sustainability

MDPI

Review

Drought Management Planning Policy: From Europe to Spain

Carmen Hervás-Gámez [1,*] and Fernando Delgado-Ramos [2]

[1] Department of Structural Mechanics and Hydraulic Engineering, ETSICCP, University of Granada, 18001 Granada, Spain
[2] Institute of Water Research, ETSICCP, University of Granada, 18001 Granada, Spain; fdelgado@ugr.es
* Correspondence: karmina.doctorado@gmail.com

Received: 1 March 2019; Accepted: 20 March 2019; Published: 28 March 2019

Abstract: Climate change is anticipated to exacerbate the frequency, the intensity, and the duration of droughts, especially in Mediterranean countries. This might lead to more serious water scarcity episodes and fierce competition among water users. Are we really prepared to deal efficiently with droughts and water scarcity events? This paper sheds light on this question by reviewing the evolution of European drought management planning policy, recently developed scientific and technical advances, technical guidance documents, and an extensive number of journal papers. More specifically, Spain presents an ideal context to assess how drought risk has been historically addressed because this country has periodically suffered the impacts of intense droughts and water scarcity episodes, and has developed a long track record in water legislation, hydrological planning, and drought risk management strategies. The most recent Drought Management Plans (DMPs) were approved in December 2018. These include an innovative common diagnosis system that distinguishes droughts and water scarcity situations in terms of indicators, triggers, phases, and actions. We can conclude that DMP should be a live and active document able to integrate updated knowledge. The DMP needs also to set out a clear strategy in terms of water use priorities, drought monitoring systems, and measures in each river basin in order to avoid generalist approaches and possible misinterpretation of the DMP that could lead to increase existing and future conflicts.

Keywords: drought; water scarcity; drought management plan; European Union; Spain

1. Introduction

Worldwide, we are already experiencing the impacts of climate change such as the increase in frequency and magnitude of extreme weather events such as droughts, floods, heat waves, wildfires, rising sea levels, and biodiversity loss. These events, especially when they occur in cascade, can significantly harm people's lives in terms of damage to health, economic losses, labor productivity, housing, critical infrastructures, as well as disruption of basic services and social networks [1].

The latest IPCC (Intergovernmental Panel on Climate Change) Special Report on Global Warming of 1.5 °C predicts even worse future wide-ranging climate-change impacts up and until 2100: "*Climate-related risks to health, livelihoods, food security, water supply, human security, and economic growth are projected to increase with global warming of 1.5 °C and increase further with 2 °C*" [2].

In response to this, great international efforts are being made to agree on commitments towards greenhouse gas emission reductions, integration of sustainable development, as well as fostering climate resilience, adaptation, and disaster risk reduction strategies [3]. An example of this collaborative work is the *2030 Agenda for Sustainable Development* and the *17 Sustainable Development Goals* [4], which stresses the importance of adaptive and resilient strategies to climate-related hazards and disasters. Other examples in relation to risk reduction and disaster management are the *Hyogo*

Framework for Action: Building the resilience of nations and communities to disasters [5] and *Sendai Framework for Disaster Risk Reduction* 2015–2030 [6].

In this complex scenario, water plays a critical role as it is intricately linked to health and well-being, food security, energy, critical infrastructures, economy, and the environment. The water management sector is threatened by climate change and other significant pressures such as population growth, urbanization, and socio-economic activities. If action is not taken to mitigate climate change impacts, a considerable fraction of the world population will be exposed to absolute or chronic water scarcity [7].

Whilst water users, managers, and policy-makers generally agree on the importance of protecting water resources to ensure that enough good quality water is available for its long-term use, this is not always reflected on how water resources are actually planned, managed, and used at local, regional, and national scales. Indeed, Rosenzweig [8] highlights that at local scale, cities and municipalities are key players at the frontline of adaptation.

As a result, many regions in the world suffer from an imbalance between water demands and available water resources, especially in arid and semi-arid basins. Additionally, changes in rainfall and temperature patterns are affecting the hydrological water cycle at local and global scales (timing, intensity, duration, and spatial distribution) and therefore, the water availability. This adds further uncertainty and difficulty in predicting and planning water resources.

At the European Union level, substantial efforts and progress have been made in terms of developing policy instruments, research projects, and non-legally binding technical guidance documents to deal with droughts and water scarcity. The most important and ambitious piece of European water and environmental legislation was introduced with the adoption of the *Water Framework Directive* (WFD) in 2000. Whilst one of the purposes of the WFD is the mitigation of drought impacts (Art.1 (e)), droughts are only succinctly dealt with within the WFD, and the development of Drought Management Plans (DMPs) is not compulsory.

Another key milestone in terms of European drought-risk management was set by the 2007 EC Communication "*Addressing the Challenge of Water Scarcity and Droughts in the European Union*" and the publication of the technical guidance "*Drought Management Plan Report Including Agricultural, Drought Indicators and Climate Change Aspects*" [9].

This first one presented an initial set of seven policy instruments for tackling water scarcity and drought issues at European, national and regional levels to address and mitigate water scarcity and droughts. These included options in relation to '*putting the right price tag on water*', '*allocating water more efficiently*', and '*fostering water efficient technologies and practices*'. The Communication also recommended the development of DMPs, as supplementary documents of the River Basin Management Plans (RBMPs), art. 13(5) of the WFD. The EU has adopted other instruments to identify and deal with droughts and water scarcity such as the internet-based interactive map European Drought Observatory and the water exploitation index plus.

The second one provided methodological guidance on the development and implementation of DMPs in terms of their content, the drought indicator system, thresholds and recommended measures, as well as other key elements such as the consideration of "*prolonged drought*" and consequences of climate change.

Recent studies highlight the Mediterranean area "*as a climate change hotspot, both in terms of projected stronger warming of the regional land-based hot extremes compared to the mean global temperature increase*" [10] and equally in relation to "*robust increases in the probability of occurrence of extreme droughts at 2 °C vs. 1.5 °C global warming*" [1].

Spain is a Mediterranean country that presents an ideal context to assess how drought risk has been historically addressed. This country has periodically suffered the devastating consequences of intense droughts and water scarcity episodes. Spain is also one of the pioneering EU Member States along with the longest track record in water legislation and hydrological planning. As many other European countries, Spain has moved from the traditional emergency drought management approach towards a drought risk-reduction management, as this was reflected in the most recent Drought Management Plans (DMPs) approved in December 2018.

This paper provides a review on the evolution of European drought management planning policy, recently developed scientific and technical advances, technical guidance documents, and an extensive number of journal papers. Then, the case of Spain is studied in detail in relation to how drought risk has been historically addressed and in particular, how the most recently adopted DMPs deal with drought and water scarcity. The key innovative aspect introduced in the DMPs is the delivery of a common diagnosis system that distinguishes droughts from water scarcity situations (using different indicators, triggers, and phases), recommending a different set of actions to deal with each phenomenon. This has not only shown the significant strides made by all River Basin Authorities (RBA) in Spain towards the harmonization of technical procedures across all the basins but also an effective intergovernmental co-ordination between all the organizations and processes involved at the political, technical, and institutional levels.

2. Droughts and Water Scarcity

2.1. Overview

The terms of drought and water scarcity are sometimes used indistinctly. However, it is important to differentiate them in terms of underlying causes and consequences, so they can be monitored, diagnosed, and dealt with accordingly.

Droughts are defined as natural phenomena caused by a deficiency in precipitation, which represents a certain statistical anomaly with respect to the long-term average over a certain period of time and specific area. In contrast, water scarcity episodes occur when the water consumption is greater than the renewable available water resources, resulting in overexploited water resources [11].

When a drought event strikes, not only the water quantity is likely to be affected (depletion in the available water resources) but also the water quality might be seriously compromised (less dilution and higher concentration of contaminants). This would reduce, even more, the volume of water that is suitable for human consumption, while making its treatment more costly and difficult.

Water scarcity might be triggered by a drought event (depending on the duration and magnitude). However, water scarcity can be also triggered or aggravated by other pressures such as unsustainable or inefficient water usage and water pollution.

Depending on the robustness and resilience of the water infrastructures in a determined water system, water scarcity might lead to water restrictions (irrigated crops, industrial and touristic activity, environmental flows, urban and household water uses) and increased competition and conflicts among water users.

Therefore, the social, economic and environmental consequences of water scarcity episodes can be substantial and will depend on the drought magnitude and resilience of the affected area (adaptation and mitigation strategies in place) [12]. These will be more severe in water-scarce basins [11], regions lacking water storage infrastructures [13], or in the absence of contingency plans [14].

2.2. Drought Management

Droughts have been traditionally managed only as a crisis situation, by implementing emergency procedures and urgent measures. However, that approach usually failed in achieving the most sustainable and cost-efficient solutions in the long-term. Consequently, this led to a paradigm shift towards applying drought risk-reduction management strategies that are reflected in the academic work, political agenda, and policy-making process. This latter approach has received substantial attention, especially, in drought-prone countries such as Australia, South Africa, and the United States [15].

In this context, DMPs represent key strategic tools to support sustainable water resources management and build resilience to drought extremes. DMPs should define relevant drought and water scarcity indicators and their thresholds, provide robust early warning systems, and establish priorities among water users together with a clear action roadmap to be followed during each drought phase. In order to be effective tools and provide reliable support to water decision-makers, DMPs should promote simple, practical, and scientifically sound approaches, based on technical evidence, the latest engineering and science knowledge, as well as integration of learning lessons from historical droughts.

Although the organizational and institutional framework of each country is different, three drought management levels can be pointed out: Strategic, Operational, and Contingency (or Emergency). For example, in Spain each RBA is the competent authority responsible for not only preparing the Strategic DMP at the river basin scale, but also its management, monitoring, control, and follow-up. The ultimate approving body is the Directorate General for Water (DGW) of the Ministry for the Ecological Transition (MITECO). Additionally, water companies should elaborate Operational and Contingency DMPs for urban water supply systems serving more than 20,000 people in order to ensure water services under drought situations in accordance with the directions provided in the Strategic DMP.

At the strategic level, using reliable and accurate drought forecasting is crucial to inform the preparation of preventive drought-risk management strategies. However, forecasting the key drought elements (onset, end, thresholds, drought phases, affected area and users, direct droughts impacts, etc.) is a considerably complex task. It is difficult to define exactly when the drought begins: unlike other natural disasters (such as floods and earthquakes), droughts do not occur suddenly. Additionally, the duration of droughts might vary from months to years. In terms of the affected area, it is not easy to delimit the exact area (unlike floods), the interaction between droughts, and the propagation mechanisms.

Different drought indicators have been developed to target different types of droughts. Among the most common indices are the Palmer Hydrological Drought Index [16], the Standardized Precipitation Index [17], the Drought Frequency Index [18], and the Reconnaissance Drought Index [19]. Tsakiris [20] and Rossi and Cancelliere [12] provide a comprehensive, helpful and comparative critical review of the different drought indices.

Mishra and Singh [21] classified droughts into four categories: (i) meteorological defined as "*a lack of precipitation over a region for a period of time*"; (ii) agricultural defined as a "*period with declining soil moisture and consequent crop failure without any reference to surface water resources*"; (iii) hydrological defined as "*a period with inadequate surface and subsurface water resources for established water uses of a given water resources management system*" and (iv) socio-economic drought defined as "*a failure of water resources systems to meet water demands and thus associating droughts with supply of and demand for an economic good (water)*".

Rossi and Cancelliere [12] also provide a classification of the main drought risk-management areas: planning, monitoring, implementing planned measures, managing emergency situations and recovery. These authors also highlight that the strategic measures "*for improving drought preparedness are generally more complex, since the spectrum of potential long-term actions is large*". They also stated that "*the operational measures, to be implemented once a drought begins, require an adaptive response to the dynamic character of drought*" (due to the uncertainty in evolution, duration, and severity).

3. Droughts and Water Scarcity in Europe

3.1. Overview

In Europe, water scarcity and droughts are increasingly frequent and widespread phenomena that affect over 100 million people and around one third of the European territory [22]. It is estimated that between 1976 and 2006 the economic impacts of droughts in Europe were approximately 100 billion euros [23]. Hydrological assessments have shown that "*there was a 24% decrease in renewable water resources per capita across Europe between 1960 and 2010, particularly in southern Europe*" [24].

Recent studies highlight the Mediterranean area "*as a climate change hotspot, both in terms of projected stronger warming of the regional land-based hot extremes compared to the mean global temperature increase*" [10] and equally in relation to "*robust increases in the probability of occurrence of extreme droughts at 2 °C vs. 1.5 °C global warming*" [1]. Climate change is projected to increase the intensity, the duration, and the frequency of severe droughts in most of Europe, especially in southern and south-eastern Europe, which will lead to greater water scarcity issues [25,26]. This situation is placing emphasis not only on Governments and institutions to work towards an effective drought risk-based management approach but also on water users who increasingly compete for a scarce, vulnerable, and valuable resource. In particular, the agriculture sector, especially in Mediterranean countries, has been in the spotlight over the last few years as well as the water governance ability to promote water saving policies and efficiently assign water resources.

3.2. Legislative Framework, Policy Context, and Technical Guidance

The most important and ambitious piece of water and environmental legislation in terms of the protection and improvement of all surface waters, transitional waters, coastal waters, and groundwater was introduced with the adoption of the Water Framework Directive [27] by the European Parliament and Council in 2000. This provides a common legal framework to assess, manage, safeguard, and enhance the quality of water resources across Europe. The key pioneering elements of the WFD were the introduction of an ecological dimension and economic instruments within a comprehensive basin-wide management scale, facilitating the tools for transboundary cooperation and stakeholder' involvement.

The backbone of the WFD is to achieve and maintain the "*good status*" for all waters within a fixed timescale based on an integrated river basin water management approach. The River Basin Management Plans (RBMPs) are the key instruments to reaching those environmental goals (protection of drinking and bathing waters, aquatic ecosystems, groundwater resources, etc.) set out in the WFD. These documents present the proposed detailed strategy to achieve the environmental objectives established for all water bodies by a set deadline.

The EU Member States publish their RBMPs on a six-years planning cycle. The first RBMP cycle was 2009–2015, the second one 2015–2021, and the 3rd, RBMP documents (2021–2027), is being prepared. Following the submission of the RBMPs, the European Environment Agency (EEA) assesses and reports the status of EU waters. The latest report was published in 2018 [28]. This report informs the European Commission (EC) about the assessment of the second RBMPs in line with the WFD.

Droughts are only succinctly dealt with within the WFD. These are only mentioned in Art. 1(e) in relation to mitigating drought effects: "*The purpose of this Directive is to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater which: (e) contributes to mitigating the effects of floods and droughts*" and Art. 4.6 in relation to prolonged drought: "*Temporary deterioration in the status of bodies of water shall not be in breach of the requirements of this Directive if this is the result of circumstances of natural cause or force majeure which are exceptional or could not reasonably have been foreseen, in particular extreme floods and prolonged droughts*".

Unlike floods, for which a specific Directive was adopted in 2007 (Directive 2007/60/EC), droughts are not yet the subject of EU law [13]. The development of DMPs is not compulsory. The DMPs are however recommended to be prepared as supplementary documents to RBMPs (Art. 13.5). The link between RBMPs (and Programme of Measures) and DMPs has not yet been defined [13].

Water scarcity is not explicitly dealt with within the WFD. Nevertheless, Article 9 enables Member States to implement incentive and transparent water pricing policies to attain water efficiency and foster improved water allocation strategies, thus putting a price on a scarce resource whilst helping to reduce water scarcity problems. Certainly, the critical role played by water quantity in ensuring good water quality and thus, good ecological and chemical status has already been recognized by the EC. In this respect, the WFD can positively contribute towards preventing and managing drought and water scarcity management [9].

After the devastating economic, environmental, and social impacts from the 2003 drought in Europe, droughts and water scarcity were considered as a major challenge afflicting the European territory. Consequently, a number of policy mechanisms as well as extensive non-legally binding technical guidance documents to deal with droughts and water scarcity were developed in the EU.

From 2007 to the present, the European policy development on water scarcity and droughts includes three main water policy documents: (i) the 2007 Communication "*Addressing the Challenge of Water Scarcity and Droughts in the European Union*" [29]; (ii) the Follow-Up Reports which periodically assess the implementation of the WFD [30–32], and (iii) the 2012 Policy Review "*Review of the European Water Scarcity and Droughts Policy*" [33].

These documents, among others, informed the major assessment of water resources and thorough policy review on water scarcity and droughts across Europe completed in 2012 with the publication of the "*Blueprint to Safeguard Europe's Water Resources*" [34].

The 2007 Communication [29] presented an initial set of seven policy instruments for tackling water scarcity and drought issues at European, national, and regional levels in order to address and mitigate water scarcity and droughts. These included options in relation to '*putting the right price tag on water*', '*allocating water more efficiently*', and '*fostering water efficient technologies and practices*'. The Communication also recommended the development of DMPs, as supplementary documents of the RBMPs, art. 13(5) of the WFD, in order to move from the traditional crisis (or reactive) approach to a drought risk-based (or proactive) management approach. The proposed water hierarchy considered additional water supply as the last resort option, only to be pursued once water saving, water-efficiency, water pricing policy, and cost-effective alternative solutions had been exhausted.

The EC undertakes annual Follow-up Reports that evaluate the implementation of the above policy options throughout the EU. So far, three Follow-up Reports [30–32] have been completed. The last and final report of 2011 identified aspects to be improved, and confirmed that water scarcity and drought episodes affect not only Mediterranean basins but all of Europe.

Following that, the 2012 Policy Review [34] carried out a thorough evaluation of the first cycle 2009 RBMPs to assess whether and to what extent the 2007 Communication policy options had been applied, as well as to identify any potential gaps in the EU drought and water scarcity policy. The overall conclusion of this study was that the objective of the 2007 Communication (i.e., to revert trends) had not been achieved. A stronger focus was required on quantity issues as well as further integration with sectorial policies in the implementation of the next WFD cycles.

The identified policy gaps and specific solutions were addressed in the EC Communication '*Blueprint to Safeguard Europe's Water Resources*' [34]. The aim was to identify the difficulties and set out actions to be undertaken by policy-makers and water managers to protect European water resources in the long-term. Some of these include a better implementation and integration of European water legislation as well as specific actions towards "*improving land use, addressing water pollution, increasing water efficiency and resilience*", as well as "*improving governance by those involved in managing water resources*". It is expected that the Blueprint will lead to the EU water policy development path in the long term.

Additionally, no legally-binding but technical guidance documents have been published in the context of the WFD to support the Member States in the transition towards a planned drought risk-based management approach. For example, the "*Drought Management Plan Report Including Agricultural, Drought Indicators and Climate Change Aspects*" [9] or "*Guidelines for preparation of the Drought Management Plans*" [35]. These provide methodological guidance on the development and implementation of DMPs in terms of its content, the drought indicator system, thresholds and required measures, as well as other key elements such as the consideration of "*prolonged drought*" and consequences of climate change. That said, there is not a proposed common agreed indicator system to be used across the EU.

3.3. Elaboration of DMPs in Different EU Member States

The development of DMPs (or similar tools) is receiving increasing attention by the Member States. Up to 78 River Basin Districts (RBDs) (42%) have implemented DMPs (or similar tools) or have planned them in the framework of the Programme of Measures, while other 89 (48%) show no explicit intention in this regard, though may count on some simpler drought management tools. Finally, results in the same report concluded that in 19 RBDs (10%), the available information was still not sufficient to assess [36].

For example, in Cyprus the DMPs are included as an Annex of the RBMP while in Spain the latest approved DMPs have been developed as supplementary documents of the RBMPs in the middle of the RBMP cycle. In contrast, in the UK the private water supply companies are required to develop Water Resources Management Plans ("*strategic plan setting out the planned investments required over a 25 year planning horizon to demonstrate their ability to ensure sufficient supply to meet anticipated demand*") and DMP ("*describes the company's tactical and operational responses during a drought event*") [37]. France and Netherlands have their own drought operative management tools. Other countries have tools focused on emergency management or specific early warning systems [36].

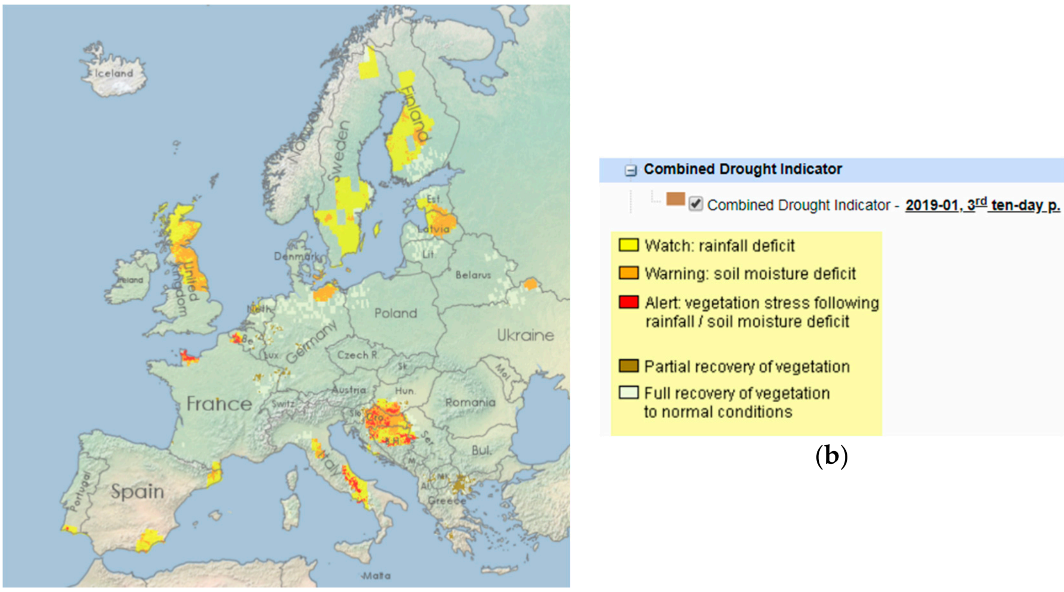
3.4. Research Projects, Scientific and Technical Advances

At the European Union level, substantial efforts and progress have been made in terms of developing policy instruments, research projects, and non-legally binding technical guidance documents to deal with droughts and water scarcity.

Important European research projects in this area are: INDRO (anticipated to finish in April 2019, Remote Sensing Indicators for Drought Monitoring), DrugCrops (anticipated to finish March 2019, Drought discovery to improve drought tolerance in crops), WATER INCENT (May 2017, Economic Instruments for Sustainable Water Management in Water Scarce and Drought Prone Irrigated Areas), MARSOL (November 2016, Demonstrating Managed Aquifer Recharge as a Solution to Water Scarcity and Drought), TransDRiM (September 2015, Transboundary Drought Risk Management—an Application to the Guadiana River Basin), DROP (September 2015, Benefit of Governance in Drought Adaptation), DROUGHT-R&SPI (March 2015, Fostering European Drought Research and Science-Policy Interfacing), EPI-WATER (December 2013, Evaluating Economic Policy Instruments for Sustainable Water Management in Europe), DMCSEE (March 2012, Drought Management Centre for South East Europe), XEROCHORE (April 2010, an Exercise to Assess Research Needs and Policy Choices in Areas of Drought), PRODIM (June 2008, PROactive Management of Water Systems to face Drought and Water Scarcity in Islands and Coastal Areas of the Mediterranean), MEDROPLAN (July 2007, Mediterranean Drought Preparedness and Mitigation Planning, guidelines for drought preparedness plans and to set up a Network for drought preparedness in Mediterranean countries).

The EU has adopted other practical instruments to identify and deal with droughts and water scarcity such as the interactive map and the European Drought Observatory (EDO) [38]. This was developed by the Joint Research Centre (JRC) of the European Commission and is an interactive tool that provides a considerable amount of drought indicators at different scales. The user can choose the location, time series (from 2012 onwards), drought indicator (Standardized Precipitation Index, Standardized Snowpack Index, Soil Moisture Anomaly, Anomaly of Vegetation Condition, etc.), as well as precipitation and soil moisture forecasts. For each index, a detailed factsheet is provided to support and build the knowledge of the user.

An example of the information provided is shown in Figure 1:



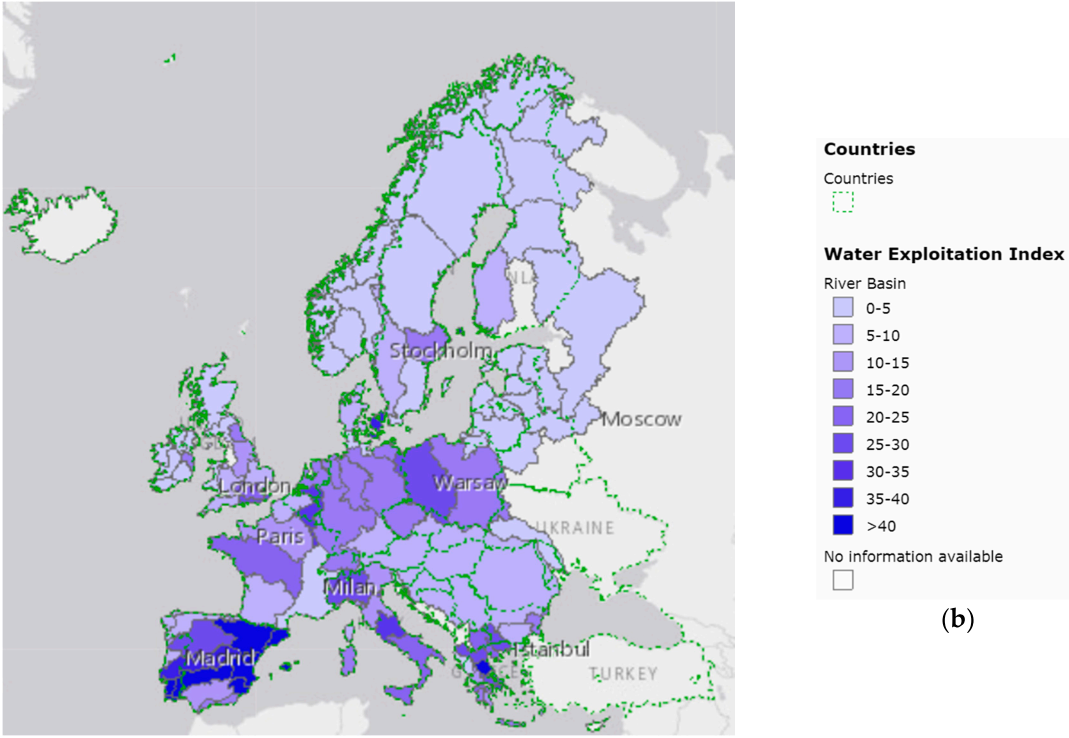
(**a**) (**b**)

Figure 1. Combined Drought Indicator in the European Union (Source: EDO webpage, [38]): (**a**) EDO interactive map viewer; (**b**) Legend.

The EDO acts as an early-warning system to increase drought preparedness, providing Member States with robust and valuable technical information and support to easily integrate drought risk-reduction management strategies in their national planning policies and decision-making processes. Since January 2018, the EDO forms part of the Copernicus Emergency Management System. This is an integrated internet-based tool that provides emergency response information for different types of disasters (floods, tsunamis, earthquakes, landslides, humanitarian crises, etc.).

Equally, the *water exploitation index plus*, WEI+ [39], for the pressures caused by water abstractions [20] has been used. The WEI+ represents the percentage used of the total renewable freshwater resources available in a defined territory (basin, sub-basin, etc.) for a given time step (e.g., seasonal, annual). It is an interactive map that presents the evolution over time (1990–2015) in water abstraction by source, water use by sector, and water stress level at sub-basin or river basin scale.

An example of the information provided is shown in Figure 2:



(**a**) (**b**)

Figure 2. Water Exploitation Index (July 2003) (Source: WEI webpage, [39]): (**a**) WEI interactive map viewer; (**b**) Legend.

Additionally, there is an important publically available European database called "*European Drought Reference database*" and the "*European Drought Impact Report Inventory*" which provides considerable information about historical drought events in Europe [40].

Despite all the aforementioned development, there is still further research required to better understand and manage droughts and water scarcity issues. For example, Rossi and Cancelliere [12] suggests that "*a better coordination of drought-preparedness planning tasks, adaptive operation of water supply systems to prevent severe shortages, and more extensive use of early drought warning systems are needed*". Stahl [41] highlights that "*systematic quantitative knowledge on the environmental and socioeconomic impacts of drought, however, is often the missing piece in drought planning and management*".

4. Droughts and Water Scarcity in Spain

4.1. Overview

Spain is characterized by a highly irregular spatial and temporal rainfall distribution. The annual average rainfall varies from 2200 mm in the northern mountainous areas (Serra do Gerês, Navarra and in some areas of Galicia) to below 300 mm in the southeast (Almeria, Murcia, Alicante). Figure 3 shows the mean annual precipitation in the Iberian Peninsula (1971–2000).

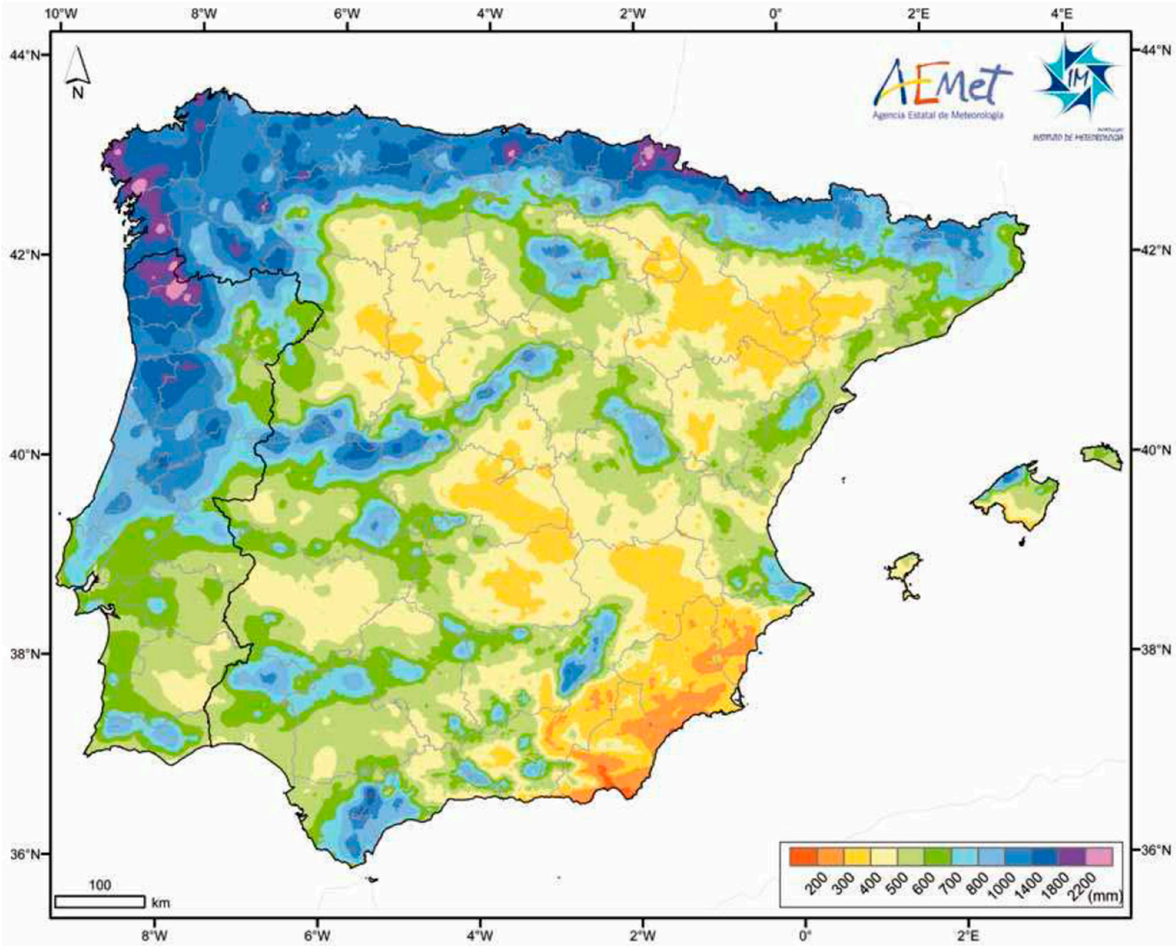
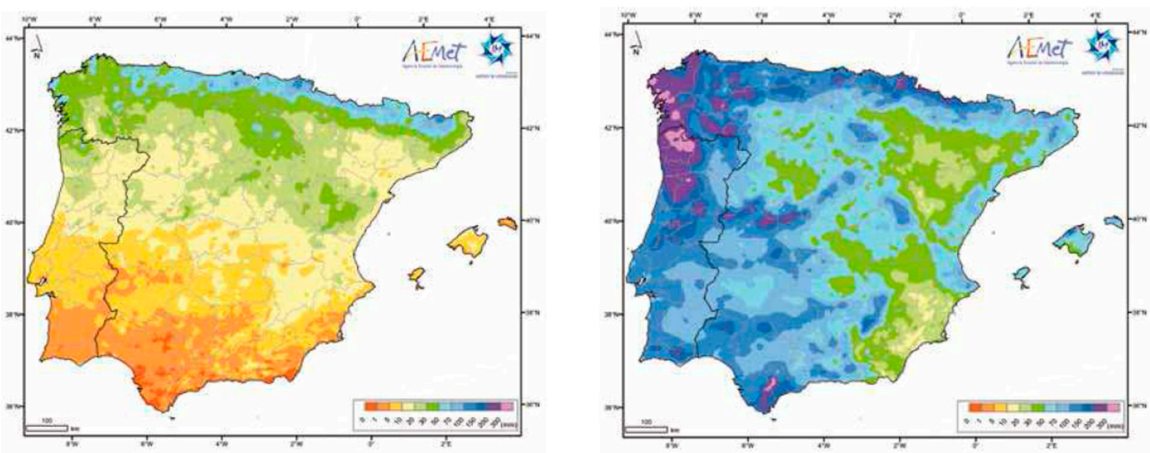


Figure 3. Mean Annual Precipitation 1971–2000 (Source: AEMET Atlas, [42]).

There is also a notable seasonality throughout the year, especially stronger in the southern half of the Iberian Peninsula (Figure 4). Indeed, a considerable reduction in rainfall is produced during the summer months, July being the driest month of the year [42]. The total long-term average annual renewable water resources in Spain are about 111,500 hm^3/year. The regulation capacity provided by dams and reservoirs in Spain provides approximately 53,810 hm^3/year of regulated surface water resources [43].



(**a**) (**b**)

Figure 4. Seasonal variability: (**a**) July Mean monthly precipitation 1971–2000, (**b**) December Mean monthly precipitation 1971–2000 (Source: AEMET Atlas, [42]).

Spain already suffers from, on the one hand, large increases in temperature, heatwaves, and high evaporation rates (which translate into greater water agriculture demands) and on the other hand, decreases in precipitation and river flows, thus further reducing available water resources [25]. Additionally, it is important to note that Spain is a drought-prone country (especially, the southern and south-eastern regions). Spain has historically suffered from intense drought episodes, some of the most notorious ones in terms of impact were produced during the periods: 1941–1945, 1979–1983, 1991–1995 and 2004–2007 [44]. These precipitation deficit episodes, especially during the 90s drought, resulted in important water scarcity problems and significant economic, social, and environmental consequences (harvest losses, severe water restrictions to all users, disruptions to services, drinking water deterioration, very low river flows, contamination issues, etc.).

The observed temperature change in Europe (1976–2006) showed significant warming in Spain when compared with the rest of the EU, particularly in summer and the south-eastern region of Spain. The average temperature rise in Spain was 1.2–1.5 °C compared with 1 °C in Europe and 0.8 °C globally. The observed changes in annual precipitation (1961–2006) show a reduction of precipitation in southern Spain of around 23%. This reduction is greatest in the northwest and lowest in the east [45].

Climate models for Spain show a general trend towards further increases in temperature and decreases in precipitations, with "*severe impacts expected in arid and semi-arid areas (approximately 30% of the national territory), where water yields may decrease by 50%. Hydrological variability will increase in the Atlantic basins, while more irregularity is expected in flood patterns of the Mediterranean basin*" [46].

Particularly, climate change is projected to reduce natural resources between 3%–12% up to 2033 (in relation to the control series 1960/1961 to 1990/1991, [47]), thus posing a substantial risk in maintaining the integrity of water-dependent systems (such as human health, river ecology, and socio-economic activities).

In terms of water demands, approximately 68.19% of the total water used in Spain is consumed by agriculture, in contrast with the 17.59% and 14.21% used by the industry and household sectors, respectively [43]. In fact, Spain leads water consumption in the agriculture sector (25.47×10^9 m^3/year) in Europe in absolute terms. In relative terms, Spanish agricultural water consumption (68.19%) is only exceeded by Greece (82.24%), and Portugal (95.85%) [48]. Based on the information provided on the Statistical Office of the European Union [49], a reduction can be seen in the total gross water abstraction from 2007 (259.4 million m^3) to 2014 (192 million m^3).

The economical productivity of the agriculture sector is especially relevant in intensive-irrigated areas in the southern (driest) part of the Iberian Peninsula. For example, there are 861,065 ha irrigated in the region of Andalusia, which represents approximately 24% of the total national sector [43]. Paneque [50] states that agriculture use reaches 81.2% of water use compared to 15% for domestic use and 3% for industrial use.

Additionally, the greatest agricultural water demand occurs precisely when the temperature and evaporation are higher and precipitation is lower (usually, from April to September). This puts large amounts of pressure on water resources (quantity and quality) combined with the fact that the tourism sector is mainly concentrated in coastal areas during summer months. This makes the Spanish water scenario unique in its complexity.

Even without the occurrence of a drought event, water demands cannot be met during the summer months of a normal hydrological year using exclusively natural available water resources. Many rivers and streams are completely drained dry during summer due to the excessive surface and underground water abstractions.

In response to that, the Spanish Water legislation and Hydrological Planning has been historically based on implementing a resilient infrastructure to better manage the irregularity in precipitation in relation to the demand pattern, as well as to deal with the effects of extreme hydrological and climate phenomena (flood protection and drought preparedness). This philosophy has mainly resulted in the construction of 1172 large dams combined with the use and development of alternative (non-conventional) water supply technologies, such as desalinated water in the Mediterranean coast and the Balearic and Canary Islands (100.2 hm^3) and treated wastewater (496 hm^3/year) [43]. Groundwater is also strategically used to increase water resources in those dry and water scarce areas, and especially to alleviate the effects of droughts [51]. Direct use of groundwater in Spain is approximately 6884 hm^3 [43], but the water quality is easily deteriorated due to point-source pollution or diffuse pollution caused by agricultural and livestock activities [52]. Apart from these, it is important to highlight that substantial efforts have been made in recent years across all Spanish basins in terms of improving water efficiency, water tariffs, and water management strategies.

Water scarcity problems are related to climate (availability of renewable water resources) and water use and demand patterns (related to population and socio-economic trends). Therefore, based on the above climate change forecasts, it is anticipated that water scarcity problems in Spain will increase as the 21st century advances [53].

4.2. Legislative Framework, Policy Context, and Technical Guidance

Spain is one of the countries with the longest track record in water legislation and hydrological planning all over the world. The following facts are proof of that: (i) the first water law was implemented in 1879; (ii) the "Confederaciones Sindicales Hidrográficas" (later on the RBA) and basin management concept were firstly established in 1926 [54]; (iii) the RBMPs have been mandatory since 1985 (15 years earlier than the WFD 2000) and the (iv) the first formal RBMPs were finished 1998–1999 (10 years earlier than the first RBMPs in Europe).

The 1978 Spanish Constitution is the supreme law of the Spanish legal system which defines the competences of the State and the different Autonomous Communities that form Spain. There are 16 Autonomous Communities in Spain (in addition to Navarra, Ceuta, and Melilla) and these are administrative entities with specific legislative, executive and administrative autonomy. The rivers that flow completely within the territory of one Autonomous Community are exclusive competence of the Autonomous Community (called "*intra-community basins*"), while those catchments which are shared by more than one Autonomous Community, are exclusive competence of the State (called "*inter-community basins*").

In the Spanish Water Act of 1985 objectives were set at "*meeting of water demands, balancing and harmonising the regional and sectoral development by increasing the availability of the resource, protecting its quality, making its use sustainable and rationalising its use while respecting the environment and other natural resources*" (Art. 38).

Apart from the preparation of individual hydrological management plans at the river basin scale, a National Hydrological Plan (NHP) was required. The NHP has higher legal status and authority since its main purpose is precisely to address water management issues which cannot be resolved at the river basin scale (such as the water transfers between river basins). The first RBMPs in Spain were adopted in 1998 by the Government (Royal Decree 1664/1998, of 24 July) while the NHP was approved in 2001 (Act 10/2001, of 5 July, on the NHP).

At the same time, the WFD (Directive 2000/60/EC) was approved by the European Parliament and the Council of the European Union. Member States were required to transpose it into their own national legislation by 2003. In Spain, this was transposed into Spanish legislation on 31 December 2003 by amending the 'Real Decreto Legislativo 1/2001' (which amended the Water Act 1985).

A number of additional regulations were approved to enable the planning process to commence. The Regulation of Hydrological Planning (Real Decreto 907/2007, de 6 julio, BOE 07–07-2007 and its subsequent modification by RD 1161/2010 de 17 de septiembre), the definition of the limits of River Basin Districts (by RD 125/2007, de 2 de febrero, artículo 16 bis 5 del TRLA) as well as the definition of Competent Authorities (RD 126/2007, de 2 de febrero, artículo 36 bis del TRLA) [55].

The Hydrological Planning Instruction (ORDEN ARM/2656/2008, de 10 de septiembre) is a complementary intra-ministerial regulation instrument. Given the intrinsic heterogeneous nature of the Spanish river basins, the aim of this Instruction was to provide a common technical and methodological approach to prepare the RBMPs and for general hydrological planning processes in line with the most recent legislation and scientific advances. The Instruction is only compulsory for inter-community river basins, although it is generally followed by all river basins in Spain. The Instruction details the common procedure in relation to the general description of the river basin, identification of the significant anthropic uses and pressures, protected areas, the state of water bodies, the environmental objectives, regimen of ecological flows, cost recovery, program of measures, etc.

Although the underlying principles and objectives of the Spanish Water Act 1985 remained practically the same after transposing the WFD into the Spanish legislation, the key new concept was the "environmental objective" to achieve the "good status". In fact, the amended Water Act included as the first objective: "achieving good status and protection of the hydraulic public domain". The introduction of this concept required a management change in the traditional Spanish hydrological planning and a behavioral change in water users.

The hydrological planning shifted from the historical water-quantity management approach to a more integrated water quantity, quality, and environmental protection. To fill this gap, the concept of the 'ecological flow' was introduced in the Spanish legislation, defined as: "*The regime of ecological flows will be established in such a way as to sustainably maintain the functionality and structure of aquatic ecosystems and associated terrestrial ecosystems, contributing to achieve good status or ecological potential in rivers or transitional waters*". It is also important to note that droughts form part of the regular climatic variability which also affects the development of local ecosystems.

For each specific river system, the ecological flow regime is composed of minimum and maximum flows as well as a specific temporal distribution (seasonality), together with induced flood flows and sediment control patterns. The ecological flows in Spain are not considered as a water demand but a water restriction (or water constraint). This means that ecological flows must be satisfied in the first instance prior to meeting the water demands of the system in all situations, except when there is a prolonged drought situation. In this state, urban water supply has the highest priority of water use. The legal compliance of ecological flows in Spain is currently a real challenge in practice, due to the complex management, monitoring, and inspection processes.

The efficient allocation of scarce water resources to comply with environmental needs and meet water demands is not an easy task. In some instances, the pressure on water resources raises hot conflicts between water users, water managers, and authorities.

4.3. Drought Management Approach Evolution

As many other European countries, Spain has traditionally managed droughts as a crisis situation only, by applying emergency procedures and urgent measures (through the adoption of Emergency Drought Orders or Decrees). However, the experience and lessons learnt have demonstrated how that approach failed in achieving the most sustainable and cost-efficient solutions in the long-term. It was precisely after the devastating environmental, social, and economic consequences of the 1991–1995 drought period, that a paradigm shift towards a drought risk-reduction management approach in Spain was necessary.

The NHP was approved in 2001 (Act 10/2001, of 5 July, on the NHP) and sets out the basic principles for managing droughts for inter-community basins (art. 27).

Section 1 of this article requires the MITECO to establish a global system of hydrological indicators in order to identify early enough and foresee drought situations, thus supporting the RBAs when declaring formal drought situations. In compliance with this legal requirement, the National Drought Indicator was set up which provides drought monitoring and diagnosis for all the inter-community basins on a monthly basis (providing a summary report and is freely available at refs. [56,57].

Section 2 of the same article 27 of the NHP requires the RBAs to prepare DMPs, which will be submitted to the MITECO for approval. Additionally, water companies or municipalities should also elaborate Operational and Emergency DMPs for urban water supply systems serving more than 20,000 people in order to ensure water services under drought situations. General Guidance Documents have been developed by the MITECO in Spain to facilitate the process of developing these plans [58].

The first DMPs for all inter-community river basins were developed by the RBAs in compliance with the art.27 of the NHP and approved in 2007 (Orden MAM/698/2007 de 21 de marzo). A global system of hydrological indicators was set up that monthly diagnosed the situation and the information was publicly made available in the National Drought Indicator webpage.

Even though the DMPs were not approved until 2007, the 2004–2007 drought was already managed in accordance with those principles established in the DMPs. These proved to be effective strategic management tools which positively contributed to avoid public supply restrictions, reduced and mitigated drought impacts, and highlighted the importance of involving the relevant stakeholders and interested parties (including the general public) in the decision-making processes associated with drought planning [59].

Since the first DMPs were approved in 2007, two hydrological planning cycles (2009–2015 and 2015–2021) have been completed in compliance with the WFD. During the review process corresponding to the second hydrological planning cycle, it was found necessary to update the 2007 DMPs, so that they were in line with the most recent planning framework. The objectives of this review were to: (i) adapt the DMPs to the latest information included in the hydrological plans (in terms of resources, demands, ecological flows, climate change conditions, etc.), and (ii) distinguish droughts (as a natural phenomenon independent of the use of water by humans) and water scarcity (related to temporary problems to meet the existing demands for different socio-economic uses of water).

The experience gained during more than a decade of application of the DMPs has shown the importance of having common criteria (including a global system of hydrological indicators) to avoid heterogeneities in the diagnosis and the nature of the actions and measures to be applied in the different scenarios [59].

Based on this, the Royal Decree 1/2016 instructed the revision of all DMPs for the inter-community RBDs in accordance with the technical instructions provided by the MITECO named "*Technical Instruction for the Elaboration of the Special Drought Plans and the definition of the global system of indicators of prolonged drought and scarcity*". These instructions ensure a common methodology to be applied among all the RBAs in Spain when diagnosing drought and water scarcity situations and implementing actions and measures of similar type and nature.

The RBAs are the competent authority responsible for not only preparing the DMPs in accordance with the Spanish Law 10/2001 NHP (art. 27) and European Water Framework Directive (Directive 2000/60/CE–Art. 4.6) but also its management, monitoring, control, and follow-up. The ultimate approving body is the DGW of the MITECO.

5. Newest Drought Management Plans (December 2018)

5.1. Overview

The draft versions of the newest DMPs were published on 21 December 2017 in accordance with the 2001 NHP Act (art. 27 de la Ley 10/2001 de 5 de Julio del Plan Hidrológico Nacional) and following the methodological guidance provided by the MITECO Technical Instructions. These plans were subject to a three-month public consultation period (from 21 December 2017 to 21 March 2018).

As part of the public consultation process, different queries were raised by relevant stakeholders and interested parties (water companies, irrigation associations, ecologist groups, and public institutions). In response to this, each RBA prepared a Statement of Response containing each concern and associated response, together with the revised version of the DMP, which were published in May 2018. The final adopted DMPs were approved by the DGW in December 2018. Figure 5 shows the development process of the 2018 DMPs in Spain.

The adopted 2018 DMPs supersede the previous 2007 DMPs (Orden MAM/698/2007 de 21 de marzo). The 2018 DMPs were developed in the context of the WFD, as supplementary documents to the RBMPs. The adopted 2018 DMPs integrated the latest information included in the already approved 2nd RBMP cycle (2015–2021) in terms of resources, demands, ecological flows, climate change conditions, etc.

The goal is to periodically update the DMPs every six years, two years after the end of every RBMP cycle (in the middle of every RBMP cycle). These will be based on the information published in the last approved RBMP.

5.2. Aim and Key Elements of the Newest DMP

The aim of the 2018 DMPs in Spain is to minimize the environmental, economic, and social impacts of possible drought episodes (in accordance with the NHP art. 27.1 Law 10/2001).

For example, the *Guadalquivir River Basin Drought Management Plan* (the largest river basin in the south of Spain) establishes the following specific objectives: (a) *guarantee sufficient water availability to ensure population life and health (while minimising negative effects of droughts and water scarcity on the urban water supply*), (b) *avoid or minimise the negative drought effects on the water status (those situations of temporary deterioration or less stringent minimum ecological flows will be only associated with natural situations of prolonged drought)*, and (c) *minimise negative effects on economic activities, according to the prioritisation of uses established in the water legislation and River Basin Management Plans*.

At the same time, the following instrumental or operational objectives are proposed in the same document: (a) *define mechanisms to detect as early as possible, and assess, situations of prolonged drought and water scarcity*; (b) *define the prolonged drought scenario*; (c) *set scenarios to determine the severity of water scarcity episodes*; (d) *define the actions to be applied in the scenario of prolonged drought and the corresponding measures in each water scarcity phase*; (e) *ensure transparency and public participation in the development of the plans*.

5.3. Content of the DMP

The MITECO Technical Instruction [60] required the DMPs to be formed in a main report, accompanied by the necessary annexes, in which at least the following contents are developed:

(a) Description of the basin and identification of territorial units for analysis of the prolonged drought and water scarcity.
(b) Detailed description of territorial water scarcity units and information on water demands, ecological needs, and resources.
(c) Record of historical droughts and climate change.
(d) Definition of the system of indicators.
(e) Diagnosis procedure.
(f) Actions to be applied in scenarios of prolonged drought.
(g) Measures to be applied in scenarios of water scarcity.
(h) Public information measures.
(i) Measures of administrative organization in a situation of drought.
(j) Criteria for the preparation of impact assessment reports and post-drought reports.
(k) Strategic environmental report.
(l) Emergency Plans in supplies of more than 20,000 inhabitants.
(m) Monitoring and review of the DMPs

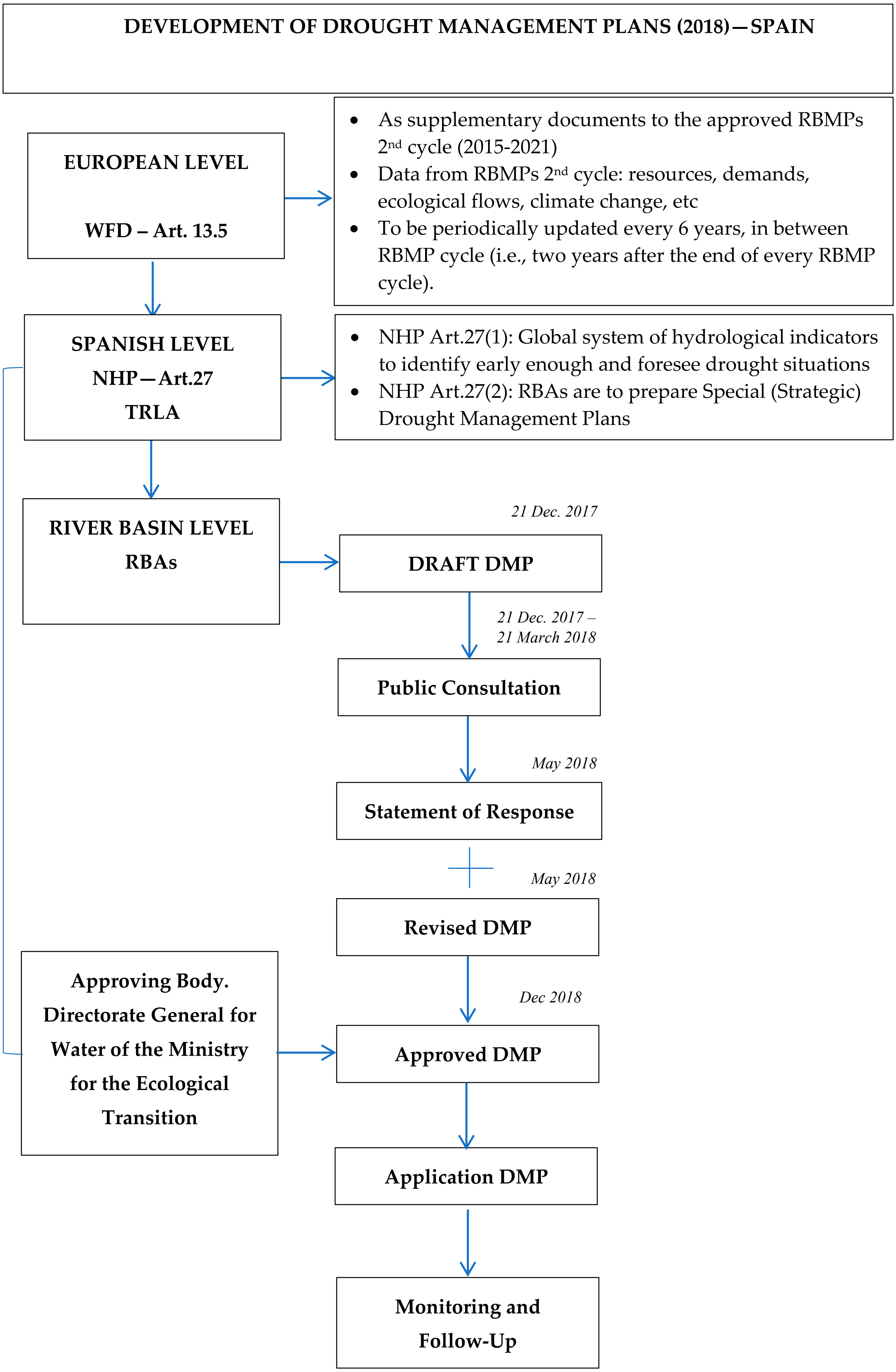


Figure 5. Development Process of 2018 DMPs in Spain.

5.4. Drought Management Approach

Unlike the previous 2007 DMPs, the current 2018 DMPs differentiate drought events from water scarcity episodes in terms of root causes, consequences, and required actions to deal with each phenomenon. A drought is defined as "*a natural phenomenon produced by the reduction of rainfall and natural run-off, which occurs independently of anthropic action*". Water scarcity is defined as "*the temporary problem of a determined area to meet the water demands for the different socio-economic uses*" [60].

It is important to note that the DMPs distinguish two different water scarcity situations: "temporary" and "permanent". The DMPs only deal with "temporary" water scarcity situations associated with temporary problems of meeting the water demands, even when the guaranteed criteria established in the RBMP are met. This means that, those water demands can be met from the hydrological planning perspective but there are operational risks which the DMP tries to identify, prevent (where possible) and mitigate. On the other hand, the "permanent" water scarcity situation is associated with permanent problems of meeting the water demands, and therefore it is not the result of a temporary situation caused by a deficiency in rainfall. This should be analyzed, valued, and solved through ordinary hydrological planning, i.e., addressed in the RBMPs [61].

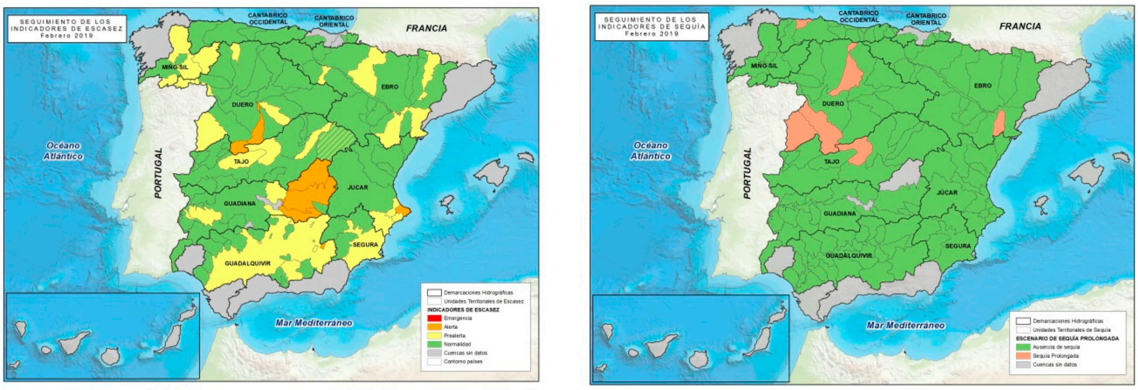
One of the objectives of the newest DMPs in Spain is to manage separately situations of prolonged drought and water scarcity. To achieve this, different territorial management units (TMUs) were identified to characterize the drought and water scarcity phenomena.

On the one hand, the "*prolonged drought TMUs*" are related to homogeneous hydrogeological areas in terms of water resources generation (including all watersheds and groundwater recharge areas according to the RBMP). The "*water scarcity TMUs*" are on the other hand related to the water demands (or consumption points) and associated ecological systems (according to the water exploitation systems established in the RBMPs). Overall, the "*prolonged drought TMUs*" are equal or greater in size than the "*water scarcity TMUs*". This is, a "*prolonged drought TMU*" which is composed by one or more "*water scarcity TMUs*". For example, the Guadalquivir RBD in southern Spain includes 25 "*prolonged drought* TMUs" and each of these is formed by one or more "*water scarcity TMUs*".

The purpose of the diagnosis system is to establish different drought and water scarcity triggers and phases that could lead to activating or deactivating determined actions and measures for each specific territorial management unit. A global system of hydrological indicators was established in order to identify early enough and foresee drought and water scarcity situations (in compliance with NHP art.27 paragraph 1). The methodology consisted of the following steps:

First, the most representative hydrological variable (precipitation, reservoir inflow, reservoir storage, groundwater level, etc.) is selected. For example, the precipitation was selected for characterizing the drought events in all "*prolonged drought TMU*". One variable or a combination of them was selected for characterizing the water scarcity phenomenon in each "*water scarcity TMU*". Second, the relevant hydrological variables time series are prepared. Third, the indicators are calculated based on the sub-basin specific data, scaled between the values of 0 and 1, weighted and finally validated with historical data. According to the indicator status value and thresholds, a progressive implementation of actions and measures is defined in the DMPs.

Figure 6 shows the National drought and water scarcity indicator system in February 2019 and Figure 7 shows the evolution of the water scarcity indicator in the Guadalquivir river basin (southern Spain) for the available 2006–2018 period:



(**a**) (**b**)

Figure 6. National indicator system February 2019 (Source: www.miteco.gob.es): (**a**) Water Scarcity indicator system (normal, pre-alert, alert, and emergency); (**b**) Drought indicator system (absence of prolonged drought in green and prolonged drought in red).

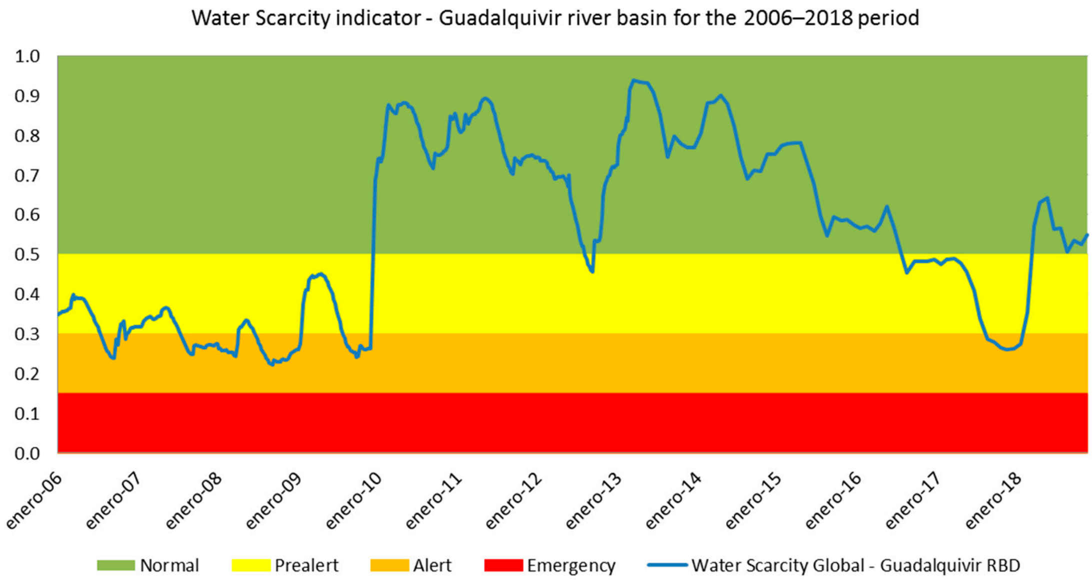


Figure 7. Evolution of Water Scarcity indicator in the Guadalquivir river basin for the 2006–2018 period (elaborated with data taken from the Indicator System of the Guadalquivir RBA).

In each drought and water scarcity phase, a set of different measures is proposed (refer to Tables 1 and 2). For example, during a water scarcity situation, the progressive implementation of measures can vary from strategic planning and monitoring (absence of water scarcity or normal situation); water saving, monitoring and public awareness (pre-alert situation); demand and supply management, monitoring and control (alert), and intensification of actions and possible exceptional actions (emergency). Finally, a monitoring and follow-up system to evaluate the implementation of the DMP is included.

Table 1. Measures to be applied during the different drought scenarios (own elaboration, data from the MITECO Technical Instructions, [60]).

Prolonged Drought	**Definition**	Reduction in precipitation that considerably affects the available natural water resources (superficial or groundwater). It does not depend on the existing water demands	
	Impacts	It can naturally produce a significant reduction in water quantity and deterioration of water quality	
	Types of variables	Precipitation and streamflow in natural regime	
	Global Indicator Value	0.3–1	0–0.3
	Scenario	Absence of prolonged drought	Prolonged drought
	Type of actions	Control and monitoring. No temporal deterioration. Comply with ecological flow regime	Possibility of justifying a temporal deterioration and adoption of ecological flow regime during prolonged drought situation.
	Objective	To limit the temporary deterioration of the water status as well as less stringent ecological flows (set out in the hydrological plan) to objective natural situations of prolonged drought only (not related to scarcity problems)	

Table 2. Types of measures to be applied during the different water scarcity scenarios: *normal* in green, *pre-alert* in yellow, *alert* in orange, and *emergency* in red (own elaboration, data from the MITECO Technical Instructions, [60]).

Operational Water Scarcity	**Description**	Reduction in available water resources that could risk meeting the existing socio-economic water demands			
	Impact	Socio-economic impacts due to the limitation in available water resources for water uses (which could be otherwise addressed in a normal situation)			
	Type of variable	Storage volume, reservoir inflow, streamflows, snow storage, groundwater level, etc.			
	Indicator	To detect the impossibility of meeting the water demands in a specific sub-basin			
	Global Indicator Value	1–0.5 Absence	0.3–0.5 Moderate	0.15–0.3 Severe	0–0.15 Extreme
	Scenario	Normal	Pre-alert	Alert	Emergency
	Type of actions and measures to be activated	General Planning and monitoring	Public Awareness, water saving and monitoring	Management (demand/supply), control and monitoring (art. 55 TRLA)	Intensify actions already considered in Alert Scenario. Possible adoption of Extraordinary Measures (art. 58 TRLA)
	Objective	Progressive establishment of measures in order to delay or avoid the entrance in the most severe phases of scarcity, mitigating their negative consequences on socio-economic uses			

The great advantage of this common indicator system is that despite the diverse climatic, geographical or water demand specific conditions, the diagnosis and results are comparable among all the different sub-basins in Spain. This common indicator system allows a homogeneous treatment among all the different sub-basins in Spain. This means that if a similar (drought or water scarcity) indicator value is found in two different sub-basins, the (drought or water scarcity) situation is expected to be similar. Therefore, actions and measures to be taken are expected to be of the same type and nature.

This highlights substantial efforts and significant strides made by all RBAs in Spain towards the harmonization of technical procedures across all the basins. This system will not only provide support to the RBA decision-making processes (especially when declaring formal drought situations) but also when disseminating information to Stakeholders and interested parties (including the general public). This also demonstrates how a similar common indicator system could be implemented at the EU level.

Despite the doubtless advantages of having a global indicator system, site-specific peculiarities relevant to each sub-basin cannot be ignored since ad-hoc solutions might be required. This is especially important in those basins characterized by complex conflict resolution, for example, where fierce competition exists among water users who share scarce water resources.

Ortega-Gomez [62] recommends using a global indicator system together with a distributed drought map to better understand if there are any areas with specific problems. Additionally, González-Hidalago [63] recommends further understanding in spatial propagation gradients of droughts, as well as the onset of a drought. This study found that: "*events at different temporal scales can overlap in time and space. Spatially, the propagation of drought events affecting more than 25% of the total land indicates the existence of various spatial gradients of drought propagation, mostly east–west or west–east, but also north–south, have been found*".

One of the deficiencies in the current DMPs is the absence of using streamflow forecast models or seasonal climate forecasts. The water scarcity thresholds and critical decisions on controlled released outflows from reservoirs are based on streamflow and historical probabilistic precipitation information only. Given the improvements in the accuracy and reliability of advanced hydrological information and streamflow forecasts, it is considered essential to use predictive models (at least for the current hydrological year) to anticipate and evaluate future impacts of a drought, as well as to take adequate and proportionate actions in each situation [64,65].

Therefore, the DMP should be a live and active document able to integrate the most updated knowledge that is relevant, credible, and delivered in a timely manner. The DMP also needs to set out a clear strategy in terms of water use priorities, drought monitoring systems, and measures in each river basin in order to avoid generalist approaches and possible misinterpretation of the DMP that could lead to increasing existing and future conflicts.

6. Conclusions

Worldwide, we are increasingly suffering the consequences of extreme climate-related events. In Europe, climate change is anticipated to exacerbate the frequency, the intensity, and the duration of severe droughts, especially in Mediterranean countries (arid, semi-arid, and water-stressed basins). This situation will likely reduce the availability of water resources, thus posing a substantial risk in maintaining the integrity of water-dependent systems (such as human health, river ecology, and socio-economic activities). Other pressures such as population and economy growth combined with aquatic protection needs are to be considered.

Traditionally, droughts were only managed as a crisis situation, by implementing emergency procedures and urgent measures. However, that approach usually failed in achieving the most sustainable and cost-efficient solutions in the long-run. Consequently, this led to a paradigm shift towards applying drought risk-reduction management strategies which are reflected in academic work, the political agenda, and the policy-making process.

Although the terms of drought and water scarcity are sometimes used indistinctly, it is nonetheless important to differentiate them (underlying causes and consequences) in order to appropriately diagnose them, and with that to prevent (where possible) and manage their impacts. Droughts are defined as natural phenomena (i.e., a regular climate feature) caused by a deficiency in precipitation, which represents a certain statistical anomaly with respect to the long-term average over a certain period of time and specific area. In contrast, water scarcity occurs when the water consumption is greater than the renewable available water resources, resulting in overexploited water resources.

In this context, DMPs represent key strategic tools to support sustainable water resource management and build resilience to drought extremes. In order to be effective tools and provide reliable support to water decision-makers, DMPs should promote simple, practical but scientifically sound approaches (based on technical evidence, the latest engineering and science knowledge, and by integrating learned lessons from historical droughts).

At the European Union level, substantial efforts and progress have been made in terms of developing policy instruments and non-legally binding technical guidance documents to deal with droughts and water scarcity. The most important and ambitious piece of European water and environmental legislation was introduced with the adoption of the WFD in 2000. However, droughts are only succinctly dealt with within the WFD and the elaboration of the DMPs is not compulsory. After the important economic, environmental, and social impacts from the 2003 drought in Europe, droughts and water scarcity were considered as a major challenge afflicting the European territory.

A key milestone in terms of European drought-risk management was set by the 2007 EC Communication "*Addressing the Challenge of Water Scarcity and Droughts in the European Union*". This presented an initial set of seven policy instruments for tackling water scarcity and drought issues at European, national, and regional levels. These included options in relation to '*putting the right price tag on water*', '*allocating water more efficiently*', and '*fostering water efficient technologies and practices*'. The Communication also recommended the development of DMPs (as supplementary documents of the RBMPs, art. 13(5) of the WFD).

The EU has adopted other instruments to identify and deal with droughts and water scarcity such as the internet-based interactive map and the European Drought Observatory and the water exploitation index plus, WEI+. Additionally, there is an important publically available European database called "*European Drought Reference database*" and the "*European Drought Impact Report Inventory*" which provide considerable information about historical drought events in Europe.

Spain is one of the EU Member States with the longest track record in water legislation and hydrological planning. Proof of this is the fact that the 1985 Water Act already introduced the innovative concept of river basin management approach (which would be incorporated 15 years later in the WFD 2000), although all the RBAs were established between 1926 and 1961 [54].

Possibly, the reason for this might be that Spain has historically and periodically suffered the negative consequences from severe droughts and water scarcity episodes. Some of the most notorious ones in terms of impact were produced during the periods: 1941–1945, 1979–1983, 1991–1995 and 2004–2007 [44]. In response to this, Spanish water legislation and hydrological Planning has been historically based on implementing a resilient infrastructure to better manage the irregularity in precipitation in relation to the demand pattern, as well as to deal with the effects of extreme hydrological and climate phenomena (floods and droughts).

As many other European countries, Spain has traditionally managed droughts as a crisis situation only by applying emergency procedures and urgent measures (through the adoption of Emergency Drought Orders or Decrees). However, the experience and lessons learnt after the devastating environmental, social, and economic consequences of the 1991–1995 drought, demonstrated that a paradigm shift towards a drought risk-reduction management approach in Spain was necessary.

The first DMPs were developed by the RBA and approved in 2007. At this time, a common National Drought Indicator had already been established in Spain. Even though the DMPs were not approved until 2007, the 2004–2007 drought was already managed in accordance with those principles established in the DMPs. These proved to be effective strategic management tools which positively contributed to avoid public supply restrictions, reduced and mitigated drought impacts, and highlighted the importance of involving the relevant stakeholders and interested parties (including the general public) in the decision-making processes associated with drought planning [59].

After the experience and lessons learnt during ten years of applying the 2007 DMPs, the latest DMPs were approved in 2018. These set out the framework for a drought risk-reduction management approach. They define relevant droughts and water scarcity indicators and their thresholds, early warning systems, and measures to be applied progressively during each drought phase. Important innovative aspects have been integrated such as a clear differentiation between drought events and water scarcity episodes in terms of different conceptual definition, diagnosis and indicator systems, as well as measures to deal individually with each phenomenon.

A common global indicator system has been set out across all the river basins, which allows comparable diagnosis and results among all the different river sub-basins in Spain. This means that if a similar (drought or water scarcity) indicator value is found in two different sub-basins, the (drought or water scarcity) situation is expected to be similar. Therefore, actions and measures to be taken are expected to be of the same type and nature. This highlights that there have been significant strides made by all RBAs in Spain towards the harmonization of technical procedures across all the basins. This shows also that there has been an effective intergovernmental coordination between all the organizations and processes involved at the political, technical, and institutional levels.

Based on the review carried out, it can be concluded that it is necessary to build further knowledge in the following areas:

- phenomenon of drought (spatial and temporal propagation and interaction, impact of global climate patterns);
- further integration of the drought monitoring tools and drought forecasting models into water planning approaches;
- economic, environmental and social impacts of droughts in different water sectors as well as drought impact forecasting;
- further involvement of all interested parties and the public during the consultation period.

A DMP should be a live and active document able to integrate the most updated knowledge that is relevant, credible, and delivered in a timely manner. The DMP needs also to set out a clear strategy in terms of water use priorities, drought monitoring systems, and measures in each river basin in order to avoid generalist approaches and possible misinterpretation of the DMP that could lead to increase existing and future conflicts.

Author Contributions: Writing—preparation, editing, visualization, finalization, C.H.-G.; supervision, F.D.-R.

Funding: This research received no external funding.

Acknowledgments: The authors thank the reviewers and editor for the constructive comments which have helped to improve the quality of the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

CEDEX	Spanish Centre for Public Works Studies and Experimentation (Centro de Estudios y Experimentación de Obras Públicas)
DGW	Spanish Directorate-General for Water of the MITECO
DMP	Drought Management Plan
EDO	European Drought Observatory
EEA	European Environmental Agency
EU	European Union
IPH	Instruction for Hydrological Planning, (Spain)
MITECO	Spanish Ministry for the Ecological Transition
NHP	National Hydrological Plan (Spain)
RBA	River Basin Authority
RBMP	River Basin Management Plan
RD	Royal Decree (Spain)
RPH	Hydrological Planning Regulation (Spain)
TRLA	Recast Text of the Water Act (Spain)
WEI+	Water Exploitation Index Plus
WFD	Water Framework Directive (European Union)

References

1. Hoegh-Guldberg, O.; Jacob, D.; Taylor, M.; Bindi, M.; Brown, S.; Camilloni, I.; Diedhiou, A.; Djalante, R.; Ebi, K.; Engelbrecht, F.; et al. Impacts of 1.5 °C Global Warming on Natural and Human Systems. In *Global Warming of 1.5 °C*; An IPCC Special Report on the Impacts of Global Warming of 1.5 °C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty; Intergovernmental Panel on Climate Change (IPPC): Geneva, Switzerland, 2018.
2. Masson-Delmotte, V.; Zhai, P.; Pörtner, H.-O.; Roberts, D.; Skea, J.; Shukla, P.R.; Pirani, A.; Moufouma-Okia, W.; Péan, C.; Pidcock, R.; et al. IPCC, 2018: Summary for Policymakers. In *Global Warming of 1.5 °C*; An IPCC Special Report on the Impacts of Global Warming of 1.5 °C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global; Intergovernmental Panel on Climate Change (IPPC): Geneva, Switzerland, 2018.
3. Mysiak, J.; Surminski, S.; Thieken, A.; Mechler, R.; Aerts, J. Brief communication: Sendai framework for disaster risk reduction—Success or warning sign for Paris? *Nat. Hazards Earth Syst. Sci.* **2016**, *16*, 2189–2193. [CrossRef]
4. UN 70/1. Transforming Our World: The 2030 Agenda for Sustainable Development Transforming Our World: The 2030 Agenda for Sustainable Development Preamble. Available online: https://docs.google.com/gview?url=http://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf&embedded=true (accessed on 5 February 2019).
5. UN Hyogo Framework for Action (HFA) 2005–2015: Building the Resilience of Nations and Communities to Disasters. 2014. Available online: https://www.unisdr.org/we/coordinate/hfa (accessed on 5 February 2019).
6. UN Sendai Framework for Disaster Risk Reduction 2015–2030—UNISDR. 2015. Available online: https://www.unisdr.org/we/inform/publications/43291 (accessed on 5 February 2019).
7. Schewe, J.; Heinke, J.; Gerten, D.; Haddeland, I.; Arnell, N.W.; Clark, D.B.; Dankers, R.; Eisner, S.; Fekete, B.M.; Colon-Gonzalez, F.J.; et al. Multimodel assessment of water scarcity under climate change. *Proc. Natl. Acad. Sci. USA* **2014**, *111*, 3245–3250. [CrossRef]
8. Rosenzweig, C.; Solecki, W.; Romero-Lankao, P.; Mehrotra, S.; Dhakal, S.; Bowman, T.; Ali Ibrahim, S. *Climate Change and Cities: Second Assessment Report of the Urban Climate Change Research Network*; Cambridge University Press: Cambridge, UK, 2018. [CrossRef]
9. European Commission (EC). *Drought Management Plan Report Including Agricultural, Drought Indicators and Climate Change Aspects Water Scarcity and Droughts Expert Network*; European Commission: Luxembourg, 2007.
10. Seneviratne, S.I.; Wartenburger, R.; Guillod, B.P.; Hirsch, A.L.; Vogel, M.M.; Brovkin, V.; Van Vuuren, D.P.; Schaller, N.; Boysen, L.; Calvin, K.V.; et al. Climate extremes, land-climate feedbacks and land-use forcing at 1.5 °C. *Philo. Trans. R. Soc. A* **2018**, *376*, 20160450. [CrossRef] [PubMed]
11. Schmidt, G.; Benítez, J.J.; Benítez, C. *Working Definitions of Water Scarcity and Drought*; TYPSA Intecsa-Inarsa: Madrid, Spain, 2012.
12. Rossi, G.; Cancelliere, A. Managing drought risk in water supply systems in Europe: A review. *Int. J. Water Resour. Dev.* **2013**, *29*, 272–289. [CrossRef]
13. Estrela, T.; Sancho, T.A. Drought management policies in Spain and the European Union: From traditional emergency actions to Drought Management Plans. *Water Policy* **2016**, *18*, 153–176. [CrossRef]
14. Martin-Carrasco, F.; Garrote, L.; Iglesias, A.; Mediero, L. Diagnosing Causes of Water Scarcity in Complex Water Resources Systems and Identifying Risk Management Actions. *Water Resour. Manag.* **2013**, *27*, 1693–1705. [CrossRef]
15. Wilhite, D.A.; Botterill, L.; Monnik, K. Drought and water crises: Science, technology, and management issues. In *Chapter 6: National Drought Policies: Lessons Learned from Australia, South Africa and the United States*; Taylor & Francis: Boca Raton, FL, USA, 2005; p. 406. ISBN 0824727711. [CrossRef]
16. Palmer, W.C. *Meteorological Drought Research Paper No. 45*; US Weather Bureau: Washington, DC, USA, 1965.
17. Mckee, T.B.; Doesken, N.J.; Kleist, J. *The Relationship of Drought Frequency and Duration to Time Scales*; Eighth Conference on Applied Climatology: Anaheim, CA, USA, 1993.

18. González, J.; Valdés, J.B. New drought frequency index: Definition and comparative performance analysis. *Water Resour. Res.* **2006**, *42*, W11421. [CrossRef]
19. Tsakiris, G.; Pangalou, D.; Vangelis, H. Regional drought assessment based on the Reconnaissance Drought Index (RDI). *Water Resour. Manag.* **2007**, *21*, 821–833. [CrossRef]
20. Tsakiris, G. Drought Risk Assessment and Management. *Water Resour. Manag.* **2017**, *31*, 3083–3095. [CrossRef]
21. Mishra, A.K.; Singh, V.P. A review of drought concepts. *J. Hydrol.* **2010**, *391*, 202–216. [CrossRef]
22. European Commission (EC). Water Scarcity and Drought in the European Union—Environment. 2019. Available online: http://ec.europa.eu/environment/water/quantity/scarcity_en.htm?cookies=disabled (accessed on 15 January 2019).
23. European Environment Agency (EEA). *Water is Life—EEA Signals 2018*; European Environment Agency: Copenhagen, Denmark, 2018; ISBN 9789292139803.
24. European Environment Agency (EEA). *Water Use and Environmental Pressures*; European Environment Agency: Copenhagen, Denmark, 2018.
25. European Environment Agency (EEA). *Climate Change, Impacts and Vulerability in Europe 2016*; An Indicator-Based Report; European Environment Agency: Copenhagen, Denmark, 2016; ISBN 978-92-9213-835-6.
26. European Environment Agency (EEA). *Climate Change Poses Increasingly Severe Risks for Ecosystems, Human Health and the Economy in Europe*; European Environment Agency: Copenhagen, Denmark, 2017.
27. European Parliament and Council of the European Union Directive 2000/60/EEC of the European Union and of the Council of 23 October 2000 establishing a framework for community action in the field of water policy. *Off. J. Eur. Communities* **2000**, *L327/1*, L327.
28. European Environment Agency (EEA). *European Waters Assessment of Status and Pressures 2018*; European Environment Agency: Copenhagen, Denmark, 2018.
29. European Commission (EC). *Addressing the Challenge of Water Scarcity and Droughts in the European Union*; Commission of the European Communities: Brussels, Belgium, 2007.
30. European Commission (EC). *First Follow up Report to the Communication on Water Scarcity and Droughts in the European Union COM (2007) 414 Final 19.12.2008 COM (2008) 875 Final*; Commission of the European Communities: Brussels, Belgium, 2008.
31. European Commission (EC). *Second Follow up Report to the Communication on Water Scarcity and Droughts in the European Union 18.5.2010 COM (2010) 228 Final*; Commission of the European Communities: Brussels, Belgium, 2010.
32. European Commission (EC). *Third Follow up Report to the Communication on Water Scarcity and Droughts in the European Union COM (2007) 414 Final SEC(2011) 338 Final*; Commission of the European Communities: Brussels, Belgium, 2011.
33. European Commission (EC). *Commission Communication on the Report on the Review of the European Water Scarcity and Droughts Policy, Adopted Together with the Blueprint. COM(2012) 672, 14.11.2012*; Commission of the European Communities: Brussels, Belgium, 2012.
34. European Commission (EC). *A Blueprint to Safeguard Europe's Water Resources. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions*; Commission of the European Communities: Brussels, Belgium, 2012.
35. Global Water Partnership Central and Eastern Europe. *Guidelines for Preparation of the Drought Management Plans*. Available online: http://www.droughtmanagement.info/literature/GWPCEE_Guidelines_Preparation_Drought_Management_Plans_2015.pdf (accessed on 5 February 2019).
36. Benítez Sanz, C.; Schmidt, G. *Analysis of the Implementation of Drought Management Plans in the Wider Context of the River Basin Management Plans*; INTECSA-INARSA: Madrid, Spain, 2012.
37. Water UK. Water Resources Long Term Planning. 2016. Available online: https://www.water.org.uk/publication/water-resources-long-term-planning/ (accessed on 18 January 2019).
38. European Commission (EC). EDO—European Drought Observatory. 2019. Available online: http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1000 (accessed on 15 January 2019).
39. European Economic Area (EEA). WEI+—Water Exploitation Index plus. 2019. Available online: https://www.eea.europa.eu/data-and-maps/explore-interactive-maps/water-exploitation-index-for-river-2 (accessed on 15 January 2019).

40. European Drought Centre European Drought Reference database and European Drought Impact Report Inventory. 2013. Available online: http://www.geo.uio.no/edc/droughtdb/index.php (accessed on 5 February 2019).
41. Stahl, K.; Kohn, I.; Blauhut, V.; Urquijo, J.; De Stefano, L.; Acacio, V.; Dias, S.; Stagge, J.H.; Tallaksen, L.M.; Kampragou, E.; et al. Impacts of European drought events: Insights from an international database of text-based reports. *Nat. Hazards Earth Syst. Sci.* **2016**, *16*, 801–819. [CrossRef]
42. Agencia Estatal de Meteorología; Instituto de Meteorologia. *Iberian Climate Atlas Gobierno de España*; Ministerio de Medio Ambiente y Medio Rural y Marino: Madrid, Spain; Instituto de Meteorologia de Portugal: Lisbon, Portugal, 2011.
43. Food and Agriculture Organization (FAO). AQUASTAT—FAO's Information System on Water and Agriculture. 2019. Available online: http://www.fao.org/nr/water/aquastat/countries_regions/index.stm (accessed on 15 January 2019).
44. MAPAMA. Recurrencia y Efectos de las Sequías. 2019. Available online: https://www.mapa.gob.es/es/desarrollo-rural/temas/politica-forestal/rec_ef_sequia_tcm30-152609.pdf (accessed on 15 January 2019).
45. EEA-JRC-WHO. *Impacts of Europe's Changing Climate—2008 Indicator-Based Assessment*; European Environment Agency: Copenhagen, Denmark, 2008; ISBN 92-9167-692-6.
46. Ministry of Environment. Spanish National Climate Change Adaptation Plan. 2008. Available online: https://www.miteco.gob.es/es/cambio-climatico/temas/impactos-vulnerabilidad-y-adaptacion/plan-nacional-adaptacion-cambio-climatico/default.aspx (accessed on 15 January 2019).
47. Spanish Directorate General for Water; Spanish Centre for Hydrographic Studies. Summary of Spanish River Basin Management Plans Second Cycle of the WFD (2015–2021). 2017. Available online: https://www.miteco.gob.es/es/agua/temas/planificacion-hidrologica/sintesispphh2cicloborrador_tcm30-379039.pdf (accessed on 15 January 2019).
48. Tójar-Hurtado, J.-C.; Mena-Rodríguez, E.; Fernández-Jiménez, M.-Á.; Tójar-Hurtado, J.-C.; Mena-Rodríguez, E.; Fernández-Jiménez, M.-Á. Spanish Agriculture and Water: Educational Implications of Water Culture and Consumption from the Farmers' Perspective. *Water* **2017**, *9*, 964. [CrossRef]
49. Eurostat—European Statistics Database. Available online: https://ec.europa.eu/eurostat/web/environment/water/database (accessed on 15 January 2019).
50. Paneque, P.; Lafuente, R.; Vargas, J. Public attitudes toward water management measures and droughts: A study in Southern Spain. *Water* **2018**, *10*, 369. [CrossRef]
51. Garrote, L.; Rodríguez, I.; Estrada, F. Una evaluación de la capacidad de regulación de las cuencas de la España peninsular. *VI Jornadas Españolas de Presas* **1999**, *2*, 645–656.
52. Estrela, T.; Marcuello, C.; Iglesias, A. *Water Resources Problems in Southern Europe*; European Environment Agency: Copenhagen, Denmark, 1996; p. 49.
53. CEDEX. *Evaluación del impacto del Cambio Climático en los recursos hídricos y sequías en España*; Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente: Madrid, Spain, 2017; p. 320.
54. De Stefano, L.; Hernandez-Mora, N. Multi-level interactions in a context of political decentralization and evolving water-policy goals: The case of Spain. *Reg. Environ. Chang.* **2018**, *18*, 1579–1591. [CrossRef]
55. European Commission (EC). *Report on the Implementation of the Water Framework Directive River Basin Management Plans Member State: Spain Accompanying the document Communication 2018, SWD(2015) 56 Final/2 17.7.2018*; Commission of the European Communities: Brussels, Belgium, 2018.
56. Ministry for the Ecological Transition. Informes y Mapas de Seguimiento. 2019. Available online: https://www.miteco.gob.es/es/agua/temas/observatorio-nacional-de-la-sequia/informes-mapas-seguimiento/ (accessed on 17 January 2019).
57. Estrela, T.; Vargas, E. Drought Management Plans in the European Union. The Case of Spain. *Water Resour. Manag.* **2012**, *26*, 1537–1553. [CrossRef]
58. Ministry for the Ecological Transition (MITECO). *Guía para la Elaboración de Planes de Emergencia por Sequía en Sistemas de Abastecimiento Urbano (Borrador)*; Ministry for the Ecological Transition: Madrid, Spain, 2007.
59. Ministry for the Ecological Transition (MITECO). Planes de Gestión de Sequías. 2019. Available online: https://www.miteco.gob.es/es/agua/temas/observatorio-nacional-de-la-sequia/planificacion-gestion-sequias/ (accessed on 15 January 2019).

60. Ministry for the Ecological Transition (MITECO). *Instrucción Técnica para la Elaboración de los Planes Especiales de Sequía y la Definición del Sistema Global de Indicadores de Sequía Prolongada y de Escasez*; Ministry for the Ecological Transition: Madrid, Spain, 2017; pp. 1–20.
61. Guadalquivir River Basin Authority. Guadalquivir River Basin—Drought Management Plan. 2018. Available online: http://www.chguadalquivir.es/plan-de-sequia-vigente#PlanesEspecialesdeSequíavigentes (accessed on 16 January 2019).
62. Ortega-Gomez, T.; Perez-Martin, M.A.; Estrela, T. Improvement of the drought indicators system in the Jucar River Basin, Spain. *Sci. Total Environ.* **2018**, *610*, 276–290. [CrossRef]
63. González-Hidalgo, J.C.; Vicente-Serrano, S.M.; Peña-Angulo, D.; Salinas, C.; Tomas-Burguera, M.; Beguería, S. High-resolution spatio-temporal analyses of drought episodes in the western Mediterranean basin (Spanish mainland, Iberian Peninsula). *Acta Geophys.* **2018**, *66*, 381–392. [CrossRef]
64. Delgado-Ramos, F.; Hervás-Gámez, C. Simple and Low-Cost Procedure for Monthly and Yearly Streamflow Forecasts during the Current Hydrological Year. *Water* **2018**, *10*, 1038. [CrossRef]
65. Tayyab, M.; Ahmad, I.; Sun, N.; Zhou, J.; Dong, X. Application of Integrated Artificial Neural Networks Based on Decomposition Methods to Predict Streamflow at Upper Indus Basin, Pakistan. *Atmosphere* **2018**, *9*, 494. [CrossRef]