BOTÍN FOUNDATION / ROSENBERG INTERNATIONAL FORUM

International Workshop on Drought Management in Spain and California: Lessons Learned

LUCIA DE STEFANO
BÁRBARA A. WILLAARTS
HEATHER COOLEY
ALBERTO GARRIDO

FUNDACIÓN
BOTÍN

BOTÍN FOUNDATION / ROSENBERG INTERNATIONAL FORUM

International Workshop on Drought Management in Spain and California: Lessons Learned

LUCIA DE STEFANO

WATER OBSERVATORY, BOTÍN FOUNDATION; UNIVERSIDAD COMPLUTENSE DE MADRID, SPAIN

BÁRBARA A. WILLAARTS

WATER OBSERVATORY, BOTÍN FOUNDATION; UNIVERSIDAD POLITÉCNICA DE MADRID, SPAIN

HEATHER COOLEY

PACIFIC INSTITUTE, WATER AND SUSTAINABILITY PROGRAM, CA, USA

ALBERTO GARRIDO

WATER OBSERVATORY, BOTÍN FOUNDATION; UNIVERSIDAD POLITÉCNICA DE MADRID, SPAIN

Editor
Fundación Botín. 2015

Authors
Water Observatory, Fundación Botín
Lucia De Stefano
Bárbara A. Willaarts
Alberto Garrido Colmenero
Pacific Institute
Heather Cooley

ISBN
978-84-15469-52-0

1. INTRODUCTION

In January 2015 the Rosenberg Forum and the Botín Foundation gathered scientists and water practitioners from California and Spain to discuss drought management in their regions and to share the lessons that can be learned from droughts.[1] The present document summarizes the key messages emerging from the discussion held during the workshop around three main axes: a) how to cope with drought in practice; b) how water management has adapted over time to address water scarcity; and c) what lessons can be drawn from the measures Spain and California have been implementing to adapt to and mitigate drought impacts.

2. LIVING AND COPING WITH DROUGHTS

Prolonged droughts occur approximately every decade

California and Spain share common climatic and socioeconomic features. With similar populations, size and latitudes, both regions have a Mediterranean climate with large spatial and temporal variability in precipitation, and are prone to droughts. In fact, both California and Spain face multi-year droughts over large geographical areas nearly every decade. Spain has experienced four major droughts since rainfall records began: 1941-1945; 1979-1983; 1990-1995; and 2005-2008. While no country-wide severe drought has occurred since the end of the 2000s, at present, some of Spain's Mediterranean basins are being hit by drought. California has weathered four droughts in the past four decades: 1976–77; 1987–92; 2007-09; and the current one, which began in 2012, is the worst drought in nearly 120 years of instrumental records. For the fourth year in a row, precipitation is well below average, and dry conditions across the state have been exacerbated by high temperatures. Surface water shortages experienced during 2014 in California have reached almost 8,100 Mm^3, although they have been partly compensated by an annual increase in groundwater pumping of 6,100 Mm^3.

Drought impacts are wide-ranging but uneven

The consequences of droughts are felt either directly or indirectly in all sectors. During the 1991-95 drought, in Spain water restrictions were severe, affecting up to eight million Spaniards according to official estimates. This prompted the water authorities and utility companies to invest in increasing the resilience of domestic supply, especially in cities and tourist areas along the Mediterranean coast. Similarly, in California, most of the large urban areas have so far managed to avoid water shortages during the current drought. This is happened because of investments made following the 1987-92 drought to reduce water demand through conservation and efficiency and diversify the water supply portfolio. The result has been to reduce vulnerabilities in many communities, especially larger urbanized areas. Still, some small rural communities dependent on a single water source and with little interconnectivity to other water systems are facing severe water shortages.

During droughts, the delivery of surface water for irrigation is reduced and those farmers who have no alternative water sources are forced to fallow their fields. Those who can shift to groundwater manage to continue their activities, sometimes obtaining higher profits relative to average years. For instance, during the current drought in California, despite local losses, statewide agricultural sector had record-high crop revenue and employment: in 2014, Californian farmers harvested 9 percent fewer acres than before drought; however, crop revenue peaked in 2013 at $34 billion and, in 2014, declined by only 1.4 percent from the previous year. Statewide agriculture-related jobs also marked a record with 417,000

[1] All presentations can be downloaded from: http://www.fundacionbotin.org/noticia/seminario-internacional-fundacion-botin-rosenberg-international-forum-sobre-gestion-de-la-sequia-y-la-escasez-del-agua-en-california-y-espana-el-proximo-29-de-enero-de-2015-en-madrid.html

people in 2014. This highlights the sector's ability to endure the reduction of available water, largely due to the fact that farmers shifted to intensive groundwater pumping and, to a lesser extent, transferred water, planted higher value crops, and implemented efficiency improvements.

Impacts of low surface-water availability are also felt in the energy sector. In California the reductions in hydropower generation over the period October 2012-October 2014 increased electricity production costs by approximately $1.4 billion dollars. Similarly, in 2005 Spain's national hydropower production suffered a reduction of 36% relative to the average of the five previous years. The cost of compensating the hydropower reduction with fossil fuels amounted to 713 Million €.

Since the start of the current drought in California, wetlands and river ecosystems have experienced record-low flows and poor water quality, which is harming native and non-native fishes, migratory birds and other wildlife. Moreover, also related economic activities such as fishery and aquaculture are also suffering. Similar impacts on aquatic ecosystems have been identified also in Spain during drought. For instance, during the 1991-1995 drought, the Júcar river (eastern Spain) ran dry, mainly because of the intensive groundwater pumping in its headwaters. To avoid this situation, in the 2005-08 drought the Júcar river basin organization activated a program for leasing-out groundwater rights and ensuring a minimum in-stream flow.

3. PAST AND FUTURE CHALLENGES IN WATER RESOURCES MANAGEMENT

Traditional water supply infrastructure has brought major benefits to both regions but new approaches are needed

California and Spain have a long history in managing water resources in response to significant spatial and temporal variability. The prevailing semi-arid climate, combined with their mature economies and continued population growth, has forced both regions to adapt their water management systems in light of limited water resources. Water availability and demand follow an inverse geographical distribution in both regions. Mean annual precipitation in Spain ranges from 2,000 millimeters per year (mm/yr) in some of the more humid northern regions to 300 mm/yr in central regions and the drier southeast. A similar precipitation pattern can be found in California, with an average annual rainfall ranging between 1800 mm/yr in the north to less than 400 mm/yr in the south. Largest urban and agricultural demands in Spain are concentrated along the Mediterranean coast, whereas in California much of the irrigated agriculture is situated in the Central Valley. Also, the great majority of the population in California lives in the southern part and along the coast. While much of the precipitation falls during the winter and early spring, most human water demands occur during the late spring and summer.

Over the last century, large hydraulic infrastructures have been built in both regions in order to address these geographical and temporal imbalances and protect residents from hydrologic extremes events. In Spain, investments in water supply infrastructure throughout the last century have resulted in the construction of more than 1,200 major dams, 20 major seawater desalinization plants, and several inter-basin water transfers of varying capacity and regional significance, transporting an average of 500 Mm^3 of water annually. This intensive development of water resources has allowed the irrigation of 3.5 million hectares, the development of hydropower facilities supplying nearly 10% of the country's electricity demand, and domestic water supply to over 46 million people.

California has also developed a vast and interconnected water system that moves water from North to South and East to West, with over 1,400 dams and a 2800 km-long network of rivers, canals, pipelines and aqueducts. This system is capable of storing half of the State's mean annual precipitation, and moves up to 10,000 Mm^3 of water annually to meet water demands. Such water infrastructure has allowed the irrigation of nearly 3.6 million hectares, provision of drinking water for 38 million people, and generation of roughly 15% of the state's annual electric supply.

Despite the role of building new water supplies to improve water supply reliability in California and Spain, competition over water continues and today both water systems are close to their physical limits. This competition is particularly acute during water shortages like the drought California is now facing or the one Spain suffered in 1993-1995 and more recently in 2005-2008. To compensate for surface water shortages, additional water sources have been developed, particularly groundwater but also non-conventional sources like recycled or desalinated water. In Spain, total water supply today is 76% surface water; 19% groundwater; 3.5% desalinated, and 1.5% recycled. In California, the water supply is 60% surface water; 38% groundwater; and less than 2% recycled or desalinized water.

Intensive water use has brought about ecosystems and water resource degradation

The prevailing supply-oriented approach to water management in both regions has not been able to solve conflicting demands, and it has also left profound scars on California and Spain's rivers and ecosystems. The massive infrastructure developed in the 20th century has modified the natural flow of many streams, drained wetlands, and led to the extinction of many native species and introduction of alien ones. Over-allocation of water resources, river fragmentation and the pollution caused by agriculture, industries and cities have greatly affected the ecology of rivers, streams and wetlands. Intensive groundwater has caused the overdraft of many aquifers in the two regions (e.g., Central Valley in California or southeast of Spain), causing saltwater intrusion and other water quality impacts, land subsidence, lost storage, increased energy costs, and drainage of groundwater-dependent ecosystems, such as wetlands. Today, 50% of the surface water bodies and 42% of the aquifers in Spain are in poor condition, with over extraction and pollution as the main drivers. California's streams and aquifers are also largely degraded for similar reasons, and recent figures highlight that over 71% of native fish species are threatened and 7% have become extinct. Improving groundwater management is therefore key to avoid shifting the burden to others, including future generations.

Institutional frameworks are strong but could be improved

In California, important changes have been introduced over the last two decades to improve water management. Water management in California is highly decentralized despite the role played by state and federal governments in developing much of the state's water system. Local water management authorities manage over 85% of total water resources and involve over a thousand local government agencies, water companies and other organizations. The institutional diversity of local water managers creates the potential for innovation but also limits the scope for effective coordination. Nevertheless, institutional efforts are now being developed to promote greater cooperation among all local water authorities to integrate water management activities at the basin level to effectively address current water challenges as well as environmental and flood protection.

In Spain, the current legal framework for managing water resources and allocation is the Spanish Water Act and the European Union Water Framework Directive (WFD), which was transposed into Spanish Law in 2003. The enforcement of the WFD has meant, at least on paper, a radical shift away from the previous hydraulic approach of managing water resources. The WFD advocates for a change in water policy from large, environmentally destructive projects to more demand-side solutions to address water stress. This strong focus on environmental sustainability, however, is hardly compatible with Spain's long hydraulic tradition and the transition to a new model of water management is slow and at times difficult. From an organizational point of view, water management and allocation in Spain is arranged in a multi-level structure largely controlled by the central government in cooperation with water users. The majority of water resources are managed at the basin scale, through river basin management plans that are key instruments for water allocation among users. Since the 2000s, Spain is experiencing a progressive decentralization of water management, with regional governments claiming greater control over water resources flowing through their territories. These centripetal tensions challenge the institutional *status quo* and are creating some instability within the traditional water institutions.

California's and Spain's water management approaches share strengths and weaknesses resulting from their past and present pathways of development

Spain and California water management share some strong points. First, the hydraulic era has provided them with a sophisticated infrastructure capable of delivering water to distant urban and agricultural areas and to successfully protect residents from frequent floods. Second, the two regions are now progressively decoupling economic growth from the use of water, increasing their resilience to water scarcity problems. And third, the sizable proportion of agricultural water still allocated to low-value crops provides an opportunity for reallocating water more efficiently and avoid important economic losses. This reallocation, however, so far has rarely materialized, as it has complex legal implications, can face cultural resistance and can have significant social and environmental consequences. In California, the large share of water now used for landscape irrigation in urban areas also indicates significant opportunity to reduce water use.

At the same time, both regions share some weaknesses. First, their prevailing water management paradigm does not match the current socio-economic and environmental challenges and there is a need to move from supply- to demand-driven approaches. Second, their water infrastructure is aging, which could shortly impede conveying water services securely, particularly in urban areas. And, finally, groundwater overdraft, water quality deterioration and ecosystem degradation are compelling and still unsolved problems despite past and present efforts for reversing negative trends.

4. SHARING EXPERIENCES IN MANAGING DROUGHTS

MONITORING, MEASURING AND PLANNING

Every drought is unique and having a drought monitoring system is crucial for mapping its spatial extent and intensity over time

In Spain the Ministry for Agriculture, Food and the Environment (MAGRAMA) manages a country-wide drought monitoring system that issues monthly bulletins on the severity of the drought in each water management unit ("*Sistema de Explotación*"). The monitoring system combines hydrological variables to classify the drought situation as "normal", "pre-alert", "alert" and "emergency", and each drought alert level is associated with specific management actions detailed in the drought management plan for each basin. For instance, when a pre-alert level is reached, the river basin authority can encourage farmers to revise their cropping plans taking into account the available resources; on in an alert situation, the river water authority can establish mandatory restrictions in surface water use both for irrigation and urban supply.

In the United States, the US Drought Monitor issues weekly updates of drought severity and is managed by a partnership between the National Drought Mitigation Center at the University of Nebraska-Lincoln, the United States Department of Agriculture, and the National Oceanic and Atmospheric Administration. The drought severity index includes several hydrological indicators and expert opinion, and classifies the situation as "abnormally dry", "moderate drought", "severe drought", "extreme drought", and "exceptional drought". While it is not used as a reference to activate specific drought management measures, it is a powerful tool for increasing awareness about the spatial extent and severity of drought.

Plans are critical even if they are not followed in full when drought sets in, as they force us to think ahead and prepare for uncertainty

Developing drought preparedness and mitigation plans are one of the pillars of a risk-management approach to drought, as they create a framework for action during emergency. These plans provide tools to inform decision making, define tasks and responsibilities for all drought management, and identify a host of mitigation and response actions. However, since every drought is unique and its evolution cannot be foreseen with certainty, government and agencies have to deploy some ad-hoc mechanisms to respond to dynamic and evolving conditions. Preparedness plans or protocols developed during wet or average-rainfall periods help to create a framework for action, and ad-hoc measures become an expression of the need to face unexpected challenges. Since 2007 the main Spanish river basins have developed drought management plans that guide the actions of the river basin organization during dry spells. Similarly, water suppliers of towns having more than 20,000 inhabitants are required to prepare Drought Contingency Plans. The effectiveness of these plans, however, has still to be tested during a severe and prolonged drought, which has not yet occurred since 2007.

Hydrological modeling informed by stakeholders is key to define viable drought response and mitigation strategies

As opposed to floods, when a drought sets in, it is impossible to predict how long it will last and how severe the precipitation deficit will be. Moreover, the severity of its consequences results not only from actions taken to manage drought, but also from the decisions taken before it sets in or when it is in its initial stages. Water management models produce scenarios of possible evolution of drought that take into account the effect of specific measures implemented to manage water shortage. These models provide estimates of potential impacts that undoubtely have a certain degree of uncertainty. The contribution of water users and stakeholders in providing input to the model and participating in the discussion of its results is crucial, as it permits the inclusion of local knowledge and increases the acceptance of management decisions based on the models. This requires transparency about the criteria used to make decisions and the costs and benefits of investments and management decisions. An example of such models is the one used in the Júcar River Basin, in eastern Spain, where the river basin authority during the 2005-08 drought used an hydrological model to predict the vulnerability of the different components of the water system depending on what management options were to be implemented. The different scenarios were discussed with key stakeholders in the basin in monthly meetings, in order to get their input and increase the acceptance of their resulting management decisions.

There is a clear need to keep working on improving the quantity and quality of water-related data

In California the current drought has shown that the existing water-related data are not sufficient, and improving them should be a policy priority. During both wet and dry times there should be a comprehensive, up-to-date and public water-use data collection, including groundwater pumping, surface water extraction, water rights, stream flows, water usage, water rates, etc. This is the only way to effectively inform actions to address actual water needs.

IMPLEMENTING A WATER PORTFOLIO

Groundwater acts as a buffer during droughts although mismanagement jeopardizes its strategic role

Groundwater is a strategic resource during droughts. In California, on an average year, groundwater accounts for about 38-40% of human uses, while this percentage rises to 60% or even 70% during droughts. In Spain, on average groundwater meets about one third of the overall water demands. During droughts, aquifers are used to ensure water supply for both cities and irrigated agriculture.

In some areas, surface and groundwater are managed conjunctively and, once the drought is over, the water table is allowed to recover from intensive pumping. In other areas, however, the buffering capacity of groundwater is jeopardized by chronic overdraft. For instance, in Spain, over 42% of the groundwater bodies are in poor condition according to EU legislation. In California, the State Department of Water Resources estimates groundwater overdraft to be 1.2 billion to 2.5 billion cubic meters per year. While the ongoing drought created the momentum for passing the Sustainable Groundwater Management Act (SGMA), more rational and sustainable use of California's groundwater resources is still decades away. The Act calls for management plans, state intervention if local plans are inadequate, and the establishment of groundwater sustainability agencies with authority to allocate groundwater within their boundaries. While SGMA is an important step in the right direction, its effectiveness is not yet known.

In Spain, groundwater is regulated by the 1985 Water Act and its subsequent amendments. Its enforcement has run into several pitfalls, e.g., related to the registration and monitoring of groundwater rights, suggesting that a command-and-control approach alone may not be sufficient to manage groundwater. This is especially true in in arid and semiarid regions, where economic benefits from groundwater uses can be high and can compensate for the risk of being sanctioned for unauthorized abstraction. Over time, water users have begun to organize themselves, mainly forced by the negative implications of overdraft and poor quality for their economic activities. This organization of water users, combined with higher water use efficiency and the diversification of water sources (e.g., reclaimed water, desalination, surface water), is contributing to slow down the pace of aquifer degradation, although it does not provide a durable solution to unsustainable groundwater use.

It is important to fully implement the potential for water conservation in both domestic uses and irrigated agriculture

Over the last fifteen years, total urban water use in Spain and California kept roughly constant as urban population increased. In California, there is a large potential for water saving in domestic water uses, as landscape irrigation accounts for about half of domestic consumption, and its reduction is less harmful for the economy compared to reductions in agriculture. At present, in Californian urban areas, drought is triggering increased investments in water efficiency measures, including lawn-to-garden conversion programs, and in raising awareness about the need for shifting toward a more sustainable model.

In Spain, most of the water saving potential is in irrigated agriculture, as its urban structure is much more compact and less water consuming than in California (140 versus 630 liters per capita per day). California also shows great potential to save agricultural water beyond the savings that can be achieved from reducing urban water use. Since 2002 the Spanish government has supported the modernization of irrigation systems with more than 7,000 M€, to generate planned water savings in the order of 3,100 hm^3. Also in California there have been important efforts to improve efficiency of water use in the agricultural sector. However, in both regions, empirical studies evaluating the impact of modernization programs have questioned their benefits in terms of net reduction of water consumption. Thus, while the water efficiency improvements for agriculture have clear benefits (e.g., reduced chemical and energy costs, water quality improvements, greater instream flows, reduced vulnerability to water supply constraints, and higher farm income), all of the water saved may not be available to reallocate to other uses.

Low value irrigated agriculture can buffer water shortages during droughts by offering opportunities for reallocation

Irrigated agriculture accounts for nearly 80% of the total water demand in California and Spain, although its contribution to employment (3-5%) and GDP (1-2%) is limited in both cases. Today over 60% of the agricultural water in Spain and over 65% in California is used to produce less than 15% of the total crop revenues. While these figures include crop rotations (i.e. the alternation of high- and low-value crops on the same plot for agronomic reasons) and the use of low-value crops for high-value livestock, they also pinpoint existing opportunities to manage actual demand more efficiently e.g. reallocation to water uses that are economically more productive. However, the high revenues obtained from specialty crops is promoting a shift towards perennial crops in California and to a lesser extend in Spain, which could reduce the flexibility of the agricultural sector to fallow crops during droughts, eventually increasing the costs of agricultural water shortages.

Globalization of food markets provides opportunities to save water resources and increase productivity of agricultural water

During the last two decades, California and Spain have become very important food baskets. Spain supplies about 25% of EU annual fresh fruit production and over 10% of its fresh vegetables, while California supplies nearly 50% of US demand of fruits, nuts and vegetables, and has growing presence in international food markets. The favorable climate and the increasing global food demand are likely to foster growth for these high-value crops in both regions. Spain is currently a net exporter of high value crops and a net importer of low-value crops like cereals and oilseeds. Likewise, California has been replacing low-value field crops with higher value fruits and nuts. From a water management perspective, this trade balance translates into higher economic water productivity of water, since the volume of water embedded in the imported cereals and oilseeds is four times that one required to produce high value crops. During droughts, importing high water demanding products becomes particularly advantageous since it allows the release of local scarce resources that would otherwise be needed to produce those crops.

Water trading can contribute to improve the economic productivity of water during droughts, by transparency about prices and trade volumes is needed

In California, the 1987-1992 drought prompted interest and experimenting with water markets, including the shift from leasing (annual contracts) to permanent purchases. The flow of water moved from agricultural sellers to serve other farms, cities, and the environment. In addition to surface water trading, California has established water ‘banks’ that in some cases involve groundwater storage and recovery. Despite growing activity, trading activity remains constrained by regulatory barriers and limited information on historic water use, third party impacts, and reluctance by some farmers and irrigation districts to participate.

In Spain, water trade was introduced by the 1999 reform of the Water Act but was barely operative until the 2005-2008 drought, when the central government authorized inter-basins transactions to bring water to some regions of the Mediterranean coast. Although traded volumes represented less than 1% of all annual consumptive uses, drought contributed to open the door to permanent inter-basin water markets, which currently are allowed under the Water Act only in very special circumstances, requiring to be authorized by the Government. In both California and Spain, comprehensive information on the total volumes of water traded, the value of those trades, the conditions of the water trading contracts, the contracting parties, or the socio-economic or environmental impacts of the transactions is still dispersed and incomplete.

Desalination is an option for securing water during drought, but its economic viability is questionable

Producing freshwater from seawater is a solution that in Spain was boosted by the AGUA Program, approved in 2004, which foresaw the construction of 20 seawater desalinization plants with an overall capacity of over 676 hm^3 annually. Since then, desalination plants have contributed to address water supply and water quality problems in several cities in the islands and along the Mediterranean coast, where both high-value crops and tourism is are important and demanding water users. In several areas, however, desalination plants are used only during droughts, leaving open the question of who pays for their maintenance and for their amortization during the wet or average years. Information about the current status and operation of several desalinization plants is scarce, public data about the distribution of costs is absent, and so far there has been no comprehensive evaluation of the AGUA Program. This lack of information hampers the debate about the value of desalination to address scarcity during droughts and in a scenario of increased water variability due to climate change.

In California, desalination is being considered by coastal communities as a possible solution to drought. However, California should carefully consider the experience of other countries, including Spain, and ensure that this solution is embraced being well aware that using it as a measure to address temporary water shortages can be politically and socially convenient but has to be paid for also during average or wet years, when desalination plants cost money even if they are not producing any water.

LEARNING FROM DROUGHT

Both top-down and bottom-up approaches can work: the key is to get the most out of each management level

During the current drought in California, mitigation and response actions have been implemented at several administrative levels, from local to federal ones. Local governments are instrumental in managing drought on the ground and prove to have great commitment to their constituency. Federal and state agencies have a prominent role in drought management especially through the elaboration of legislation to support drought management, the provision of funds for relief programs, and the elaboration of studies to inform decision making. In Spain, even if actions to manage drought are taken at all levels - irrigation communities, small and large urban supply providers - the river basin authorities, which mostly depend on the national government, play a pivotal role, as they are in charge of allocating and distributing water among water users and of applying the drought management provision established by the Spanish Water Act. No matter what the approach is – bottom up or top down – in both California and Spain drought acts as a catalyst for cooperation at all levels and across levels, as all the parties acknowledge the need to join efforts when facing a severe drought.

Droughts provide an opportunity to understand how the future may look like and get ready for it

For both regions, short-term water scarcity during droughts poses challenges that can become chronic due to sustained population and economic growth and projected climate change. Indeed, their water systems are approaching their physical limits and have little room to accommodate new uses (including environmental needs) or projected changes in rainfall and temperature patterns without significant changes in water use and management. Thus, droughts represent an opportunity to build more resilient societies by critically revisiting current water uses and management in light of a drier future.

NOTE: Data presented in this summary was extracted from the presentations of the participants in the workshop. Moreover, the following sources were consulted while drafting this document:

COOLEY H., DONNELLY K., PHURISAMBAN R., SUBRAMANIAN M. (2015). Impacts of California's ongoing drought: Agriculture. Pacific Institute Report, 25 pp. Available from: http://pacinst.org/wp-content/uploads/sites/21/2015/08/ImpactsOnCaliforniaDrought-Ag.pdf [Last Access: October 2015]

DG ENVIRONMENT, EUROPEAN COMMISSION (2007). Water Scarcity and Droughts. Second Interim report. June 2007. Available from:

http://ec.europa.eu/environment/water/quantity/pdf/comm_droughts/2nd_int_report.pdf
[Last Access: October 2015]

DE STEFANO, L. AND E. LOPEZ-GUNN (2012). Non-authorized Groundwater Use: institutional, social and ethical considerations. Water Policy. Vol 14 No S1 pp 147–160.

ESTEVAN, A. (2008). Desalación, energía y medio ambiente. Fundación Nueva Cultura del Agua. Panel científico técnico de seguimiento de la política de aguas. Convenio Universidad de Sevilla-Ministerio de Medio Ambiente, Sevilla.

GARRIDO, A., REY, D., CALATRAVA, J. (2013). Water trading in Spain. In: De Stefano, L., Llamas, R. (Eds.) Water, agriculture and the environment in Spain: Can we square the circle? CRC Press / Balkema, Taylor & Francis Group, pp: 217-225.

GLEICK, P. H. (2015). Impacts of California's Ongoing Drought: Hydroelectricity Generation. March 2015. Pacific Institute. March 2015. Available online at http://pacinst.org/publication/impacts-of-californias-ongoing-drought-hydroelectricity-generation

HANAK E, LUND J, DINAR A, GRAY B, HOWITT R, MOUNT J, ET AL. (2011). Managing California's water. From conflict to reconciliation. San Francisco, CA: Public Policy Institute of California; 2011.

HANAK, E. AND E. STRYJEWSKI (2012). "California's Water Market, By the Numbers: Update 2012," Public Policy Institute of California, San Francisco, CA. Available from:
http://www.ppic.org/content/pubs/report/R_1112EHR.pdf [Last Access: October 2015]

HERNÁNDEZ-MORA, N., L. DEL MORAL, F. LA ROCA, A. LA CALLE, AND G. SCHMIDT. (2013). "Interbasin water transfers in Spain. Interregional conflicts and governance responses". In: Globalized water: A question of governance, G. Schneider (ed). Springer.

HERNÁNDEZ-MORA, N. AND L. DEL MORAL (2015). Developing markets for water reallocation: Revisiting the experience of Spanish water mercantilización . Geoforum.

MOUNT, J., E. HANAK, J. LUND, R. FRANK, G. GARTREL, B. GRAY, P. MOYLE AND B. "BUZZ" THOMPSON. California's Water: Managing Drought April 2015.

LÓPEZ-GUNN, E., MAYOR, B. AND DUMONT, A. (2012). Implications of the modernization of irrigation systems. In Water, Agriculture and the Environment in Spain: Can We Square the Circle? (Eds. L. DE STEFANO AND M.R. LLAMAS). Leiden, Netherlands: CRC Press/Balkema.

MANN, M.E. AND P.H. GLEICK. (2015). Climate change and California drought in the 21st century. Proceedings of the National Academy of Sciences, 112(13): 3858–3859.
www.pnas.org/cgi/doi/10.1073/pnas.1503667112.

FUNDACIÓN
BOTÍN