

1           **DOCUMENTARY EVIDENCE OF DROUGHTS IN SWEDEN BETWEEN THE**  
2   **MIDDLE AGES AND c1800**

3  
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6  
7           **Abstract**

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9           This article explores documentary evidence of droughts in Sweden in the pre-instrumental  
10           period (1400-1800). The database has been developed using contemporary sources such as  
11           private and official correspondence letters, diaries, almanac notes, manorial accounts, and  
12           weather data compilations. The primary purpose is to utilize hitherto unused documentary data  
13           as an input for an index that can be useful for comparisons on a larger European scale.

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15           The survey shows that eight sub-periods can be considered as particularly struck by summer  
16           droughts with concomitant harvest failures and great social impacts in Sweden. That is the case  
17           with 1634-1639, 1652-1657, 1665-1670, 1677-1684, 1746-1750, 1757-1767, 1771-1776 and  
18           1780-1783. Within these sub-periods, 1652 and 1657 stand out as particularly troublesome  
19           years. A number of data for dry summers are also found for the middle decades of the 15<sup>th</sup>  
20           century, the first decade of the 1500s and the 1550s.

21  
22           *Introduction*

23  
24           The purpose of this paper is to present documentary evidence of drought in Sweden for the  
25           period 1400 to 1800. We also try to present a link between instrumental data from precipitation  
26           and temperature to our drought index. Is it possible to distinguish periods of drought in Sweden  
27           through documentary sources from the 15<sup>th</sup> till the 18<sup>th</sup> century?

28                         Stretching from 55° N to 69° N Sweden is characterized by arctic climate in the  
29           extreme north and temperate climate in the south. Located between the Baltic Sea and the  
30           Scandian mountain range wet weather from the Atlantic affects the western part of Sweden,  
31           while the eastern part is protected both by the Scandian mountain range and highland in the  
32           south, rendering average precipitation in the eastern part between 300 and 700 mm a year,  
33           compared to western part which ranges between 800 and 1200 mm a year. The length of the  
34           winter and the length of the growing period, which varies in a southern-northerly direction,  
35           have the most distinct effect on agricultural production and society in general. Still, the early  
36           modern history of Sweden gives evidence of repeated periods of severe droughts.

37                         In general, drought at the latitude of Sweden is caused by deficient precipitation  
38           and only occasionally by excessive temperature and evapotranspiration. Sometimes several  
39           meteorological and hydrological factors do combine to produce severe drought with serious  
40           socioeconomic consequences. For example, apart from deficiency in precipitation  
41           (meteorological drought) seasonal lack of streaming water can also be the result of late spring  
42           or low summer temperatures in the Scandian mountain range when snow fail to melt at a normal  
43           pace resulting in insufficient discharge into the rivers which produces streamflow  
44           (hydrological) droughts and/or low flows (Hisdal and Tallaksen 2000). Insufficient spring  
45           floods also partly lies behind failed harvests of hay grown in wet meadows and in historical  
46           times concomitant raised cattle mortality. Conversely, low water levels in streams due to dry  
47           autumn/summer weather facilitates quick freezing in the early winter and implies further  
48           obstacles to running watermills. Therefore, in the long run droughts do affect agriculture but  
49           strike more directly at industrial activities depending on water power. Socioeconomically this

50 has had serious consequences for Sweden, to a large degree dependent on mining and exports  
51 of iron and copper especially from the 17<sup>th</sup> century onwards.  
52

### 53 *Sources*

54

55 The indices used in this paper have been constructed from a database launched by prof. emer.  
56 Johan Söderberg, Department of Economic History, Stockholm university, where both authors  
57 of this paper have contributed too through adding weather information by excerpting original  
58 data from letters, chronicles, newspapers etc. The database consists of a wide variety of  
59 documentary sources: diaries, official letters, chronicles, as well as published articles in papers  
60 from the Royal Swedish Academy of Sciences and early newspapers. This database will be  
61 available to the public through the Bolin Centre later this year (only in Swedish though.) The  
62 database has some 20,000 entries from 1500 to 1870.

63 A typical statement of a severe drought is found in the diary of the parish priest  
64 Petrus Magnii Gyllenius, who also made summarized descriptions of entire years, in the  
65 province of Värmland. For the year 1652 he writes (our translation): “In the beginning of May  
66 it rained a little. Then there was a great drought, this year was called the great drought year. No  
67 rain fell, neither in Sweden or Finland, between early May and late September, with the  
68 exception of 25 June when some thunder rain fell over Letstigen in [the province of] Närke, as  
69 on 30 June when it rained a little in Karlstad. In Sweden there was a quite great harvest failure  
70 this year for grain due to the severe drought and heat. The drought destroyed the grain in many  
71 places, so that nothing was saved of the spring seed, and there were dear times. At the same  
72 time there was little hay [...] Forest fires caused great damages in Sweden and Finland. Bridges  
73 and hay barns burned” (Hausen 1880: 198-201).

74

### 75 *Instrumental measurements*

76

77 In this study we have used homogenized historical instrumental data from Stockholm  
78 observatory. The temperature record begins in 1756 and precipitation data in 1786. The first  
79 thing we wanted to do was to examine if there was any relationship between  
80 precipitation/drought and temperature since precipitation data before 1859 seem more  
81 unreliable than after that year: the data are not represented with decimals and correlation  
82 coefficients between precipitation and temperature become non-existent. Precipitation data  
83 before 1893 also exhibit severe under-catch problems (Moberg et al, 2003: 1501). Moberg et  
84 al adjust precipitation data with different factors, which we have not done, since our focus is  
85 the drought index and the kind of factor increasing adjustments done there will have no effect  
86 on correlation coefficients.

87

### 88 *Method*

89

90 In this article, the annual indices from documentary data have been based on the stated intensity  
91 of the drought event and its spatial extension. It has only been possible to construct reliable  
92 indices for the 16<sup>th</sup>, 17<sup>th</sup> and 18<sup>th</sup> centuries since no continuous time series can be reconstructed  
93 before that due to insufficient amounts of documentary records. Nevertheless, an overview of  
94 documentary data from the 15<sup>th</sup> century will be given.

95 For some years, the documentary data are too contradictory to enable any definite  
96 conclusions. In some cases, it derives from regional variations. One example is from 1554,  
97 when there was “severe drought” in the province of Uppland and at the same time good harvest  
98 in the Kronoberg province further to the south (Forssell 1884, bil A: 161). But even when data  
99 are relatively plentiful, they can be contradictory. One such example is the year 1733. Some

100 data from that year speak of an “unusual” drought in the provinces of Västergötland in the west,  
101 and Hälsingland and Dalarna further to the north in May (Broman 1911-1949: Olofsson and  
102 Liedgren, 1974: 261). In a period of 18 weeks between early March and the end of June only  
103 three short showers of rain are said to have fallen in Västergötland, a province with typical  
104 humid weather conditions, and the water level of Lake Vänern was quite low (Bergstrand 1934:  
105 196; Wallén 1910: 13). At the same time the harvests were good in general in Sweden and there  
106 are no reports of harvest failures (Utterström 1957: 429). In Västergötland itself the harvest was  
107 even said to have been plentiful (Olander 1951: 119). The explanation for this discrepancy may  
108 be different timings of sowing of different crops, where e.g. early-maturing crops like barley  
109 and wheat (the latter of those was cultivated in Sweden only to a small degree before the 19<sup>th</sup>  
110 century) (Söderberg and Myrdal 2002) suffered most and crops with a long growing season,  
111 like rye and buckwheat, could survive. In no case there are evidence of droughts covering the  
112 entire growing season, which means that no generalized nutritional catastrophe has been  
113 registered. A mitigating factor was that periodically local demand for foodstuffs was reduced  
114 through the absence abroad of a large part of the male population in the numerous wars Sweden  
115 fought in Europe between 1563 and 1718.

116 The most important part of the present analysis is the construction of an index.  
117 The construction was made comprehensively so that notices on drought or precipitation were  
118 evaluated within the context of the database.

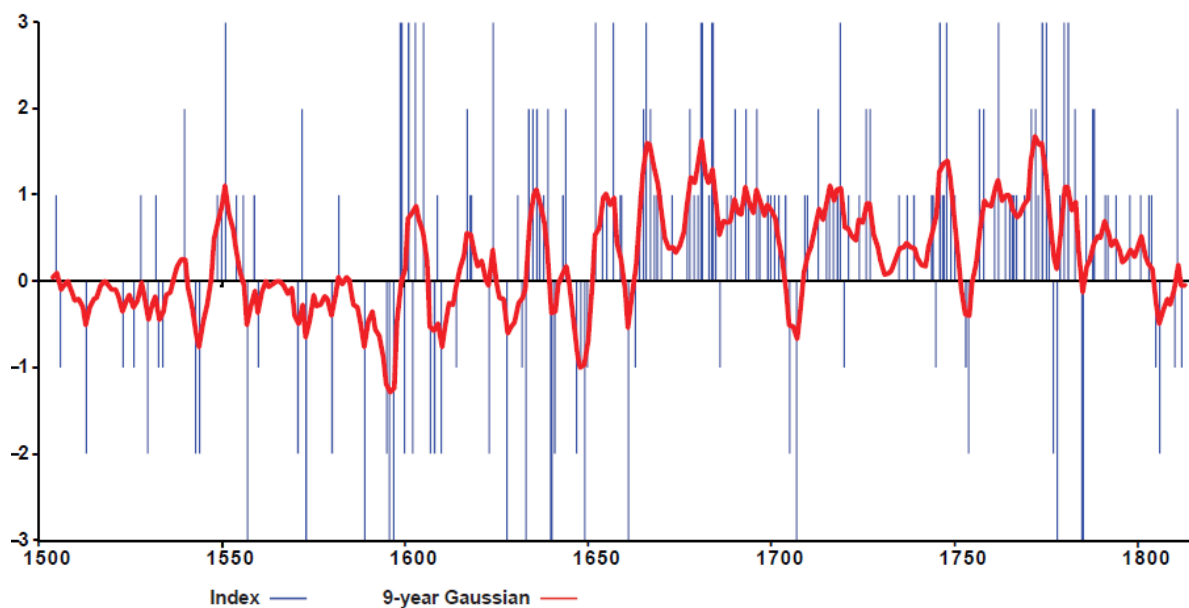
119 As can be seen in Figure 1, there are many more notices which we have  
120 labelled “dry”, especially in the 18<sup>th</sup> century, than there are notices on “wet” conditions. The  
121 word “rain” occurs 3,361 times in the database (of a total of 20,896 entries), while the word  
122 “sun” only occurs 1,224 times. However, varieties of “heat”, “dry”, “warm” occur 1,726 times  
123 compared to the two words describing “wet” in Swedish, which only occur 292 times. Many  
124 notices regarding rain are of the kind “A beautiful rain fell”; suggesting that rain was  
125 welcome. Generally, wet conditions are defining for agriculture in Scandinavia, but many  
126 fields are located such that they have a natural drainage (Leijonhufvud 2001: 130). These  
127 findings suggest that although notices of rain are more frequent than notices describing fine  
128 weather, consequences of “fine” weather were more troublesome. Figure 1 depicts the  
129 drought/precipitation index that has been constructed. Positive signs indicate descriptions of  
130 droughts that have caused problems or concern and negative values indicate years when  
131 precipitation have been the cause for such impressions. Superimposed is a 9-year quasi-  
132 Gaussian smoothing filter.

133

134 Fig. 1. Drought/precipitation index 1500–1816

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137  
 138 Note: We wish to thank associate professor Fredrik Charpentier Ljungqvist at the Stockholm University for his  
 139 help with the graphs.

140  
 141 Correlation between proper instrumental data of temperature and precipitation, from the same  
 142 observational site of Observatorielunden in central Stockholm showed, rather surprisingly, a  
 143 slightly negative correlation between summer (JJA) temperatures and precipitation of -0.35.  
 144 This result is similar to Moberg et al 2003, Table VI, which is higher, probably because of a  
 145 slightly different period (1873-2000).

146 Since there are no reliable precipitation/drought data before 1860, we have  
 147 tested the index against the Stockholm temperature series from 1756. Correlation between the  
 148 index and average monthly temperature for the period 1756-1816 turned out significantly for  
 149 the months May, June and July (Table 1) with the highest correlation received using MJJ-  
 150 temperatures. However, since correlation for instrumental data between precipitation and  
 151 temperature in May was very weak (non-existing), we argue that the standard season of  
 152 summer months (June, July, August) will be more adequate in our exploration of droughts.  
 153 Correlation between the index and average monthly temperature for the period 1756-1816  
 154 turned out significantly for the months May, June and July (Table 1).

155  
 156 Table 1: Correlation between average monthly temperatures against the drought index 1756-  
 157 1816 and precipitation of Stockholm for the period 1859-2011 (daily observations calculated  
 158 to monthly values).

	April	May	June	July	Aug	MJJ	JJA	C-Scan
Index	0.26	0.30	0.52	0.38	0.13	0.51	0.47	0.08
Precip	-0.15	-0.24	-0.30	-0.38	-0.33	-0.25	-0.35	0.20 (Jan)

159 Precipitation data were downloaded from <https://www.smhi.se/data/meteorologi/ladda-ner-meteorologiska-observationer/#param=precipitation24HourSum.stations=all.stationid=98210> on 22<sup>nd</sup> January 2020

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 163 *Documentary data on droughts for the 15<sup>th</sup> and 16<sup>th</sup> centuries*

164  
 165 For the 15<sup>th</sup> and 16<sup>th</sup> centuries documentary data are scarce, uneven and spread out in a  
 166 number of different source categories. Indeed, there is a number of evidences for harvest  
 167 failures, although the reasons are rarely stated (Retsö 2015). It is possible that prices of certain

168 other goods contain climatological information, in particular wax and honey, both highly  
169 dependent on weather conditions in the summer. During the last three decades of the 16<sup>th</sup>  
170 century, production of bee wax was much reduced in Sweden, probably due to the transition  
171 to a cooler and wetter climate which was damaging to the bees (Husberg, 1994). Further  
172 archival research is needed to expand wax price series needed for climatic research. Grain  
173 prices seem to be more associated with temperature than drought variability (Charpentier  
174 Ljungqvist, 2021, in print).

175 Data on agricultural activities in the province of Ostrogothia are found for a few  
176 years in the first and last decades of the 15<sup>th</sup> century. Harvesting dates for 1402, 1407 and  
177 1410 suggest close to normal summer temperature and precipitation (Lundén, 1958: 141, 161,  
178 133; Retsö, “Normality and anomaly”, in preparation) while available data on dates for  
179 sowing of barley and other grains and fodder for swine indicate somewhat late or cold spring  
180 in 1491, and early or warm spring in 1489, 1490 and 1492 (Alvered, 1999: 104, 145, 192,  
181 245).

182 Food crises are frequently mentioned in the 15<sup>th</sup> century, in particular the four decades  
183 between 1430 and early 1470s. It is assumed here that the mentioning of a food crisis in a  
184 particular year reflects a harvest failure the preceding year. As for the 1430s, we know that a  
185 period of crisis years began in 1435 and although we have no Swedish evidence of dearth for  
186 the first years of the decade, it can be noted that Danish and German sources mention hard  
187 times and high corn prices in 1433 that could be connected to cold springs (see Camenisch et  
188 al., 2016: 2110). It is also conspicuous that a major peasant uprising occurred in Sweden in  
189 1434 and it can be suspected that it had something to do with a food crisis in combination  
190 with unusually high taxes. In the spring of 1437, there was a lack of food grains in Finland  
191 and famine and dearth in Sweden are mentioned in early 1438 (Hausen, 1921 no. 2220;  
192 Tunberg, 1937: 214). The monetary valuations of the barley tithes in Funbo parish in Uppland  
193 in 1438 and 1439 more than doubled compared to the preceding years (Andræ, 1965). These  
194 years are well-known in continental Europe as a time of food crises with concomitant social  
195 and economic impacts. The harvests of 1437 and 1438 were the worst in England during the  
196 15<sup>th</sup> century, and the price of grain rose to an exceptionally high level in 1439. The famines of  
197 the mid-1400s occurred in a context of repeated plague epidemics also hitting Sweden  
198 (Myrdal, 2003: 249). They also fall within a subperiod of colder summers related to a Spörer  
199 minimum of solar activity within a longer period (1400-1550) of slightly warmer summers as  
200 compared to the 20<sup>th</sup> century, at least in northern Fennoscandia, according to tree-ring data;  
201 the eruption of Mount Fuji in 1435/1436 in Japan may have contributed to cold winters and  
202 late and cool summers in north-western Europe during these years (Moberg et al., 2006: 24,  
203 26ff; Campbell, 2009: 30; Camenisch et al., 2016: 2110).

204 The 1440s were also troubled by harvest failures. In 1442 the rye and hops harvest  
205 failed in Finland (Hausen, 1921 nos. 2512 and 2517; Bunge and Hildebrand, 1889 no. 955.  
206 See also Hausen, 1921 nos. 2521, 2528, 2529, 2535) and just a few years later the Vadstena  
207 abbey was forced to sell some of its valuable chalices and shrines in order to buy food, due to  
208 the harvest failures in 1445 and 1446 (RA = Riksarkivet (National Archives of Sweden),  
209 Stockholm, Medieval codex A21 fol. 89r-v). From 1446 there is information on famine in  
210 Sweden (Hadorph, 1674: 370ff) and 1448 was described as a year of dearth in Stockholm due  
211 to a dry spring and much rain from late May onwards (Klemming, 1866: 255).

212 The Vadstena annals describe the years 1454-1457 as struck by famine, which in the  
213 first of these years was combined with an outbreak of plague (Gejrot, 1996: 286f, 292f;  
214 Styffe, 1870: 85. See also Christensen, 1895: 297 n. 2; Fant, 1818: 173, 175; Codex dipl. lub.  
215 1:9, no. 328; Ropp, 1883 nos. 516, 520) and in 1470 there was famine in Finland (Hausen,  
216 1924 no 3142). This, as well as the harvest failure of 1460, may have had something to do

217 with a volcanic eruption in the Pacific in 1453, marking the onset of a 15-year cool period  
218 (Esper et al., 2017).

219 Also the early 1470s display evidence of a period of hot and dry weather, apparently an  
220 all-European phenomenon (Camenisch et al., 2020). In August 1474 the council of the  
221 Swedish realm issued a statute regulating the use of watermills due to repeated droughts, i e  
222 presumably causing lack of water (Hadorph 1676 no. 9). Furthermore, food crisis is indicated  
223 in a letter from Åbo (Turku), Finland, from May 1471 (Hausen 1890 no. 625), in Sweden  
224 nominal grain prices display an unprecedented peak in the early 1470s, (Franzén and  
225 Söderberg 2006) and the Danish Roskilde annals speak of a “severely hot and burning  
226 summer” in Denmark in 1473 (Rørdam 1873).

227 Summarizing, the years in the 15<sup>th</sup> century with harvest failures and/or unusually early  
228 onsets of the growing season are the following: 1402, 1405, 1436-1437, 1439, 1442, 1445-  
229 1446, 1448, 1453-1456, 1460, 1469-1470, 1473-1474, 1489, 1490 and 1492.

230 From the first decade of the 16<sup>th</sup> century there are a number of reports of harvest failures  
231 and famine. In Västergötland, Småland and the Stockholm area they speak of unsown fields,  
232 starving peasantry forced to eat bark, and expensive corn that point to a harvest failure in 1503  
233 (RA Sturearkivet nos 255, 637; Styffe 1875 no 232). Shortage and poverty among the peasants  
234 is reported for the following year (Wegener 1866-1870: 319-20). In southwestern Finland the  
235 harvest of 1507 had been consumed already in July 1508 and the peasantry suffered famine and  
236 “ate more bark than ever” (Hausen 1930 nos. 5324, 5329). Similar reports are found for the  
237 same year from mid-Sweden and the Stockholm area (RA Sturearkivet nos 573, 597). 1508  
238 seems to have been even worse. Again, prices on rye were high in March 1509, but already by  
239 harvest time in 1508 prices were rising in Finland and the misery was said to be the worst in  
240 ten years; by the end of the year the country was ravaged by both great poverty and plague,  
241 unabling the peasantry to pay their taxes (Sjödin 1937: 336; Hausen 1930 nos. 5341, 5347,  
242 5354, 5368). The same was reported from Sweden; in March 1509 the peasants northeast of  
243 Stockholm starved and ate bark (Sjödin 1937: 322, 344, RA Sturearkivet no. 1053, Styffe 1875  
244 no 229). Widespread poverty was also reported as a result of a bad harvest in 1509, already in  
245 December in central Sweden, and in the spring and summer of 1510 (Sjödin 1937: 350; Styffe  
246 1875 nos. 302, 304, RA Sturearkivet no. 1467).

247 In both Finland and south-eastern Sweden there was severe drought in late spring and  
248 summer of 1551 (Almquist 1905: 115ff, 123ff, 212f, 430ff). Also, in the autumn there was a  
249 severe drought in the Bergslagen mining area (Almquist 1905: 430ff, Johansson 1882: 159f).  
250 In June 1559 the harvest of both rye and barley in Östergötland and southeastern Småland were  
251 in danger already in its blooming time due to both night frost and drought (Almquist 1916: 190,  
252 202, 651). The same was reported from Finland in September (Almquist 1916: 287). Apart from  
253 1551 and 1559 there are also reports from other years of the 16<sup>th</sup> century but they are sporadic  
254 and it is uncertain as to how extensive the droughts were. In 1599, there are evidence from  
255 southeastern Småland of severe heat and forest fires (Edman 1985: 74; see also Utterström  
256 1955: 29, Hallendorff 1902: 79) and the production of honey was reduced drastically (Husberg  
257 1994: 275).

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#### 260 *Documentary data on droughts for the 17<sup>th</sup> and 18<sup>th</sup> centuries*

261  
262 For the 17<sup>th</sup> and 18<sup>th</sup> centuries sources are far more abundant and continuous, among other  
263 things thanks to a number of private diaries. Some periods stand out as particularly hit by  
264 moderate to extreme drought. That is the case with 1634-1639, 1652-1657, 1665-1670, 1677-  
265 1684, 1746-1750, 1757-1767, 1771-1776 and 1780-1783 (with two years of extreme drought  
266 each) and 1634-1639 (with one year of extreme drought). Among these, 1652 and 1657 stand

267 out as particularly troublesome. Other single years seem to have been dry on an all-European  
268 scale, like 1540 (Wetter et al 2014). Although some of the dry periods recorded in Sweden  
269 coincide with similar drought episodes in other areas of Europe (see e.g. Brázdil et al., 2016),  
270 negative spatial correlations are to be expected between northern and southern Europe.

271 Eight periods stand out as particularly critical in terms of drought in the 17<sup>th</sup> and  
272 18<sup>th</sup> centuries (for references for the particular years, see Table 4 below).

273 1) 1634-1639. There are reports of drought from the north as well as the south  
274 every year in this period. Weather conditions are characterized in the relatively detailed sources  
275 as generally dry with a typical pattern of dry and cold springs, hot and warm summers and  
276 rather wet autumn seasons. The result was disaster for the harvest of hay but rather good  
277 harvests of rye. The hardships could even have begun earlier than 1634; in June 1635 Gabriel  
278 Gustafsson Oxenstierna wrote to his brother that poverty was widespread in the whole country  
279 after “the last years [i.e. plural] of dearth” (Sondén 1890: 363).

280 2) 1652-1657. 1652 was called the Great Drought Year already in contemporary  
281 sources. Several reports from virtually all regions of the country tell about dry weather caused  
282 by lack of rain and excessive heat. According to one source no rain fell between early May and  
283 late September, except for some thunder rains in Karlstad and at Letstigen in the province of  
284 Närke in June. Grain and hay harvests suffered severely except for rye and particularly in  
285 Finland, which fared slightly better. Great bushfires were rampant, destroying forests and rye  
286 in the fields. Watermills stood still due to dried out rivers. The heat caused epidemics killing  
287 many people, including members of the Royal Council. Also, from 1657 there are reports  
288 covering all of Sweden about severe drought. Already in April the gardens were “longing for  
289 rain”. In Johan Rosenhane’s diary from Östergötland every day is noted to have been hot or  
290 very hot weather from early May to late August. Both the month of August and the entire year  
291 is said to have been so dry and hot that wells and streams went dry in Småland and Östergötland  
292 and that no one could remember such a drought. In the spring, eleven out of 65 iron mills in the  
293 Bergslagen region were unable to operate due to lack of water, especially those located by  
294 smaller rivers, and most of them had to limit their operations considerably during the whole  
295 year. The lack of water in the rivers running into Lake Mälaren is also shown by the fact that  
296 the water level of the lake was so low that sandbanks were visible. Even in the northern province  
297 of Norrbotten the summer drought caused forest fires and much damage on the harvest.

298 3) 1665-1670. The last years of the 1660s was a new period of dry years. 1666  
299 seems to have been the worst; already in July harvests were forecasted to fail and at least in the  
300 west there was a lack of rain between late June and late September. But also in all of the  
301 following four years harvest failures are reported and water levels in lakes and streams were  
302 extremely low.

303 4) 1677-1684. The same pattern was repeated in the end of the 1670s and early  
304 1680s. In particular, 1681 and 1684 stand out; in the former year Stockholm had no rain at all  
305 in April and May and hay harvests were weak, and in 1684 there was a food crisis, the peasants  
306 requiring to pay their church tithes in cash rather than in grains.

307 5) 1746-1750. A new prolonged drought period occurred in the mid-1700s.  
308 Beginning in 1746, there are repeated reports on spring drought, and in the following years also  
309 summer drought from Hälsingland in the north to Västergötland in the west. Streams dried up  
310 and harvests failed and bark beetles, favoured by the hot weather, destroyed timber wood.

311 6) 1757-1767. Most of the growing seasons of this period were affected by dry  
312 weather with harvest failures and dried up wells and marshes. Spring was particularly late in  
313 1758; in the Stockholm harbor ice was said to be one meter thick in late April and there was  
314 still ice in inlets and small lakes in early May. The following summer was hot and dry, as were  
315 the summers of 1759, 1762 and 1764. According to one source, the dry period extended from  
316 1749 to 1767 at least in the north and with annually varying degrees of intensity.

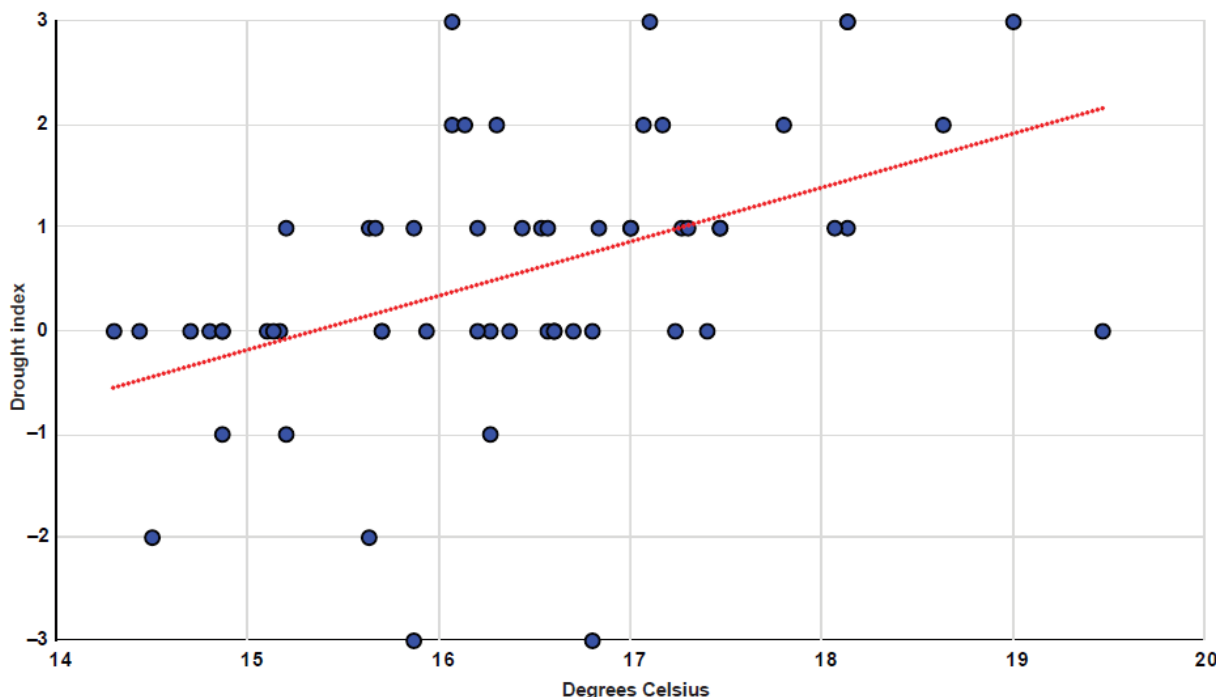
317 7) 1771-1776. According to sources covering most of the southern half of the  
318 country these years were all characterized by cold springs and hot and dry summers. Hay  
319 harvests failed due to dried up wet meadows and even rye failed to mature in due time. In  
320 particular 1775 stand out as a critical year. Barley, peas and hay suffered severely and lake  
321 water levels reached record lows. In the Stockholm region famine threatened in 1771.

322 8) 1780-1783. From Västerbotten in the north to Blekinge in the south there are  
323 reports on cold springs and dry summers, dried-up wells and streams, bushfires, and in  
324 Västergötland marshes were even so dry that they caught fire. In 1782, sowing was delayed  
325 until the first week of May in the Stockholm region due to persisting ground frost. In  
326 Västerbotten in the north it only rained twice from summer to October in 1780 and roots and  
327 cabbage failed, while the rye harvests were quite good as was the hay harvest, probably due to  
328 cultivation on wet meadows watered by meltwater from the mountains. On the other hand, in  
329 all regions in the south the hay harvest seems to have failed and the price of rye rose with more  
330 than a third over the year. The same pattern was repeated in 1781 and 1783.

331  
332 *Results*

333  
334 Figure 2 shows a scatter plot between summer temperatures and the drought index. The  
335 correlation from Table 1 of 0.47 is expressed as  $R^2$  in Figure 2. This might be a consequence  
336 of the precipitation data prior to 1893 not being very good. Another possibility is of course  
337 that the drought index really is more of a JJA temperature index.

338  
339 Fig. 2: Scatter plot of JJA temperature 1756-1816 and the drought index for Sweden



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343  
344 Note that “Very dry” is +3, which should correspond to low levels of precipitation.

345  
346 Another difference to precipitation data is that the index hardly has any correlation with  
347 August temperatures, while instrumental data renders a (slight) correlation between  
348 temperature and precipitation in August. We believe the main reason for this might be that the



349 database may be more stringent when it comes to weather related events occurring during the  
 350 first half of the year. It is also possible that a cool May, may be experienced as “wet”, and  
 351 therefore described as such in the sources forming the foundation of the index.

352 These tentative results of comparing the drought index made from descriptions of droughts  
 353 and precipitation indicate that the descriptive sources are indeed correlated to climatic  
 354 variables of temperatures and precipitation. Also, although correlation is higher between  
 355 temperature and index, than between precipitation and index, the original data concern  
 356 descriptions of dry or wet conditions: i.e. a description like “a hot/warm summer” is not  
 357 included in the index.

358 Since we have temperature measurements for the latter half of the 18<sup>th</sup> century, it  
 359 is possible to quantify periods 6, 7 and 8 (1757-1767, 1771-1776 and 1780-1783) in the section  
 360 above. In Table 2, average monthly temperature for June, July and August, as well as the  
 361 summer season JJA, are compared to average monthly temperature for the entire period 1756-  
 362 1816, i.e. until that year the index ends. None of the dry sub-periods differ significantly from  
 363 average monthly temperature for any of the summer months, or of the summer season. The  
 364 period of 1771-1776 has the highest difference compared to average monthly temperature for  
 365 the whole period 1756-1816, being c. 1 degree C warmer.

367 Table 2: Dry periods in the 2<sup>nd</sup> half of the 18<sup>th</sup> century in Sweden reflected in instrumental  
 368 measurements. Average monthly temperature for 3 sub-periods

<i>Period</i>	<i>June</i>	<i>July</i>	<i>Aug</i>	<i>JJA</i>
<b><i>1756-1816</i></b>	14.88	17.81	16.47	16.39
<b><i>(Index period)</i></b>	(1.62)	(1.61)	(1.51)	(1.17)
<b><i>1757-1767</i></b>	15.69	17.99	16.19	16.62
	(1.44)	(1.59)	(1.18)	(0.63)
<b><i>1771-1776</i></b>	16.50	18.95	17.13	17.53
	(1.44)	(1.16)	(1.68)	(1.13)
<b><i>1780-1783</i></b>	15.63	18.58	17.53	17.24
	(1.58)	(2.25)	(2.02)	(1.56)

369 From Figure 2 it is visible that when average JJA temperature is 17 degrees C or higher, there  
 370 are no indications of excessive precipitation. Droughts, on the other hand, are prevalent from  
 371 +15 degrees C, and very dry conditions may occur if temperatures are above 16 degrees C,  
 372 confirming the average temperatures in Table 2.

374  
 375  
 376  
 377 *Discussion and conclusions*

378  
 379 In this paper we tried to show that turning descriptions of drought (and precipitation) into an  
 380 index do correlate with instrumental measures of drought and temperature. We also provided  
 381 descriptions of periods that suffered harvest failures through drought, precipitation as well as  
 382 some adverse temperatures for the 15<sup>th</sup> century. Since the data are so scarce for the period, we  
 383 have not included 13<sup>th</sup> to 15<sup>th</sup> centuries into the index. Even results concerning, at least the first  
 384 half of, the 16<sup>th</sup> century ought to be regarded as uncertain.

385 The main problem with the precipitation/drought index is that we have a very  
 386 short period (1786-1816) with overlapping data of precipitation/drought. Also, instrumental  
 387 data on precipitation might not be of very high quality. Therefore, lack of any correlation  
 388 between the index and precipitation data may have three reasons. 1) The index rather reflects  
 389 summer temperatures than drought/precipitation. 2) The instrumental precipitation data for the  
 390 late 18<sup>th</sup> and early 19<sup>th</sup> century is not of very high quality. There is some correlation between  
 391 the drought index and summer temperatures in Stockholm, just like there is some correlation

392 between precipitation and summer temperatures. Correlation between the drought index and  
 393 summer temperatures is higher than between summer temperatures and precipitation, so it is  
 394 possible that the drought index is rather a temperature-index. Hot summer temperatures will  
 395 cause drought, because in Sweden, it very seldom rains when the weather is hot. 3) The drought  
 396 index reflects data that come from different parts of Sweden. Instrumental precipitation data  
 397 are, of course, from a very limited geographical area and will not reflect a general drought in  
 398 Sweden.

399 Despite the shortcomings of the index, we still think that some conclusions may  
 400 be drawn from it.

401 First: the height of the Little Ice Age, between c. 1570-1630, is, characterized by  
 402 very high variations with some years extremely wet, and some years extremely dry.

403 Secondly, after the early 1660s, wet years became increasingly uncommon, and  
 404 most years are either dry or very dry, especially from the mid-1700s onwards. Although  
 405 previous estimates of Stockholm temperatures after 1756 have showed to be positively biased,  
 406 this seems to correspond to trends in TRW and density in at least northern Fennoscandia  
 407 (Moberg et al 2003, Grudd 2008).

408 For the late 13<sup>th</sup> to the early 16<sup>th</sup> century, lack of data has made it impossible to  
 409 extend the index so far back in time. Grain prices suggest difficulties for grain production  
 410 around the turn of the century 1300. The highest price ever might reflect the catastrophic years  
 411 of 1314-16 – but the harvest failed that year because of wet and cold (Slavin, 2018: 495-515)  
 412 Therefore, we argue that just grain prices cannot determine a specific climatic parameter (at  
 413 least not for Sweden), since different conditions (too wet or too dry) result in the same outcome  
 414 (dearth and higher prices).

415 Since the index is a made of discrete variables, we thought it less meaningful to  
 416 try out a regression analysis and model (which would only render 7 different “temperatures”),  
 417 especially since we have been concentrating on precipitation and not temperature. Finally,  
 418 Table 3 summarizes the index presented in Figure 1:

419

420 Table 3. Number of years that have been labelled anything but “normal”

421

Index number	-3	-2	-1	1	2	3
Number of years	13	19	18	69	24	19

422

423 Table 3 indicates that slightly dry (index value +1) years have been regarded as more  
 424 “exceptional”, than wetter (-1) years. When it comes to very wet (-2) or very dry (+2) and  
 425 exceptional wet (-3) or exceptional dry (+3) years, there are a few more years denoted as dry  
 426 than as wet. Out of 316 years, only 13 years were exceptionally wet and 19 were exceptionally  
 427 dry. Additional 19 years were very wet and 24 were very dry. That so few years, comparably,  
 428 were regarded as “wet” years (only 18) compared to 69 that were regarded as dry years, may  
 429 be a result of perception: nice summers will be commented upon.

430

431

### 432 Archival sources

433

434 Riksarkivet (National Archives of Sweden), Stockholm, Medieval codex A21

435 Riksarkivet (National Archives of Sweden), Stockholm, Sturearkivet

436 Riksarkivet (National Archives of Sweden), Stockholm, Brev från Catharina Wallenstedt,  
437 1627-1719. Brev till dottern Margareta och sonen Carl. RA, Sjöholmsarkivet 1 enskilda  
438 samlingar, Ehrensteens samling, vol 2  
439 Riksarkivet (National Archives of Sweden), Stockholm, Landshövdingars skrivelse t K M:t,  
440 Jönköpings län, Östergötlands län, Södermanlands län, Uppsala län, Stockholms län  
441 Riksarkivet (National Archives of Sweden), Stockholm, Kollegiers m fl skrivelser t K M:t.  
442 Generalguvernörers skrivelser, generalguvernören över Skåne, Halland samt Göteborgs-  
443 och Bohus län  
444 Stockholms stadsarkiv (City archives of Stockholm), Magistratens ämbets- och byggnings  
445 Kollegium, Slussverket. Wattu journal 1774–1819  
446

#### 447 **Temperature and precipitation datasets**

448  
449 The datasets are freely available and were downloaded from Bolin centre  
450 <https://bolin.su.se/data/stockholm-historical-temps-monthly> on 7th December 2019 and from  
451 SMHI: [https://www.smhi.se/data/meteorologi/ladda-ner-meteorologiska-](https://www.smhi.se/data/meteorologi/ladda-ner-meteorologiska-observationer/#param=precipitationMonthlySum,stations=all,stationid=98210)  
452 [observationer/#param=precipitationMonthlySum,stations=all,stationid=98210](https://www.smhi.se/data/meteorologi/ladda-ner-meteorologiska-observationer/#param=precipitationMonthlySum,stations=all,stationid=98210) on 5th  
453 February 2020.  
454

455 E-mail contact with SMHI confirmed that precipitation data from 1863 are missing.  
456  
457

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Table 3: Documentary evidence of droughts in Sweden 1600-1800

**1634-1639**

Year	Date	Location	Index	Source	Comment
1634	spring, summer, autumn	[Sweden], Västergötland, Norrland	2	Falkengren 1781; Bergh 1886: 194; Bergh 1888: 56; Wittrock 1948; Sondén 1890: 363; Edén 1905: 216	dry April, dry and hot summer, harvest failures, great drought and hailstorms, lack of water, poverty
1635	summer	[Sweden]	2	Falkengren 1781; Edén 1905: 216	great drought, lack of water, bad hay harvest
1636	spring, summer	[Sweden]	2	Falkengren 1781	dry spring, hot and dry summer, no rain in May and only little before June 13
1638	spring, summer	Dalarna, Stockholm	1	Falkengren 1781; Norberg 1958-1959: 23	drought, lack of water, dry late spring and early summer
1639	spring, summer	Värmland, [Sweden]	2	Löf 1942: 151; Falkengren 1781	dry spring, June hot and dry, harvest failure in Värmland due to persistent drought

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**1652-1657**

Year	Date	Location	Index	Source	Comment
1652	summer	[Sweden, Finland]	3	Hausen 1880: 183, 198-201; Ambrosiani 1923: 255; Malmberg 1917: 87; Rääf 1856: 349; Hannerberg 1941: 206; Sillén 1855: 103; Ahlqvist 1825: 295; Weibull 1923: 114	Great drought; no rain in Sweden or Finland and forest fires between early May and late September, except for 25 and 30 June in Närke and Karlstad, Great harvest failure for both grain and hay, although somewhat better for rye, lack of water in streams
1655	July	Värmland	1	Hausen 1880: 219	Dry weather all July
1657	summer	Västergötland, Östergötland, Västerbotten, Västmanland	3	Sjöberg 1915: 21; Jansson 1995; Ambrosiani 1923: 256; Weinhagen 1947: 68; Isacson 2004: 130; Göthe 1929: 119; Hülphers Abramsson 1793: 318; Steckzén 1981: 77	Hot and very dry

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**1665-1670**

Year	Date	Location	Index	Source	Comment
1665	summer	Stockholm, Småland	2	Fryxell 1836: 137-138; Thunaeus 1968: 252	Strong heat, dead fish, great city fires due to drought
1666	summer, autumn	Värmland, Blekinge, Västergötland, Halland	3	Hausen 1880: 338, 340-2; Petersson 1942: 66; Landshövdingen öfver Skaraborgs län	drought, grain and grass die, low water in lakes and streams, watermills stand still due to lack of

				Tord Bonde Ulfssons berättelser för åren 1661-1666: 144; Osbeck 1922: 18; Ahlqvist 1825: 295	water, forest fires, cabbage hit by worms due to the drought, cattle disease, great poverty, in Halland no rain between midsummer and late September
1667	spring, summer	Värmland, Östergötland	2	Hausen 1880: 363; Rääf 1856: 349; Westerlund and Setterdahl 1917: 6	cold and dry spring, dry summer, general harvest failure
1668	spring, summer	Västergötland, Norrbotten, Östergötland	1	Tilander 1976: 186; Olofsson 1974: 227; Rääf 1856: 349	dry spring, harvest failures
1669	spring	Östergötland	1	Rääf 1856: 349	dry spring
1670	spring	Dalarna	1	Lindroth 1955: 157	drought, watermills stand still

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**1677-1684**

Year	Date	Location	Index	Source	Comment
1677	autumn	Västerbotten, Uppland, Västergötland	1	Nordlander 1938: 115; Sjöberg 1976: 35; Bergstrand 1955: 36	great drought, harvest failure, low water in streams, watermills stand still
1678	summer	Dalarna, Västergötland	2	Söderberg 1999: 110; Bergstrand 1955: 37	Tiny grain due to drought, harvest failures
1679	summer	Uppland, Småland, Öland, Skåne, [Sweden]	1	Jansson 1947: 74-5; Brunnström 1913: 78-9; Hegardt 1975: 144; Fredriksson 1979: 175	low water in streams, some watermills standing still half a year, no rain in southeastern Småland and Öland between midsummer and 25 July, great drought and harvest failures
1680	summer	Uppland	1	Jansson 1947: 74-5	watermills stand still for 11 weeks due to lack of water in the streams
1681	spring, summer	Stockholm, Södermanland	3	Wijkmark 1995: 246, 265; RA Brev från Catharina Wallenstedt 4 May and 30 June 1681; Levander 1934: 37	unprecedented heat in April, no rain for 8 weeks and much heat in May and June, bad hay harvest, people eat bark bread
1683	spring	Gästrikland, Skåne	1	Norberg 1958-1959: 376; RA Kollegiers m fl skrivelser t. K. M:t Generalguvernören över Skåne, Halland samt Göteborgs och Bohus län 11 July 1684	watermills stand still since September 1682 due to lack of water in streams, harvest failures
1684	summer	Östergötland, Småland, Skåne,	3	RA Landshövdingens i Östergötlands län skrivelse till K. M:t 20 June 1684; RA Landshövdingens i Jönköpings län skrivelse till K. M:t 9	great drought, harvest failures, poverty, grain price increases, watermills stand still due to lack of water in streams

				<p>July 1684; RA Landshövdingens i Södermanlands län skrivelse till K. M:t 13 October 1684; RA Kollegiers m fl skrivelser t. K. M:t Generalguvernören över Skåne, Halland samt Göteborgs och Bohus län 21 and 28 July, 21 August, 15 September, 6 October 1684; Omberg 1992: 46</p>	
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**1746-1750**

Year	Date	Location	Index	Source	Comment
1746	spring, summer	Medelpad, Västergötland, Uppland, Hälsingland, [Sweden]	3	Nordenström 1894: 43; Utterström 1957: 430; Olander 1951: 119; Pehrsson 1781; Lindgren 1971: 127; Hiorter 1747; Broman 1911: 524;	heat and drought before midsummer, forest fires, harvest failures particularly for grain
1747	spring, summer	Hälsingland, Uppland, Västergötland, [Sweden]	1	Broman 1911: 530; Utterström 1957: 109, 431; Lindgren 1971: 127; Wallén 1910: 3, 13; Olander 1951: 119; Pehrsson 1781; Fritz 2010: 68	severe drought with no rain in all of May, drought in July, August and September, poor grain and flax harvest in Hälsingland, great harvest failure on grain, and bark beetles proliferate in spruce forests, low water in lakes and streams
1748	spring, summer	Västergötland, Uppland, Östergötland, Hälsingland, Medelpad, Småland, [Sweden]	3	Trolle-Bonde 1894: 149; Elvius 1748: 39, 53-4; Hiorter 1752: 101-9; Nordenström 1894: 44; Hofrén 1984: 296-7; Broman 1911: 530; Olander 1951: 119; Utterström 1957: 109; Palm 1997: 134; Wallerius 1779; Lindgren 1971: 127; Ilmoni 1853: 127; Trolle-Bonde 1894: 149; Ejdestam 1969: 77-9; Wallén 1910: 3; Fritz 2010: 68	heat and drought, only little rain in July, low water in lakes and streams, hay harvest reduced to 25-33% in relation to the previous year in Västergötland, only little rain May- September in Stockholm,
1749	spring, summer	Uppland, Medelpad, Hälsingland, Östergötland, Närke	1	Utterström 1957: 109; Fritz 2010: 68; Nordenström 1894: 42, 44; Osvald 1965: 68; Hannerberg 1941: 215	heat and drought in the spring, low water in lakes and streams, only little rain in the north May- September, bad potato harvest

1750	summer	Medelpad, Västmanland, Uppland, Hälsingland	1	Nordenström 1894: 42; Omberg 1992: 50; Utterström 1957: 431; Schissler 1972: 52	very hot and dry summer, only little rain in the summer and low water in the streams in Medelpad and Västmanland, bad hay harvest
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**1757-1767**

Year	Date	Location	Index	Source	Comment
1757	summer	Västergötland, Medelpad, Skåne, Halland, Öland	2	Pehrsson 1781; Nordenström 1894: 45; Ejdestam 1969: 77-9; Wallén 1910: 14; Osbeck 1922: 17; Ahlqvist 1825: 295;	hot and dry summer, harvest failures, June- August no rain in Skåne, low water levels in lakes, marshes dried up,
1758	spring, summer	Södermanland, Värmland, Västergötland, Östergötland, Halland,	2	Tessin 1819: 334; Hellgren 1996; Pehrsson 1781; Widegren 1828: 449; Wallén 1910: 14	dry spring, summer and autumn, tiny grain harvest, low water levels in lakes
1759	spring, summer	Halland, Västergötland, Uppland	0	Pehrsson 1781; Wallerius 1779; Osbeck 1922: 17;	dry spring and hot summer
1761	spring, summer	Uppland, Södermanland	1	Ejdestam 1969: 77-9; Tessin 1819: 358	drought spring and summer, in many places grain harvest failures
1762	summer	Medelpad, Västergötland, Småland	3	Nordenström 1894: 45; Pehrsson 1781; Ejdestam 1969: 77-9; Sidenbladh 1908: 94	only little rain in Medelpad in July, severe drought in June and July in Småland and before midsummer in Västergötland but rain in the autumn, severe drought and bad hay and grain harvest in Uppland
1763	summer	Medelpad, Uppland	0	Nordenström 1894: 45; Sidenbladh 1908: 94	drought in June, bad hay and grain harvest in Uppland
1764	spring, summer	Medelpad	1	Nordenström 1894: 45-6; Sidenbladh 1908: 94; Wallerius 1779	tiny harvest due to cold spring and dry summer, severe drought and bad hay and grain harvest in Uppland
1765	summer	Medelpad	1	Nordenström 1894: 46	dry fields and northern winds, lack of food
1766	summer	Medelpad, Västergötland	1	Nordenström 1894: 46; Pehrsson 1781	drought and worms destroyed the grain harvest, July dry in Västergötland
1767	summer	Medelpad	1	Nordenström 1894: 46	drought, rain in mid-July could not be absorbed by the dry soil

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**1771-1776**

Year	Date	Location	Index	Source	Comment
1771	spring, summer	Uppland, Stockholm, Värmland, Östergötland	2	RA Landshövdingens i Uppsala län skrivelse till K Maj:t 18 June 1771; Landshövdingens i	cold spring, severe and protracted drought in early summer and then rain, harvest failures

				Stockholms län skrivelse till K Maj:t 12 October 1771; Ejdestam 1969: 77-9	
1772	spring, summer	Uppland, Östergötland, Västergötland	2	Wallerius 1779; Hushållnings Journal October 1786; Ejdestam 1969: 77-9	dry spring and early summer, drought and harvest failures, widespread hunger
1773	summer	Halland	1	Barchaeus 1924: 97	severe drought in July, harvest failure
1774	summer, autumn	Stockholm, Östergötland	3	Stockholms stadsarkiv, Magistratens ämbets- och byggnings Kollegium, Slussverket. Wattu journal 1774; Hushållnings Journal October 1786	severe drought early July to mid-October, bad grain harvest
1775	summer	Östergötland, Uppland, Värmland, Västergötland	3	Hushållnings Journal October 1786; Anteckningar ur Statistiska tabeller för Stockholms-Näs, 1749-1859; Wallerius 1779; Danielson 1974: 37; Schiller 1933: 340-1	dry spring and severely hot summer, bad harvests of hay, peas and grain, high grain prices, low water levels in lakes
1776	summer	Västergötland	1	Schiller 1933: 341	bad hay and grain harvests, low water levels in lakes

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**1780-1783**

Year	Date	Location	Index	Source	Comment
1780	spring, summer, autumn	Hälsingland, Stockholm, Blekinge, Västergötland, Västerbotten, Öland, Dalarna, Skåne	3	Ny journal uti hushållningen 1776-1813, del 1: 159, 172, 174, 176-7, 232-3; Stockholms stadsarkiv, Magistratens ämbets- och byggnings Kollegium, Slussverket. Wattu journal 1780; Schiller 1933: 342	dry spring and summer, low water levels in lakes, streams and wells, extreme drought in the autumn, bushfires, few bees
1781	spring, summer	Stockholm, Värmland, Östergötland, Västernorrland, Västergötland, Västerbotten, Småland, Öland	3	Ny journal uti hushållningen 1776-1813, del 3: 192, 235-6; Utterström 1957: 435; Stockholms stadsarkiv, Magistratens ämbets- och byggnings Kollegium, Slussverket. Wattu journal 1781; Hushållnings Journal October 1786; Schiller 1933: 342-3; Åmark 1915: 238; Bergstrand 1954: 40-1	repeated drought periods April to September, harvest failures particularly for hay, low water levels in lakes, forest fires

1782	spring, summer	Stockholm	0	Ny journal uti hushållningen 1776-1813, del 3: 239	cold and dry spring
1783	spring, summer, autumn	Stockholm, Halland, Östergötland, Uppland, Halland [Sweden]	2	Ny journal uti hushållningen 1776-1813, del 3: 234, 243-5; Utterström 1957: 436; Stockholms stadsarkiv, Magistratens ämbets- och byggnings Kollegium, Slussverket. Wattu journal 1783; Anteckningar ur Statistiska tabeller för Stockholms-Näs, 1749-1859; Osbeck 1922: 17;	cold and dry spring, protracted summer drought, harvest failures, low water levels in streams in the autumn

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