component of both elements of the geographic environment, since growing pressure has been applied to natural resources in a context of changes in the physical environment, especially in its climatic component which is subject to an undeniable warming process. The last two decades have been plagued with transformations in the physical environment of the Spanish Mediterranean coast and with changes in the way such alterations are interpreted. The intensive use of natural resources has given rise, furthermore, to situations of risk that, in some cases, have been derived in crisis situations owing to the development of events of an extraordinary range. Natural resources and risks have merited various studies by Spanish geographers in recent years that have included conceptual, methodological and diagnostic aspects, as well as assessments of status and planning and management proposals. All of these have enriched the corpus of environmental analysis by Spanish geographers, incorporating new circumstances that have led to the incorporation of ideas, concepts and methods and where increasing weight is given, fortunately, to sustainability as the governing principle for spatial actions.

Table 6.1 shows the new topics that have arisen in the studies of climate and water on the Spanish Mediterranean coast over the last 20 years, in relation with the thematic and methodological renewal of geographic focuses and their adaptation to the spatial processes experienced in this dynamic geographic space.

These changes of focus have been accompanied by the appearance of regulations (European, state, autonomous community) that have favoured the applied focuses. This is the case of the regulations on land, water and environmental impact, which include the obligation to prepare reports and mapping of these elements of the physical environment, as resource and risk, in land-use transformation processes. Table 6.2 summarizes the processes of study, analysis and planning of the resources

Table 6.1 New focuses in studies of climate and water on the Spanish Mediterranean coast. (Own elaboration)

Element	Process behind change	New topics of study
Climate	Climate change and associated atmospheric risks	Effects of climate change on climatic elements, on water resources and on economic activities
		Increased temperature of the Mediterranean Sea and its climatic effects (risks and comfort)
		Atmospheric extremes and their effects on the territory
		Climatic risk mapping
Water	Demand-side planning and management of resources	Demand-side water planning
		Social behaviour in the light of situations of scarcity
		New “nonconventional” water resources (reuse and desalination)
		Water from risk to resource: rainwater harvesting and new urban drainage systems
		Proposals for adaptation of water quality according to requirements of use (“fit for purpose”)

Table 6.2 Planning of resources and risks with regard to climate and water and the role of geography (2000–2018). (Own elaboration)

Element	Processes	Role of geography
Water	Water Framework Directive (60/2000)	Studies on planning and management of water: for and against the measures of the national hydrological plan (NHP)
	Water Law (2001, amended 2007 and 2016)	Creation of platforms for sustainable management and new water governance (new water culture)
	Law on the National Hydrological Plan (2001, amended 2005)	Preparation of studies and mapping of flood risks
	Preparation of new River Basin District Plans	Studies on hazards and vulnerability. New focus on risk analysis (role of the human being as creator of risk territories)
	Floods Directive (60/2007)	Studies on the relationship between climate change and water resources (for the purpose of planning)
	Important flood episodes	Studies on drought risk management
	Risk mapping. Creation of the National Mapping System of Flood-Prone Areas (SNCZI)	
	Drought management plans. New guidelines 2017	
	Autonomous community risk reduction plans (floods)	
Climate	Climate Change Reports (IPCC, 2007, 2013–2014)	Studies on climatic elements
	Climate Change Report Spain (2005)	Studies on atmospheric dynamic (isobaric connection processes: ENSO, NAO, WeMO)
	Autonomous community climate change reports (Catalonia and Basque countries)	Participation in international, national and autonomous community reports on climate change
	Intense episodes of atmospheric pollution in large cities	Studies on the effects of climate change: postures for and against the hypothesis of warming owing to the greenhouse effect
	Climate Change Bill (2018)	Studies on atmospheric pollution
	Proliferation of amateur meteorology associations	Participation of geographers in amateur meteorology associations

and risks linked to climate and water that have been developed on the Spanish Mediterranean coast between 2000 and 2018. It also indicates the role played by geography in each case and which has materialized in the form of studies, participation in research projects, official reports and plans or platforms for the defence of new values in natural resource planning (Olcina 2012).

The resources and risks of climate and water are at a nexus of union in the diagnoses of the analyses performed since the undue or excessive use of these resources in the area has led, in many cases, to the creation of risk situations and spaces (Olcina 2014). And the application of these processes in the territory shows that planning is, to a great extent, incorrect, inappropriate, inefficient or, simply, inexistent.

Significant changes have also been observed, however, from the point of view of consideration of these aspects since the 1990s (Hernández et al. 2016). With regard to both rainwater and wastewater, scientific literature points to a clear change of paradigm since, from originally being considered from the point of view of an environmental risk (floods, pollution, etc.) they have progressively come to be dealt with from the point of view of flows that can be harnessed (Sedlak 2014; Stec and Kordana 2015). In the case of rainwater and urban drainage, the changes in land use generated during recent decades in the urban and tourism nuclei of the Mediterranean coast have in many cases caused a disorganization and alteration of the natural drainage systems that, together with the proliferation of soil sealing, have led to an increase in the frequency and seriousness of diffuse flood episodes (López-Zavala et al. 2016). The increase of urbanized areas and the apparent inability of the conventional drainage systems to confront new urban growth, as well as the flows circulating in situations of high hourly intensity and the effects of sealing on the urban water cycle, have, since the 1990s, given rise to proposals of "sustainable urban drainage systems" (SUDS) which advocate the adoption of strategies that are more respectful towards the environment and the water cycle (Morote and Hernández 2017).

6.2 Climate: Resource and Risk – The Uncertainties of Climate Change

The increasingly evident manifestations of the global warming process have encouraged studies of its effects on the Spanish Mediterranean coast. Climate is a fundamental element for an understanding of the evolution of this regional space throughout history, and, especially since the middle of the twentieth century, it has been the foundation for the consolidation of a dynamic economy based on activities that depend to a great extent on atmospheric conditions (market agriculture and tourism).

Climate studies have undergone changes with regard to the topics analysed, in the light of the climate change processes that are forecast. And there has been an increase in approaches of an applied nature with the objective of preparing precise and useful analyses for the implementation of new land uses or the reduction of risk. Table 6.3, which follows, includes the new study topics in relation with the effects of climate change that have been undertaken in recent years on the Spanish Mediterranean coast.

The function of a geographic space is defined on the basis of factors that favour the development of economic activities. The existence of social dynamism, entrepreneurial capacity, the possibilities of access to natural resources, the development of fast transport and communication networks, the consolidation of financing mechanisms or the introduction of public policies are basic to the understanding of the greater or lesser success of the initiatives for economic development. All of these aspects comprise the set of endogenous and exogenous factors that, since the

Table 6.3 New topics of study in relation with the effects of climate change on the Spanish Mediterranean coast. (Own elaboration)

New topics of study	Temperature increase (warming)
	Increase of "tropical nights" (temp. > 20 °C)
	Loss of climatic comfort
	Changes in the seasonal nature of precipitations
	Increase in intense precipitations (hourly) and effects on urbanized spaces
	Changes in local wind patterns (breezes)
	Increase in atmospheric extremes (gales, heavy rain, heat waves)
	Climatic risk mapping

nineteenth century, have enabled the consolidation of the different forms of economic organization of the geographic area, with their evident socio-spatial effects. And, together with these, the existence of a natural environment with features that favour the activities introduced by societies that have developed in the area, are a basic component, especially in those sectors that depend to a large extent on these elements of the physical environment.

The excellent climatic conditions of the Spanish Mediterranean coast are ideal for the implementation of agricultural, leisure and recreational activities which are the main foundation for its economic development. The main climate characteristics can be summarized in: mild temperatures during a large part of the year, high number of sunny days (in other word, not cloudy), coastal breezes and sufficient annual rainfall for the development of the economic activities and to supply urban water demands. Added to the generally fair Mediterranean climatic conditions is the predominance of warm waters on the shore of the Mediterranean during the 6 months of summer, especially in the second half, when they are very propitious for sun and sand tourism (26 °C on average), still reaching around 21 °C in autumn.

Some of the effects of global warming are already apparent in the climatic elements of the Spanish Mediterranean coast. In general, Spain is a territory especially exposed to possible climate changes owing to its geographic position in the middle latitudes and in the Mediterranean basin. The Mediterranean coast is especially vulnerable, with a concentration of population and economic activities with a high economic value that may be affected considerably by the effects of climate change. Five atmospheric processes are already apparent in the features of the Mediterranean climate and which have direct implications on the territory and socioeconomic effects:

- Increase in atmospheric extremes (greater climatic hazard).
- General reduction of precipitations and, therefore, of water volumes available.
- Increase in the irregularity and hourly intensity of precipitations.
- Increase in average temperatures (0.8 °C in the last century).
- Increase in tropical nights, which have tripled, on average, on the Mediterranean coast as a whole, from 1980 to date.

Table 6.4 Changes in the main climatic variables[a] of the regions of the Spanish Mediterranean (2100 Horizon) (AEMET 2015; Arahuetes and Olcina 2019, p. 768)

	Catalonia	Balearic Is.	Valencian C.	Murcia	Andalusia
Max. temperature (°C)	+1.5 to +5.5	+2.5 to +5.5	+1 to +5	+2 to +5	+2.5 to +5.5
Duration of heat waves (no. of days)	10–35	10–25	5–35	10–45	7–27
Warm days (%)	20–50	25–55	15–50	20–55	20–50
Min. temperature (°C)	+2.5 to +5.5	+2 to +5	+1 to+4.5	+2.5 to +4.5	+2 to +4.5
Warm nights (%)	20–50	20–50	15–50	20–50	20–50
Change in volume of precipitation (%)	0 to+5	−5 to −10	0 to −10	0 to-5	−7 to −15
Change in intense precipitations (%)	0 to −5	0 to −2.5	0 to −7	+1 to −1	+2 to −5
Duration of dry periods (no. of days)	0	0 to +2	0 to +2	0 to +2.5	+2 to +4
No. of rainy days (no. of days)	+2 to +10	−5	−2 to +5	−2.5 to +2.5	−5

[a]The interpretation of these variables can be found at http://www.aemet.es/es/serviciosclimaticos/cambio_climat/result_graficos/ayuda. (Consulted: August 2018)

Related to these atmospheric processes, Arahuetes and Olcina (2019, p. 767) highlight:

> The report *climate projections for the twenty-first century* (AEMET 2015), as an update of the projections prepared in 2011, has handled three variables (maximum temperature, minimum temperature and precipitation) in the analysis of the modelled evolution of the climate in Spain for the forthcoming decades. It is interesting to highlight the values of different temperature and rainfall variables calculated in this report, with a 2100 horizon, for the regions of the Mediterranean coast, since the planning of economic activities and water planning itself, a basic factor to guarantee the supply of water resources in this large regional space, will depend on their future evolution. Table 6.4 summarizes the change values of the climatic variables for the territories of the Mediterranean coast of the Iberian Peninsula.

In relation with temperatures, the most notable aspect of climate change that is already apparent in the series of the principal cities of the Mediterranean coast is the considerable increase in hours of nocturnal heat, expressed in the increase of what are known as "tropical nights" (temp. > 20 ° C). From 1970 to date, they show a very notable rising trend, with their number actually tripling at present, compared with that base year (Fig. 6.1).

The rise in the temperature of the Mediterranean Sea is, without doubt, the base for this important increase in nocturnal heat which, furthermore, is a source of climatic discomfort in the cities of the Mediterranean coast. For the Mediterranean basin as a whole, an absolute increase has been estimated of 0.22 °C per decade, from 1973 to 2008 (Skliris et al. 2012). Shaltout and Omstedt (2014) have pointed out that the maritime sector of the Balearic Sea has experienced the sharpest

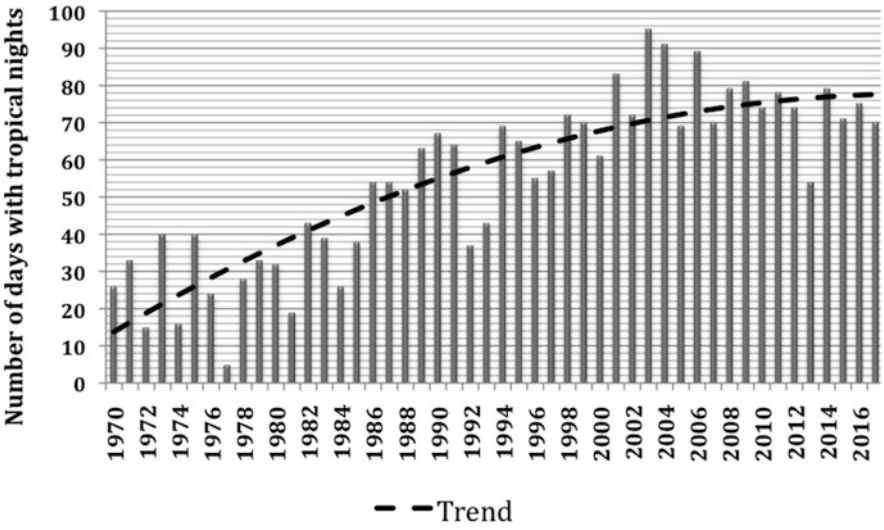

Fig. 6.1 Evolution of the annual number of "tropical nights" (>20 °C) in the city of Alicante (1970–2017). Observatory of Ciudad Jardín. (AEMET – Open Data, own elaboration)

temperature increase in the western basin of the Mediterranean (a rising trend of 0.033 °C/year between 1982 and 2012). In the central sector of the western basin of the Mediterranean (Balearic Sea), the increase of these, a surface temperature calculated from satellite images (NOAA), has been 1.3 °C from 1980 to date (Pastor et al. 2017). A significant detail is that the increased warming of the waters of the Mediterranean Sea off the coast of Spain especially takes place during the months of spring and early summer (April–June) and, to a lesser extent, October. Thus, confirmation is provided not only of the trend for an increase in seawater temperatures, which in the midsummer months can reach values of up to 28 and 29 °C (Fig. 6.2), but the above-mentioned prolongation of the annual period with warm waters off the Spanish Mediterranean coast.

With regard to precipitation on the Spanish Mediterranean coast and Iberian Peninsula, in recent year various studies (Arahuetes and Olcina 2019; CEDEX 2017; De Luis et al. 2010; Marcos-García and Pulido-Velázquez 2017; Serrano 2017) have pointed to the development of changes in precipitation. These studies show:

(a) Decrease in rainfall, although this is not uniform.
(b) An increase in the intensity of precipitation which is evident in the Spanish Mediterranean regions.
(c) A significant negative trend in the analysis of the maximum annual precipitation in one day, for the 1950–2012 period (Arahuetes and Olcina 2019; Serrano 2017). This means that a smaller quantity of total precipitation is accumulated in the most extreme events.

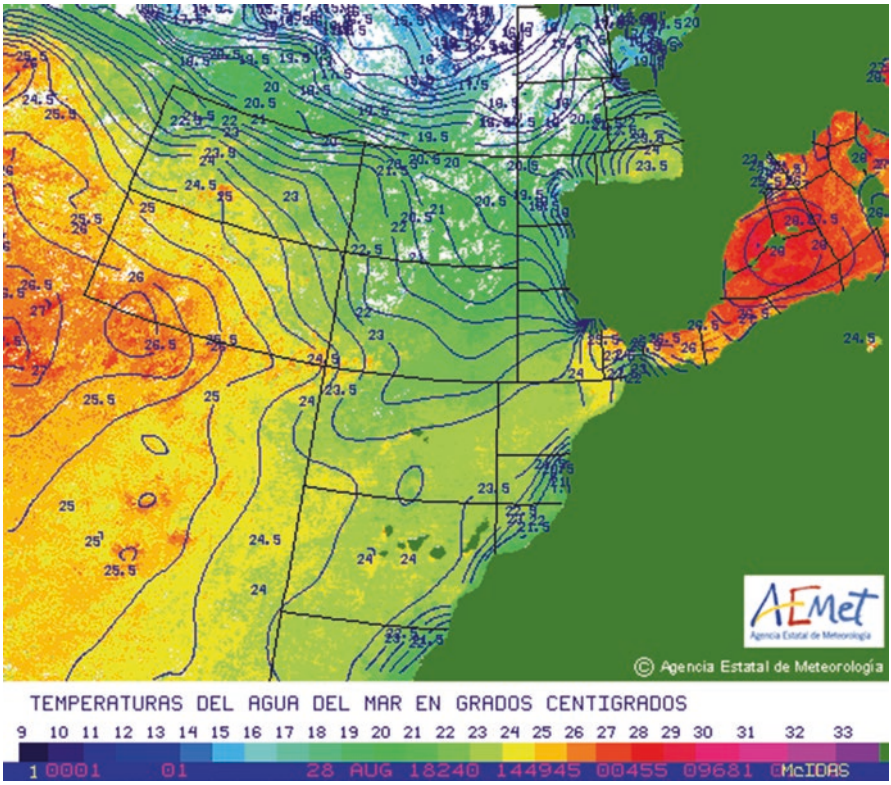

Fig. 6.2 Sea surface temperature in the western basin of the Mediterranean. 29 August 2018 (NOAA-19) (AEMET. Open Data)

(d) A positive trend in the contribution of intense precipitation to the accumulated annual totals, which means that the episodes of intense rain are more frequent, although the quantity accumulated in them is lower (Serrano 2017).

Taking into account these changes in precipitation, the study of rainfall extremes has become a priority subject in various studies. For the 1805–2014 period, González Herrero and Bech (2017) show that no records have been broken in the last 20 years with regard to absolute maximum quantity, but the values for intense precipitation in a short time span have become more frequent. Also worth noting is the fact that these record values for rain in less than 60 minutes have been recorded in weather stations located on the Mediterranean coast.

The increase in the intensity of rain (Fig. 6.3) is an aspect of great relevance for the planning of urban spaces and the problem of floods, which have been seen increasingly in recent decades (Olcina et al. 2010). The analysis of this matter in the city of Alicante serves as an example (Olcina 2017). Specifically Arahuetes and Olcina (2019, p. 768) highlight:

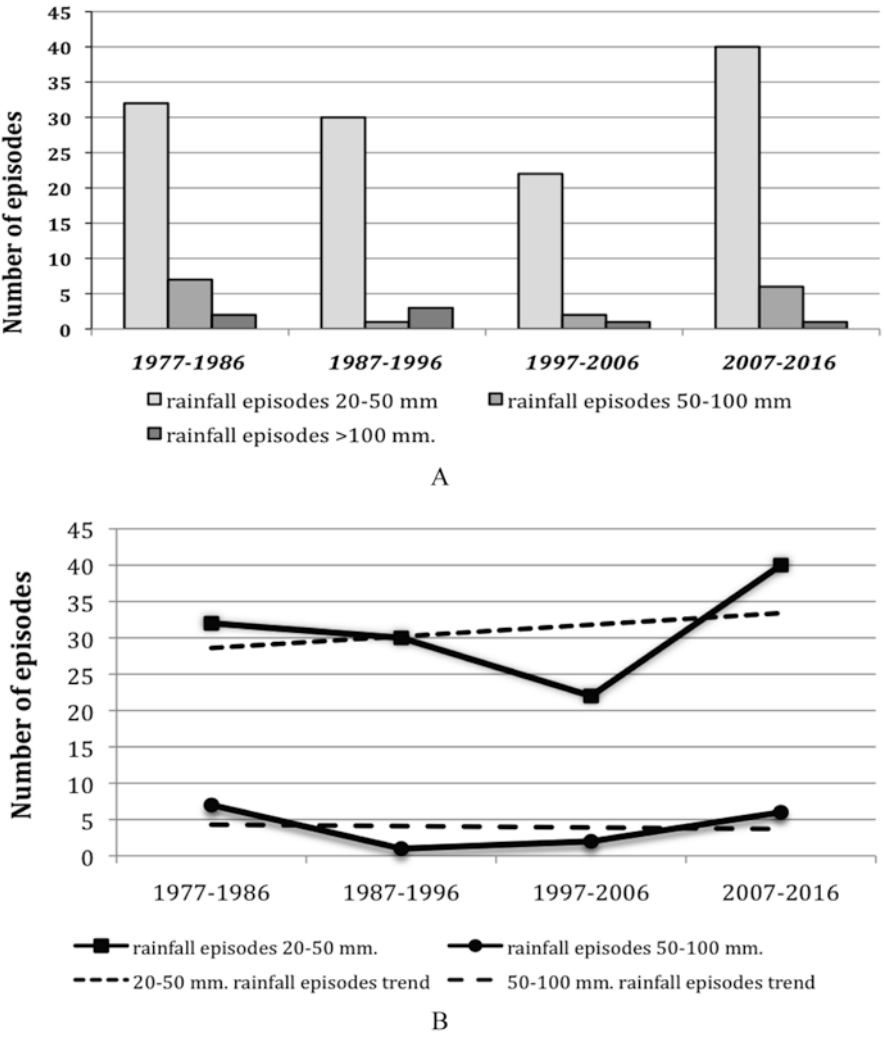

Fig. 6.3 Evolution (**a**) and trend (**b**) of precipitation episodes of hourly intensity in Alicante (1977–2016) (AEMET 2015; Arahuetes and Olcina 2019, p. 769, own elaboration)

- Episodes of short and intense downpours show a decrease in their number between 1977 and 2006, with a really significant upturn during the last decade.
- With regard to episodes between 50 and 100 mm, there was a significant reduction during the 1987–1996 period.

In summary, the climate of the Spanish Mediterranean coast already shows aspects of change, which may intensify in future if the forecasts of the climate models for the end of this century are accurate. This is an evolution towards a climate with more extreme features that requires the adoption of measures to avoid

considerable economic damages or the loss of human lives. This affects both temperatures, regarding which the effects of the progressive increase of average values, and of the hours of nocturnal heat and the increase in extreme events (heat waves), are already apparent, and precipitations, which have lost seasonal regularity and gained hourly intensity. It is not currently possible to establish a single, set period of torrential rains in the annual flood risk calendar. Episodes of this type can occur at any time of the year and not exclusively in autumn as was usually habitual until the end of the last century. And, moreover, excessive quantities of precipitation of above 300 mm/24 h. are not necessary to cause serious economic damage or human victims in conditions of great atmospheric instability with the downpour of abundant rains. Rains of between 50 and 100 mm. that fall in 60–90 minutes are sufficient for that. It is possible to affirm that the episodes of intense rain with flooding occurring on the Spanish Mediterranean seaboard are closely related to the increased temperature of the Western Basin of the Mediterranean Sea. This fact is at the origin of the intensification of the rainfall processes that has been recorded, since 2000, in localities of the Spanish Mediterranean coast.

6.3 Water: From Supply Paradigm to Demand Management

Studies on water resources have undergone changes with regard to the topics of analysis as a result of the increase in demand and the pressure on a resource considered to be of vital importance for socioeconomic development and the availability of which is conditioned by environmental, regulatory and economic factors. Table 6.5 shows the new topics in relation with water resources that were developed between 2000 and 2017 in the territory of the Spanish Mediterranean coast.

In Spain, during the second half of the twentieth century, the expansion of irrigated land, urban development, industrialization, the development of tourism activities and hydroelectric power meant a sharp increase in demand for water, exceeding, on occasions, the natural supply of available resources (Rico 2004). Regarding urban uses, a notable increase in water consumption on the Spanish Mediterranean

Table 6.5 New topics of study in relation with the water resource on the Spanish Mediterranean coast. (Own elaboration)

New topics of study	Urban development types and water consumption
	Demand-side planning and management of water resources
	Scarcity of resources and conflicts in access to water
	Incorporation of nonconventional resources (treatment and desalination)
	Incorporation of alternative water resources in urban areas (grey water and rainwater)
	Drought plans
	Governance and participation of agents in water management
	Social and institutional players, values and discourses related to water

coast has taken place, to a great extent, since the 1960s and 1970s, reaching maximum peaks at the end of the 1990s and the beginning of the twenty-first century (Gil et al. 2015). The increase in urban demand is related to the increase in population and in residential properties and urbanized land that has taken place in recent decades, especially coinciding with the latest real estate boom (1997–2007) (Burriel 2008; Lois et al. 2016). This has been based on the proliferation of low-density urban sprawl, characterized by high consumption levels (Rico 2007). In the city of Alicante, for example, consumption per property per day in detached houses amounts to 1052 litres, whilst in the compact urban development type (households without gardens or swimming pools), this is reduced to 244 litres (Morote et al. 2016). This is related to the presence of private garden areas and swimming pools, which may represent more than half of the daily water consumption of the whole household. The analysis of plant types and formations in the gardens, in which there is a predomination of Atlantic-type vegetation, not very appropriate for the climatic conditions, explains these high-water requirements. Some of the studies that have analysed these topics have been carried out in the Metropolitan Area of Barcelona (Domene and Saurí 2006; Parés et al. 2013), Girona (García 2013; Llausàs et al. 2018; Padullés et al. 2014), the Balearic Islands (Hof and Wolf 2014), Seville (Fernández et al. 2011), Zaragoza (Salvador et al. 2011) and in the province of Alicante (Morote 2017).

This increase in demand was accompanied by the different political administrations and regimes in Spain and by a "traditional water policy" (water basin transfers, reservoirs and groundwater harnessing,) based on an increase in the supply of water to attend to the growing demands. A paradigmatic action was the opening of the Tagus-Segura Aqueduct (ATS). The arrival of flows from the Upper Tagus to the Segura Basin was decisive in guaranteeing the supply for urban and residential-tourism uses and, to a lesser extent, irrigated areas (Hernández and Morales 2008). But it also generated notable expectations, both urban and for the transformation of unirrigated land into new irrigated areas, which, in turn, required obtaining new water resources.

The growing problems in environmental, social and economic terms associated with conventional measures such as the regulation of river courses by means of the construction of reservoirs and river basin transfers appear to have led to a general reconsideration of these solutions, as was demonstrated by the National Hydrological Plan of 2001 and the strong opposition faced by its principal project, the Ebro transfer (Saurí and Del Moral 2001). Based on the Water Framework Directive 2000/60/EC and on the appearance of movements such as the New Water Culture, different authors call into question infrastructures of this type in Europe. This is owing to their high level of environmental impact and the socioeconomic conflicts they generate between donor and recipient regions. And they also support the need to contemplate water planning alternatives that consider to a greater extent the preservation of water bodies, the environmental and cultural values of water, the participation of agents in water management and the demand-side management of this resource (Del Moral and Silva Pérez 2006; Ferreira 2013; Hernández-Mora et al. 2010). During recent years, the idea has been reinforced that water management should be

understood as an instrument at the service of an explicit spatial policy and that the latter, moreover, should be supported by the growing demand for integration between water management and sectoral policies, a key concept of the Water Framework Directive (Del Moral 2009). The progressive incorporation of this new focus has been favoured, furthermore, by the change of paradigm in the management of drought risk, one of the principal risks in Spain owing to its geographic position. There has been a change from initiatives integrated in what has been called the "crisis management focus" to a "risk management focus", measures of a proactive nature and aimed at prevention and mitigation of the impacts (Vargas and Paneque 2017).

Until the Iberian drought, recorded from 1992 to 1995, the solution to the problems of shortage of water resources was based on the possibility of obtaining, and making available to users, new volumes of water that guaranteed these demands. Priority was given to actions and policies aimed at generating a greater supply of resources without adopting measures to control demand (Morales 2001; Swyngedouw 2015). In support of these arguments, studies have been performed that relate the increase in water resources with a greater risk of hydrological drought (Del Moral and Giansante 2000; Hernández-Mora and Del Moral 2015; Morote et al. 2017a, b). The lack of water infrastructures, the increase in consumption or the precarious management of the supply have extended their effects to regions theoretically well-endowed with resources, such as the Atlantic Coast (Olcina 2001). As Del Moral et al. (2017) argue, unlike meteorological drought (which only takes into account precipitation in the affected area), hydrological drought is frequently merely the state that has been brought about by a policy of continued increase in water supply.

This period of scarcity in precipitation opened the debate on the need for integrated exploitation and management of the totality of potentially useful resources, focusing attention on what are known as nonconventional sources, which include treated wastewater and the production of desalinated water and, to a lesser extent, the use of rainwater and grey water (Rico et al. 2016). Together with the incorporation of these nonconventional resources in recent years, reference has been made to the possibility of using water of different qualities according to its final use. This is what is known as "fit for purpose" (Hernández et al. 2016). Higher quality water (desalinated water, conventional resources) can be set aside for human consumption, whilst that of a lower quality (reclaimed treated water or grey water) can be allocated to other uses such as watering the garden, washing the streets or agricultural uses (Morote and Hernández 2017).

Desalination was given a great boost with the National Hydrological Plan (2001) and the AGUA (Actions for the Management and Use of Water) Programme (2004). One of the central features of this programme was the replacement of the 1050 hm^3 contemplated in the repealed Ebro transfer with resources provided by desalination. The adoption of desalination has been considered the most appropriate alternative supply to stabilize water balances in the deficit basins. On the one hand, it would put an end to the interregional conflicts and social tensions generated around the construction of water transfers. And, on the other, it represents an efficient measure in the light of scarcity of resources in the Mediterranean regions, accentuated in

periods of drought, thanks to the availability of a resource (seawater) that is independent from climatic conditions (Morote et al. 2017a, b). According to the Spanish Association of Desalination and Reuse (Asociación Española de Desalación y Reutilización, AEDyR), at the end of 2017, Spain had some 900 desalination plants, for both brackish and seawater, with a production capacity ranging from 100 to over 100,000 m^3/day and reaching a capacity of approximately 1.2 million m^3/day (438 hm^3/year) of which 700,000 m^3/day corresponds to the desalination of seawater (58.33%) and the rest to brackish water (aquifers). The highest production capacity for desalinated water on the Mediterranean coast is concentrated in the area served by the Taibilla Canals Association (Mancomunidad de los Canales del Taibilla, MCT) (San Pedro del Pinatar I and Alicante I and II plants) with 96 hm^3 (Fig. 6.4).

The adoption of this nonconventional resource has not been exempt from controversy linked to matters relating to energy dependence, the cost of this resource, the environmental impacts or its very consideration as a resource able to combat water scarcity whilst at the same time generating social scarcity linked to the final price of the resource, which makes access difficult for certain users (farmers and more modest urban classes) (March et al. 2014; Swyngedouw and Williams 2016). Together with these questions, reference is also made to the strategic nature of this resource and its substitution for other resources and drought situations.

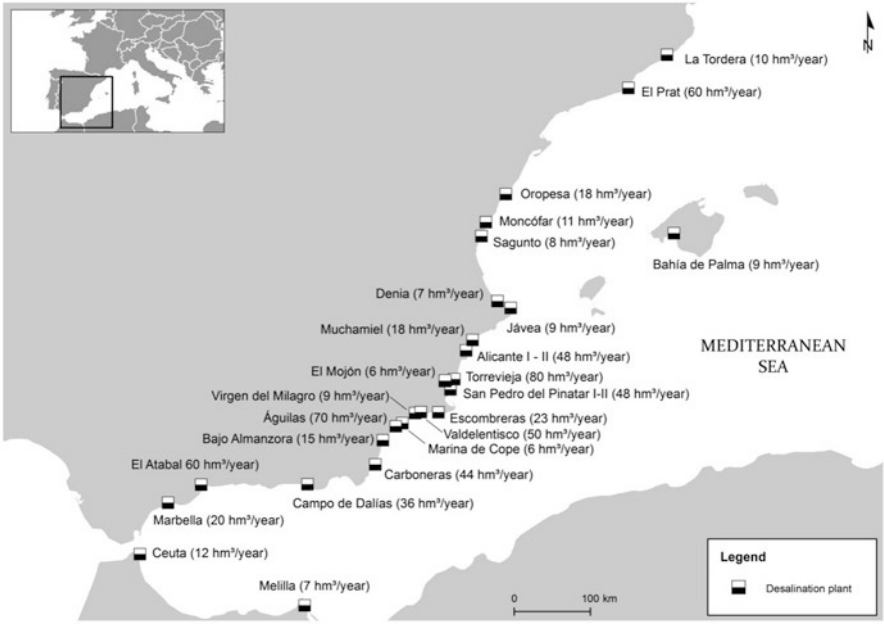

Fig. 6.4 Location of the desalination plants on the Spanish Mediterranean coast (Ministerio de Medio Ambiente 2006; Morote et al. 2016, Own elaboration)

Desalination has become a key water resource in arid and semiarid areas (March et al. 2015). In the Mediterranean Basin, for example, this resource is already considered an ordinary supply source in some regions and, especially, in many island areas. The incorporation of water from desalination to the water resources available in the Segura basin has notably reduced the drought threshold for urban uses. The population nuclei on the coast of this territory have been guaranteed a supply of water, regardless of the drought circumstances that may arise. During the drought of 2015–2018, transfers from the ATS were replaced by desalinated water, satisfying without problems the demands for urban (and in some cases agricultural) uses and avoiding cuts in supply and restrictions. Since desalinated water has been supplied (2003), water originating from the ATS represents 48.74% and desalination 20.25%. Its production has increased during recent years owing to the cuts in transfers from the ATS as a consequence of the drought. Between May 2017 and April 2018, a period in which the ATS was closed as the reserves in the headwaters of the Tagus were below the non-transfer threshold (400 hm^3), desalination has represented approximately 60% of the water supplied by the MCT. The 2017 was the year in which the most desalinated water was produced (85.3 hm^3) of the 96 hm^3 possible (88%). Its generalization as a substitute resource for the transfers from the ATS will be accentuated in the medium and short term because of the reduction of the intakes from the headwaters of the Tagus in light of more frequent drought episodes, increased demand in the headwaters and management rules that are more conservative and fairer for the donor basin (Morote et al. 2017a, b).

Reclaimed treated water has become an alternative to supply certain types of consumption and expand the supply of water resources. This interest increases, especially, coinciding with episodes of drought, since the pressure on conventional resources is reduced, allowing a greater margin for manoeuvre to guarantee the supply of potable water. The considerable development of these resources since the end of the twentieth century is due, partly, to compliance with the Water Framework Directive (WFD 2000/60/EC) and to the Community Directives 91/271/EEC and 98/15/EC on the treatment of urban wastewater which oblige wastewater to be treated before being discharged or reused (Rico et al. 2016).

According to data of the Ministry of the Environment and Rural and Marine Affairs, reflected in the National Water Quality Plan, in 2010 the volume treated exceeded 3300 hm^3, and there were more than 2533 Wastewater Treatment Plants (WWTP). Andalucía (545 treatment plants; 21.5%), Catalonia (281; 11.1%) and the Valencian Community (270; 10.6%) were the autonomous communities with the greatest number of facilities. According to Olcina and Moltó (2010) in that year, in theory, more than 4500 hm^3/year of water was treated, although its effective use (reuse) was limited to just 450 hm^3 (10%). According to the latest data available from the National Statistics Institute, in 2014, the volume of treated water amounted to 4942 hm^3, 530 hm^3 (10.7%) being reused. However, notable regional differences can be observed: 25% of all the volume reused in Europe is used in the Valencian Community and the Region of Murcia (Spain). The analysis on a regional scale reflects the relevance acquired by these resources in the regions of Murcia and the

Table 6.6 Volume treated and reused in Spain per Autonomous Community (2014). (Instituto Nacional de Estadística 2016)

Autonomous com.	Volume treated	Volume reused	% of water reused
Andalusia	732.1	57.3	7.8
Aragón	201.6	1.5	0.7
Asturias	201.5	13.9	6.9
Balearic Islands	122.3	55.6	45.5
Canary Islands	139.6	27.7	19.8
Cantabria	97.4	1.9	2.0
Castilla y León	390.6	3.9	1.0
Castilla-La Mancha	192.7	5.5	2.9
Catalonia	629.6	25.2	4.0
Valencian com.	419.8	248.9	59.3
Extremadura	162.1	55.1	34.0
Galicia	330.1	0.4	0.1
Madrid	613.8	14.5	2.4
Murcia	132.8	66.8	50.3
Navarra	78.8	0.0	0.0
Basque Country	425.9	6.7	1.6
Rioja, La	54.0	0.0	0.0
Ceuta and Melilla	16.6	0.1	0.6
Spain	4942.0	530.7	10.7

Valencian Community, both in terms of the percentage reused and in relationship with the absolute volume treated (Table 6.6).

With the passing of time, these resources have gradually gained weight, becoming an alternative source to mitigate water insufficiency in Spain (Pérez et al. 2014). This is connected to the growing concern regarding the availability of water in sufficient quantity and of sufficient quality, as well as the need to progress towards a focus on sustainability in the planning and integrated management of water resources (Del Moral 2009). And, in addition, in recent years use has been made of rainwater and grey water. The examples of the use of grey water and rainwater in urban environments refer to the metropolitan area of Barcelona associated with approaches of degrowth and the circular economy (Domenech and Saurí 2011; Domènech et al. 2013; Valles-Casas et al. 2016). The importance of these nonconventional resources (and with growing attention being paid to the use of rainwater) is accentuated even more if one takes into account the consequences of, and adaptation to, climate change, which constitutes one of the greatest challenges for societies on a global scale (IPCC 2014). In Spain, the highest number of actions for reduction and adaptation in light of climate change have been related to improvements in the management of energy and water, especially in areas with a shortage of water resources such as the Spanish Mediterranean coast and the Canary Islands (Gabarda-Mallorqui et al. 2017; Hof and Blázquez 2015), territories in which the importance of tourism as an economic sector is undeniable (Olcina and Vera-Rebollo 2016). Taking into

account the possible effects of climate change in the Spanish Mediterranean area, the policies for mitigation have been oriented towards new forms of diversification with alternative sources of water and towards water resource planning and management that lean increasingly towards demand-side management.

In parallel with the incorporation of new nonconventional resources, actions have been adopted from the point of view of management, in both urban and agricultural uses. Although between the 1980s and 1990s a spectacular increase was recorded in water consumption for urban uses, since the middle of the decade of 2000, a decrease has been observed in empirical lying urban areas of developed countries (Gil et al. 2015; Morote 2016; Valles-Casas et al. 2017). This decrease is due to an amalgam of multiple and interrelated causes, both structural and circumstantial, such as:

(a) The improvement in efficiency of the volume of water supplied associated with technological improvements and better management (installation of smart meters, control of leaks, fraud, etc.) introduced in the supply network to improve water performance and the volume of water recorded and billed.
(b) The installation of water-saving devices in the home and the presence of domestic appliances that consume water more efficiently. Their introduction has led to savings of around 40–60% in the use of washing machines and dishwashers compared to traditional models and 50% in dual-flush cisterns and baths (Gil et al. 2015).
(c) The increase in tariffs and the price paid for water and, at the same time, the decrease in the level of economic income of families since the beginning of the crisis (2008). Some authors argue that the tariffs and price of water are considered as a tool for the control of consumption (Arbués et al. 2003; Sánchez and Blanco 2012).
(d) A greater environmental awareness of the population linked to the encouragement of more sustainable practices in the use of this resource and fostered in many cases by episodes of drought March, Domènech and Saurí (2013).
(e) The use of reclaimed treated water and rainwater, as mentioned above.

Management of the demand associated with irrigation is connected to the efficiency of irrigation systems and the improvements introduced for their modernization. These initiatives are considered key for various reasons: (a) the agricultural sector is of considerable economic, social and cultural importance, being, moreover, the main consumer of water, and (b) the modernization of irrigation allows savings in water consumption but also an improvement in the management and efficiency of water resources, so that such savings can serve to meet environmental targets in both groundwater and surface water bodies. This interest is accentuated in river basin districts such as those of the Segura and the Júcar, where the deficit in water resources is greater.

6.4 Challenges for the Future in the Planning of Climate and Water Resources

The two major processes that are conditioning the recent evolution of climate and water resources on the Spanish Mediterranean coast (climate change and demand-side planning and management) imply the need to adopt measures to reduce their socioeconomic and spatial effects (Olcina 2013). Basically, it is a matter of planning the future exploitation of climate and water resources in order to be able to maintain a level of development in this regional space, which favours sustainability as the guiding principle for the actions to be undertaken in forthcoming decades.

The guiding principles that should be considered in the planning of these two elements of the natural environment in different economic sectors and territorial scopes are as follows:

6.4.1 Agriculture

Mediterranean agriculture should be based on quality productions that make prudent use of water. It should be pointed out that unirrigated agriculture, with no guarantees of auxiliary irrigation, may be seriously affected if intense droughts occur more frequently as shown in the climate change models for the Mediterranean region. Likewise, some crops will see changes to their cultivation calendar, and some cultivation practices will have to be modified. As for irrigated agriculture, this should adapt its productions to the existing water resources. An increase in production costs will be experienced because the proportion of areas irrigated with non-conventional resources will be higher. On the other hand, new crop varieties may be introduced (fruit trees) adapted to the new temperature conditions. Irrigated agriculture under plastic will reduce its production costs since the need to provide extra heating will drop owing to the reduction in cooler hours per year. Furthermore, greater coordination will be required between agricultural policies and the management of water resources. The creation of irrigated areas and the conversion of traditional unirrigated to irrigated crops have been encouraged in search of higher productivity, and new farmlands have been introduced without taking into account the impacts on water resources or the profitability of these farmlands. Taking into account the consequences deriving from uncoordinated actions, the need is imposed for the implementation of a state agricultural policy in which irrigation is contemplated from a perspective of efficiency in two respects, economic and social, causing the lowest environmental impact and respecting European guidelines, both with regard to the CAP and to the natural environment and the management of water resources. In this respect, it will be necessary to adopt the regulation of irrigated crops.

6.4.2 Tourism

For tourism activity, an essential component of the economy of the regions of the Spanish Mediterranean coast, climate change will entail alterations to climatic comfort, especially in the midsummer months, as well as the need to have a guaranteed water supply, of sufficient quantity and quality, in the light of the perspectives of the forecast alteration of the rainfall regime. The tourism sector must be prepared for the certain possibility of a prolongation of the calendar of the "high season" (currently centred on mass influx in the months of July and August) towards June (beginning) and September – beginning of October (end) which will be more appropriate months for tourism stays in this geographical area (Olcina and Vera-Rebollo 2016). The sector must tackle the need for climatic adaptation of tourism establishments, of residential properties and urban layouts to a more habitual situation of high temperatures and increased humidity, both day and night, in order to compensate for the thermal discomfort which is expected to increase in coastal areas, especially from the middle of this century (Olcina et al. 2018).

6.4.3 Water

The adoption of demand-side management in the planning of water resources on the Spanish Mediterranean coast is an indispensable process with no going back. Overcoming the traditional paradigm, based on the continuous supply of resources, which is not appropriate in a climate change scenario with less precipitation and a decrease in surface water resources, the growing use of "nonconventional" water resources is presented as a need for the forthcoming decades on the Spanish Mediterranean coast, within the paradigm of demand management and sustainable water use. It will be necessary to carry out improvements to the wastewater treatment facilities to obtain water that is adequate for the quality requirements of crops (tertiary systems and with desalination treatment) as well as the construction and improvement of infrastructure to allow the use of current flows. A relevant line of action is that relative to the perception of these flows by users. The rejection of their use by potential users may considerably condition their potential future use. In collaboration with the state administration, studies should be performed for the introduction of new strategic desalination plants for urban and agricultural use. This would involve seeking European aid aimed at reducing the costs of desalinated water, which should be considered a necessary resource in the areas of the Spanish Mediterranean coast with greater scarcity of water resources (Alicante, Murcia and Almería). Furthermore, actions should be encouraged for cooperation between urban and rural areas for the assignment of water between them.

6.4.4 Sustainable Spatial Planning

Management of the climate and water in a scenario of global warming poses a considerable challenge for spatial and urban planning. In addition to the need to advocate "zero-emission" territories and cities and with a decarbonized economy, territories should adopt sustainable planning of the land uses to be implemented. The handling of the "green infrastructure" tool should be assumed as a normal practice in spatial planning, together with the approval of municipal bylaws for adaptation to climate change and urban planning adapted to the new climatic conditions (green zones, sustainable transport). Cities, in collaboration with private agents of the sector, should have well-designed water supply systems to minimize the forecast reduction in available volumes of surface water. Lastly, specific protocols should be designed for civil protection and public health, since the risk calendars will be altered with regard to certain hazards with a climatic cause (storms and heavy rain owing to the presence of warm waters in the Western Mediterranean during a longer period of the year) as well as the frequency and intensity of the appearance of atmospheric extremes (heat waves and their effects on at-risk groups). Regarding this matter, it will be necessary to improve the systems for the drainage of intense precipitations in the cities of the Mediterranean coast with a view to reducing the sectors at risk of inundation and flooding and in turn to be able to make use of the flows which, conveniently treated, are inserted into the hydro-social cycles of the cities.

The Spanish Mediterranean coast is a territory at risk from climate change, its environmental effects and its associated risks (increase in atmospheric phenomena of extreme range, reduction of precipitations and surface water resources). The forthcoming decades will be decisive in confirming the current working hypotheses of the Intergovernmental Panel on Climate Change, improving climatic modelling even further to reach more detailed scales. The need to maintain climate research with a view to confirming all the details of the main working hypothesis (greenhouse effect caused by anthropic actions) should not mean inaction by the public authorities or private agents with regard to the measures for mitigation and adaptation that should be applied in the territories. On the contrary, the next few years are crucial for the design of policies in the light of climate change and the sustainable planning of water resources in this Spanish territory that will make it possible to anticipate the events that may develop. Geography has a fundamental role to play, as a spatial and social science, in the formulation of proposals that convert climate change into an opportunity for socioeconomic development according to the principles of environmental and spatial sustainability, overcoming the paradigm of growth without limits and predation of resources that has characterized recent decades with the effect of a radical transformation of landscapes.

References

AEMET. (2015). *Proyecciones Climáticas para el siglo XXI en España*. Available on: http://www.aemet.es/es/serviciosclimaticos/cambio_climat. Accessed on 18 June 2018.

Arahuetes, A., & Olcina, J. (2019). The potential of sustainable urban drainage systems (SuDS) as an adaptive strategy to climate change in the Spanish Mediterranean. *International Journal of Environmental Studies, 76*(5), 764–779. https://doi.org/10.1080/00207233.2019.1634927.

Arbués, F., García, M. A., & Martínez, R. (2003). Estimation of residential water demand: A state-of-the-art review. *Journal of Socio-Economics, 32*, 81–102.

Burriel, E. (2008). La "década prodigiosa" del urbanismo español (1997–2006). *Scripta Nova, XII*(64), 270. Available on: http://www.ub.edu/geocrit/sn/sn-270/sn-270-64.htm. Accessed on 5 Sept 2018.

CEDEX. (2017). *Evaluación del impacto del cambio climático en los recursos hídricos y sequías en España*. Madrid: Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente y Ministerio de Fomento.

De Luis, M., Brunetti, M., Gonzalez-Hidalgo, J. C., Longares, L. A., & Martin-Vide, J. (2010). Changes in seasonal precipitation in the Iberian Peninsula during 1946–2005. *Global and Planetary Change, 74*(1), 27–33. https://doi.org/10.1016/j.gloplacha.2010.06.006.

Del Moral, L. (2009). Nuevas tendencias en gestión del agua, ordenación del territorio e integración de políticas sectoriales. *Scripta Nova, 13*, 281–309.

Del Moral, L., & Giansante, C. (2000). Constraints to drought contingency planning in Spain: The hydraulic paradigm and the case of Seville. *Journal of Contingencies and Crisis Management, 8*, 93–102. https://doi.org/10.1111/1468-5973.00128.

Del Moral, L., & Silva Pérez, R. (2006). Grandes zonas regables y reparto del agua en España. El caso de la cuenca del Guadalquivir. *Mélanges de la Casa de Velázquez, 36*(2), 125–148. https://doi.org/10.4000/mcv.2168.

Del Moral, L., Hernández-Mora, N., De Stefano, L., Paneque, P., Vargas, J., Brufao, P., Olcina, J., & Martínez-Fernández, J. (2017). Acerca del Real Decreto Ley 10/2017, de 9 de junio, por el que se adoptan medidas urgentes para paliar los efectos producidos por la sequía en determinadas cuencas hidrográficas y se modifica el texto refundido de la Ley de Aguas, aprobado por el Real Decreto Legislativo 1/2001, de 20 de julio. *Notas para el debate*. Fundación Nueva Cultura del Agua.

Domene, E., & Saurí, D. (2006). Urbanization and water consumption: Influential factors in the metropolitan region of Barcelona. *Urban Studies, 43*(9), 1605–1623. https://doi.org/10.1080/00420980600749969.

Domenech, L., & Saurí, D. (2011). A comparative appraisal of the use of rainwater harvesting in single and multifamily buildings of the Metropolitan Area of Barcelona (Spain): Social experience, drinking water savings and economic costs. *Journal of Cleaner Production, 19*, 598–608. https://doi.org/10.1016/j.jclepro.2010.11.010.

Domènech, L., March, H., & Saurí, D. (2013). Degrowth initiatives in the urban water sector? A social multi-criteria evaluation of non-conventional water alternatives in Metropolitan Barcelona. *Journal of Cleaner Production, 38*, 44–55. https://doi.org/10.1016/j.jclepro.2011.09.020.

Fernández, R., Ordovás, J., & Herrera, M. A. (2011). Domestic gardens as water-wise Landscapes: A Case Study in Southwestern Europe. *HorTechnology, 21*(5), 616–623.

Ferreira, M. T. (2013). Calidad ecológica en la Demarcación Hidrográfica del Tajo: Una perspectiva integrada. In D. Baeza Sanz et al. (Eds.), *El Tajo. Historia de un río ignorado* (pp. 45–171). Zaragoza: Fundación Nueva Cultura del Agua.

Gabarda-Mallorqui, A., Garcia, X., & Ribas, A. (2017). Mass tourism and water efficiency in the hotel industry: A case study. *International Journal of Hospitality Management, 61*, 82–93. https://doi.org/10.1016/j.ijhm.2016.11.006.

García Acosta, X. (2013). Urbanització difusa i consumd'aigua per a usos domèstics. Una exploració de relacions. *Documents d'Anàlisis Geogràfica, 59*(2), 347–362. https://doi.org/10.5565/rev/dag.42.

Gil, A., Hernández, M., Morote, A. F., Rico, A. M., Saurí, D., & March Corbella, H. (2015). *Tendencias del consumo de agua potable en la Ciudad de Alicante y Área Metropolitana de Barcelona, 2007–2013*. Alicante: Hidraqua, Gestión Integral de Aguas de Levante S.A. and University of Alicante.

González Herrero, S., & Bech, J. (2017). Extreme point rainfall temporal scaling: A long term (1805–2014) regional and seasonal analysis in Spain: Extreme point rainfall temporal scaling in Spain. *International Journal of Climatology, 37*(15). https://doi.org/10.1002/joc.5144.

Hernández, M., & Morales, A. (2008). Trascendencia socio-económica del trasvase Tajo-Segura tras 30 años de su funcionamiento en la provincia de Alicante. *Investigaciones Geográficas, 46*, 31–48. https://doi.org/10.14198/INGEO2008.46.02.

Hernández-Mora, N., & Del Moral, L. (2015). Developing markets for water reallocation: Revisiting the experience of Spanish water mercantilización. *Geoforum, 62*, 143–155. https://doi.org/10.1016/j.geoforum.2015.04.011.

Hernández, M., Saurí, D., & Moltó, E. (2016). Las aguas pluviales y de tormenta: del abandono de un recurso hídrico con finalidad agrícola a su implantación como recurso no convencional en ámbitos urbanos. In F. Vera, J. Olcina, & M. Hernández (Eds.), *Paisaje, cultura territorial y vivencia de la Geografía. Libro homenaje al profesor Alfredo Morales Gil* (pp. 1099–1120). Alicante: Publicaciones de la Universidad de Alicante.

Hernández-Mora, N., La Calle, A., Del Moral, L., La Roca, F., & Schmidt, G. (2010). *Transboundary water allocation in Spain. A report for WWF-UK*. Zaragoza: Fundación Nueva Cultura del Agua.

Hof, A., & Blázquez, M. (2015). Changing tourism patterns, capital accumulation, and urban water consumption in Mallorca, Spain: A sustainability fix? *Journal of Sustainable Tourism, 23*(5), 770–796. https://doi.org/10.1080/09669582.2014.991397.

Hof, A., & Wolf, N. (2014). Estimating potential outdoor water consumption in private urban landscapes by coupling high-resolution image analysis, irrigation water needs and evaporation estimation in Spain. *Landscape and Urban Planning, 123*, 61–72. https://doi.org/10.1016/j.landurbplan.2013.12.010.

Instituto Nacional De Estadistica. (2016). *Encuesta sobre el suministro u saneamiento del agua*. Available on: https://www.ine.es/dyngs/INEbase/es/operacion.htm?c=Estadistica_C&cid=1254736176834&menu=resultados&idp=1254735976602. Accessed on 29 July 2018.

IPCC (Intergovernmental Panel on Climate Change). (2014). *Climate change 2013 and climate change 2014* (3 vols.). Available on: http://www.ipcc.ch/. Accessed on 29 July 2018.

Llausàs, A., Hof, A., Wolf, N., Saurí, D., & Siegemund, A. (2018). Applicability of cadastral data to support the estimation of water use in private swimming pools. *Environment and Planning B: Urban Analytics and City Science, 6*. https://doi.org/10.1177/2399808318756370.

Lois, R. C., Piñeira, M. J., & Vives, S. (2016). El proceso urbanizador en España (1990–2014): una interpretación desde la geografía y la teoría de los circuitos de capital. *Scripta Nova, XX*(539).

López-Zavala, M. A., Castillo Vega, R., & López Miranda, R. A. (2016). Potential of rainwater harvesting and greywater reuse for water consumption reduction and wastewater minimization. *Water, 8*(264). https://doi.org/10.3390/w8060264.

March, H., Domènech, L., & Saurí, D. (2013). Water conservation campaigns and citizen perceptions: the drought of 2007–2008 in the Metropolitan Area of Barcelona. *Natural Hazards, 65*, 1951–1966. https://doi.org/10.1007/s11069-012-0456-2.

March, H., Saurí, D., & Rico, A. M. (2014). The end of scarcity? Water desalination as the New Cornucopia for Mediterranean Spain. *Journal of Hydrology, 519*, 2642–2651. https://doi.org/10.1016/j.jhydrol.2014.04.023.

March, H., Hernández, M., & Saurí, D. (2015). Percepción de recursos convencionales y no convencionales en áreas sujetas a estrés hídrico: el caso de Alicante. *Revista de Geografía Norte Grande, 60*, 153–172.

Marcos-García, P., & Pulido-Velázquez, M. (2017). Cambio climático y planificación hidrológica: ¿Es adecuado asumir un porcentaje único de reducción de aportaciones para toda la demarcación? *Ingeniería del Agua, 21*(1), 35–52. https://doi.org/10.4995/ia.2017.6361.

Ministerio de Medio Ambiente. (2006). *Plantas desalinizadoras. Situación a 31 de marzo de 2006.* Available on: https://www.iagua.es/2006/04/el-ministerio-de-medio-ambientepublica-un-mapa-de-desaladoras-en-espana.

Morales, A. (2001). *Agua y Territorio en la Región de Murcia*. Murcia: Fundación Centro de Estudios Históricos e Investigaciones Locales.

Morote, A. F. (2016). La disminución del consumo de agua urbano-turística en la costa de Alicante (España): Una amalgama de causas múltiples e interrelacionadas. *Revista de Estudios Regionales, 106*, 133–164.

Morote, A. F. (2017). Espacios ajardinados privados en España y su incidencia en el consumo de agua: Estado de la cuestión. *Anales de Geografía de la Universidad Complutense, 37*(2), 415–443.

Morote, A. F., & Hernández, M. (2017). El uso de aguas pluviales en la ciudad de Alicante. De Viejas ideas a nuevos enfoques. *Papeles de Geografía, 63*, 7–25. https://doi.org/10.6018/geografia/2017/279451.

Morote, A. F., Hernández, M., & Rico, A. M. (2016). Causes of domestic water consumption trends in the city of Alicante: Exploring the links between the housing bubble, the types of housing and the socio-economic factors. *Water, 8*(374). https://doi.org/10.3390/w8090374.

Morote, A. F., Olcina, J., & Rico, A. M. (2017a). Challenges and proposals for socio-ecological sustainability of the Tagus–Segura Aqueduct (Spain) under climate change. *Sustainability, 9*(11), 1–24. https://doi.org/10.3390/su9112058.

Morote, A. F., Rico, A. M., & Moltó, E. (2017b). Critical review of desalination in Spain: A resource for the future? *Geographical Research, 55*(4), 412–423. https://doi.org/10.1111/1745-5871.12232.

Olcina, J. (2001). Causas de las sequías en España. Aspectos climáticos y geográficos de un fenómeno natural. In A. Gil & A. Morales (Eds.), *Causas y consecuencias de las sequías en España* (pp. 49–109). Alicante: Instituto Universitario de Geografía de la Universidad de Alicante.

Olcina, J. (2012). Globalisation and Sustainability: Threats to the environment in a globalised world. The point of view of Spanish geography. In Comité Español de la Unión Geográfica Internacional (Ed.), *New trends in the XXI century Spanish geography* (pp. 374–392). Madrid: Comité Español de la UGI.

Olcina, J. (2013). Experiences in adapting to climate change and climate risk in Spain. In P. Schmidt-Thome & J. Klein (Eds.), *Climate change adaptation in practice: From strategy development to implementation* (pp. 253–268). Chichester: Wiley-Blackwell.

Olcina, J. (2014). Cambios en la consideración territorial, conceptual y de método de los riesgos naturales. In F. Calvo García-Tornel (Ed.), *Enfrentados a un destino adverso. De las calamidades naturales hacia las ciencias cindínicas* (pp. 47–68). Barcelona: Editorial Geocrítica.

Olcina, J. (2017). Incremento de episodios de inundación por lluvias de intensidad horaria en el sector central del litoral mediterráneo español: análisis de tendencias en Alicante. *Rev Semata, 29*, 143–163.

Olcina, J., & Moltó, E. (2010). Recursos de agua no convencionales en España: estado de la cuestión. *Investigaciones Geográficas, 51*, 131–163. https://doi.org/10.14198/INGEO2010.51.06.

Olcina, J., & Vera-Rebollo, J. F. (2016). Climate change and tourism policy in Spain: Diagnosis in the Spanish Mediterranean coast. *Cuadernos de Turismo, 38*, 565–571.

Olcina, J., Hérnandez, M., Rico, A. M., & Martínez, E. (2010). Increased risk of flooding on the coast of Alicante (Region of Valencia, Spain). *Natural Hazards, 10*(11), 2229–2234. https://doi.org/10.5194/nhess-10-2229-2010.

Olcina, J., Campos, A., Casals, I., Ayanz, J., Rodríguez, M., & Martínez, M. (2018). Resilience in the urban water cycle. Rainfall. extremes and adapting to climate change in the Mediterranean area. *Aqua Papers, 8*, 97.

Padullés, J., Vila, J., & Barriocanal, C. (2014). Maintenance, modifications, and water use in private gardens of Alt Empordà, Spain. *Hort Technology, 24*, 374–383. https://doi.org/10.21273/HORTTECH.24.3.374.

Parés, M., March, H., & Saurí, D. (2013). Atlantic gardens in Mediterranean climates: Understanding the production of suburban natures. *International Journal of Urban and Regional Research, 37*(1), 328–347. https://doi.org/10.1111/j.1468-2427.2012.01118.x.

Pastor, F., Valiente, J. A., & Palau, J. L. (2017). *Sea surface temperature in the Mediterranean climatology, trends and spatial patterns*. In Poster presented in 10th Hymex workshop in Barcelona. Available on: http://www.ceam.es/VERSUS/publications.html. Accessed on 19 July 2018.

Pérez, A., Gil, E., & Gómez, J. M. (2014). Las aguas residuales regeneradas como recurso para los regadíos de la Demarcación Hidrográfica del Segura (España). *Boletín de la Asociación de Geógrafos Españoles, 64*, 151–175.

Rico, A. M. (2004). Sequías y abastecimientos de agua potable en España. *Boletín de la Asociación de Geógrafos Españoles, 37*, 137–181.

Rico, A. M. (2007). Tipologías de consumo de agua en abastecimientos urbano-turísticos de la Comunidad Valenciana. *Investigaciones Geográficas, 42*, 5–34. https://doi.org/10.14198/INGEO2007.42.01.

Rico, A. M., Arahuetes, A., & Morote, A. F. (2016). Depuración y reutilización de aguas residuales regeneradas en las regiones de Murcia y Valencia. In F. Vera, J. Olcina, & M. Hernández (Eds.), *Paisaje, cultura territorial y vivencia de la Geografía. Libro homenaje al profesor Alfredo Morales Gil* (pp. 1169–1202). Alicante: Publicaciones de la Universidad de Alicante.

Salvador, R., Bautista, C., & Playán, E. (2011). Irrigation perfomance in private urban landscapes: A study case in Zaragoza (Spain). *Landscape and Urban Planning, 100*(3), 302–311. https://doi.org/10.1016/j.landurbplan.2010.12.018.

Sánchez, V. E., & Blanco, F. J. (2012). El uso sostenible del agua en núcleos urbanos: las tarifas como herramienta de control del consumo. *Observatorio ambiental, 15*, 35–59. https://doi.org/10.5209/rev_OBMD.2012.v15.40331.

Saurí, D., & Del Moral, L. (2001). Recent development in Spanish water policy. Alternatives and conflicts at the end of the hydraulic age. *Geoforum, 32*(3), 351–362. https://doi.org/10.1016/S0016-7185(00)00048-8.

Sedlak, D. (2014). *Water 4.0. The past, present and future of the world's most vital resource*. New Haven: Yale University Press.

Serrano, R. (2017). *Reconstrucción climática instrumental de la precipitación diaria en España: ensayo metodológico y aplicaciones*. Tesis doctoral, inédita. Universidad de Zaragoza.

Shaltout, M., & Omstedt, A. (2014). Recent sea surface temperature trends and future scenarios for the Mediterranean Sea. *Oceanologia, 56*(3), 411–443. https://doi.org/10.5697/oc.56-3.411.

Skliris, N., Sofianos, S., Gkanasos, A., Mantziafou, A., Vervatis, V., Axaopoulos, P., & Lascaratos, A. (2012). Decadal scale variability of sea surface temperature in the Mediterranean Sea in relation to atmospheric variability. *Ocean Dynamics, 62*(1), 13–30. https://doi.org/10.1007/s10236-011-0493-5.

Stec, A., & Kordana, S. (2015). Analysis of profitability of rainwater harvesting, gray water recycling and drain water heat recovery systems. *Resources, Conservation and Recycling, 105*(parta), 84–94. https://doi.org/10.1016/j.resconrec.2015.10.006.

Swyngedouw, E. (2015). *Liquid power. Contested hydro-modernities in twentieth-century Spain*. Cambridge, MA: MIT Press.

Swyngedouw, E., & Williams, J. (2016). From Spain's hydro-deadlock to the desalination fix. *Water International, 41*(1), 54–73. https://doi.org/10.1080/02508060.2016.1107705.

Valles-Casas, M., March, H., & Saurí, D. (2016). Recycling: The case of Sant Cugat del Vallès, Barcelona, Spain. *Built Environment, 42*(2), 243–257.

Valles-Casas, M., March, H., & Saurí, D. (2017). Examining the reduction in potable water consumption by households in Catalonia (Spain): Structural and contingent factors. *Applied Geography, 87*, 234–244. https://doi.org/10.1016/j.apgeog.2017.07.015.

Vargas, J., & Paneque, P. (2017). Situación actual y claves de la gestión de sequías en España. In F. La Roca & J. Martínez (Eds.), *Informe del Observatorio de Políticas del agua 2017. Retos de la planificación y gestión del agua en España* (pp. 42–54). Zaragoza: Nueva Cultura del Agua.