1 # Human response to severe drought in Early Modern
2 # Catalonia. The case of Barcelona, Western Mediterranean
3 # (1620-1650)

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

34

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

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

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

99 In contrast to the development of historical climatology research in Catalonia, little work
100 has been done on the human response to drought beyond acknowledging that climate
101 conditions in the 17th century accentuated the agricultural, social and political crisis (Serra
102 i Puig and Ardit, 2008). The research of Antoni Simon i Tarrés, who highlighted the
103 importance of drought among the complex interaction of factors that led to social unrest
104 in Barcelona and Catalonia during the late 1620s and 1630s stands out among the few
105 publications on the topic (Simon i Tarrés, 1981, 1992). The relevance of the climatic
106 factor in the Spanish context during the 17th century has also been underlined by Geoffrey
107 Parker, who pointed out that during the reign of Philip IV Spain "suffered extreme
108 weather without parallel in other periods, particularly in 1630–2 and 1640–3" (Parker
109 2013:289) and examined the revolt of Catalonia against the Spanish King (1640-1651) in
110 this context.

111 However, neither Parker nor Simon i Tarrés explicitly address the human response to
112 climatic disturbances in Catalonia during these years. More recently, Mar Grau-Satorras
113 has used the example of the town of Terrassa (Barcelona region, Catalonia) to examine
114 how local communities combined different strategies to cope with drought, including
115 infrastructural, institutional and symbolic responses which changed throughout time
116 (Grau-Satorras *et al.*, 2016, 2018; Grau-Satorras, 2017). Along these lines, our research
117 focuses on Barcelona as an example of Western Mediterranean urban agglomeration
118 (40,000 citizens). We discuss the elaboration of the Book of Fountains among other
119 adaptation strategies, underlining the relevance and novelty of the attempt of Barcelona
120 government to codify water knowledge in the form of a book as a tool for future water
121 managers.

122 The article proceeds as follows. In the next section, we provide an overview of droughts
123 during the period 1521-1825. Due to lack of instrumental data, we use a compilation of
124 archival religious and municipal sources about *pro pluvia* rogations (rain rogations) as
125 proxy data for drought (Martín-Vide & Barriendos, 1995; Barriendos, 1996; Barriendos,
126 1997). Our work demonstrates the comparative significance of the period of study (1620-
127 1650). Following this, in section 3, we draw on municipal sources to narrate the growing
128 difficulties experienced by water supply in Barcelona to face the severe drought episodes
129 that started in 1626-1627. We analyse the proposal of the city government to build a water
130 canal from the river Llobregat under the light of the water scarcity caused by drought.
131 Similarly, we interpret the great expansion of windmills supported by the Consell de Cent

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

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

146

147 **2. Climatic context**

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149 The climatic conditions during the 17th century can be considered as part of the climatic
150 episode known as the Little Ice Age (LIA). Paleoclimatic research has pointed to a higher
151 frequency and severity of cold spells during this episode (Pfister et al., 1996; Pfister et al.
152 1998; Ogilvie 2001). More recently it has also identified and analysed a general increase
153 in the irregularity of rainfall patterns, manifested in the emergence of
154 hydrometeorological extreme episodes with great social and environmental impact. At
155 the climatic scale, in the Spanish Mediterranean this increase in the frequency and
156 severity of extreme hydrometeorological events manifests in periods of around 40 years
157 for the case of extraordinary rainfalls leading to floods (Barriendos and Martin-Vide,
158 1998; Llasat *et al.*, 2005; Barriendos *et al.*, 2019). In the case of extreme drought episodes,
159 the behaviour observed in the frequency of these type of events in the coast of Catalonia
160 allows to identify many recurring events of medium intensity and some of very high
161 intensity for the Catalan cities studied (Barcelona, Girona, Tarragona, and Tortosa, see
162 Figure 1): 1520s, 1540s, 1560s, 1620s (c. 1625-1635), 1750s, 1812-1824.

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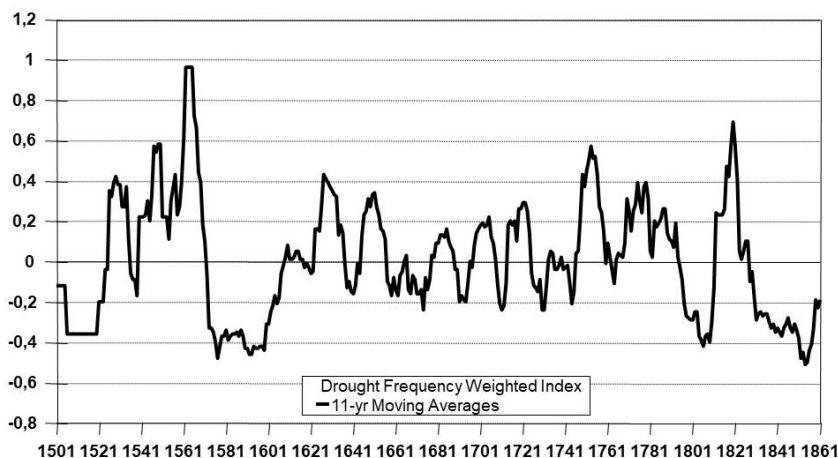
Figure 1. Drought Frequency Weighted Index. Standardised values. 11 years moving averages from 4
locations Girona, Barcelona, Tarragona and Tortosa. Data adapted from Oliva *et al.*, 2018.

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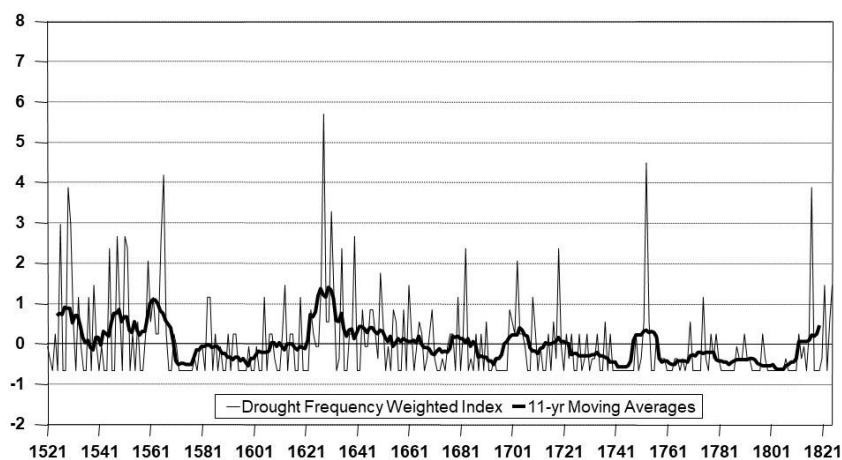
Figure 2. Drought Frequency Weighted Index. Standardised values. City of Barcelona (1521-1825).

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.

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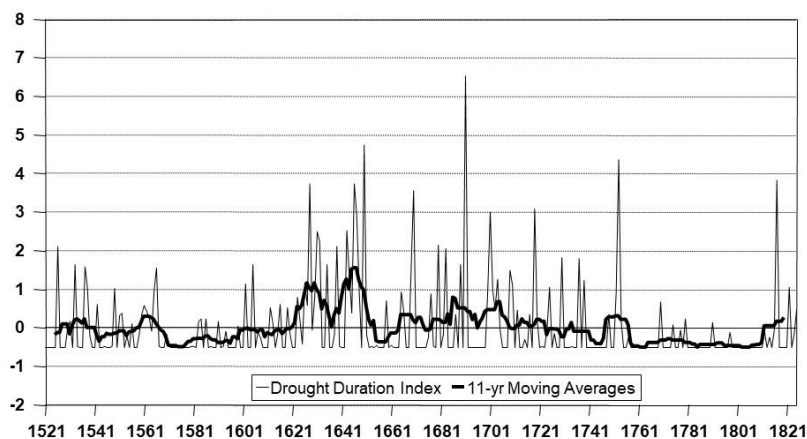
Figure 3. Drought Duration Index. Standardised values. City of Barcelona (1521-1825).

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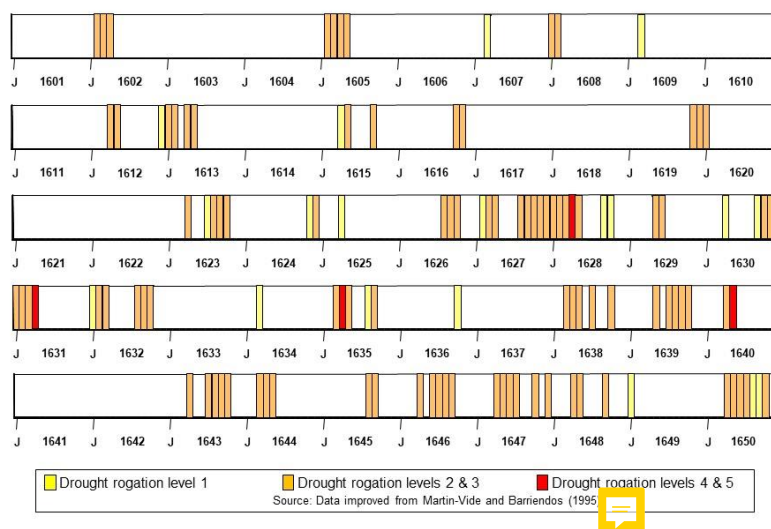
The analysis of drought duration presented in Figure 3 reveals another significant detail. After the severe 1620s drought, there was a less intense episode of drought, but very close in time, around the 1640s. Perhaps impressed by the previous drought, in this occasion the duration of rain rogations 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 response 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.

224

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

227

228 **3. Struggling for water supply in Barcelona**

229

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

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

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

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

279 While the Consell de Cent promoted this massive water infrastructure, the situation of
280 water supply kept worsening. The acute dry conditions experienced during 1627 and early
281 1628 (see Figure 4) forced to cut off water supply to almost all private users in the city
282 and stimulated an urgent search for nearer water sources. Aware that the Llobregat canal
283 would only be available – in the best scenario – in the medium term, the city government
284 resolved to expand the network of the so-called "water mines" (*qanats*). As a result,
285 Francesc Socies started working on a new *qanat* draining the Sant Gervasi torrent. This
286 was a far less costly option, easier to connect with the rest of the water catch of the city,
287 and works progressed rapidly between 1627 and 1629, eventually providing a significant
288 increase in the waters delivered to Barcelona (Perelló Ferrer 1996: 126-127). According
289 to Socies, the rich *qanat* of Sant Gervasi was key to keep the supply of the city running
290 during the driest years between 1627 and 1650 (AS1, chapter 65). The city government
291 complemented this intervention with substantial efforts, both in 1630 and 1631, for the
292 conservation and upkeeping of the city pipes, fixing broken sections and cleaning other
293 clogged by earth and trees (Perelló Ferrer 1996: 127). Lacking support and resources for
294 a major infrastructural work like the Llobregat canal, local authorities focused in
295 improving the efficiency of the existing system.

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

301   (Simon i Tarrés 1992: 165-169). The unreliability of watermills in dry years was invoked
302   by the city government in their plea to bring the waters of Llobregat river to Barcelona
303   via a water canal. As explained in this document, this was the reason why the city
304   government owned two windmills outside the city walls since earlier times (AS2).
305   However, due to the almost absence of dry years since the 1570s, these windmills had
306   been little used. In 1628, the Consell de Cent had to request its renovation due to its poor
307   condition. Two new windmills were commissioned the same year, and five more would
308   follow in 1629. Therefore, the Consell addressed the unreliability of watermills during
309   dry years with a great expansion of the city windmills, which grew from two to nine
310   (450%) between 1628 and 1631 (Perelló Ferrer 1996: 286-288).

311   However, the real challenge was the very lack of grain to be milled in the face of the
312   drought impacts on regional agriculture. In a context of diminishing grain supplies, the
313   development of an alternative infrastructure to secure the transformation of grain into
314   flour avoiding the reliance on water was futile. The impacts of the severe drought of 1627
315   extended throughout the following years and went beyond Barcelona. A very cold winter,
316   with snowstorms that killed many fruit trees, was followed by a very dry summer. By
317   1628, a contemporary witness stated, "the dioceses of Barcelona, Tarragona and the plain
318   of Urgell cry of thirst" (Simon i Tarrés 1992: 161-162). Between 1628 and 1631, dry
319   years and extreme climate events critically affected agriculture in Catalonia, resulting in
320   bad crops and adding new tensions to both local and regional conflicts (Simon i Tarrés
321   1992:158-161). An international conjuncture of war and plague in Milan and southern
322   France prevented grain imports from these regions, which could have compensated for
323   the local losses. As a result, prices in cities like Girona and Barcelona went skyrocketing,
324   and by the beginning of 1631 the supply of bread in Barcelona was in a critical situation.

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

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

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

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

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

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

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

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

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

412

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

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

424

425   *4.1 The origins of the Book of Fountains*

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

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

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

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

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

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

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

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

499

500 *4.2 Structure and contents of the Book of Fountains*

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

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

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

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

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

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

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

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

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

594

595 **5. Conclusions**

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

604 Building on this, the main part of the paper has explored the institutional strategies
605 deployed by the city government in response to severe drought between 1626 to 1650. A
606 key determinant to this analysis is the long period without significant droughts
607 immediately before these years (1570-1620). Several sources point to an expansion of the
608 urban water supply and the water concessions granted by the Barcelona city government
609 during the first quarter of the 17th century. Both rain rogations, the testimony of the city
610 water officer and printed sources confirm that these times of abundance finished in 1626-
611 1627. During the following five years, drought and general climate variability, combined
612 with the international context of war and plague in Milan contributed to produce a supply
613 crisis in Barcelona, where riots for bread took place in 1631. During these years, water
614 scarcity was felt both in the city fountains and the watermills, which in some occasions
615 could not mill the grain. The city government launched several initiatives to alleviate the
616 problems caused by water scarcity. Large infrastructural projects such as the Llobregat
617 water canal failed due to the lack of financial and political support. This failure privileged
618 other, softer measures of adaptation: the expansion of water supply sources in the hills
619 near Barcelona, the investments to maintain and clean the city pipes, or a great expansion
620 of windmills as an alternative to mill grain not depending on water.

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

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

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.

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Competing interests

The authors declare no competing interests.

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