https://doi.org/10.5194/cp-2020-33
Preprint. Discussion started: 16 April 2020

Climate of the Past Discussions
Open Access
EGU

Human response to severe drought in Early Modern Catalonia. The case of Barcelona, Western Mediterranean (1620-1650)

Santiago Gorostiza[1,2], Maria Antònia Martí Escayol[3], Mariano Barriendos[4]

[1] Centre d'Histoire de Sciences Po, Paris, 75006, France

[2] Institut de Ciència i Tecnologia Ambientals, ICTA-UAB, Barcelona, 08193, Spain

[3] Department of Modern and Contemporary History, Autonomous University of Barcelona, 08193, Spain

[4] Department of History and Archaeology, University of Barcelona, 08001, Spain

Correspondence to: Santiago Gorostiza (santiago.gorostiza@sciencespo.fr)

ABSTRACT: Combining historical climatology and environmental history, this article examines the diverse range of strategies deployed by the city government of Barcelona to confront the recurrent drought episodes experienced between 1626 and 1650. First, our reconstruction of drought episodes for the period 1525-1821, based on *pro pluvia* rogations as documentary proxy data, identifies the years 1625-1635 and 1640-1650 as the most significative drought events of the period 1521-1825 (highest Drought Frequency Weighted Index of the series). Throughout the article, we focus on human responses to drought and discuss how water scarcity was perceived and confronted by Barcelona city authorities. We present the ambitious water supply projects launched by the city government, together with the construction of windmills as an alternative to watermills in order to mill grain, as attempts to cope with diminishing water flows. The context was aggravated by political instability, related first to the tensions between the centralising efforts of the Spanish King Philip IV and later to the impact of the Thirty Years' War in the border region between the French and Spanish Crowns (1635-1659). Finally, we interpret the efforts of the city government to codify and appropriate knowledge about urban water supply as an attempt to systematise historical information on infrastructure to improve institutional capacities to cope with water scarcity in the future. These efforts materialised in the elaboration of the *Llibre de les Fonts de la Ciutat de Barcelona* ("Book of Fountains of the City of Barcelona"), a manual compiling the knowledge of Barcelona's water supply from source to tap, written by the Barcelona water city officer in 1650, after three decades of experience in his post.

https://doi.org/10.5194/cp-2020-33
Preprint. Discussion started: 16 April 2020

Climate of the Past Discussions
Open Access
EGU

1. Introduction

In July 1650, during one of the hardest droughts remembered in Barcelona, Francesc Socies, the city water officer ("mestre de les fonts"), started writing a book that described in great detail the water supply and distribution system of the city: the *Llibre de les Fonts de la Ciutat de Barcelona* ("Book of Fountains of the City of Barcelona"). At the time, Socies had been in his post for over thirty years, overseeing the city's fountains and water supply, and was approaching retirement. He was a crucial actor and a unique witness of the turbulent times that the water supply of the main city of Catalonia was going through, marked by recurrent droughts since the mid-1620s. In 1627 he had taken part in the ambitious – and eventually unsuccessful – project to build a water canal from the Llobregat River to Barcelona. In 1634, he had been excommunicated by the Cathedral's Chapter of Barcelona after cutting its water supply following the orders of the city government – the Consell de Cent. During the 1640s he left no stone unturned to find the origin of the water losses that affected one of the main fountains of the city and worked hard to increase the sources of the urban water supply system. With three decades of experience behind him, he was growing old with no successor in sight. Suffering the impacts of drought almost every year, and well-aware of the precious knowledge that Francesc Socies embodied, the city government approached him with a proposal. They asked the city water officer to write a book compiling all his knowledge about Barcelona's water supply system, from source to tap. This book would perpetually be kept in the city archives, in order to illuminate the work of future water city officers and improve water management. Socies took months to reply, but finally accepted under the condition of receiving a lifetime pension. On November 1650, he delivered what became known as the *Llibre de les Fonts* ("Book of Fountains") (Archival source AS1).

This article focuses on the three decades (1620-1650) leading to the codification of Barcelona water knowledge into the Book of Fountains and examines them from the perspective of historical climatology and environmental history. This period coincides with the years of Francesc Socies as city water officer. Key to the relevance of our case study, a systematic analysis of 165 tree-ring series in the Mediterranean for the last 500 years points to an acute period of drought between 1620 and 1640, an episode that affected the whole Western Mediterranean (Nicault *et al.*, 2008). Our analysis of documentary sources for the city of Barcelona, drawing on *pro pluvia* rogations as proxy data, confirms this assessment. We document how the severe droughts experienced in the city during 1625-1635 and 1640-1650 stand out within the period covered by *pro pluvia* rogations (1521-1825). While the period 1625-1635 had already been identified by research on historical climatology as severely dry in Catalonia (Díaz, 1984; Martín-Vide and Barriendos, 1995; Rodrigo and Barriendos, 2008), in this paper we establish that Barcelona suffered the most significative drought event of the period 1521-1825 during these years (highest Drought Frequency Weighted Index of the series).

Once the local and regional significance of drought during the period of study (1620-1650) has been established with biological proxies from the existing literature and with our documentary data, we move on to examine the different strategies deployed by the city to cope with drought, as well as several conflicts that broke out during this period, related to power struggles around food and water supply. Throughout the article, we combine the detailed account written by Francesc Socies in 1650 with abundant municipal and religious documents from the previous thirty years. Finally, we interpret the efforts of the city government to codify and appropriate water supply knowledge –successfully materialised in the Book of Fountains– as an attempt to systematise historical information

https://doi.org/10.5194/cp-2020-33
Preprint. Discussion started: 16 April 2020

Climate of the Past Discussions
Open Access
EGU

on infrastructure to improve the institutional abilities to cope with water scarcity and manage water resources more efficiently – in other words, to better adapt to drought or other disturbances affecting water supply.

Our research is the first academic analysis of the Book of Fountains, which has been kept in Barcelona city archive since it was delivered in 1650. While the book has been mentioned in the literature about Barcelona's history (Voltes Bou, 1967; Cubeles, 2011), there is no systematic analysis of Francesc Socies work. No modern editions of the Book of Fountains have ever been published, and during our research we have carried out the first complete transcription of the text. This is therefore the first article that presents the Book of Fountains and contextualises its elaboration within the historical climatology of the city of Barcelona (Western Mediterranean). As a manual of urban water supply, the Book of Fountains constitutes a rare documentary source. Although urban water supply was a common problem in the context of pre-modern Europe, we have only identified another book that shares some of its features. It is *Le Livre des Fontaines de Rouen*, written by Jacques Le Lieur between 1524 and 1525 (Sowina, 2016).

In contrast to the development of historical climatology research in Catalonia, little work has been done on the human response to drought beyond acknowledging that climate conditions in the 17th century accentuated the agricultural, social and political crisis (Serra i Puig and Ardit, 2008). The research of Antoni Simon i Tarrés, who highlighted the importance of drought among the complex interaction of factors that led to social unrest in Barcelona and Catalonia during the late 1620s and 1630s stands out among the few publications on the topic (Simon i Tarrés, 1981, 1992). The relevance of the climatic factor in the Spanish context during the 17th century has also been underlined by Geoffrey Parker, who pointed out that during the reign of Philip IV Spain "suffered extreme weather without parallel in other periods, particularly in 1630–2 and 1640–3" (Parker 2013:289) and examined the revolt of Catalonia against the Spanish King (1640-1651) in this context.

However, neither Parker nor Simon i Tarrés explicitly address the human response to climatic disturbances in Catalonia during these years. More recently, Mar Grau-Satorras has used the example of the town of Terrassa (Barcelona region, Catalonia) to examine how local communities combined different strategies to cope with drought, including infrastructural, institutional and symbolic responses which changed throughout time (Grau-Satorras *et al.*, 2016, 2018; Grau-Satorras, 2017). Along these lines, our research focuses on Barcelona as an example of Western Mediterranean urban agglomeration (40,000 citizens). We discuss the elaboration of the Book of Fountains among other adaptation strategies, underlining the relevance and novelty of the attempt of Barcelona government to codify water knowledge in the form of a book as a tool for future water managers.

The article proceeds as follows. In the next section, we provide an overview of droughts during the period 1521-1825. Due to lack of instrumental data, we use a compilation of archival religious and municipal sources about *pro pluvia* rogations (rain rogations) as proxy data for drought (Martín-Vide & Barriendos, 1995; Barriendos, 1996; Barriendos, 1997). Our work demonstrates the comparative significance of the period of study (1620-1650). Following this, in section 3, we draw on municipal sources to narrate the growing difficulties experienced by water supply in Barcelona to face the severe drought episodes that started in 1626-1627. We analyse the proposal of the city government to build a water canal from the river Llobregat under the light of the water scarcity caused by drought. Similarly, we interpret the great expansion of windmills supported by the Consell de Cent

https://doi.org/10.5194/cp-2020-33
Preprint. Discussion started: 16 April 2020

Climate of the Past Discussions
Open Access
EGU

as an alternative for milling grain when there was not enough water in the city's mills' canals. Finally, we introduce the major conflict that confronted the city government with the Cathedral in 1634, leading to the excommunication of the city water officer and the members of the Consell, and relate it to the power struggles about food and water supply.

In section 4, we turn our attention to the efforts that the city government carried out to increase its control of water supply and improve its management. After discussing the difficulties faced by Francesc Socies to prevent water thefts during the 1640s, we focus on the proposal presented by the Consell de Cent to the city water officer. We examine the Book of Fountains as an example of codification of water knowledge of the past to prevent future problems; in other words, both as a book depositary of knowledge and as a tool to improve adaptation to diminishing water flows. Finally, in the conclusions we summarise the relevance of our case study in the context of the 1620-1640 drought in the Western Mediterranean and call for interdisciplinary work that combines climate reconstruction with critical analysis of social responses to extreme climate events.

2. Climatic context

The climatic conditions during the 17th century can be considered as part of the climatic episode known as the Little Ice Age (LIA). Paleoclimatic research has pointed to a higher frequency and severity of cold spells during this episode (Pfister et al., 1996; Pfister et al. 1998; Silvie 2001). More recently it has also identified and analysed a general increase in the irregularity of rainfall patterns, manifested in the emergence of hydrometeorological extreme episodes with great social and environmental impact. At the climatic scale, in the Spanish Mediterranean this increase in the frequency and severity of extreme hydrometeorological events manifests in periods of around 40 years for the case of extraordinary rainfalls leading to floods (Barriendos and Martin-Vide, 1998; Llasat *et al.*, 2005; Barriendos *et al.*, 2019). In the case of extreme drought episodes, the behaviour observed in the frequency of these type of events in the coast of Catalonia allows to identify many recurring events of medium intensity and some of very high intensity for the Catalan cities studied (Barcelona, Girona, Tarragona, and Tortosa, see Figure 1): 1520s, 1540s, 1560s, 1620s (c. 1625-1635), 1750s, 1812-1824.

https://doi.org/10.5194/cp-2020-33
Preprint. Discussion started: 16 April 2020

Climate of the Past Discussions
Open Access
EGU

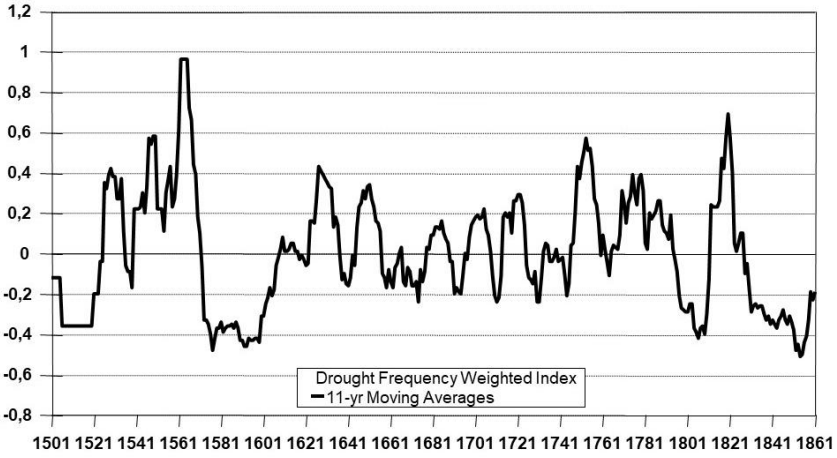

Figure 1. Drought Frequency Weighted Index. Standardised values. 11 years moving averages from 4 locations: Girona, Barcelona, Tarragona and Tortosa. Data adapted from Oliva *et al.*, 2018.

Figure 1 also shows how the drought that characterises the period of study in Catalonia extends during a significantly long period, including a lower intense drought immediately after the 1625-1635 pulse. But in order to better interpret the impact and perception of these drought episodes, it is crucial to set them against the very lack of any similar experience in the previous 50 years. During most of the period 1570-1600 there are no traces of drought episodes in the Catalan coast, and the episodes of the early 1600s were less intense and relatively brief (Figure 1).

If we focus in the case of Barcelona and examine in detail the behaviour of drought drawing on the records of *pro pluvia* rogations, the results show a distribution of frequent droughts between 1521 and 1825, with different degrees of intensity. By using yearly weighted indexes, we can identify the decade of 1560s and 1625-1635 as the two most significative drought events of these three centuries in the city of Barcelona. But the latter stands out for its extreme severity (Figure 2).

https://doi.org/10.5194/cp-2020-33
Preprint. Discussion started: 16 April 2020

Climate of the Past Discussions
Open Access
EGU

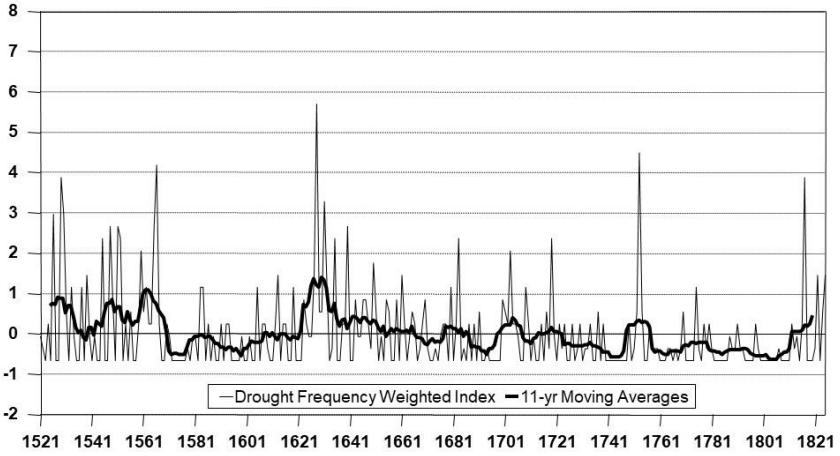

Figure 2. Drought Frequency Weighted Index. Standardised values. City of Barcelona (1521-1825).

In order to improve the characterisation of climatic events in Barcelona, there is a variable that provides useful information to understand how drought was perceived and the responses it generated. In the case of Barcelona, the level 2 of *pro pluvia* rogations involved the public exhibition of a specific relic: the remains of Santa Madrona (Martín-Vide & Barriendos, 1995). The public exhibition of this relic in the high altar of the Cathedral lasted until the authorities established that the drought was over. In this moment, the urn containing the Saint's remains was taken back to the Chapel of Santa Madrona in the near mountain of Montjuïc. This liturgical pattern allows for determining the perception of drought by the Barcelona city authorities at a daily resolution. In other words, it introduces the possibility of analysing the duration of drought episodes as perceived by local authorities. On this base, the development of an index of drought duration shows relevant results (Figure 3). Figure 3 illustrates that the 1620s drought and its successive episodes were perceived as longer than any other registered until the time. While it is difficult to extract more details with these historical records, it is evident that the drought registered had an extraordinary magnitude. However, the long duration of the rain rogations may also be related to the perception of an extreme anomaly by the city authorities, since almost no drought conditions had been experienced in the previous 50 years.

https://doi.org/10.5194/cp-2020-33
Preprint. Discussion started: 16 April 2020

Climate of the Past Discussions
Open Access
EGU

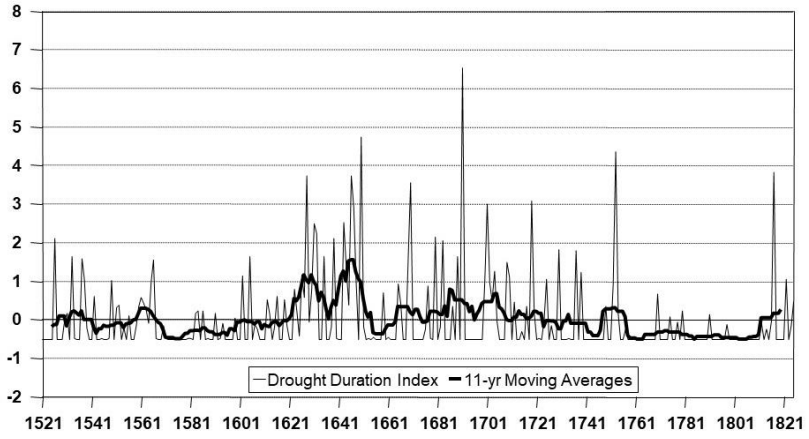

Figure 3. Drought Duration Index. Standardised values. City of Barcelona (1521-1825).

The analysis of drought duration presented in Figure 3 reveals another significant detail. After the severe 1620s drought, there was a less intense episode of drought, but very close in time, around the 1640s. Perhaps impressed by the previous drought, in this occasion the duration of rain rogations of level 2 – involving the exhibition of Santa Madrona– was as long or even more than in the previous episode (Figure 3). These results do not allow to analyse in detail the development of the drought episode as a natural episode but provide an entry point to the perceptions and social responses to an extraordinary climate event. The first drought episode of the period of study (1620s) had such a social impact that the almost consecutive episode of the 1640s generates a proportional response. In front of the impact of drought on water resources and due to the limited references available after two generations without experiencing similar events, the duration of the religious responses may have been extended as a response against a challenging situation for local authorities.

~~After describing the recurrence of drought during these years~~, the following sections examine how Barcelona, an urban human community of nearly 40,000 people, experienced the years 1620-1650. We interpret several events of the period of study in relation to drought, from institutional efforts to build water infrastructure to the elaboration of the Book of Fountains. In order to better integrate the role of rain rogations as proxy data for drought with the events discussed in the following sections, Figure 4 presents drought rogations in Barcelona month by month, from 1601 to 1650.

https://doi.org/10.5194/cp-2020-33
Preprint. Discussion started: 16 April 2020

Climate of the Past Discussions
Open Access
EGU

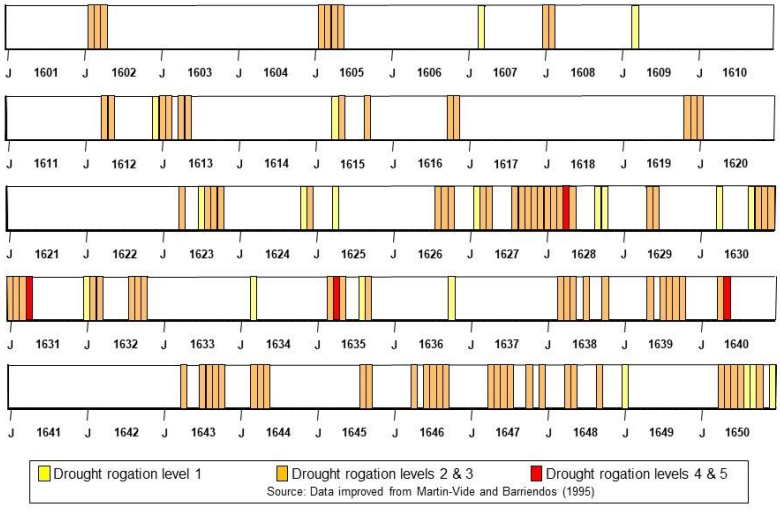

Figure 4: Monthly drought rogations levels in Barcelona, 1601-1650. Data improved from Martín-Vide and Barriendos, 1995.

3. Struggling for water supply in Barcelona

The years 1626-1627 were a turning point for the water supply of the city of Barcelona. During the first two decades of the 17th century there had been a great abundance of water, even accompanied with extreme rain episodes such as the catastrophic floods of 1617 (Thorndycraft *et al.*, 2006). In line with these years of abundance, during the early 1620s the city government supported the expansion of the water distribution system, ongoing in the first quarter of the 17th century, and gave water concessions to several aristocratic houses and monasteries, as well as completing a pipe to supply the city harbour (AS1, chapters 65, 69, 79 and 98). This perception of abundance came to an end between 1626 and 1627. In the words of Francesc Socies, responsible for the management of water supply in the city, "the abundance of waters lasted until the year 1626 (…). Already in the year 1627 came a great drought and in the fountains of the city there was a great lack of water" (AS1, chapter 65). Socies account concurs with the available information from rain rogations, which points to the second half of 1626 as the beginning of six years of recurrent droughts (1626-1632, see Figure 4).

During these years, the water supplied to Barcelona's fountains came from several underground drainage channels originating in the hills surrounding the city. These structures, known as *mines d'aigua* ("water mines") in Catalan and as *viajes de agua* ("water journeys") in Spanish, were common in all the Mediterranean and originated in the medieval *qanats* established by Muslim settlers (Guàrdia, 2011; Custodio, 2012). The recurrent dry years starting in 1626-1627 seriously reduced the amount of water coming from these sources and prompted serious efforts from the Consell de Cent to diversify the water supply sources of the city. In addition, the reduction in water flows in irrigation

https://doi.org/10.5194/cp-2020-33
Preprint. Discussion started: 16 April 2020

channels near Barcelona sometimes compromised the use of watermills to mill the grain, and therefore put in danger the supply of flour. To confront these problems, the city government developed a wide array of responses, from ambitious water transfer projects to the improvement of the existing water supply or the shift from mills relying on waterpower to windmills. In this section, we discuss these initiatives and argue that recurrent drought and limited water supply during the years 1626-1650 heightened micro and macropolitical tensions in Barcelona.

A first major response by the Barcelona city government came already in 1627 in the form of an ambitious proposal: a project for an open water canal (approximately 12 km long) connecting the river Llobregat to the city. The Consell de Cent regarded the Llobregat waters as the "universal solution" to the recurrent problem of water supply, and published a pamphlet detailing the many advantages of the project. According to this, if the project was completed, water would be secured even in dry years, new fountains would be built, water concessions given to more buildings, cleaning of the supply network would be improved and, perhaps most importantly, agriculture based in irrigation could be developed. The city government invited several experts in water supply infrastructure from outside Barcelona, who joined Francesc Socies and set out to examine the best possible itinerary for the canal. These experts drafted a detailed proposal which accounted for significant funds required to compensate landowners and also included details about bridges to be built (AS2). Still in 1627, while the consequences of drought extended throughout Catalonia, the city government presented a petition to support the project to the Viceroy, who redirected it to King Philip IV. The Spanish king showed interest in the project, but also concerns about the landowners affected by it (Voltes Bou 1967: 58-59). Moreover, the petition arrived in the aftermath of Philip IV meeting with the representative body of Catalonia (*Corts*), held in 1626, where the King's proposal to raise an economic and human contribution from Catalonia to support the Spanish army had utterly failed (Elliott, 1984).

While the Consell de Cent promoted this massive water infrastructure, the situation of water supply kept worsening. The acute dry conditions experienced during 1627 and early 1628 (see Figure 4) forced to cut off water supply to almost all private users in the city and stimulated an urgent search for nearer water sources. Aware that the Llobregat canal would only be available – in the best scenario – in the medium term, the city government resolved to expand the network of the so-called "water mines" (*qanats*). As a result, Francesc Socies started working on a new *qanat* draining the Sant Gervasi torrent. This was a far less costly option, easier to connect with the rest of the water catch of the city, and works progressed rapidly between 1627 and 1629, eventually providing a significant increase in the waters delivered to Barcelona (Perelló Ferrer 1996: 126-127). According to Socies, the rich *qanat* of Sant Gervasi was key to keep the supply of the city running during the driest years between 1627 and 1650 (AS1, chapter 65). The city government complemented this intervention with substantial efforts, both in 1630 and 1631, for the conservation and upkeeping of the city pipes, fixing broken sections and cleaning other clogged by earth and trees (Perelló Ferrer 1996: 127). Lacking support and resources for a major infrastructural work like the Llobregat canal, local authorities focused in improving the efficiency of the existing system.

Extreme drought did not only mean an immediate problem for the city fountains, but also for the water mills that milled the grain and produced flour. During dry years, the water level in the irrigation channels was not high enough for the watermills to function. This situation forced the city government to transport the grain to locations farther from the city, thus increasing the associated costs and occasionally jeopardizing the city's supply

https://doi.org/10.5194/cp-2020-33
Preprint. Discussion started: 16 April 2020

Climate of the Past Discussions
Open Access
EGU

(Simon i Tarrés 1992: 165-169). The unreliability of watermills in dry years was invoked by the city government in their plea to bring the waters of Llobregat river to Barcelona via a water canal. As explained in this document, this was the reason why the city government owned two windmills outside the city walls since earlier times (AS2). However, due to the almost absence of dry years since the 1570s, these windmills had been little used. In 1628, the Consell de Cent had to request its renovation due to its poor condition. Two new windmills were commissioned the same year, and five more would follow in 1629. Therefore, the Consell addressed the unreliability of watermills during dry years with a great expansion of the city windmills, which grew from two to nine ~~(450%)~~ between 1628 and 1631 (Perelló Ferrer 1996: 286-288).

However, the real challenge was the very lack of grain to be milled in the face of the drought impacts on regional agriculture. In a context of diminishing grain supplies, the development of an alternative infrastructure to secure the transformation of grain into flour avoiding the reliance on water was futile. The impacts of the severe drought of 1627 extended throughout the following years and went beyond Barcelona. A very cold winter, with snowstorms that killed many fruit trees, was followed by a very dry summer. By 1628, a contemporary witness stated, "the dioceses of Barcelona, Tarragona and the plain of Urgell cry of thirst" (Simon i Tarrés 1992: 161-162). Between 1628 and 1631, dry years and extreme climate events critically affected agriculture in Catalonia, resulting in bad crops and adding new tensions to both local and regional conflicts (Simon i Tarrés 1992:158-161). An international conjuncture of war and plague in Milan and southern France prevented grain imports from these regions, which could have compensated for the local losses. As a result, prices in cities like Girona and Barcelona went skyrocketing, and by the beginning of 1631 the supply of bread in Barcelona was in a critical situation.

In this context, some profited from selling bread that did not comply with the legal weight or mixed different types of grain. In the spring of 1631, the protests for the price, scarcity and bad quality of bread in Barcelona ended up in violent riots that threatened the very lives of the members of the city government. In response, the Consell de Cent decided to assume full control of bread production, strictly banning any production or distribution of bread by other authorities. In an attempt to secure the distribution of bread to the population, the Consell de Cent organized a centralized, street-by-street rationing system. In the end, a wheat cargo coming from Mallorca in May 1631 alleviated the shortage (Simon i Tarrés, 1992). However, the strategy of enforcing a centralized rationing system during scenarios of scarcity – or whenever these scenarios seemed feasible – remained in use during the following years.

During 1632 Barcelona experienced again several months without rain (Figure 4). Despite the efforts devoted to improve urban water supply sources and take care of the maintenance of the infrastructure, this year Barcelona received less than a third of its usual water supply (Voltes Bou 1967: 59). This critical situation contributed to a brief comeback of the project of a canal from the Llobregat River proposed to the Spanish king five years earlier (Perelló Ferrer 1996: 128). The city officers called water supply experts to resume the work on the canal and even started marking it on the ground (AS3). In 1633 the Consell de Cent decided to go ahead with the project. However, it required the permission and Royal Privilege from King Philip IV. This could not come at a worse moment, for the 1632 meeting of the king with Catalan representative body, the *Corts*, had repeated the 1626 fiasco. The tensions between the Catalan Corts and the King in the years 1626-1632 certainly did not help to bring the Llobregat canal project any closer to fruition. After the city petition, Philip IV consulted the Viceroy of Catalonia as he had done in 1627 (AS4: 137, 154-155). There is no trace of the Viceroy's reply, but some of

https://doi.org/10.5194/cp-2020-33
Preprint. Discussion started: 16 April 2020

Climate of the Past Discussions
Open Access
EGU

the aristocratic landowners of the territories where the canal had to be built consistently opposed the project (Voltes Bou 1967: 59-60). After 1633 we find few more references to it. Three centuries were still to pass until the waters of Llobregat were channelled to Barcelona (Burgueño, 2008; Saurí, March and Gorostiza, 2014).

The very mechanisms established to cope with the subsistence crisis of 1627-1631 intertwined with power struggles, setting the scene for new conflicts. During 1633 the city government attempted to enforce its control of bread production and distribution, put into practice two years earlier. The insistent public calls issued to the monasteries and the Cathedral to prevent from producing and circulating bread suggest that these regulations were far from followed, and bread was distributed in several stalls in the city – not only in those depending from the city government. In this context, on the 4th of January 1634, a representative from the Consell de Cent confiscated a piece of bread that had been produced by the Cathedral. This proved that this institution was disobeying the city government calls. When the member of the Consell de Cent who had confiscated the bread refused to hand in the proof to the Cathedral, this institution arrested him and imprisoned him on ecclesiastical grounds (AS5). The reprisals from the city government came immediately in the form of arrests of several persons connected to the Cathedral, but also with a different action. The Consell de Cent ordered the water officer, Francesc Socies, to cut off the water supply to the Cathedral. This decision triggered a dramatic confrontation between the city government and the ecclesiastical powers.

As previously explained, during the first quarter of the 17th century the Consell de Cent had pursued the expansion of the urban water network and gave water concessions to different aristocrats and monasteries, while at the same time retaining the right to cut off the water supply if needed. The Cathedral, however, was no ordinary monastery. When Francesc Socies carried out the city's orders and water stopped flowing to the ecclesiastical grounds of the Cathedral, the conflict immediately escalated. The water cut lasted only a couple of hours and supply was restored, for the city government seems to have confirmed that an agreement dating back to 1355 granted the Cathedral with the right of water provision. But even if the precious liquid was soon flowing again in the Cathedral's cloister, the offense was not without results. The Cathedral's Chapter immediately excommunicated Francesc Socies and the members of the Consell de Cent for offending the property of the Church, causing a great scandal in the city (AS5). While it was bread production and distribution, and not water, what had originally been the cause of the dispute, legal rights about water supply and its value in time of drought were at stake.

Moreover, the reaction of the city's government aggravated the offence against the Cathedral. Far from accepting the Cathedral's authority, the Consell de Cent called dozens of church doctors and theologians from several monasteries of the city and asked them if the excommunication was legal and valid. After deliberating on the matter, these experts concluded that the excommunication could be considered invalid due to errors in the way it had been carried out – a written statement that the city hastened to make public, printing a pamphlet and distributing it widely (AS6).

The Consell de Cent, even if acknowledging the Cathedral's rights to water, publicly reasserted its own role as the institution responsible of maintaining and overseeing urban water supply. As put in one of the pamphlets published in 1634, the city declared itself "master and owner of the waters that flow to its fountains" (AS7). In order to justify the water cut-off, they argued that they had not been aware that the Cathedral hold old rights to these waters, and that they immediately restored the service when they realised their

https://doi.org/10.5194/cp-2020-33
Preprint. Discussion started: 16 April 2020

mistake. Accordingly, the lawyers of the Consell de Cent pointed out that committing a sin by ignorance could not justify a punishment as severe as an excommunication (AS7). The Cathedral's Chapter, on the other side, considered that both the city government and the city water officer had been perfectly aware that waters belonged to the Cathedral, and therefore underlined that the water cut-off had to be considered an aggravated crime against the Church properties – one that was punished with excommunication (AS8).

The legal case fell in the hands of the Archbishop of Tarragona, and mutual accusations between the Cathedral and the Consell continued for months, even if the excommunications were provisionally lifted after a few weeks (AS4:205-206). Soon afterwards, major events seem to have taken over this quarrel. War broke out between Spain and France in 1635, and Catalan territories immediately became a space in dispute. Moreover, the Catalan revolt of 1640 split the region from the Spanish crown until 1652. Beyond these grand changes, however, the daily work to keep the water running to Barcelona remained a challenge – and Francesc Socies remained in charge.

4. Codifying knowledge about water supply: The Book of Fountains (1650)

The scandal of the excommunication of the Consell de Cent and the city water officer came after some of the driest years remembered in Barcelona (1626-1632). The city government emerged from the conflict with renovated sensibility about the importance of enforcing control over water supply, but also over the very knowledge about water concessions, which could help avoiding similar conflicts in the future. In line with the declaration that the city was "master and owner of the waters that flow to its fountains", during the following years the city government devoted more and more attention to watch out its water resources and remained wary of any violation of its water rights. At the same time, it launched an initiative to take over the water knowledge embodied by the city water officer.

4.1 The origins of the Book of Fountains

In 1641 the Barcelona water officer, Francesc Socies, completed his 21st year in his post. It was not without surprises. In December, water stopped flowing to the fountain of Sant Joan. Despite all efforts, it was impossible to determine the cause, and when the water flow resumed after two months, it left Socies puzzled. When this repeated next year around the same dates, the water officer was convinced that someone was illegally tapping into the network. During the following years, the water loss in the fountain of Sant Joan became one of Socies' main headaches. His inability to find the reason behind it compromised his authority in front of the Consell. This problem may have been not so serious had it not been accompanied by another long repetition of dry years. But the extreme weather suffered throughout Spain in 1640-1643 (Parker 2013: 289), followed in Barcelona by several dry years in a row (1643 to 1651, see Figure 4), made it more pressing.

In 1644, the city government went as far as approving a search into all the houses close to the main pipe to find where the water leak was or who had illegally drilled into the pipe and set a tap. It even offered rewards in exchange for information, but all attempts to find out the cause of water loss proved fruitless. Eventually, in 1647, Socies was ordered to remake the whole sector of the pipeline that supplied the fountain, connecting it to another branch of the distribution system (AS1, chapter 22; Perelló Ferrer 1996:128). These efforts to enforce control of water distribution came hand in hand with initiatives to expand the water sources of the city supply system. During the second half of the 1640s

https://doi.org/10.5194/cp-2020-33
Preprint. Discussion started: 16 April 2020

Climate of the Past Discussions
Open Access
EGU

the Consell de Cent approved the construction of a new *qanat* in Pedralbes, while also devoting funds to the improvement of the city fountains (Perelló Ferrer 1996:129). Crucially, however, the Consell lacked a detailed knowledge of the water system and therefore depended on the city water officer for carrying out almost any change or improvement to the water supply and distribution infrastructure. The persistent droughts of these years only made this circumstance more evident. Francesc Socies was aging with no successor in sight. In this context, during the summer of 1648 the city government decided to put forward a proposal to him.

Traditionally, when approaching retirement, it was the city water officer who would ask the city government to perform his duties accompanied with an assistant – usually his son or son-in-law. After working together several years – receiving only one salary – the apprentice would then replace the city water officer in his post (Perelló Ferrer 1996:77). This father-to-son tradition kept knowledge in the hands of city water officers' families and away from the Consell de Cent, which therefore remained fully dependant on him. Francesc Socies, however, had no direct relatives to work with. His son was a monk in Montserrat monastery, and his two sons-in-law already had their own profession.

Perhaps taking advantage of Socies' situation and his questioned authority after the unresolved water thefts, this time it was the Consell de Cent that took the initiative. On July 8, 1648, after a significantly dry spring (see Figure 4), it formally required Socies to write a book about the city water supply and the operation of the city's fountains. According to the Consell's instructions, the book would remain perpetually in the city government's grounds, "for the clarity of [the officer's] successors in his post", therefore showing an explicit intention of appropriating the knowledge inherently associated to the water officer's job post and codifying it for future uses, always under the Consell's control. The manifest objective of keeping the proposed book in the Consell's grounds also made clear another aim of the city government: to reinforce its position as the only institution managing and owning water in the city, and therefore to reaffirm its capacity to use water as a tool to control urban space (AS9:325-326). The writing of a book about the city waters, kept by the Consell de Cent, was fully in line with the statement made in 1634. In terms of water property and rights, writing was an instrumental juridical tool for the city government to reassert itself as the "master and owner of the waters that flow to [Barcelona] fountains".

Moreover, from the perspective of the Consell, water knowledge was also key to attain a more efficient and less-costly daily management of water supply. The proposed book, according to the Consell's proposal, should result in great benefit of the fountains and would reduce the expenditure they required, since it would facilitate finding out about any problem they could suffer (AS9:325-326). After all, aside from his regular salary to maintain the water distribution system, the city water officer had to be paid for each specific work he carried out. Considering the troubled decades of 1620-1650, the Consell's attempt to appropriate the city water officer's knowledge can also be interpreted as an attempt to anticipate future difficulties by codifying the knowledge of the past – in other words, by developing tools for future generations to cope with the variability of the climate and its impact into the water supply and distribution network of the city.

Francesc Socies took two years to provide a formal answer. In September 1650, amid a very severe drought (see Figure 4), he finally offered to write the proposed book, under one condition. In exchange for it, he demanded to receive a salary until the end of his life, whether he was working or not. On September 6, 1650, the Consell accepted Socies' offer, highlighting that the water officer had been more than three decades at the service of the

https://doi.org/10.5194/cp-2020-33
Preprint. Discussion started: 16 April 2020

Climate of the Past Discussions
Open Access
EGU

city and stating that payments would start as soon as the book was delivered (AS9:325-326). In fact, Socies had started to write what would later be known as the *Llibre de les Fonts* ("Book of Fountains") at least two months earlier, in July 1650. In his writing, Francesc Socies went over the water geography of the city, but also revisited more than thirty years of Barcelona's water supply history.

4.2 Structure and contents of the Book of Fountains

The Book of Fountains adopts the form of a manual about urban water supply, a text where Socies provides instructions that codify both the knowledge of his profession and the experience of his job position, aimed at guiding future interventions in the supply system and communicating what new workers will need to know. Its elaboration shall be contextualised within the emergence of technical and practical manuals to transmit knowledge (Eamon, 1994; Long, 2001; Cifuentes i Comamala, 2006). The water distribution system is described as an interconnected network, from the drainage underground channels in the hills of Barcelona known as "water mines" (*qanats*) to the city fountains. Water supply is conceived as part of a human system, where urban elements are interdependent (if water is cut in one section, other sections will be left unsupplied). This network is examined and described both technologically and socially. The knowledge that the city water officer pours into the book is a thorough technical description of the journey followed by water through the city, indicating with high precision where each element is located, both for those visible and those hidden from view, underground or behind walls (water taps, pipes, water tanks or wells).

The Book of Fountains is a knowledge manual but was also conceived as a tool to be used. When referring to specific places in the city, the author often establishes a symbolic relation between the written text and the urban fabric. Text and territory become inseparable, and as a connector, the author uses a figure – the cross – sometimes in the text but more often in its margins, making its location faster to readers. These crosses written in the text refer to crosses chiselled in the stone walls of the street buildings, indicating specific elements of water infrastructure hidden from view and thus binding the book pages with the urban fabric of the city. In other words: the author inscribes water urban geography into the pages of the Book of Fountains.

As both a manual and a tool, the Book of Fountains does not only provide readers with a geography of the water network elements, but also with a calendar for the system's maintenance. Instructions are provided within a particular urban space and time. Socies specifies where to intervene and how often, for instance in relation to the cleaning of pipes and curtailing the growth of trees' roots that can disrupt sections of the system (e.g. every two, four of five years). Nevertheless, Socies' temporal specifications do not only apply to maintenance, but also to key historical information about water property rights. While writing the book, Socies visited the city archive and consulted the Consell's meeting proceedings in order to record the water right concessions to several monasteries, dating from 1611. He left a clear reference to where these legal documents could be found. Similarly, he visited the archive of the Cathedral's Chapter, providing detailed information about the old pipes underground the building and reminding future readers about the agreement between the Cathedral and the city government, dating from 1355, which granted the Cathedral the ownership of the waters flowing to it (AS1, chapters 26 and 56). In other words, he recorded this information for the future city water managers, setting the basis to prevent conflicts such as the one occurred in 1634.

https://doi.org/10.5194/cp-2020-33
Preprint. Discussion started: 16 April 2020


Climate of the Past Discussions
Open Access
EGU

Additionally, in order to ensure that the Book of Fountains remained a useful tool, Socies demanded the involvement of his readers – the future city water officers. Socies asked them to use the book, recording any intervention in the water network in the margins of the text, and therefore keeping knowledge to date for future generations (AS1:262). By involving future water officers into the authorship in a transgenerational endeavour, the book aimed at becoming collective heritage. In this way it became useful for the present as a physical object, but more than that, a perdurable, indispensable tool for the city's future. The transmission of knowledge to the future became a tool to manage risks affecting the city water supply.

Starting at the main water tank distributor of Barcelona, outside the city walls, the Book of Fountains provides a detailed description of the main pipe supplying the city, each of its branches and sections, along with the buildings receiving water supply and the location of the very water conduits. Later in the text, Socies turns his attention to the "water mines" (*qanats*) in the hills of the city. Therefore, with his writing the water city officer establishes the water's urban journey from source to tap, fixing and at the same time defining who the proprietor of this knowledge is, and institutionalizing who has the power to control it. This intention of controlling urban space, based on the need of preserving water supply, it is well apparent in Socies' instructions to future managers. In order to keep a regular water flow running in the city's fountains, the city government needs to be able to detect and solve any incident rapidly, particularly in relation to water thefts. To this end, Socies narrates how he has been remaking the water network that runs through internal parts of buildings, moving it to their external sections, in order to hinder any attempt to illegally tap into the water network. He recommends continuing with these reforms in order to put the network as close as possible to the control of the water city officer and the city government (AS1, chapters 26, 78 and 79).

Among the detailed knowledge demonstrated, Socies also provided his testimony on the state of water supply during the summer of 1650, when he was writing the Book of Fountains. In July 1650, when he started the book, the dry spell in Barcelona was already ongoing, with *pro pluvia* rogations in the streets since April (see Figure 4). Exploring the *qanats* of Nostra Senyora del Coll, Socies pointed out that it was the first time in his life that he saw them dry, and commented that as years passed by, the flow of water in the city had been decreasing. He specifically pointed to the years 1626-1627 as the moment when this "lack of waters" had started, and underlined the importance of the Sant Gervasi *qanat*, whose construction he had led in the late 1620s, to keep Barcelona supplied in these dry years (AS1, chapter 65).

Likewise, throughout the book Francesc Socies reminded readers of the many works and improvements he carried out in the water network and the date when they took place. Writing provided social and historical prestige, and the Book of Fountains not only institutionalized the control of the city government over water, but also qualified Francesc Socies as the water expert of his epoch. In this regard, the book has a similar function to that which institutional chronicles had at the time, authored by the political institutions of Catalonia (Simon i Tarrés, 2005). Moreover, in relation to the water officer, the prestige associated with authorship of the Book of Fountains could overshadow his compromised position in relation to the unresolved 1640s water thefts and perhaps the scandalous 1634 excommunication.

The dry summer of 1650 eventually caused the loss of the harvest and made the year known as "the year of misery" (Guàrdia, Pladevall i Font and Simon i Tarrés, 1986:105). However, rains finally arrived in mid-October, a few days after the Consell organized a

https://doi.org/10.5194/cp-2020-33
Preprint. Discussion started: 16 April 2020

major *pro-pluvia* rogation. A week of rain saved the sowing and was celebrated with a *Te Deum Laudamus* at the Cathedral on October 23. Socies probably finished the Book of Fountains around the time. On November 14, 1650, he walked into the meeting of the Consell de Cent and made a ceremonious presentation of the Book of Fountains (AS9:400).

5. Conclusions

This article has examined the human response to drought in the city of Barcelona (Western Mediterranean) during the years 1620-1650. After establishing the regional significance of drought in the Western Mediterranean during 1620-1640 with literature on climate history relying on ecological proxies (Nicault *et al.*, 2008), in the first part of the article we analysed the historical climatology of Catalonia and Barcelona drawing on *pro pluvia* rogations as documentary proxy data. This analysis has identified two main periods of drought in the city (1625-1635 and the 1640s) as the most significant drought events of the period 1521-1825 (highest Drought Frequency Weighted Index of the series).

Building on this, the main part of the paper has explored the institutional strategies deployed by the city government in response to severe drought between 1626 to 1650. A key determinant to this analysis is the long period without significant droughts immediately before these years (1570-1620). Several sources point to an expansion of the urban water supply and the water concessions granted by the Barcelona city government during the first quarter of the 17th century. Both rain rogations, the testimony of the city water officer and printed sources confirm that these times of abundance finished in 1626-1627. During the following five years, drought and general climate variability, combined with the international context of war and plague in Milan contributed to produce a supply crisis in Barcelona, where riots for bread took place in 1631. During these years, water scarcity was felt both in the city fountains and the watermills, which in some occasions could not mill the grain. The city government launched several initiatives to alleviate the problems caused by water scarcity. Large infrastructural projects such as the Llobregat water canal failed due to the lack of financial and political support. This failure privileged other, softer measures of adaptation: the expansion of water supply sources in the hills near Barcelona, the investments to maintain and clean the city pipes, or a great expansion of windmills as an alternative to mill grain not depending on water.

In this context of water scarcity, tensions around water availability increased. One of the loudest public conflicts of the period was related to water and confronted the city government and the Barcelona Cathedral in early 1634. As proven by drought reconstruction, the conflict broke out after several dry years (1627-1632), but no direct causality can be established between drought and social conflict. After the 1626-1627 drought and the climate variability that contributed to the supply crisis and the 1631 riots in Barcelona, the city government had introduced a centralized rationing system for the distribution of bread. Even if the shortage was over by 1633, the system remained in use and the city government continued to enforce it. It is the power to produce and distribute bread that originally sparked the conflict with the Cathedral. Cutting off water supply was one of the reprisals carried out by the Consell against the Cathedral – and certainly one that had scandalous consequences and developed its own course. But it was not the cause of the conflict. Nonetheless, the severe drought experienced the previous years and the diminished flow of water available in the city's pipes made water a handy weapon to use. So while we cannot interpret the 1634 confrontation as caused by water scarcity, the impact of drought in water supply certainly helps explaining how the precious liquid

https://doi.org/10.5194/cp-2020-33
Preprint. Discussion started: 16 April 2020

Climate of the Past Discussions
Open Access
EGU

637 became a weapon, transforming a quarrel over bread distribution rights into a major legal
638 case leading to the excommunication of the city government officials – including the city
639 water officer.

640 Beyond this, the relevance of the 1634 conflict for water management during the
641 following years is twofold. First, it illustrated the ambiguities and difficulties of the city
642 government when dealing with water concessions. The Consell de Cent rapidly
643 acknowledged it had committed a mistake when cutting off water supply, because the
644 agreement between both institutions to guarantee the water flows to the Cathedral dated
645 back to 1355. Regardless of the political intentions of the city government, the existence
646 of diverse agreements, contracts and water concessions between the city and other
647 institutions – signed in past times, when water supply was more abundant – justified the
648 codification of water knowledge into a unique book/tool. From this perspective, the Book
649 of Fountains can be interpreted as an outcome of the institutional learning of the most
650 severe drought period experienced in Barcelona between 1521 and 1825, and as a tool to
651 prevent similar conflicts such as the one sustained with the Cathedral. In addition, from a
652 political perspective, the 1634 conflict only reinforced the city government's legal claims
653 over the management of urban water supply. In the legal discussion following the conflict,
654 the Consell de Cent declared itself the "master and owner of the waters that flow to
655 [Barcelona] fountains". A coherent step to reassert these claims was to codify knowledge
656 about urban water rights, water distribution and maintenance into a book. On top of this,
657 as previously discussed, the contract to produce the Book of Fountains underlined its
658 critical value and banned the removal of the book from the city government's premises.
659 On its own, the Book of Fountains is a technical manual describing urban water supply.
660 But its contextualisation within the social conflicts and historical climatology of the
661 period points to its unequivocal political character. Crucially, this is only possible by
662 combining several documentary sources, since the author of the Book of Fountains
663 follows a descriptive pattern with a neutral tone, making no explicit political claims on
664 water.

665 In conclusion, the appropriation of the city water officer's knowledge by the Consell de
666 Cent, legally binding the resulting Book of Fountains and the knowledge it embodies to
667 the city's premises, can be interpreted as an adaptation strategy and an attempt to make
668 the water supply system more efficient in a context of frequent and severe drought.
669 Anticipating the future is required in order to adapt to variability, and the codification of
670 knowledge aims at taking it from a specific family line or profession, to use it for the
671 common good of the city. It is a "public" effort to overcome the private transmission of
672 information from father-to-son and use it for the common future good, but also a
673 reinforcement of the authority of the city government in relation to a precious resource in
674 times of drought: water. The knowledge collected in the Book of Fountains has the
675 potential to make the functioning of the urban water supply more efficient, avoiding
676 conflicts and reducing expenditure. Hence the key call to involve future water city officers
677 in updating the Book of Fountains, aiming at the creation of a transgenerational tool to
678 cope with future risks associated with urban water supply.

679 Last but not least, the Book of Fountains is also useful as a source for historical
680 climatology. Not only it originates during the most significant drought period identified
681 in Barcelona between 1521-1825, but it provides access to the perception of water flows
682 from a very authoritative voice: that of the local expert on water supply, in office for three
683 decades (1620-1650). Writing in the summer of 1650, during an extreme episode of
684 drought, Francesc Socies testimony depicts the years 1626-1627 as the beginning of a
685 period of water scarcity in Barcelona. Both references are coherent with the analysis of

https://doi.org/10.5194/cp-2020-33
Preprint. Discussion started: 16 April 2020

drought presented in the first part of this article (figures 2, 3 and 4), drawing on *pro pluvia* rogations as documentary proxy data. Considering the regional extent of the dry period of 1620-1640 in the Western Mediterranean (Nicault *et al.*, 2008), our case study shows the potential of examining human response to drought and water stress from the institutional perspective.

Author contribution

Santiago Gorostiza conceived this research with Maria Antònia Martí Escayol and wrote the introduction, conclusion and section 3 of the text. He made significant contributions to the rest of the text. In addition, he handled the coordination, integration, translation and revision of texts.

Maria Antònia Martí Escayol conceived this research with Santiago Gorostiza and wrote section 4 of the text. Martí Escayol transcribed the *Llibre de les Fonts de la Ciutat de Barcelona* and made significant contributions to the introduction, section 3 and conclusions of the text.

Mariano Barriendos prepared the drought series for Catalonia and Barcelona, handled the database organization, statistical treatment, graphic production, and preparation of the tables and figures. Barriendos wrote the section 2 of the text.

Acknowledgments

Santiago Gorostiza acknowledges financial support from the Spanish Ministry of Science, Innovation and Universities, through the "María de Maeztu" program for Units of Excellence (MDM-2015-0552). This research was presented at the European Society of Environmental History in Tallinn (August 2019) and the Watermarks workshop at ICTA-UAB (October 2020). The authors thank the participants in these events for their comments and criticisms. Santiago Gorostiza thanks Ekaterina Chertkovskaya for revising the text.

Competing interests

The authors declare no competing interests.

Archival sources

[AS1] *Llibre de les Fonts*, Manuscrits, L-15, Arxiu Històric de la Ciutat de Barcelona (AHCB).

[AS2] Consell de Cent, Barcelona. "Discurs fet per orde dels... consellers, obrers, y saui Concell de Cent, en lo aniuellar y aportar una sequia de aygua del riu de Lobregat, à la ciutat de Barcelona, als 9 de maig 1627", Manuscrits Bonsoms, F. Bon. 5410, Biblioteca de Catalunya.

[AS3] AHCB, Deliberacions, Consell de Cent II-142, 1633, fol. 144-147.

[AS4] AHCB, *Manual de novells ardits vulgarment apellat Dietari del Antich Consell Barceloní*, vol. 11 (1632-1636).

https://doi.org/10.5194/cp-2020-33
Preprint. Discussion started: 16 April 2020

[AS5] Consell de Cent, Barcelona. "Informacion de la ivsticia qve tiene la civdad de Barcelona en la cavsa sobre qve aora trae pleyto con el Cabildo de la Santa Iglesia Catedral de la misma ciudad en el Tribunal y Corte eclesiastica del Illustrissimo Señor Arçobispo de Tarragona", 1634. F.Bon. 5402, Biblioteca de Catalunya.

[AS6] "Resolucion theologica en la duda que en esta ciudad de Barcelona ha hauido sobre sí los que concurrieron en quitar el agua que sale en las fuentes de los claustros de la Santa Iglesia del Asseo desta ciudad por espacio de algunas horas incurrieron en las censuras de las constituciones prouinciales tarraconeneses y apostolicas", 1634. F.Bon. 4873, Biblioteca de Catalunya.

[AS7] Consell de Cent, Barcelona. "Por la civdad de Barcelona y Francisco Sossies, maestro de las fventes, con el Cabildo de la Iglesia Maior acerca de las censuras declaradas contra el dicho Sossies", 1634. F.Bon. 10964, Biblioteca de Catalunya.

[AS8] Capítol de la Catedral de Barcelona. "Per lo Capitol y canonges de la Seu de Barcelona, en defensa de la sentencia proferida per lo official ecclesiastich a 5 de Ianer 1634, declarant que Fra[n]cesch Socies, mestre de les fonts de la ciutat, y los demes complices en lleuar la aygua de la font que te dita iglesia eran excomunicats y posant entredit", 1634. F.Bon. 11466, Biblioteca de Catalunya.

[AS9] AHCB, Deliberacions, Consell de Cent II-159, 1650.

References

Barriendos, M. (1996) 'El clima historico de Catalunya (siglos XIV-XIX). Fuentes, métodos y primeros resultados', *Revista de Geografía*, 30–31, pp. 69–96.

Barriendos, M. (1997) 'Climatic variations in the Iberian Peninsula during the late Maunder minimum (AD 1675-1715): An analysis of data from rogation ceremonies', *Holocene*, 7(1), pp. 105–111. doi: 10.1177/095968369700700110.

Barriendos, M. *et al.* (2019) 'Climatic and social factors behind the Spanish Mediterranean flood event chronologies from documentary sources (14th – 20th centuries)', *Global and Planetary Change*. Elsevier, 182(July), p. 102997. doi: 10.1016/j.gloplacha.2019.102997.

Barriendos, M. and Martin-Vide, J. (1998) 'Secular climatic oscillations as indicated by catastrophic floods in the Spanish Mediterranean coastal area (14th-19th centuries)', *Climatic Change*, 38(4), pp. 473–491. doi: 10.1023/A:1005343828552.

Burgueño, J. (2008) *El Mapa com a llenguatge geogràfic. Recull de textos històrics (ss. XVII-XX) : Diago, Borsano, Aparici, Canellas, Massanés, Bertran, Cerdà, Papell, Ferrer, Vila*. Barcelona: Societat Catalana de Geografia.

Cifuentes i Comamala, L. (2006) *La ciència en català a l'Edat Mitjana i el Renaixement*. 2a ed. rev. Palma de Mallorca: Universitat de Barcelona.

Cubeles, A. (2011) 'El "Llibre de les fonts" del mestre Socies i l'abastament d'aigua de beure a Barcelona al segle XVII', in Guàrdia i Bassols, M. (ed.) *La Revolució de l'aigua a Barcelona : de la ciutat preindustrial a la metròpoli moderna, 1867-1967*. Barcelona: Ajuntament de Barcelona, pp. 45–50.

https://doi.org/10.5194/cp-2020-33
Preprint. Discussion started: 16 April 2020

779 Custodio, E. (2012) 'The History of Hydrogeology in Spain', in Howden, N. and
780 Mather, J. (eds) *History of Hydrogeology*. Boca Raton: Taylor & Francis, pp. 291–316.

781 Díaz, M. P. (1984) 'Aproximación a la climatología en la Cataluña del siglo XVII
782 (según fuentes de la época)', in *Primer Congrés d'Història Moderna de Catalunya:*
783 *Barcelona, del 17 al 21 de desembre de 1984*, pp. 255–266.

784 Eamon, W. (1994) *Science and the secrets of nature : books of secrets in medieval and*
785 *early modern culture*. Princeton, N.J.: Princeton University press.

786 Elliott, J. H. (1984) *The revolt of the Catalans: a study in the decline of Spain (1598-*
787 *1640)*. Cambridge: Cambridge University Press.

788 Grau-Satorras, M. *et al.* (2016) 'Long-term community responses to droughts in the
789 early modern period: the case study of Terrassa, Spain', *Ecology and Society*, 21(2).
790 doi: 10.5751/ES-08232-210233.

791 Grau-Satorras, M. (2017) *Adaptation before anthropogenic climate change: a historical*
792 *perspective on adaptation to droughts in Terrassa (1600-1870s, NE Spain)*. UAB.
793 Available at: https://www.tesisenred.net/handle/10803/405252.

794 Grau-Satorras, M. *et al.* (2018) 'Prudent peasantries: Multilevel adaptation to drought in
795 early modern Spain (1600-1715)', *Environment and History*. Available at:
796 http://www.whpress.co.uk/EH/papers/1375-Grau-Satorras.pdf.

797 Guàrdia, J., Pladevall i Font, A. and Simon i Tarrés, A. (1986) *Guerra i vida pagesa a*
798 *la Catalunya del segle XVII : segons el Diari de Joan Guàrdia, pagès de l'Esquirol, i*
799 *altres testimonis d'Osona*. Barcelona : Curial.

800 Guàrdia, M. (2011) 'L'aigua de les fonts', in *La Revolució de l'aigua a Barcelona : de*
801 *la ciutat preindustrial a la metròpoli moderna, 1867-1967*. Barcelona: Ajuntament de
802 Barcelona, pp. 40–44.

803 Llasat, M. C. *et al.* (2005) 'Floods in Catalonia (NE Spain) since the 14th century.
804 Climatological and meteorological aspects from historical documentary sources and old
805 instrumental records', *Journal of Hydrology*, 313(1–2), pp. 32–47. doi:
806 10.1016/j.jhydrol.2005.02.004.

807 Long, P. O. (2001) *Openness, secrecy, authorship : technical arts and the culture of*
808 *knowledge from antiquity to the Renaissance*. Baltimore: Johns Hopkins University
809 Press.

810 Martín-Vide, J. and Barriendos, M. (1995) 'The use of rogation ceremony records in
811 climatic reconstruction: a case study from Catalonia (Spain)', *Climatic Change*, 30(2),
812 pp. 201–221. doi: 10.1007/BF01091842.

813 Nicault, A. *et al.* (2008) 'Mediterranean drought fluctuation during the last 500 years
814 based on tree-ring data', *Climate Dynamics*, 31(2–3), pp. 227–245. doi:
815 10.1007/s00382-007-0349-3.

816 Oliva, M. *et al.* (2018) 'The Little Ice Age in Iberian mountains', *Earth-Science*
817 *Reviews*, 177(October 2017), pp. 175–208. doi: 10.1016/j.earscirev.2017.11.010.

818 Parker, G. (2013) *Global Crisis: War, Climate Change & Catastrophe in the*
819 *Seventeenth Century*. New Haven: Yale University Press.

820 Perelló Ferrer, A. M. (1996) *L'arquitectura civil del segle XVII a Barcelona*.
821 Barcelona : Publicacions de l'Abadia de Montserrat.

https://doi.org/10.5194/cp-2020-33
Preprint. Discussion started: 16 April 2020

822 Rodrigo, F. S. and Barriendos, M. (2008) 'Reconstruction of seasonal and annual
823 rainfall variability in the Iberian peninsula (16th-20th centuries) from documentary
824 data', *Global and Planetary Change*, 63(2–3), pp. 243–257. doi:
825 10.1016/j.gloplacha.2007.09.004.

826 Saurí, D., March, H. and Gorostiza, S. (2014) 'Des ressources conventionnelles aux
827 ressources non conventionnelles: l'approvisionnement moderne en eau de la ville de
828 Barcelone', *Flux*, 97–98(4), pp. 101–109.

829 Serra i Puig, E. and Ardit, M. (2008) *Història Agrària dels Països Catalans. Volum 3:*
830 *Edat Moderna*. Barcelona : Fundació Catalana per a la Recerca.

831 Simon i Tarrés, A. (1981) 'Catalunya en el siglo XVII. La revuelta campesina y popular
832 de 1640', *Estudi general : Revista de la Facultat de Lletres de la Universitat de Girona*,
833 pp. 137–147.

834 Simon i Tarrés, A. (1992) 'Els anys 1627-32 i la crisi del segle XVII a Catalunya',
835 *Estudis d'Historia Agraria*, 9, pp. 157–180.

836 Simon i Tarrés, A. (2005) 'Un dietari institucional fins ara ignorat: el dietari del Reial
837 Consell Criminal', *Manuscrits: Revista d'Història Moderna*, (23), pp. 97–108.

838 Sowina, U. (2016) *Water, Towns and People*. Frankfurt am Main: Peter Lang.

839 Thorndycraft, V. R. *et al.* (2006) 'The catastrophic floods of AD 1617 in Catalonia
840 (northeast Spain) and their climatic context', *Hydrological Sciences Journal*, 51(5), pp.
841 899–912. doi: 10.1623/hysj.51.5.899.

842 Voltes Bou, P. (1967) *Historia del abastecimiento de agua de Barcelona*. Barcelona :
843 Sociedad General de Aguas de Barcelona.

844

845