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Long-term community responses to droughts in the early modern period: the case study of Terrassa, Spain

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ABSTRACT. New challenges posed by global environmental change have motivated scholars to pay growing attention to historical long-term strategies to deal with climate extremes. We aim to understand long-term trends in community responses to cope with droughts, to explain how many preindustrial societies coevolved with local hydro-climatic dynamics and coped with climate extremes over time. The specific goals of this work are: (1) to analyze how local communities experienced droughts over long periods of time and (2) to document the spectrum of recorded community responses to drought. Our research covers over one century (1605-1710) of responses to drought in the community of Terrassa, Barcelona, Spain. Data were collected through archival research. We reviewed and coded 2076 village council minutes. Our results show that the local community adopted a mixture of symbolic, institutional, and infrastructural responses to drought and that drought-related decisions varied through time. We discuss adaptation strategies on the basis of the distinct physical signals of drought propagation and the role of nonclimatic historical factors, such as warfare and public debt, in shaping responses. We conclude that long-term perspectives on premodern history and comparable empirical studies are fundamental to advance our understanding of past social responses to hydro-climatic extremes.

Key Words: *adaptation; drought; early modern period; environmental history*

INTRODUCTION

Global environmental change cannot be understood or tackled effectively by only looking at its current and future impacts. Understanding past societal experiences to cope with change can offer a more comprehensive perspective by situating current and future hazards within long-term historical processes (Brázdil et al. 2005, Pfister 2010). As McIntosh et al. (2000:3) noted, "by ignoring the great laboratory of millennia of responses to environmental change, we condemn ourselves to reinventing a very complex wheel in the face of one of humanity's greatest challenges."

Histories of climate disasters, hazards, and risks at national and regional scales have a long tradition (e.g., Kempe and Rohr 2003, Alberola and Olcina 2009). However, few studies have used empirical evidence to systematically analyze how past societies coped with change and to examine their resilience or vulnerability to hazards and risk (Helbling 2006, Fraser 2007, Juneja and Mauelshagen 2007, Pfister 2007, Endfield 2008, Gerrard and Petley 2013). This literature has challenged static, passive, or apocalyptic assumptions over past societies, revealing the historically changing ability of societies to effectively deal with environmental change. For example, focusing on medieval societies, Gerrard and Petley (2013) argued that experience in dealing with known threats resulted in resilient communities, which developed sophisticated coping skills and organizational accomplishments. Drawing on examples from colonial Mexico, Endfield (2012) noted that experiencing climate variability and climatic extremes challenged society's resilience, but also resulted in an increase in societies' repertoire of adaptive responses. Using data from peasant communities in southwestern Spain between the seventeenth and twentieth centuries, Gómez-Baggethun et al. (2012) documented a wide range of coping strategies to build resilience and cope with climate extremes.

Following this line of research, we systematically reconstructed past community adaptation practices to recurrent hydro-climatic extremes, specifically droughts, during the early modern period. Our research covers over one century of responses to drought at the community of Terrassa, Barcelona, Spain. We interpreted documented coping strategies by accounting for both the hydro-climatic anomalies that societies aimed to tackle and the historical factors shaping their responses.

Hydro-climatic extremes do not affect all societies equally, not even the same society at different points in time. Indeed, the literature on disasters and risks notes that human communities only perceive and experience certain physical climate anomalies as disasters, thus recognizing the social construction of hazards (Quarantelli 1998). Consequently, as Glantz and Katz (1977) argued, one should ask, "when is a drought a drought?" As many hazards, droughts are context-dependent and therefore properties from both the specific drought (e.g., intensity, duration, spatial coverage) and the system (e.g., local climatology and seasonality, land uses, water demand) need to be considered to determine when the community experiences, and therefore documents, drought (Wilhite 2000). Moreover, three distinct physical phenomena occur when a drought signal propagates through the water cycle: (1) meteorological droughts, i.e., dryness resulting from deficiencies of precipitation; (2) agricultural droughts, i.e., depletion of soil moisture supplies; and (3) hydrological droughts, i.e., shortfalls on surface and subsurface water supply (Wilhite and Glantz 1985, Wilhite 2000). However, although regional and local contexts are starting to be considered to understand past impacts from and responses to droughts (Endfield 2008), the different signals of drought propagation have not been scrutinized when reconstructing adaptation strategies.

We reconstruct short-term responses to droughts as well as long-term water management adjustments ultimately affecting drought

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response. We use the term adaptation in its broad sense as adjustments in ecological, social, and economic systems in response to actual or expected environmental stimuli, their effects, or impacts (Smit et al. 2000). However, our focus is on adaptations by communities. To increase the dialog and cross-fertilization between the study of past and contemporary adaptation processes (Carey 2012), we analyzed historical data using frameworks and terminologies developed to understand and assess adaptation to current climate change (e.g., Adger et al. 2007).

METHODS

We carried out archival research to reconstruct adaptive practices to droughts over the studied period. The chosen methodology suited our purpose because it allowed us to gather a wide range of information on adaptive practices. This information would otherwise be impossible to collect in a period for which a coherent register and database on droughts does not exist.

Case study selection: community and period

We used the following criteria to choose the case study: (1) location, prioritizing areas prone to hydro-climatic variability and droughts; (2) data availability, i.e., accessibility to long-term documentary evidence on adaptive practices; and (3) feasibility in terms of size and bureaucratic complexity. Based on these criteria, the current city of Terrassa in the Barcelona Metropolitan Region, Spain, was selected.

We aimed to analyze long-term data during the premodern period, i.e., before the economic, social, and ecological changes brought about by the secularization of social life and knowledge, industrialization, and urbanization. Because we needed continuous documentary data along a sufficiently long temporal period, we selected the seventeenth century. In the studied community, this century represents a relatively homogenous historical period preceding the beginning of two processes that completely transformed society: the transition from subsistence to market agriculture and the formation of the modern state. Moreover, we took into consideration the institutional change linked to the establishment of the Bourbon Monarchy, which entailed data discontinuity since 1715.

Data collection

Documentary sources reviewed for this research are located in the City Archives of Terrassa, the Parish Archives of Terrassa, and the Diocesan Archives of Barcelona. These sources include minutes from local (e.g., council, brotherhoods, parish) and regional (e.g., Barcelona's diocese) institutions, court proceedings, and family heritage collections. We assessed the archival records with criteria adapted from the literature on historical climatology, including acceptable density of records, optimum reliability, precise dating of events and adaptive responses, homogeneity over time, and accessibility of documentary sources (Barriendos et al. 2003, Rodrigo and Barriendos 2008). Based on these criteria, we focused our analysis on only one of the sources: the Terrassa council minutes, located in the City Archives of Terrassa (hereafter ACVOC-AHT for its Catalan acronym).

Council minutes consist of norms adopted and decisions made by the local government concerning, but not limited to, maintenance and regulation of infrastructure (e.g., fountains, pipelines, streets), regulation of resource use (e.g., pastures, quarries), public budget and taxes, leasing of public services (e.g., bakery, butchers), and regulation of activities in public spaces. The minutes are handwritten in Catalan and structured in five sections: (1) date, (2) constitution (place, type of meeting, members), (3) deliberations and agreements, (4) mayor's approval, and (5) notaries' signatures. The reliability of this primary source derives from the systematic procedure to record decisions, which remained unchanged over the study period, and the finality of the source. Because the minutes were archived in a way that they could be easily consulted by successive local authorities, they were written in detail, compiled in books, and properly filed. Furthermore, they document the diversity of views within the council and also report internal disagreements. However, council members were only male and often connected with the local elite (Hernández 1996); consequently its documentary records may reproduce biased views in terms of gender and social groups.

The council minutes were accessed online and downloaded through the ACVOC-AHT website (http://arxiumunicipal.terrassa.cat/adigital.php). We conducted a systematic compilation of information from seven volumes of the documentary series from 1600 to 1715, including 2076 council minutes. Later, we established the actual analytical period from the first to the last agricultural drought event registered in that period (1605-1710, comprising 1908 council minutes).

Data analysis

To process the minutes, we created a spreadsheet that included: (1) the date of the minutes, (2) a summary of the content of each of the minutes registered by the source (which included between 0 and 13 decisions), and (3) comments on manuscript quality. The meaning of unknown words was consulted in specialized dictionaries on folk lexicon (Alcover-Moll 2002), medieval Catalan (IEC 2015), and eighteenth century Spanish (RAE 2015). Data were analyzed using two techniques: (1) inductive coding based on grounded-theory approach and (2) deductive coding based on content analysis (Bernard 2006).

First, we reviewed the main types of decisions recorded in the minutes and coded them under the following thematic categories: (1) natural resource management, (2) religion and culture, (3) governance and institutions, (4) public services and infrastructures, (5) economic affairs, and (6) health and education. When appropriate, major themes were split into subthemes, e.g., natural resource management was divided into (1.1) water, (1.2) agriculture and food, and (1.3) other resources. This codification was used to facilitate the selection of drought-related decisions and to systematize contextual data.

Second, we selected those decisions that a priori, seemed relevant for understanding adaptation to drought. We identified 122 council meetings deliberating on water management and droughts, from which relevant decisions were transcribed following standard paleographic criteria from the International Commission of Diplomatics (Bautier 1984). Data from selected council meetings were complemented with another primary source (court proceedings) and secondary sources (e.g., regional historiographies). On the basis of this information, we selected only decisions related to adaptation to drought (comprising 110 decisions in 93 council meetings). We coded those decisions using categories from the literature on adaptation to climate change (Smit et al. 1999, Noble et al. 2014) and subcategories derived from institutional studies

(Anderies et al. 2004). We thus divided the selected decisions into three types of responses: (1) symbolic and ritual, (2) institutional, and (3) infrastructural.

To further characterize drought responses, we chose representative examples of the identified decisions and used descriptive statistics to explore variables allowing for quantitative analyses. Documentary sources are cited throughout the text as "ACVOC-AHT, Llibre de Consells de la Universitat de la vila" plus the corresponding file, the temporal period covered by the file, and the date of the minutes. Additionally, we cited unpublished complementary primary sources (i.e., court proceedings) as "ACVOC-AHT, Fons de l'Administració Reial i Senyorial."

CASE STUDY

Historical background

In the seventeenth century, the Iberian Peninsula was governed by different kingdoms. The Principality of Catalonia belonged to the Crown of Aragon (Fig. 1a), governed since the sixteenth century by the same monarch as the Crown of Castile. Catalonia was divided into several administrative territorial jurisdictions ("vegueries"; see Fig. 1b). During the study period, Terrassa was the second most populous village in the vegueria of Barcelona, ranging from 300 to 400 households (Fig. 1c), mostly composed of peasants and wool workers. As a consequence of an administrative split in the village's territory, which occurred in 1562, the village remained small in size, approximately 4 km² (Cardellach et al. 2006). During the seventeenth century, the village was mostly surrounded by traditional Mediterranean subsistence crops, including cereal croplands, olive groves, horticulture, and vineyards, as well as wastelands and forest (Roca 2013). Cash crops expanded during the eighteenth and nineteenth centuries (Badia-Miró and Tello 2014).

Recurrent threats to community livelihoods included droughts, warfare and institutional instability, debt, epidemics, and food crises. Probably among the most evident threats were the successive wars. During the confrontation between the Castilian and French monarchies in the early seventeenth century, Catalan villages such as Terrassa were forced to quarter Castilian troops (Sanabre 1996). In 1640, Catalan peasants revolted against the war-related burdens and aligned with the French. This gave rise to an armed conflict that lasted until 1652 (Elliott 1984), when French troops laid siege to the village of Terrassa (Sanabre 1996). However, insecurities and banditry were prolonged during the postwar period, in the 1650s (Messeguer 2009). The village was also affected by the War of the Spanish Succession (1701-1714) confronting the Bourbon and Habsburg monarchies.

A second important threat in this period was the public debt that accumulated as a consequence of different events including the public purchase of the lord's patrimony (1621), the endorsement of wool workers' private debt after the worsening of Mediterranean trade, the costs of the war, and the levy of taxes by the king with retrospective effect (Hernandez 1996). To pay back debts, the council of Terrassa subscribed agreements with the creditors (in 1659, 1670, and 1702), according to which debt repayment had priority over other public expenditures, and sold the lord's patrimony again (1661).

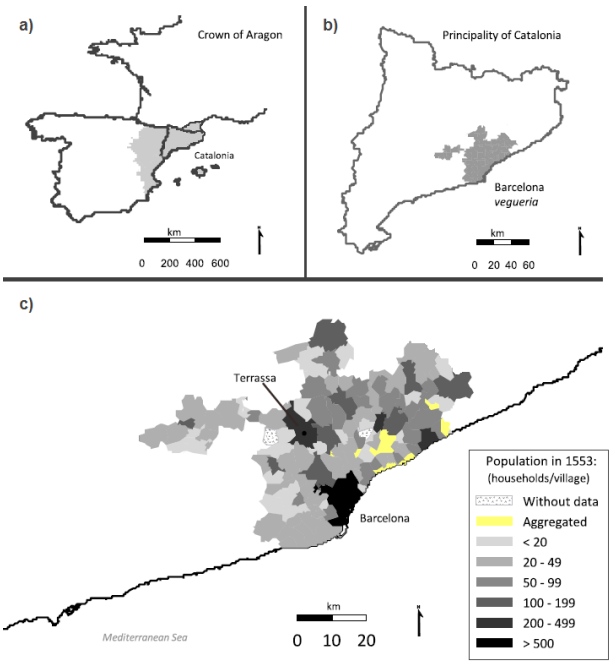


Fig. 1. Location of the studied community: (a) Crown of Aragon highlighted in gray, with the Principality of Catalonia; (b) Principality of Catalonia, with the Barcelona vegueria highlighted in gray; (c) population from the villages belonging to the Barcelona vegueria. Sources: population data are derived from the household survey of 1553 (Iglésies 1981, CED 2015). Note: village boundaries reproduce current municipal limits. Contemporary autonomous villages belonging to other municipalities in 1553 are labeled as "aggregated."

Climatology and drought patterns

The precipitation regime of the Iberian Peninsula is characterized by a marked spatial and temporal variability resulting from a complex relief and diverse atmospheric patterns (Lana and Burgueño 2000). At the study area, climate is mainly conditioned by three factors: low altitude (< 300 m), proximity to the Mediterranean Sea (< 25 km), and complex regional topography including littoral and prelittoral ranges, the Llobregat valley, and the Catalan Central Basin. Mean annual temperature is 14-15 ° C, with fluctuations along the year slightly buffered by marine thermoregulation (Martín-Vide et al. 2008). According to instrumental records from the twentieth century (compiled and homogenized by Prohom and Salvà 2011), mean annual precipitation in Terrassa is 584.1 mm with high variation from year to year (SD = 146.8 mm). The minimum annual precipitation recorded since 1925 was 338.8 mm (coinciding with a period of prolonged drought) and the maximum was 1041.5 mm in 1962 (resulting in catastrophic floods). Terrassa is situated in the transition area between two different precipitation regimes: continental, with drier winters and summers, and littoral, with summer deficits (see classifications in Clavero et al. 1997 and Martín-Vide et al. 2008). Precipitation series show that summers are the driest season, with the lowest monthly rainfall in July (average = 30 mm).

As with precipitation, drought patterns are also conditioned by topography and large-scale atmospheric circulation (Lana and Burgueño 1998) resulting in great spatial variability. Moreover, differences in spatial patterns increase with longer drought time scales (Vicente-Serrano 2006) presumably increasing spatial fragmentation and complexity in hydrological droughts.

Local values of water and the water cycle

During the medieval and until the early modern period, hazards such as earthquakes, floods, or droughts were perceived as part of God's will (Christian 1982). Such belief, mediated by the Catholic doctrine, considered that the ultimate driver of the hazard was people's immoral behavior. To obtain forgiveness for such behavior, devotees practiced vows, penitential processions to holy places, or new devotions (Bossy 1985). These rituals provided expectation of relief and maintained social cohesion during crises (Gómez-Baggethun et al. 2012).

God's will as ultimate explanation not only included hazards (Gerrard and Petley 2013) but also encompassed the whole hydrological cycle (Linton 2010). This sacred vision, integrated in the *Genesis* narrative, implied the belief of an initial creation in which chaotic waters were ordered. Waters were divided between the heaven (rain) and the earth (surface and groundwater).

Water institutions

Under the Catalan feudal regime, many local resources, e.g., woodland or surface waters, and services, e.g., the bread oven or the smithy, belonged to the local lord although villagers had access and withdrawal rights through specific licenses (Giralt et al. 2008). The crisis of the late Middle Ages, linked to the black pest of the fourteenth century, led to changes in the access and management of such common resources. During the sixteenth and seventeenth centuries, a conflictive renegotiation of rights over the commons between lords and village communities took place (Olivares 2000). Consequently, during our study period, water rights were not always clearly defined and were thus a source of conflict (ACVOC-AHT, "Fons de l'Administració Reial i Senyorial," exp. 109/31, 11/5/1616; Ibid, exp. 116/7, 18/2/1620; Ibid, exp. 124/4, 11/12/1624; Ibid, exp. 160/33, 11/8/1646). According to the Catalan Constitutions, all flowing waters and springs belonged to the king, but the villages had the right to use them (Pons 1995). In practice, however, waters were managed through local laws, which often combined elements of such constitutions with customary rules. In Terrassa, water rights were split across different actors, including the king, the lord, the community, brotherhoods, monasteries, and individuals. Rights that were clearly established included those affecting water owned by the community (e.g., fountains with their tunnels and sinks), the lord (e.g., fountain), the king (e.g., water streams and mill ponds), and some individuals (e.g., pools). For instance, in 1441 an agreement was reached between the lord and the community on the main water supply of the village by which one third of water was for the lord and two thirds for the villagers (Galí-Barba 1992). Undefined or overlapping rights often resulted in conflicts around access and distribution of water. For instance, in 1614 a conflict took place over springs and their water between the royal and the village jurisdiction (ACVOC-AHT, "Llibre de Consells de la Universitat de la vila," exp. 3/3, 1592-1616, 29/7/1614). The king claimed he was the only owner of springs and the only one who could lease use rights over spring waters. Based on local customary uses dating back to time immemorial, however, the village council defended their autonomy to lease spring waters to individuals. Although both parties recognized access, withdrawal, management, and exclusion rights for the village, they disagreed on the right of alienation, i.e., the right to sell or lease either one or more of the above rights (as defined by Ostrom and Schlager 1996). Hence, although the village was not legally entitled to alienate water, in practice and according to its customary laws, it was acting as full owner of these water resources.

In sum, our studied community consisted of (1) multiple actors with different rights, from access to management and to alienation (Ostrom and Schlager 1996); (2) a hybrid system with overlapping institutions and jurisdictions, from customary rules to premodern state laws (Roth et al. 2005); and (3) a changing institutional framework due to the constant negotiation of rights between actors across the studied period.

Water infrastructures

In the early modern period, water infrastructures in Catalonia did not differ much from previous medieval technologies. Both were mainly based on locks ("assuts"), which diverted water from rivers into canals; animal-driven water wheels ("sínies"); and underground tunnels ("mines" or "foradades"), which collected and transported groundwater using gravity (Giralt et al. 2008). The latter, slightly modified from the original Persian "qanat" system and probably introduced in Spain by the Arabs, was used in the Mediterranean and other arid regions, both for irrigation and for urban water supply (Weingartner 2012).

In the seventeenth century, the water used by the studied community belonged to the Llobregat and the Besòs river basins. The community council managed the water provided by a medieval set of local collecting facilities, including an underground tunnel built during the fifteenth century, ancient springs, sinks, and several temporary streams that were probably diverted using locks and canals (Galí-Barba 1992; ACVOC-AHT, "Fons de l'Administració Reial i Senyorial," exp. 98/8, 24/7/1604; Ibid, exp. 109/29, 10/5/1616; Ibid, exp. 126/21, 24/3/1626). Beyond the community council, other stakeholders used and managed a diversity of water infrastructures, including temporary streams (which brought the water from the prelittoral range to the village), irrigation canals for gardens and mills, springs, shallow wells, domestic cisterns or ponds to store rainwater, and farmer and industrial ponds (e.g., ACVOC-AHT, "Fons de l'Administració Reial i Senyorial," exp. 101/11, 18/7/1608; Ibid, exp. 112/12, 10/1/1618; Ibid, exp. 153/28, 8/8/1641).

RESULTS

From a total of 1908 council meetings celebrated between 1605 and 1710, only 5% (n = 93) included decisions regarding responses to drought. From these, we identified 110 drought-related decisions adopted by the council, which we classified as symbolic and ritual (26 decisions), institutional (39 decisions), and infrastructural responses (45 decisions; Table 1).

Decisions adopted in council meetings varied notably through time. We identified two periods characterized by different intensity of activity regarding drought-related decisions. The first interval, 1605-1631, covers barely ¼ of the studied period but concentrates 58% of all water-related decisions adopted by the

Table 1. Responses to droughts in the village community of Terrassa (Barcelona), as reported by documentary sources (1605-1710). N refers to the total number of decisions.

Categories Responses	N	Examples from our study period
Symbolic and ritual		
Adjusting local symbols	2	Change of the local patron to St. Eudald (protector against drought)
Community rituals	24[†]	Pilgrimages to the Virgin to plead for rain
Institutional		
Definition of boundaries (resource and users)	2	Allocation of water rights according to profession (e.g., construction workers)
Collective-choice arrangements	2	Agreements between the council and particulars to design public infrastructures
Monitoring	1	Establishing sanctions after monitoring users' behavior
Definition and enforcement of gradual sanctions	12	Gradual sanctions for diverting water courses, using watering troughs, over consumption, or degrading the sewage system
Conflict-resolution mechanisms	15	Tackling and solving conflicts between particulars and the council, between particulars, or with external agents
Recognition of rights	7	Recognition and defense of community rights for irrigation and public infrastructure
Infrastructure		
Improvement or maintenance of old water infrastructure	28	Regular maintenance of drinking fountains, channels, galleries, watering troughs, etc.
Building new collective water infrastructure	9	Searching for new water sources and building up water infrastructures
Sewage works	3	Monitoring and managing latrines
Water quality management	3	Control of pollution sources (e.g., hemp fermentation pools)
Leakage control	2	Identification of leakage causes and arrangement (e.g., waterwheels)

[†] Documented decisions regarding ordinary pilgrimages (n = 46) are not included.

council, most of them concerning institutional and infrastructural responses. During this period, the council took an average of almost three decisions on drought and water issues per year. In 1611 only, as many as eight decisions were adopted, including repairing the drinking fountain, channeling of surplus waters, establishing new sanctions to avert overconsumption, and solving water rights conflicts (ACVOC-AHT, "Llibre de Consells de la Universitat de la vila," exp. 3/3, 1592-1616, 9/2/1611, 11/4/1611, 21/4/1611, 21/5/1611, 6/6/1611, and 9/8/1611). Drought intensified over the next year, when the community and other Catalan villages conducted rituals praying for rain during April and May (ACVOC-AHT, "Llibre de Consells de la Universitat de la vila," exp. 3/3, 1592-1616, 27/4/1612; Sans 1997, Giralt et al. 2008).

The second interval, 1632-1710, was characterized by fewer regulations concerning droughts and water. This interval covers ¾ of the period studied but accounts for only 42% of drought-related decisions, with an annual average of 1.5 decisions. Between 1632 and 1710, we found few infrastructural and institutional responses although we also found a higher proportion of symbolic and ritual responses, especially over the 1640s, 1650s, and 1700s. Figure 2 shows the different types of responses to drought displayed over decades.

Symbolic and ritual responses: pilgrimages and saint patrons

The first category of responses to drought concerns includes those mediated by local religious beliefs (Table 1). Because hazards were perceived as divine punishments for the immoral behavior of people, since the eleventh century, pilgrimages were a common community response to earthquakes, epidemics, and droughts (Cardús 1947). In response to any of those hazards, local people walked to the Monastery of Montserrat, following a 24 km pathway (Fig. 3). The Virgin was asked in rogation ceremonies to intercede with God so that He would forgive the community for the sins committed and cease God's anger. Previous research has documented that people from Terrassa went on a pilgrimage in May 1428 to ask God to end the suffering caused by the aftershocks of an earthquake that occurred several months earlier. Another pilgrimage was reported in September 1578 to stop a hazardous epidemic (Sanjuan 1995).

Fig. 2. Responses to droughts displayed over decades, as reported by documentary sources. Open bars: decisions regarding symbolic responses; shaded bars: decisions regarding institutional responses; solid bars: decisions regarding infrastructural responses. See results section for a description of each category.

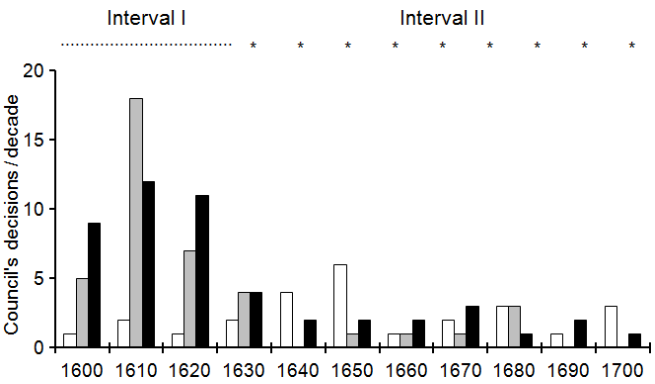
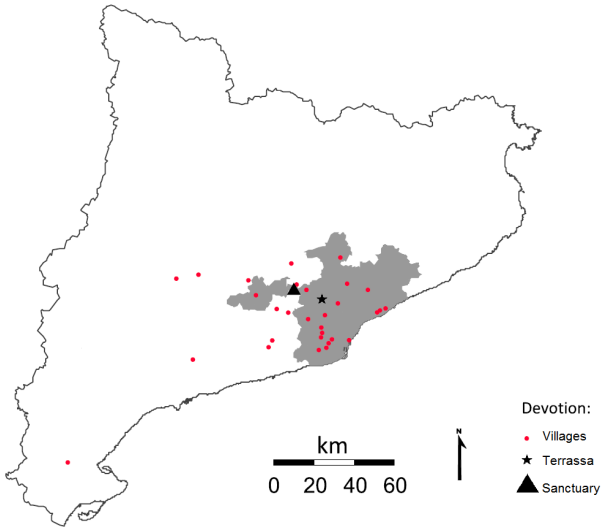


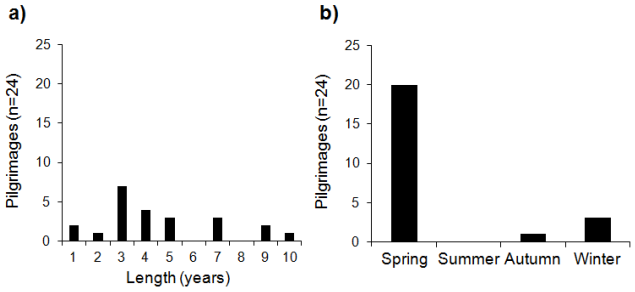
Fig. 3. Devotion to the Virgin of Montserrat and location of the sanctuary. Villages of devotees were located within the Barcelona vegueria (in gray) and in other territories of Catalonia. Sources: devotion is represented by villages performing collective pilgrimages during or before the seventeenth century, as cited by Albareda (2010) and Verdés (2007).



In 1516, the council of Terrassa started to organize periodic pilgrimages to Montserrat, which took place every year in September (Sanjuan 1995). Through those pilgrimages, the village community ratified its commitment and devotion to the Virgin of Montserrat, worshiped by many villages and cities since medieval times within the Barcelona vegueria and other Catalan territories (Fig. 3). In addition to those annual pilgrimages, in the years 1605-1710, we recorded 24 extraordinary pilgrimages to Montserrat, all of them motivated by droughts. That is, when a severe drought occurred, people organized an ad hoc pilgrimage. Pilgrims' rogations to the Virgin asked for water or rain, good crops, and solutions to problems such as soil dryness, sterile and dry weather, water shortage, and crop dryness. We documented rain pilgrimages occurring during war years, but in such instances devotees did not go to Montserrat, but to nearby hermitages (ACVOC-AHT, "Llibre de Consells de la Universitat de la vila," exp. 6/1, 1645-1657, 25/4/1651, and 2/5/1654).

The periodicity and seasonality of extraordinary pilgrimages is shown in Figure 4. We approached periodicity by calculating the time interval between two consecutive pilgrimages. Extraordinary pilgrimages were organized every 1-10 years with an average periodicity of 4.6 years. The period between pilgrimages was of 3 years in 30% of the cases and of 4 years in 17% of the cases (Fig. 4a), although we also identified differences between the first interval (1605-1631), when the average periodicity was of 6 years, and the second interval, when the average periodicity was of 4 years (see Fig. 2). Out of the 24 pilgrimages analyzed, 20 occurred in spring (especially in April and May), 3 in winter, and 1 in autumn (Fig. 4b). Our findings are, therefore, coherent with the seasonality of rogation series in other Mediterranean areas of the Iberian Peninsula (Domínguez-Castro et al. 2010).

Fig. 4. Periodicity (a) and seasonality (b) of extraordinary pilgrimages. Note: periodicity was calculated as the time interval between two consecutive pilgrimages. Seasonality was based on astronomical seasons in Spain: spring (20th March - 20th June), summer (21st June – 22nd September), autumn (23rd September – 20th December), and winter (21st December – 19th March).



The 24 drought-related pilgrimages identified differed in terms of the number of participants and invested resources. According to the sources, the number of participants typically ranged between 20 and 60 pilgrims and some priests. Representatives of brotherhoods and musicians were seldom reported in the sources. As for material symbols, the crucifix was a central element of the ritual. Candles, torches, and flags were bought when the council's budget allowed it. Aside from the public money, in some pilgrimages the brotherhoods or the villagers themselves contributed to the expenses.

Other symbolic and ritual responses related to droughts also included the adjustment of local symbols, such as the patron saint. In the Roman Catholic tradition, a patron saint is a holy person who protects a certain group of faithful (in our case, the community), interceding, advising, and tutoring them (Cunningham 2005). After the drought of 1659 and during a postwar period, the local council decided to adopt St. Eudald, the protector against bad waters ("males aigües"), as the local patron (ACVOC-AHT, "Llibre de Consells de la Universitat de la vila," exp. 7/1, 1658-1678, 4/5/1659, and 9/5/1659). St. Eudald was probably imported from the village of Ripoll, located about 70 km NE, where he was worshiped since a drought had occurred in the eleventh century (Bonet-Llach 1984).

Institutional responses

The second category of responses to drought includes institutional changes (Table 1), mainly (1) mechanisms for conflict resolution, (2) enforcement of flexible sanctions, and (3) defense of community water rights against larger institutions. These changes stemmed from council decisions or legal actions in the courts. Institutional regulations during our study period varied greatly. We found a high regulatory activity in the first decades, but since then few institutional adjustments were enacted and they were concentrated in the 1630s and the 1680s (see Fig. 2). From the 39 decisions involving institutional responses to drought, 77.5% were established before 1631.

We documented struggles over water rights, which seemed to have occurred independently of droughts. When a drought occurred,

however, conflicts were exacerbated, fostering new ways of dealing with water rights (Table 1, row 7). For instance, conflicts for surplus water in drinking fountains, i.e., the water flowing out after usage, occurred from 1610 to 1626. Since 1613, a village's dyer reclaimed his right to divert surplus water toward his business but the council denied it. Then, during the drought of 1618, the dyer was denied access to any public position, probably to avoid the likelihood that he would grant himself access to this water (ACVOC-AHT, "Llibre de Consells de la Universitat de la vila," exp. 4/1, 1616-1625, 16/6/1618, and 3/11/1618).

The council also enacted sanctions intended to adjust the behavior of villagers in relation to local rules regulating the use of water resources in sinks, fountains, troughs, and irrigation channels (Table 1, row 6). In some cases, sanctions were noneconomic and oriented to solve particular situations, such as preventing excessive aquifer consumption by individual water-lifting devices. In these cases, the sanctions consisted of the prescriptive closure of such devices by the council (ACVOC-AHT, "Llibre de Consells de la Universitat de la vila," exp. 3/3, 1592-1616, 9/5/1607; Ibid, exp. 4/1, 1616-1625, 2/9/1617). In most cases, however, sanctions were economic, with the resulting revenue being typically divided into three parts: one for the accuser or the affected person (e.g., villagers, guilds, council members, or public officers), one for the king's representative, and the third one for the construction of a new church. This system resulted in a distribution of the responsibility for monitoring rule compliance. During some drought crisis, the severity of sanctions increased, and more restrictions were enforced. For example, the typology of vessels to collect water in the public fountain was regulated in 1609, but, during the drought of 1612, new sanctions were enforced to punish the use of big vessels (ACVOC-AHT, "Llibre de Consells de la Universitat de la vila," exp. 3/3, 1592-1616, 28/10/1609, and 27/4/1612). Other institutional adjustments included the defense of community water rights, the redefinition of users' boundaries, or agreements between the villagers and the council to design water infrastructures (Table 1).

The institutional reconfigurations described above were not isolated events but rather constitute a cumulative set of local laws over a time period spanning several centuries (e.g., Cardús 2000). Because the local water resources were governed by a complex institutional system, there were multiple actors and overlapping institutions and jurisdictions. Laws or norms were pulled from this set of local laws when new conflicts or needs emerged.

Infrastructural responses

Decisions regarding water infrastructures included the maintenance of existing water infrastructures and the construction of new ones, complemented with practices related to water quality management, sewage works, and leakage control (Table 1). Most investments on maintenance were aimed at securing a water supply from the public fountain. The councilors assessed the state of the fountains' tunnels and, if convenient, hired professionals to clean them out. In times of high public debt, the villagers themselves were in charge of this task (ACVOC-AHT, "Llibre de Consells de la Universitat de la vila," exp. 4/2, 1626-1635, 10/5/1628; Ibid, exp. 6/1, 1645-1657, 16/9/1651). Maintenance was often instituted by assigning tunnel cleaning to certain public officers. For instance, the maintenance of the public sink was attributed to the herald through specific instructions starting in 1637 (ACVOC-AHT, "Llibre de Consells de la Universitat de la vila," exp. 5/1, 1635-1645, 18/7/1637). The construction of new water infrastructures often followed water shortages. For example, during the drought of 1612, the council gave permission to search for water supplies around already exploited water bodies (ACVOC-AHT, "Llibre de Consells de la Universitat de la vila," exp. 3/3, 1592-1616, 12/7/1612).

As with institutional responses, infrastructural responses followed an irregular pattern (Fig. 2). Two thirds of the actions (67%) were performed during the first interval (1605-1631), with several peaks, especially in 1611 and 1625. The second interval (1631-1710) includes several periods of over a decade without any change in infrastructure. The prioritization of infrastructure maintenance (28 decisions) over the construction of new infrastructure (n=9) is a characteristic feature of ancient regime water systems in Catalonia (Giralt 2008). Yet, during our study period, the proportion of construction over maintenance varied with time. Specifically, search for new water supplies and construction of water infrastructures concentrated mostly between 1607 and 1628, to be only reactivated after 1689 (e.g., ACVOC-AHT, "Llibre de Consells de la Universitat de la vila," exp. 3/3, 1592-1616, 9/5/1607; Ibid, exp. 4/1, 1616-1625, 18/1/1619 and 30/8/1624; Ibid, exp. 8/1, 1678-1715, 19/7/1689).

DISCUSSION

Hydro-climatic factors influencing responses to droughts

In December 1604, bread riots led by poor people, particularly women, took place in the open market of Barcelona, at the time called the "Plaça del blat" (Wheat square; Elliott 1984). A long-lasting drought was affecting many areas of Catalonia. A few weeks later, in January 1605, the Council of Terrassa organized a costly rain pilgrimage to Montserrat. During the following months, the council also agreed to purchase wheat, a decision not taken since 1599, and established new measures to secure water supply during summer (ACVOC-AHT, "Llibre de Consells de la Universitat de la vila," exp. 3/3, 1592-1616, 24/1/1605, 10/2/1605, and 4/8/1605). These responses appear constantly interlinked, but, were winter pilgrimages and summer water supply maintenance driven by similar events? We argue that to understand when communities experienced and perceived a hydro-climatic anomaly as a drought (i.e., hazard), we need to scrutinize the physical properties of drought signals and to situate them in the context in which they occurred. Unfortunately, documentary records provide few evidences to characterize with precision the specific impacts or the intensity, spatial, and temporal scope of each documented drought. In more complex bureaucracies, these properties are more likely to be recorded (e.g., Barriendos and Martín-Vide 1997) allowing the identification of the physical processes by which the accumulated precipitation deficit turned into a drought. Interpretation of historical documents enables us, however, to distinguish between two signals of drought development: agricultural and hydrological droughts.

Agricultural droughts are defined as deficits in soil moisture supplies. Other than from rainfall deficits, such droughts are driven by factors such as land uses, plant water requirements, or soil properties (Wilhite 2000). As with many preindustrial societies, the studied community was highly vulnerable to agricultural droughts, because basic food crops such as cereals were grown without

irrigation. Furthermore, soils in the study area have low water holding capacity (Roca 2013), exacerbating water stress on rain-fed crops. The major documented response to soil moisture droughts was rain pilgrimages, which explicitly asked God for good harvests or to stop soil sterility. With a mean interval of 4.6 years between pilgrimages (Fig. 4a), this strategy was recurrently pursued by the community during the study period. Interestingly, no pilgrimages were held in the summer when scarce precipitation lead to maximum deficits in soil moisture (see Fig. 4b). A possible explanation is that, because crops were adapted to recurrent summer deficits, the impact of low rain was probably lower during summer. In fact, recent studies in Spain contrasting proxies for agricultural droughts (rogation series) with instrumental data (precipitation series) confirm that the threshold of precipitation deficit that typically led to celebrate a rogation was much lower in spring than in any other season (Domínguez-Castro et al. 2012). In other words, drought related to soil water supplies was experienced and collectively tackled when water deficit affected rain-fed crops, especially the harvest of basic food crops.

Impacts in streamflow and groundwater manifest with delay from precipitation deficiencies and are reported later than agricultural droughts (Wilhite 2000). Hydrological droughts depend on the characteristics of the water basin, such as geology, topography, soil properties and vegetation, the precedent meteorological conditions, and the strategies of water management (Vicente-Serrano and López-Moreno 2005). These drought-controlling mechanisms can delay, attenuate, lengthen, and pool the propagation of rainfall anomalies into the hydrological system (Van Lanen et al. 2013). Because of the lack of perennial streams, the studied community relied on semiconfined superficial aquifers and temporary streams. Aggravated by water scarcity, hydrological droughts were documented locally as the drying up of fountains or the lowering of groundwater levels. They were especially tackled by the community when they had an impact on the village groundwater supplies. Human management was perceived as an important determinant, probably because anomalies in these water bodies appeared decoupled from climate variability. For instance, some responses to the drying up of fountains were designed after assessing the potential anthropogenic causes of the water shortage (ACVOC-AHT, "Llibre de Consells de la Universitat de la vila," exp. 3/3, 1592-1616, 4/8/1605, and 1/3/1607). As explained above, local waters were managed by institutional practices and through collective infrastructures gradually constructed since the medieval period. Community responses to hydrological droughts had to be integrated with these strategies of long-term water management.

Considering the cumulative nature of droughts and its propagation through the water cycle (McKee et al. 1993), together with key contextual factors such as local land uses and water bodies, helps to understand the complexity of the events that generated community actions in relation to droughts. As noted by Zaidman et al. (2002), this complexity has fostered an interpretation of droughts as a whole phenomenon, rather than considering the distinct interrelated elements that constitute them. The recent interest in reconstructing not only climate patterns, but also the social responses to climatic stressors, has powerfully reintroduced the constructivist approach to disasters (Quarantelli 1998, Hoffman and Oliver-Smith 2002). However, we contend that although taking into account the ideological, cultural, and social context in which hazards are constructed and perceived is important, attention should not be diverged from the physical environment in which they occur.

Historical factors influencing responses to droughts

As today, in premodern times, droughts were not always the sole reason driving adaptive responses. Recognizing and interpreting the particular historical context in which adaptive responses occur brings to light the way in which other factors play an equal or secondary role. In our case study, warfare and public debt might have influenced community responses to drought. Although we consider both factors at the local scale, they were not particular to our case study, but threatened many communities during the early modern period (Olivares 2000).

Successive wars and subsequent institutional instability affected community responses in different ways. First, insecurity associated with wars could lead to prioritize responses that strengthened social cohesion, possibly explaining the higher proportion of symbolic and ritual measures adopted in the 1640s and 1650s, compared to other decades (Fig. 2). Second, the coexistence of two authorities during war conflicts, namely the French and the Spanish viceroyalties in the 1640s and the 1690s, and the Habsburg and Bourbon monarchies since 1700, probably discouraged the enacting of new water-related institutions by the local council. And third, the mandatory supply to the armies by the village implied high costs in terms of resources and manpower, which probably reduced investments in water infrastructures (Fig. 2).

Some authors have pointed out the interconnection between wars and disasters, but mostly interpreting the first as a precondition of the second, or alternatively the second as a consequence of the first (Schnek 2007). Adamson (2014) highlighted that western colonial India was highly resilient to droughts, but the system was threatened when climatic stress was coupled with warfare. However, this work documented a punctual war, whereas our study period was plagued by successive wars. Given the frequency of both wars and droughts, the community might have accumulated experience in dealing with droughts coupled with warfare. For instance, during the ending of the Reapers' War, and a few months before the siege of the village, the council organized a rain pilgrimage, ordered water infrastructures fixed, and established new sanctions after checking out the state of drying fountains (ACVOC-AHT, "Llibre de Consells de la Universitat de la vila," exp. 6/1, 1645-1657, 16/4/1651, 25/4/1651, 16/9/1651, and 31/10/1651). Hence, although responses to drought by council were altered by such military conflicts, they continued over periods of warfare.

The mounting public debt was another factor conditioning responses to drought. Public debt limited the range of response options to those involving low costs, possibly also discouraging infrastructural responses since the 1630s (Fig. 2). Debt-induced changes in the ownership of the lord's patrimony, including the drinking fountains, conditioned both infrastructure and institutional responses in the 1680s, because the new lord claimed water rights over them and designed water infrastructures unilaterally (e.g., ACVOC-AHT, "Llibre de Consells de la Universitat de la vila," exp. 8/1, 1678-1715, 29/8/1683). Recent studies illuminate the way in which public debt influences the

water cycle. For instance, March and Saurí (2013) explain how institutional changes in water management, and specifically, recent water privatization in Metropolitan Barcelona, are justified by a large debt resulting from the combination of costly environmental European directives and austerity policies enforced during the economic crisis started in 2008. Debt has also been reported to affect vulnerability to drought at the household level. Liverman (1990), for instance, stated that low-income Mexican farmers indebted from technological investments are more vulnerable than farmers using traditional techniques. However, we still lack a general understanding on how debt directly or indirectly affects collective drought responses both in the contemporary and premodern contexts.

CONCLUSION

We presented a systematic analysis of long-term responses to drought by a premodern community. Our case study illustrated the wide range of strategies implemented and developed to cope with droughts at the community level. Symbolic and ritual responses, institutional reconfigurations, and changes in water infrastructures were put in place by the village council. We suggested that this repertoire of practices recorded during the early modern period had much in common with the accumulated and slowly changing institutional settings, water technologies, and religious practices of the medieval period.

This long-term approach enabled us to explore the ways in which responses changed over the study period (1605-1710). We discussed how the changes in temporality and in the type of responses were influenced by hydro-climatic and nonclimatic factors. Through this approach, we provided an attempt to interpret past coping strategies from a socio-environmental standpoint. First, we took into account how signals of drought propagation manifested in the local environment and were tackled separately by the community. Although limited by partial records of droughts, documentary sources enabled us to distinguish between responses dealing with agricultural droughts from those dealing with hydrological droughts. Second, we examined the combined role of drought and major historical processes threatening many communities in the early modern period. We noted that although the community might have accumulated experience in dealing with droughts coupled with warfare, public debt was probably a key factor limiting the range of response options.

More empirical cases are needed to compare social responses to hazards, historical turning points, and potential shared drivers (Helbling 2006, Carey 2012). For this endeavor, recovering and reviewing local documentary records seems a suitable option. However, our study suggests some of the challenges of undertaking such a task. Only 5% of the council meetings held during the study period recorded decisions regarding responses to drought and in some cases no decisions were made during an entire decade. In other words, even if droughts are a recurrent threat, both dispersed records and short-term analyses can favor faulty interpretations of social passivity or isolated responses. The research effort of long-term archival studies thus offers the possibility to provide coherency and linkages among past coping strategies and to explain them within their changing historical context.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/8232

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