Controlling water infrastructure, codifying water knowledge. Institutional responses to severe drought in ~~the city of~~ Barcelona (1620-1650)

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ABSTRACT: Combining historical climatology and environmental history, this article examines the diverse range of strategies deployed by the city government of Barcelona (Catalonia, NE Spain) to confront the recurrent drought episodes experienced between 1626 and 1650. Our reconstruction of drought in Barcelona for the period 1525-1821, based on *pro pluvia* rogations as documentary proxy data, identifies the years 1626-1635 and 1640s as the most significant drought events of the series (highest drought frequency weighted index and drought duration index). We then focus on the period 1601-1650, providing a timeline that visualises rain rogation levels in Barcelona at a monthly resolution. Against this backdrop, we examine institutional responses to drought and discuss how water scarcity was perceived and confronted by Barcelona city authorities. Among the several measures implemented, 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 cope~~as a diversification strategy aimed at coping better with diminishing water flows. We pay special attention to the institutional efforts to codify the knowledge about Barcelona's water supply, which in 1650 materialised in the Book of Fountains of the City of Barcelona (*Llibre de les Fonts de la Ciutat de Barcelona*). This manual of urban water supply, written by the water city officer after three decades of experience in his post, constitutes a rare and valuable source to study water management history but also includes significant information to interpret historical climate. We analyse the ~~elaboration~~production of this manual in the context of three decades marked by recurrent episodes of severe drought. We interpret the city government aspiration to codify knowledge about urban water supply as an attempt to systematise and store historical information on infrastructure to improve institutional capacities to cope with future water scarcities.

1. Introduction

~~In~~Around July 1650, during an intense episode of drought in Barcelona, the city water officer ("mestre de les fonts") Francesc Socies started writing a book that described in great detail the water supply and distribution system of the city. 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. After decades of coping with drought ~~very~~ frequently, and well-aware of the precious ~~experienced~~experience gathered by Francesc Socies, the city government had asked him to compile his knowledge about Barcelona's water supply system. The resulting book should perpetually be kept in the city archives to shed light on the work of future water city officers and improve urban water management. In November 1650, ~~he~~Socies delivered what became known as the *Llibre de les Fonts de la Ciutat de Barcelona* ("Book of Fountains of the City of Barcelona") (Archival source AS1).

This article focuses on the three decades (1620-1650) leading to the codification of ~~Barcelona water~~ knowledge about Barcelona's water supply into the Book of Fountains and examines them from the perspective of historical climatology and environmental history. ~~The period 1625-1635 in Catalonia has already been identified in the historical climatology literature~~Our analysis reconstructs the severe droughts experienced in the city during this period and examines the strategies followed by the city government to cope with them, contributing to the growing scholarship on societal adaptation to past climate changes (Degroot, 2018). First, drawing on *pro pluvia* rogations (rain rogations) as proxy data, we identify the years 1626-1635 and 1640s as the most significant drought events that occurred in Barcelona during the period 1521-1825 (highest drought frequency weighted index and drought duration index of the series). This previously unpublished drought reconstruction is the first contribution of our work, which confirms previous research on historical climatology that had pointed to the years 1625-1635 as severely dry (Díaz, 1984; Martín-Vide and Barriendos, 1995; Rodrigo and Barriendos, 2008). These results are coherent with a systematic analysis of 165 tree-ring series in the Mediterranean for the last 500 years, which points to an acute period of drought between 1620 and 1640, an episode that affected the whole Western Mediterranean (Nicault *et al.*, 2008). ~~Drawing on *pro pluvia* rogations (rain rogations) as proxy data and focusing on Barcelona, in this article we establish that the years 1626-1635 and 1640s constitute the most significant drought events that occurred in the city during the period 1521-1825 (highest drought frequency weighted index and drought duration index of the series). This previously unpublished drought reconstruction in Barcelona is the first contribution of our work.~~

~~In addition~~Second, following ~~the pioneering research~~scholarship on the social ~~dimensions of~~response to past climate variability (Pfister, Brázdil and Glaser, 1999) ~~and recent environmental history monographs that have incorporated historical climatology (White, 2011; Degroot, 2018)~~, we examine the diverse range of strategies deployed by the Barcelona city government to confront the recurrent drought episodes experienced during ~~these years. In contrast to the development of historical climatology in Catalonia, research on the human dimensions of climate variability is still scarce.~~the years 1626-1650. In contrast to the development of historical climatology in Catalonia, research on the human response to past climate variability is still scarce (Martí Escayol, 2019). The work of Antoni Simon i Tarrés, who highlighted the importance of drought among the complex interaction of factors that triggered social unrest in Catalonia during the late 1620s and 1630s stands out among the few existing publications on the topic (Simon i

125 Tarrés, 1981, 1992). Others have underlined that climate conditions in the 17th century
126 accentuated the agricultural, social and political crisis (Serra i Puig and Ardit, 2008).
127 The ~~relevance~~impact of ~~the climatic factor~~climate variability in the ~~Spanish~~
128 ~~context~~Iberian peninsula during the 17th century has also been ~~underlined~~stressed by
129 Geoffrey Parker, who pointed out that ~~during the reign of Philip IV~~ Spain "suffered
130 extreme weather without parallel in other periods, particularly in 1630–2 and 1640–3"
131 (Parker 2013:289)~~ and examined the revolt of Catalonia against the Spanish King~~
132 ~~(1640-1651) in this context. ~~. Parker examined the Catalan revolt against the Spanish
133 King Philip IV (1640-1652) emphasizing the key impact of extreme weather events in
134 Catalan society (Parker, 2013).

135 However, none of these authors ~~explicitly addressed the ~~examined in detail human
136 response to climatic ~~disturbances~~variability in Catalonia during these years. More
137 recently, ~~Mar Grau-Satorras has examined the example~~by focusing on the case of the
138 town of Terrassa (Barcelona region~~, Catalonia) to analyse~~), Mar Grau-Satorras has
139 analysed how local communities combined different strategies to cope with drought
140 during the 17th century, including infrastructural, institutional and symbolic responses,
141 which changed throughout time ~~(Grau-Satorras *et al.*, 2016, 2018; Grau-Satorras,~~
142 ~~2017).~~(Grau-Satorras *et al.*, 2016, 2021; Grau-Satorras, 2017). Along these lines, our
143 research focuses on the case of Barcelona as an example of Western Mediterranean
144 urban agglomeration (40,000 citizens) under severe environmental stress. Among other
145 institutional strategies in response to drought and diminishing water flows, we discuss
146 the ~~elaboration~~production of the Book of Fountains, underlining the relevance and
147 novelty of the attempt of Barcelona city government to codify water knowledge in the
148 form of a book for future ~~managers.~~urban city officers.

149 In line with ~~previous ~~research in the~~ field of~~ historical climatology re-assessing
150 traditional documentary sources or presenting innovative ones (Adamson, 2015; Veale
151 *et al.*, 2017), our research draws attention to the potential of urban water supply
152 manuals as a rare but significant source to be considered to critically interpret
153 institutional responses to droughts. While the Book of Fountains ~~has been mentioned~~is
154 known in ~~the literature about Barcelona's history~~Catalan historiography (Voltes Bou,
155 1967; Perelló Ferrer, 1996; Cubeles, 2011), ~~there is no systematic analysis of Francesc~~
156 ~~Socies work~~it remains unpublished and ~~no modern editions of the Book of Fountains~~
157 ~~have ever~~has not been ~~published.~~studied in depth. After carrying out the first complete
158 transcription and ~~study~~analysis of ~~this~~the text, this is the first article that contextualises
159 the ~~elaboration~~writing of the Book of Fountains within the ~~most intense dry years~~
160 ~~of~~severe droughts experienced in Barcelona during the ~~period 1521-1825.~~17th century.
161 Manuals of urban water supply constitute rare documentary sources, and we have only
162 identified ~~another book~~one similar book: *Le Livre des Fontaines de Rouen*, written by
163 Jacques Le Lieur between 1524 and 1525 in the city of Rouen, France (Sowina, 2016).

164 The article proceeds as follows. In the next section, we provide an overview of the
165 methods and sources used to reconstruct droughts during our period of study, as well as
166 to review the institutional responses to it. In the "Results" section we present three
167 previously unpublished figures that show the drought frequency weighted index and
168 drought duration index for the period 1521-1825, together with a timeline that presents
169 rain rogation levels in Barcelona between 1601 and 1650 at a monthly resolution. The
170 results about institutional responses are presented in the form of two diagrams showing
171 the main strategies followed by the city government and the specific years they were
172 implemented. Next, the discussion section is subdivided in three parts. First, we
173 examine how institutional responses to drought intertwined with urban and political

174 conflicts. Second, we discuss the Book of Fountains as a strategy for codifying
175 knowledge transmission and ~~improve~~improving urban water management. Third, we
176 analyse the Book of Fountains as a tool to enhance water infrastructure control. In the
177 conclusions, we summarise the relevance of our local case study and point out the
178 potential of urban water supply manuals as historical sources for both climate
179 reconstruction and past climate adaptation.
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2. Methodology and Sources

2.1 Drought reconstruction

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~~Research on historical climatology has pointed to a higher frequency and severity of cold spells during this episode (Pfister, Schwarz-Zanetti and Wegmann, 1996; Pfister *et al.*, 1998; Ogilvie and Jónsson, 2001; White, 2014). 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).

Rain rogations have been successfully used as a proxy for the reconstruction of rainfall variability (Martín-Vide & Barriendos, 1995; Barriendos, 1996; Barriendos, 1997). Rogations were a mechanism to respond to environmental stress, in this case drought. The institutions involved (agricultural guilds, city councils, cathedral chapters) have left reliable and detailed records, with data at a daily resolution. In Catalonia, rain rogations are classified in five levels, according to ~~its~~their severity. These categories can be identified by the typology of religious liturgies, from simple rogations inside the church (low, level 1) to pilgrimages to sanctuaries (critical, level 5). An integrated index is obtained by weighting data according to the severity of each level of rogation. This index is standardised so that it can be compared with other populations and regions (Martín-Vide and Barriendos, 1995).

Drawing on previous research based on this method and sources, Figure 1 provides a general view of the frequency of extreme droughts for the period 1501-1861 with data from four Catalan cities near the Mediterranean coast at a yearly resolution (Barcelona, Girona, Tarragona and Tortosa) (data adapted from Oliva *et al.*, 2018). This general view allows to identify many recurring events of medium intensity and some of very high intensity for the Catalan coast. The relevant drought events identified are the following: 1520s, 1540s, 1560s, 1620s (c. 1625-1635), 1750s, 1812-1824.

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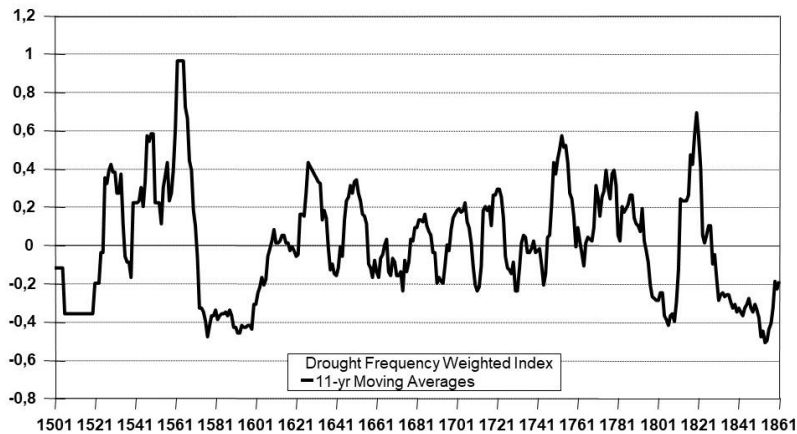
Figure 1. Drought Frequency Weighted Index (1501-1861). Standardised values. 11 years moving
averages from four cities: Girona, Barcelona, Tarragona and Tortosa. Data adapted from Oliva *et al.*,
2018.

In relation to 17th century Catalonia, Figure 1 shows two pulses of drought during our
period of study (1620-1650): a higher one approximately between 1625-1635 and a
lower one immediately after. This assessment is coherent with the systematic analysis of
165 tree-ring series in the Mediterranean for the last 500 years, which point to an acute
period of drought between 1620 and 1640, an episode that affected the whole Western
Mediterranean (Nicault *et al.*, 2008).

In order to document the impact of drought in Barcelona and the institutional measures
to adapt to it, our research delves in the Catalan capital leaving aside the other three
cities included in Figure 1. In first place, we apply the drought frequency weighted
index displayed in Figure 1 to the local data of Barcelona (see Figure 4 in the section
"Results", previously unpublished). Second, we take advantage of a variable that
provides useful information to assess the length of drought episodes. 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 that 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 introduces the possibility of analysing the duration of
drought episodes as perceived by local authorities, something that has not been studied
in this geographical context. By accounting for the amount of days per year ~~than~~that the
level 2 of drought was active in Barcelona and standardising the result to make it
comparable with other cities, we obtain an annual index of drought duration for the
period 1521-1825 (see Figure 5 in the section "Results", previously unpublished).
Finally, since the data allows for an analysis at a monthly resolution, we aim at
~~elaborating~~producing a timeline to describe the behaviour of drought and the different
rogation levels focused on the study period 1600-1650. This timeline (see Figure 6 in
the section "Results", previously unpublished) allows to distinguish if the dry months
were sporadic and irregular or appeared as a persistent anomaly for long periods.

246
2.2 Institutional response

248 Our analysis of the institutional response to drought focuses on the period 1620-1650.
249 We provide a qualitative analysis of the records produced by the Consell de Cent (city
250 government) in relation to water management during these years. Most of all, we
251 interpret the ~~elaboration~~creation of the *Llibre de les Fonts* in the context of the frequent
252 drought of our period of study. This rare source, kept at the city archives, was written by
253 the water city officer Francesc Socies during the summer of 1650, at the request of the
254 city government (AS1, Figure 2; AS2). The Book of Fountains is a manual about urban
255 water supply, a text where Socies provides instructions that codify both the knowledge
256 of his profession and the experience ~~of~~from his job position, where he was posted
257 between 1620 and 1650. The manual aimed at guiding future interventions in the supply
258 system and communicating what future water city officers should know.

262 **Figure 2**. First page of the *Llibre de les Fonts*, Manuscrits, L-15, Arxiu Històric de la Ciutat de Barcelona
263 (AHCB).

265 The structure of the book follows the water distribution system and describes it as an
266 interconnected network, from the drainage underground ~~channels~~canals in the hills of
267 Barcelona known as "water mines" (*qanats*) to the city fountains. The author indicates
268 with high precision where each element is located, both for those visible and those
269 hidden from view, underground or behind walls (water taps, pipes, water tanks or wells).
270 In addition, throughout the book, the author provides a calendar for the system's
271 maintenance within a particular urban space and time. Socies specifies where to
272 intervene and how often, for instance in relation to the cleaning of pipes and curtailing
273 the growth of trees' roots that can disrupt sections of the system (e.g. every two, four of
274 five years). Nevertheless, Socies' temporal specifications do not only apply to
275 maintenance, but also to key historical information about water property rights. Finally,
276 Socies refers several times to droughts and the lack of water supply experienced ~~several~~
277 ~~times~~ in the city during the study period.

In addition to our analysis of the Book of Fountains, a review of the secondary literature on urban history ~~has identified~~helped to identify valuable works that refer to measures approved by the city government during the 17th century to cope with drought and diminishing water flows (Voltes Bou, 1967; Perelló Ferrer, 1996). We have also reviewed the leaflets published by the city government during our period of study and found several connected to water management. In the first place, we located a pamphlet in defence of a ~~channel~~ project to build an irrigation canal to bring waters from the Llobregat River to Barcelona (AS3, published in 1627). ~~Despite~~Though this project was not carried out, we have traced several references to it in city chronicles and meeting records during the following years (AS4 and AS5). Our review has also identified four leaflets connected to a legal conflict concerning water rights, which in 1634 brought face to face the Barcelona city government and the water officer Francesc Socies with the Cathedral's Chapter (AS6, AS7, AS8, see Figure 3, and AS9).

Figure 3. First page of leaflet "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 (AS8). Source: F.Bon. 10964, Biblioteca de Catalunya.

3. Results

3.1 Drought reconstruction

Drawing on *pro pluvia* rogations, Figure 4 shows a distribution of drought frequency in Barcelona between 1521 and 1825 with different degrees of intensity. By using yearly weighted indexes, we identify the decades of 1560s and 1625-1635 as the two most significant drought events of these three centuries in the city. The latter, however, stands out for its extreme severity. Moreover, there was no similar experience with drought in the previous 50 years (approximately 1570-1620).
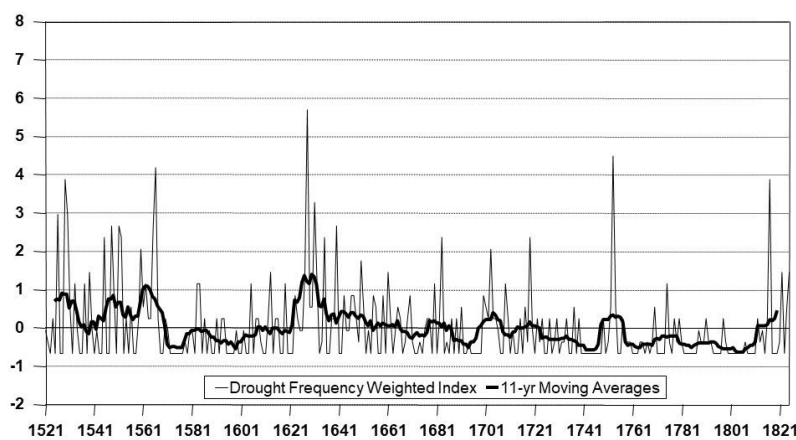
Figure 4. Drought Frequency Weighted Index. Standardised values. City of Barcelona (1521-1825). Data improved from Martín-Vide and Barriendos, 1995.

Through the development of an index of drought duration based on the records about the public exhibition of Santa Madrona relic, Figure 5 shows that the drought experienced in Barcelona during the late 1620s was perceived as longer than any other registered until that 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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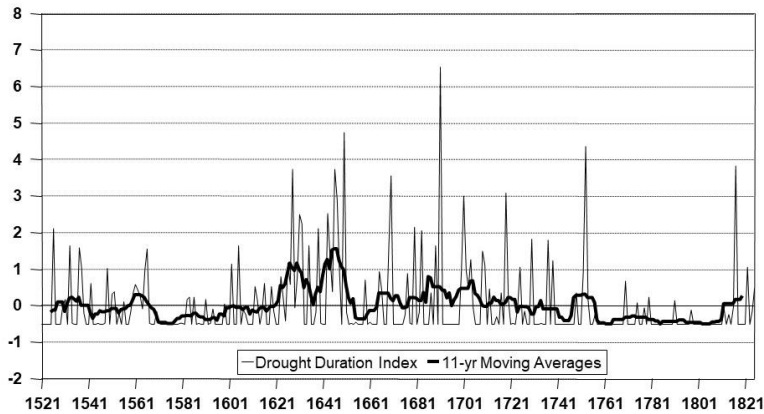
321   **Figure 5**. Drought Duration Index. Standardised values. City of Barcelona (1521-1825).

322

323   The analysis of drought duration presented in Figure 5 reveals another significant issue.
324   After the severe 1620s drought, which extends into the first part of the 1630s, there was
325   a less intense episode, very close in time, around the 1640s. ~~In~~On this occasion the
326   duration of rain rogations of level 2 —involving the exhibition of Santa Madrona– was
327   even longer than in the previous episode (Figure 5). These results do not allow to
328   analyse in detail the development of the drought episode ~~as a natural episode~~ but
329   provide an entry point to the human response to an extraordinary climate event. The
330   first drought ~~episode of the~~ period of the study (1620s to the first half of 1630s) had
331   such a social impact that the almost consecutive episode of the 1640s
332   ~~generates~~generated a proportional response. In view of the impact of drought on water
333   resources and with limited references available after two generations without similar
334   events, the duration of the rain rogations may have been extended as a response against
335   a challenging situation for local authorities.

336   Finally, Figure 6 delves into the first half of the 17th century, the period ~~when~~during
337   which the most significant and long episodes of drought have been identified in the
338   previous figures. Figure 6 visualises rain rogation levels at a monthly resolution for the
339   first time in our geographical context. This timeline allows to analyse if drought
340   appeared either sporadically and irregularly, or as a persistent anomaly for longer
341   periods. In the case of prolonged drought during the rainy seasons in the region (spring
342   and autumn), the impacts in agriculture and water supply may have been particularly
343   severe. The results shown in Figure 6 allow to identify the years 1626-1627 as the
344   beginning of the 1620-1630s drought episode shown in Figures 4 and 5. During the
345   1640s, the specific period identified spans from 1643 to ~~1648~~1650.
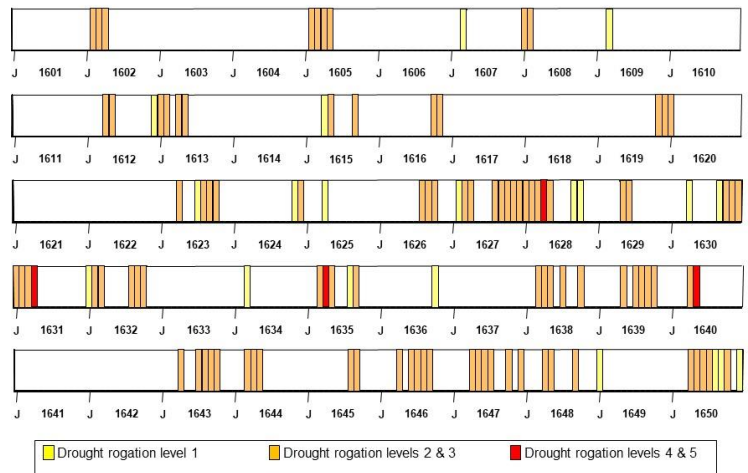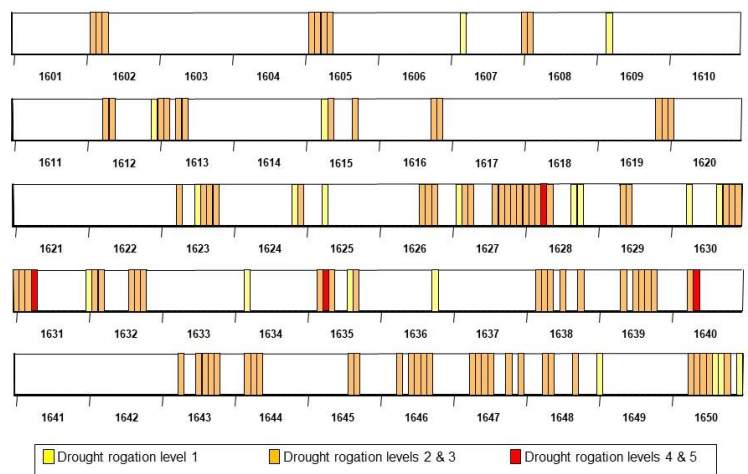
Figure 6: Monthly drought rogations levels in Barcelona, 1601-1650.

3.2 Institutional response

Throughout the period 1620 to 1650 the city government implemented a diverse range of institutional strategies to respond to drought. In the following paragraphs, we summarise these strategies, ~~which we have~~ identified ~~in~~through our review of primary

354 and secondary sources. Figures 7 and 8 synthesise these responses in relation to the two
355 periods of drought identified (1620s-1630s and 1640s).

356 One of the main strategies developed by the city council to cope with the diminishing
357 water flows caused by drought was the improvement and expansion of the urban water
358 supply sources. During the 17th century, the water supplied to Barcelona's fountains
359 came from several underground drainage ~~channels~~canals originating in the hills
360 surrounding the city. These structures, known as *mines d'aigua* ("water mines") in
361 Catalan ~~and as *viajes de agua* ("water journeys") in Spanish~~, were common in all the
362 Mediterranean and originated in the medieval *qanats* established by Muslim settlers
363 (Guàrdia, 2011; Custodio, 2012). On several occasions during our period of study water
364 flows coming from these sources decreased significantly, triggering efforts from the
365 Consell de Cent to improve and expand old *qanats* and to open new ones. Between
366 1627 and 1629, the city water officer built a new *qanat* that provided a significant
367 increase in the waters delivered to Barcelona (Perelló Ferrer 1996: 126-127). During the
368 second half of the 1640s the Consell de Cent approved the construction of a new *qanat*
369 in Pedralbes (Perelló Ferrer 1996:129).

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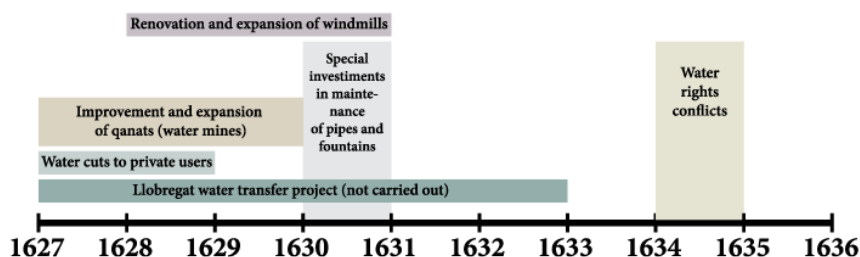
371 **Figure 7**: Strategies of institutional response to drought (1627-1636). Source: ~~Own elaboration~~The
372 authors.
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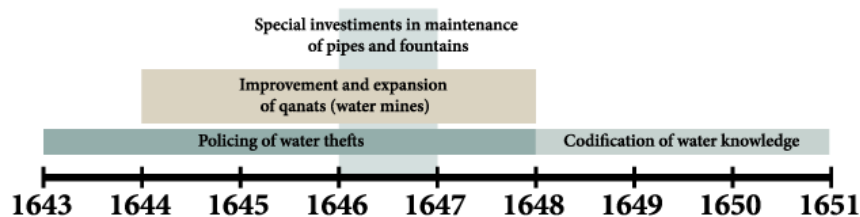
375 **Figure 8**: Strategies of institutional response to drought (1643-1650). Source: ~~Own elaboration~~The
376 authors.
377

378 Other attempts to diversify the water sources of the city were more ambitious. In 1627
379 the city government proposed to build an open water canal (approximately 12 km long)
380 connecting the river Llobregat to the city. The Consell de Cent regarded the Llobregat
381 waters as the "universal solution" to the problem of water supply, and published a
382 pamphlet detailing the many advantages of the project. Several experts in water supply
383 infrastructure came to Barcelona and worked together with the water city officer to draft

384 a detailed proposal which was submitted to the Viceroy and eventually to the Spanish
385 King (AS3). King Philip IV showed interest in the project, but also concerns about the
386 landowners affected (Voltes Bou 1967: 58-59). In 1633 the project made a comeback,
387 when the city officers called water supply experts to resume the work on the canal and
388 even started marking it on the ground (AS4). However, the Royal Privilege needed was
389 not obtained (AS5: 137, 154-155) and the project did not go ahead (Voltes Bou,
390 1967:59-60; Perelló Ferrer, 1996:127-128).

391 Along with the investments devoted to expanding and diversifying the sources of water
392 supply, the city government attempted to improve the efficiency of the existent system.
393 In 1630-1631 it devoted substantial efforts to the conservation and
394 ~~upkeeping~~maintenance of the city pipes, fixing broken sections, and cleaning those that
395 were clogged by earth and trees. During the second half of the 1640s it also invested in
396 the improvement of the city fountains (Voltes Bou, 1967:60; Perelló Ferrer, 1996:127-
397 129). ~~But in~~In moments of ~~great~~acute scarcity, the city government would actively
398 police ~~any possible theft of~~ water thefts from the urban supply system and, if needed,
399 impose restrictions to private users. The ~~acute dry conditions~~severe drought experienced
400 during 1627 and early 1628, for instance, ~~forced~~was the justification for the city
401 government to cut off water supply to almost all private users in the city (Perelló Ferrer,
402 1996:126). ~~After suspecting~~In order to confront water thefts during the 1640s, ~~in 1644~~
403 the city government went as far as approving a search into all the houses close to the
404 main pipe to find where the water leak was or who had illegally drilled into the pipe and
405 set a tap (AS1, chapter 22; Perelló Ferrer 1996:128) (see Figures 7 and 8).

406 The ~~proactive attitude of the~~city government efforts to regulate water use by ~~the~~urban
407 institutions and private actors ~~who had access to it~~sometimes created acute tensions
408 ~~with some of them.~~. A remarkable example occurred during our period of study
409 involved the Consell de Cent and the Cathedral's Chapter. In 1634, the city
410 government's decision to cut water supply to the Cathedral triggered a ~~remarkable~~
411 ~~confrontation.~~major scandal. The Cathedral's Chapter ~~immediately~~ excommunicated the
412 city water officer and the members of the Consell de Cent for offending the property of
413 the Church~~, causing a great scandal in the city~~ (AS5). ~~The~~Even if water flows to the
414 Cathedral ~~proved that~~were restored after its ~~right to~~ancient water ~~was granted by an~~
415 ~~agreement with~~rights were demonstrated and the ~~Consell dated in 1355. The~~
416 excommunications were lifted ~~the very same year, but despite accepting the Cathedral~~
417 ~~Chapter's rights~~after several weeks, the city government publicly reasserted itself as the
418 "master and owner of the waters that flow to [Barcelona's] fountains" (AS7).

419 Extreme drought did not only cause problems in the city fountains, but also in the water
420 mills needed to produce flour. During very dry ~~years~~periods, the water level in the
421 irrigation ~~channels was~~canals might not be high enough for them to function. This
422 situation forced the city government to transport the grain to locations farther from the
423 city, thus increasing the associated costs and occasionally jeopardizing the city's flour
424 supply (Simon i Tarrés 1992: 165-169). The unreliability of watermills ~~in dry~~
425 ~~years~~during severe droughts was invoked by the city government in their plea to bring
426 the waters of Llobregat river to Barcelona via a water canal. In fact, it was the reason
427 why the city government owned two windmills outside the city walls since earlier times
428 (AS3). However, due to the almost absence of dry ~~years~~periods since the 1570s, these
429 windmills ~~had been~~were little used and fell into disrepair. In 1628, the Consell de Cent
430 requested ~~its~~their renovation along with two new windmills; five more would follow in
431 1629. Therefore, the city government addressed the unreliability of watermills during

432 dry years with a great expansion of the city windmills, which grew from two to nine
433 (450%) between 1628 and 1631 (Perelló Ferrer 1996: 286-288).

434 Finally, towards the end of the study period (July 8, 1648) the Consell de Cent asked the
435 water city officer to write a book about ~~the city's~~Barcelona's water supply and the
436 operation of the city's fountains. The Book of Fountains, written during the very dry
437 year of 1650, provides a detailed description of the ~~main pipe supplying the~~ city, water
438 infrastructure, including each of ~~its~~the branches and sections of the city's main pipe,
439 along with the buildings receiving water supply and the location of the water conduits
440 and fountains (see Figure 9). The value of the knowledge compiled in the book was
441 regarded as critical, and according to the city government's instructions, it could not
442 leave the city government's grounds (AS2:325-326, 400).

443
444 **Figure 9**: The urban water supply network of Barcelona as described in the *Llibre de les Fonts*. Source:
445 Modified from Guàrdia, 2011.

446

447 The Book of Fountains did not only provide readers with a geography of the water
448 network elements, but also with a calendar for the system's maintenance and key
449 historical information about water property rights and concessions to specific buildings.
450 Moreover, it includes useful information for the reconstruction of the climate of the past.
451 Socies' account points out the years 1626 and 1627 as the beginning of a long dry
452 period in Barcelona. ~~The~~According to his testimony, the first two decades of the 17th
453 century had been a time of water abundance, when the city government supported the
454 expansion of the water distribution system and granted water concessions to several
455 aristocratic houses and monasteries (AS1, chapters 65, 69, 79 and 98). All this came to
456 an end between in 1626-1627. In Socies own words, "the abundance of waters lasted
457 until the year 1626 (…). Already in the year 1627 came a great drought and in the
458 fountains of the city there was a great lack of water" (AS1, chapter 65). When writing
459 the book in ~~the summer of~~ 1650, Socies visited the *qanats* of Nostra Senyora del Coll
460 and pointed out that it was the first time in his life that he saw them dry. After 30 years
461 on his post, Socies ~~wrote~~considered that as years passed by, the flow of water in the city
462 had been decreasing. He underlined the importance of the *qanat* construction he had led
463 in the late 1627-1629 to keep water running in Barcelona's fountains during the driest
464 ~~years~~periods (AS1, chapter 65).

465

4. Discussion

4.1 Drought stress and political tensions

In this section, we discuss how the unprecedented drought pulse started in 1626-1627 heightened micro and macropolitical tensions in Barcelona. By looking at three ways in which the institutional responses to drought intertwined with urban and political conflicts, we shed light on the complex interlinkages between drought, water scarcity, food supply and politics at the local and regional scale.

The impacts of the severe dry period started in 1627 went beyond Barcelona and critically disrupted food supply during the following years. By 1628, a contemporary witness stated that "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~~drought 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). The diminishing grain supplies could have been compensated with imports from southern France and Milan, but war and plague in these regions prevented it. The Barcelona city government ~~had~~ boosted the construction of windmills to secure the transformation of grain into flour during dry periods, when ~~water flows~~watermills were ~~too little~~unreliable (see Figure 7~~, but often there was simply no~~). However, the agricultural impact of drought in the region reduced the availability of grain~~ to be milled.~~.

During the spring of 1631, the protests for the price, scarcity, and bad quality of bread in Barcelona ended up in violent riots that ~~directly~~ threatened the lives of the city government members. In response to this subsistence crisis, the Consell de Cent assumed full control of bread production, ~~banning any production or distribution of bread by other institutions, and~~ putting in place 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. This is consistent with other studies that have identified rationing limited resources such as food or water (either by centralising its distribution or applying sanctions) as adaptive responses to climate variability (Grau-Satorras *et al.*, 2021).

~~The~~However, the very mechanisms established to cope with ~~the~~ subsistence crisis ~~of 1627-1631 in Barcelona~~ intertwined with ~~ongoing~~ power struggles, sometimes setting the scene for new conflicts. During 1633 the Barcelona city government ~~attempted~~continued to enforce ~~its~~ control ~~of~~over bread production and distribution, put into practice two years earlier. The insistent ~~public calls issued to~~warnings directed at the monasteries and the Cathedral to prevent them from producing and distributing bread suggest that these regulations were far from being followed. 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, confirming that this institution was disobeying the calls from the city government (AS5). The accusations escalated rapidly, and among the reprisals approved, the city government ordered the water officer to cut off the water supply to the Cathedral. ~~This~~In order to enforce the food rationing mechanisms, the Consell de Cent banned access to another critical resource: water.

However, this decision triggered a ~~scandal which soon went beyond the walls of the city of Barcelona. On the basis~~major conflict. Arguing that ~~they had offended~~cutting the

water flow was an offense to the property of the Church ~~by cutting the water flow,~~, the Cathedral's Chapter excommunicated the members of the Consell de Cent and Francesc Socies ~~were excommunicated~~. While it was bread production and distribution, not water, what had originally been the cause of the dispute, legal rights about water supply ~~and its value~~ were at stake. The ~~conflict cannot be interpreted as caused by water scarcity, but the recent experience on the~~ critical value of water in ~~times of~~the recent severe ~~drought~~droughts helps explaining the reprisal chosen by the Consell and the virulent response of the Cathedral. By questioning access to water, a quarrel over bread rationing and distribution rights transformed into a major legal ~~case~~dispute leading to the excommunication of the city government officials ~~ including the city~~. As pointed out by Grau Satorras *et al*. (2016), water ~~officer.~~

~~The~~ conflicts could occur independently from droughts, but were certainly intensified by them. Moreover, they often reconfigured the way water rights were dealt with. In the case of Barcelona, the city government could impose restrictions over water uses to certain monasteries or private urban users, but actors like the Cathedral's Chapter ~~soon~~actively resisted these regulations. The Cathedral's Chapter proved that~~, unlike many monasteries in the city,~~ its ~~right to receive waters~~ water rights went back as far as 1355, as ~~demonstrated~~shown by the documents kept in its archive (AS6 and AS7). Water supply to the Cathedral was restored~~, but~~ in ~~a matter of hours. In~~ the legal ~~conflict~~dispute that followed~~, even if~~ the Consell ~~acknowledged the Cathedral's rights to water, it also~~ reasserted its ~~own~~ role as the institution responsible of maintaining and overseeing urban water supply.~~In order to justify the water cut off, the city government argued that they had not been aware that the Cathedral hold old rights to these waters (AS6 and 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 was discussed in Madrid and Rome.~~ 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~~.~~; AS6, AS7, AS8, AS9).

Finally, among the diverse range of strategies launched by the city government in these years (see Figure 7) one stands out for its ambition and scale: the project to build a canal bringing the waters of Llobregat river to Barcelona. ~~Launched~~Proposed as soon as 1627, the project harmed the interests of aristocratic landowners, who opposed it consistently. The petition reached King Philip IV in the aftermath of his 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 failed ~~(Elliott, 1984). The situation repeated a few years later, in 1632, when the impact of drought in food supply had been felt and~~(Elliott, 1984; Parker, 2013). The situation repeated a few years later, in 1632, at a time when Barcelona received less than a third of its usual water supply (Voltes Bou 1967:59). The ~~conversation~~dialogue about the project was resumed ~~around the time of~~coinciding with a new fiasco at the meeting of the Catalan *Corts* with the King. The permission and Royal Privilege from King Philip IV were never obtained, and the project came to nothing despite the advanced preparations carried out by the Consell de Cent (Perelló Ferrer, 1996:127-128). Three centuries were still to pass until the waters of Llobregat were channelled to Barcelona (Burgueño, 2008; Tello and Ostos, 2012; Saurí, March and Gorostiza, 2014). ~~Lacking the political support and the resources needed for a major infrastructural work~~

563 ~~like the Llobregat canal, local authorities focused in alternative, less expensive options,~~
564 ~~such as improving the efficiency of the water supply system and expanding the already~~
565 ~~existing network of *qanats*, among other (see Figure 7). While these works increased~~
566 ~~urban water flows, they provided a precarious equilibrium in time of recurrent drought.~~

567 Facing decreasing water flows, the city government project to build a canal from the
568 Llobregat river was an ambitious attempt to increase the variety of water sources
569 supplying the city. Diversifying the sources of critical resources is an adaptive strategy
570 to cope with climate variability that has been identified in several contexts (Grau-
571 Satorras *et al.*, 2021). Lacking the political support needed for a major infrastructure
572 like the Llobregat canal, local authorities in Barcelona focused on alternative, less
573 expensive versions of the same strategy: they built new *qanats*, expanded the old ones,
574 and invested in the maintenance of the existing system (see Figure 7). Similarly, when
575 watermills proved to be unreliable, the city government rapidly approved the renewal
576 and expansion of windmills. Altogether, by diversifying water and energy sources, they
577 increased their adaptive capacity in a time of recurrent drought.

578
579 *4.2 Knowledge transmission and adaptation*

580 ~~Under the light of the troubled decades of 1620-1650 for water supply, we interpret the~~
581 ~~efforts of the city government to codify water knowledge into a book as an attempt to~~
582 ~~anticipate future difficulties by collecting the knowledge of the past. In other words, the~~
583 ~~Book of Fountains represents an effort to develop tools for future generations to cope~~
584 ~~with the impact of water stress into the urban water supply infrastructure.~~

585 ~~The city government's petition to Socies took place during~~Under the light of the
586 recurring droughts experienced between 1626 and 1650 supply, the efforts of the city
587 government to codify water knowledge into a book can be interpreted as an attempt to
588 improve future management by collecting the knowledge of the past. Like private
589 diaries (Adamson, 2015) or peasant family books (Torres i Sans, 2000; Grau-Satorras *et*
590 *al.*, 2021), the Book of Fountains aimed at gathering and transmitting experiences to
591 future generations. Following Grau-Satorras *et al.* (2021), its production can be
592 interpreted as an adaptive strategy consisting of storing information to better cope with
593 future climate variability. However, unlike private diaries or family books produced at
594 the household level, the Book of Fountains was an initiative of urban institutional actors
595 that involved the whole city of Barcelona and its water sources outside the city walls.

596 The city government asked Socies to write a book in the summer of 1648, after a
597 significantly dry spring and five years of recurrent droughts (see Figure 6). During these
598 years, the water stress suffered in the city made any suspected water theft a critical
599 matter. The aggressive ~~attitude~~approach demonstrated by the city authorities in policing
600 water thefts between 1643 and 1648 (see Figure 8) marks an increased awareness of the
601 importance of controlling urban water infrastructure (see the following section). The
602 need to expand urban water flows also involved investments in new *qanats* and
603 extraordinary funds for the maintenance of the supply network (see Figure 8). All these
604 works required additional expenditures, ~~since~~because the salary paid to the water city
605 officer included only maintenance tasks. Accordingly, the city government considered
606 that with the assistance of a book compiling urban water knowledge the expenditure
607 related to city fountains would ~~be lowered, therefore improving urban water~~
608 ~~management.~~decrease. The economic reasons to write the Book of Fountains were
609 explicitly mentioned in the petition directed to Francesc Socies (AS2:325-326).

610 ~~The city government lacked knowledge about~~When it came to intervening in urban
611 water infrastructure ~~and fully~~, the city government depended on the water city officer.
612 The severe impact of droughts during the 1630s and 1640s only made these
613 circumstances more evident. By the late 1640s, the city water officer was aging with no
614 successor in sight. ~~His~~ and the precious knowledge~~, involving almost three decades~~ he
615 embodied was in risk of ~~working with urban water infrastructure, risked~~ being lost. In
616 this context, the city government saw an opportunity to intervene in the process of
617 knowledge transmission by putting forward a proposal to write a book. Only ~~during the~~
618 ~~dry year of~~ in 1650 did Francesc Socies ~~accept this demand~~agree to the proposal, in
619 exchange of receiving a salary until the end of his life (~~AS9~~AS2:325-326). The Book of
620 Fountains was written during the continuously dry months of 1650 (see Figure 6) which
621 caused the loss of the harvest and made the year be known as "the year of misery"
622 (Guàrdia, Pladevall i Font and Simon i Tarrés, 1986:105).

623 Perhaps key to ~~his~~Socies' decision to accept writing the Book of Fountains, the water
624 officer had no direct relatives to whom pass on his knowledge and job post.

625 Traditionally, when approaching retirement, ~~it was~~ the city water officer ~~who~~ would ask
626 the city government for permission to perform his duties accompanied with an assistant
627 – usually his son or son-in-law. After working together for several years ~~— receiving~~
628 ~~only one salary —~~ the apprentice would then replace the city water officer ~~in his post~~
629 (Perelló Ferrer 1996:77). This father-to-son tradition of knowledge transmission was
630 common within guilds' structures, where family and the family house were units of
631 production (for the Catalan context, see for instance Creixell i Cabeza, 2008; Solá,
632 2008). Within this context, knowledge about professions was transmitted to direct
633 ~~family~~relatives and to apprentices. Therefore, knowledge transmission combined a type
634 of oblique transmission (teacher to pupil) with a vertical type (father to son, uncle to
635 nephew) (Leonti, 2011). This mechanism of transmission could sometimes involve the
636 creation of dynasties of the same families in the same job post, keeping knowledge
637 away from the city government (Montaner i Martorell, 1990:177).

638 By requiring Socies to write a book compiling his knowledge, the city government
639 aimed at interceding in the circuit of knowledge transmission ~~and appropriating the~~
640 ~~water city officer knowledge.~~. In other words, it aimed at putting oblique knowledge
641 transmission under institutional control. The ~~elaboration~~production of the Book of
642 Fountains shall be contextualised within the emergence of technical and practical
643 manuals to transmit knowledge (Eamon, 1994; Long, 2001; Cifuentes i Comamala,
644 2006). The ~~knowledge recorded~~information stored in these manuals, however, was not
645 meant to be made "public" in the modern sense. In the case of the Book of Fountains,
646 water knowledge could not be disseminated for the sake of the institutions' own
647 interests and for security reasons. The process of knowledge transmission revealed
648 critical details about the location of water infrastructure, potentially subject to attack or
649 disruption. Secrecy around infrastructure was strategic for the survival of the city, both
650 for external circumstances —the 1630s and 1640s were marked by war and the threat of
651 military siege— and internal struggles with other city institutions such as the Cathedral's
652 Chapter. The strategic value of this knowledge explains the city government's
653 instructions, which established that the book should remain perpetually in the city
654 government's premises. This also showed an explicit intention of appropriating the
655 knowledge inherently associated to the water officer's job post, restricting the access to
656 it to those authorised by the city government.

657 Writing the Book of Fountains was about compiling the knowledge of the past, but also
658 about creating an object that could ~~collect~~store future information. Francesc Socies

659 demanded the involvement of his readers –future water city officers– to ensure that the
660 book remained a useful tool. He ~~required~~asked them to record at the margins of the text
661 any intervention in the water network, thus keeping knowledge to date for future
662 generations (AS1:262). By involving future water officers into the authorship, the book
663 aimed at becoming a transgenerational endeavour, a collective heritage under the
664 control of the city government. In this way it became useful for the present as a physical
665 object, but also a perdurable, vital tool for the city's future. By obtaining a book that
666 transmitted knowledge to future managers, the city government aimed at improving the
667 institutional capacity ~~for adaptation to future environmental stress.~~to respond to future
668 environmental stress, while it reduced its dependence on the city water officer.
669 Moreover, armed with the knowledge compiled in the book, the city government was
670 much better equipped to impose control over urban water users.

671

672 *4.3 Enforcing control over water infrastructure*

673 The scandal of the excommunication of the Consell de Cent and the city water officer
674 after the water cut-off to the Cathedral in 1634 came after some of the driest years
675 remembered in Barcelona (see Figures 4, 5 and 6). The city government ~~emerged~~came
676 out from ~~the~~this conflict with renewed awareness about the importance of enforcing
677 control over water supply, but also of monitoring information about water concessions
678 and water rights, which could help avoiding similar conflicts in the future. In line with
679 the declaration that the city was "master and owner of the waters that flow to its
680 fountains~~", during the following years~~" (AS7), the city government devoted more and
681 more attention to watch out its water resources and remained wary of any violation of
682 its water rights.

683 The production of the Book of Fountains was ~~in line~~consistent with this
684 ~~behaviour~~strategy. The ambition to ~~elaborate~~write a book containing urban water
685 knowledge and the explicit requirement that it should be kept in the city government's
686 grounds made clear the Consell's determination to reinforce its position as the
687 institution responsible for water management in the city, and therefore to reaffirm its
688 capacity to use water as a tool to control urban space (AS2:325-326). In other words,
689 enhancing the city government's control over urban water flows was also one of the
690 goals behind the codification of water knowledge. ~~Elaborating the~~The Book of
691 Fountains was not only a way of storing information and improving adaptation to future
692 climate variability. It also meant creating a valuable tool to enforce control over urban
693 water flows and infrastructure. In terms of water property and rights, writing was an
694 instrumental juridical tool for the city government to ~~reassert itself as the "master and~~
695 ~~owner of the waters that flow to [Barcelona] fountains", fully in line with the statement~~
696 ~~made during the conflict with the Cathedral's Chapter in 1634 (AS7).~~reaffirm its
697 political power.

698 ~~With his writing~~Through the pages of the Book of Fountains, the water city officer
699 established the ~~water's~~itinerary of urban ~~journey~~waters from source to tap, defining who
700 the proprietor of this knowledge was and institutionalizing who had the power to control
701 it. When referring to specific places in the city, he often established a symbolic relation
702 between the written text and the urban fabric. ~~Text and~~To connect the text with the
703 territory ~~become inseparable, and as a connector, the author~~, Francesc Socies used a
704 ~~figure~~symbol –the cross– ~~sometimes~~either in the text ~~but more often~~or in its margins,
705 making its location ~~faster~~easier to readers. These crosses written in the book refer to
706 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 inscribed urban water ~~urban~~ geography into the pages of the Book of Fountains (see Figure 10).
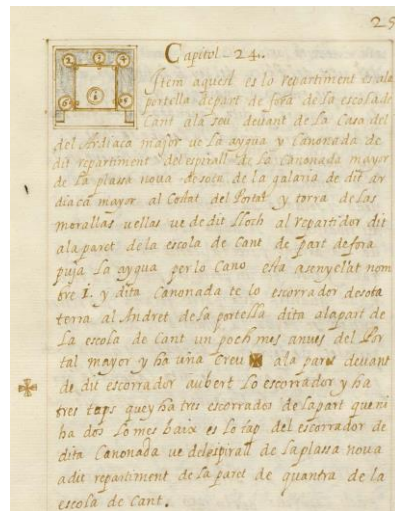
Figure 10: Book of Fountains, chapter 24. On the lower left side, a cross marks a reference for the reader. The text refers to the location of the same cross in the urban fabric. Source: *Llibre de les Fonts*, Manuscrits, L-15, Arxiu Històric de la Ciutat de Barcelona (AHCB).

This intention of controlling urban space, based on the need of preserving water supply, was also explicit in Socies' instructions to future managers. In order to keep a regular water flow running in the city's fountains, the city government needed to be able to detect and solve any incident rapidly, particularly in relation to water thefts. To this end, Socies explained how he had been remaking the water network that ~~run~~ran through internal parts of buildings, moving ~~it~~pipes to their external sections~~, in order~~ to hinder any attempt to illegally tap into ~~the water network.~~them. He recommended continuing with these reforms in the future, ~~to put the network~~so that water infrastructure remained as much as possible ~~under control~~within reach of the water city officer ~~and make~~, simplifying its surveillance ~~simpler~~ (AS1, chapters 26, 78 and 79).

5. Conclusions

This article examined past climate variability in the city of Barcelona (Western Mediterranean) ~~engaging~~focusing both ~~in~~on drought reconstruction and the institutional responses to it. First, drawing on *pro pluvia* rogations as documentary proxy data, we ~~have~~ provided a detailed reconstruction of drought frequency and duration between the years 1521 and 1825. The years 1625-1635 register the highest drought frequency weighted index of the series (Figure 4), while the 1640s stand out in the drought duration index (Figure 5). Second, we ~~have~~ examined the institutional strategies ~~launched~~followed by the city government in response to drought ~~during the period identified as most relevant (1626 to 1650).~~. Among other strategies, these involved ~~new~~diversifying the sources of urban water supply ~~infrastructure, enhanced efforts in system maintenance,~~, enforcing restrictions over water uses and ~~the elaboration of a book~~ compiling ~~urban~~the city water officer's knowledge into a book. We discussed these ~~measures taking into account~~actions considering the complex interlinkages of drought with food supply and ~~political conflict~~social unrest.

By focusing on the historical analysis of drought in Barcelona, our research corroborates and expands previous work ~~about~~ that had identified a dry period in the Western Mediterranean between 1620-1640 (Martín-Vide and Barriendos, 1995; Nicault *et al.*, 2008). ~~Moreover, by providing insights about the strategies implemented by a major city of 40,000 inhabitants to confront a severely dry period, we expand the work on human response and adaptation to drought (Grau-Satorras et al., 2018). Among these strategies~~Moreover, by examining the social impacts of drought in a major city of 40,000 inhabitants, we contribute to the discussion about the importance of climate variability among the factors that contributed to social unrest in Barcelona and Catalonia during the years leading to the Catalan Revolt (1640-1652). In addition, our analysis of the institutional strategies to cope with drought contribute to the scholarship on societal adaptation to climate variability (Degroot, 2018; Grau-Satorras *et al.*, 2021). In this regard, among the strategies analysed, the codification of urban water knowledge stands out for its novelty. Finally, by showing how the information collected in the Book of Fountains can be used both for reconstructing past drought events and for examining institutional adaptation, we argue that manuals of urban water management are rare but valuable documentary sources to be considered in the field of historical climatology.

Written in 1650, right at the end of the most significant drought period identified in Barcelona between 1521 and 1825, the Book of Fountains offers an authoritative voice on the perception of urban water flows: that of the city officer in charge and his thirty years of experience. His assessments of the severity of drought during the years 1626-1627 or the summer of 1650 correspond with ~~the~~our results of the analysis of *pro pluvia* rogations. This cross-check reinforces the authority of both documentary sources used in our research. In essence, the Book of Fountains constitutes a mechanism to store and transmit ~~and preserve~~ key knowledge to cope better with environmental stress. In a context marked by drought and diminishing urban water flows, the Book of Fountains was a complex form of adaptation directed at improving the efficiency of urban water management systematising historical information about repairs and maintenance, reducing expenditure. and preventing conflicts about water rights. ~~In order to prepare for an uncertain future, water knowledge had to be taken from a specific family line or profession and codified into a book under the control of the city government.~~

775 From this perspective, the Book of Fountains can be interpreted as an outcome of the
776 institutional learning of three decades of coping with severe water stress. Years of local
777 and regional tensions reinforced the city government's legal claims over the
778 management of urban water supply. A coherent step to reassert the position of the
779 Consell de Cent as the "master and owner of the waters that flow to [Barcelona]
780 fountains" was to codify knowledge about urban water rights, water distribution and
781 maintenance into a book. In times of drought, more than ever, the knowledge about the
782 old *qanats*, pipes, deposits and fountains that formed the water supply network, together
783 with the centenary water rights that regulated it, was key to the exercise of political
784 power. A book containing all this information was a treasure that had to be carefully
785 kept for future generations.

786

Author contribution

Santiago Gorostiza conceived this research with Maria Antònia Martí Escayol and wrote the introduction, ~~conclusion~~conclusions, and ~~section~~sections 2.2, 3.2, 4.1 and 4.3 of the text. He made significant contributions to the rest of the ~~text~~article. In addition, he handled the coordination, integration, translation, and revision of texts, as well as the peer-review process.

Maria Antònia Martí Escayol conceived this research with Santiago Gorostiza and wrote section 4.2 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~~4.1 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~~sections 2.1 and 3.1 of the text.

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Competing interests

The authors declare no competing interests.

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