



Societal impacts of historical droughts in a warming world

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Global climate change has highlighted social and economic challenges associated with water deficits, particularly in regions where demands on freshwater exceed renewable supplies. In view of ongoing global warming, climate models project increased aridity in the twenty-first century over most of Africa, parts of the Americas, Australia, and Southeast Asia, as well as the Mediterranean and the Middle East. Severe recent droughts in human-dominated environments—as experienced in California, Brazil, China, Spain, and Australia—can no longer be seen as purely natural hazards. These droughts have had devastating ecological and economic consequences and are expected to cause more damage by the end of the twenty-first century (Savelli et al. 2022). Moreover, such heat waves are projected to become more intense, more frequent, and longer lasting in a warmer climate (Cook et al. 2018).

Drought research has a long history in both the natural and social sciences. Climatologists and hydrologists have made significant progress in understanding the physical processes that underlie droughts. At the same time, historians, economists, geographers, and sociologists have studied societal impacts and perceptions of droughts. However, these

investigations have operated in relative isolation without consideration of the complex interactions between natural and human processes in both preindustrial and industrial societies. Moreover, long-term changes in the frequency and severity of drought events and heat waves remain poorly understood.

Therefore, it remains a research priority to identify historical analogs and reference points for severe drought events, adaptation, and resilience (Pfister et al. 2018). In particular, the need for climate change information at the regional to local scale is one of the key issues within global change discussions. Even droughts with a larger geographical footprint tend to demonstrate great spatiotemporal diversity, emphasizing the need for local information on drought severity and impacts.

New tools for high-resolution hydroclimate reconstruction have improved the identification and analysis of historical droughts at regional and local scales, particularly for the past two millennia. These tools include recent multi-proxy databases for temperature or precipitation reconstructions (produced by initiatives such as PAGES 2k Consortium (2017)), large regional datasets of early meteorological records (Brönnimann et al. 2019), and powerful tools such as tree ring-based drought atlases (Cook et al. 2015). These have significantly enhanced our picture of long-term and short-term climate variability in both hemispheres, providing a spatial completeness and precision not previously available.

Investigation of historical artifacts and written records can further enhance knowledge of past droughts based on natural proxies. Climate reconstruction, whether from the “archives of societies” or “archives of nature,” requires similar techniques and poses similar methodological and conceptual challenges. In many cases, historical written records can provide greater specificity than proxies in natural archives, as well as precise information relevant to societal impacts and adaptations (Brönnimann et al. 2018). These records may require additional techniques and expertise to interpret, and the noncritical use of historical datasets can produce misleading conclusions (Van Bavel et al. 2019). Methods

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for the use of historical written evidence to investigate past climatic trends and events have advanced in recent decades, and Brázdil et al. (2018) have presented a worldwide state of the art of droughts based on the wide range of documentary evidence.

This topical collection explores past drought events and their human dimensions, including both short-term direct and indirect impacts and long-term transformations. It comprises nine articles covering seven countries or regions across three continents: in both physical and written records; in fields of archeology, history, hydrology, and geography; and in the ancient, medieval, and modern eras. Together, these papers provide a representative view of emerging interdisciplinary research on historical droughts.

Kaniewski et al. (2019) explore a pivotal episode in Eastern Mediterranean history known as the 3.2 ka event. This study utilizes new paleoenvironmental data and radiocarbon dates from Syria and Cyprus to compare the timing of climatic change with agricultural and land use changes. In this way, the authors weigh the theory that severe and persistent regional drought drove harvest failures and subsistence crises during the Late Bronze Age crisis. The paper highlights environmental challenges faced by ancient Mediterranean societies and the sensitivity of regional agriculture to climatic change.

Camenisch et al. (2020) examine warm and dry weather conditions described in most of Europe during the years 1471 to 1474. These include descriptions of great drought and heat from the spring to autumn of 1473. The weather conditions of those years were exceptional for the fifteenth century, and the environmental and economic impacts of the heatwave and drought were comparable to those of 1540 (Wetter et al. 2014), if not more severe. This article illustrates the historical impacts of extreme events in Europe similar to those whose frequency is currently increasing due to anthropogenic warming.

Kiss (2020) presents the 1506–1507 drought event in Hungary and neighboring regions. Drawing on contemporary written evidence, it details the drought's extent and duration as well as related weather extremes and environmental aspects. This investigation reveals that 1506 was a dry year not only in the Carpathian Basin but also in most of Europe. The drought continued into 1507 in the Carpathian Basin and in Italy. It was characterized by major urban fires, poor harvests, and the illness and death of livestock.

Harvey-Fishenden et al. (2019) examine how episodes of dry weather in late eighteenth- and early nineteenth-century Britain affected the nation's growing network of canals for transportation. Drawing on early instrumental measurements and historical records, the authors demonstrate how frequent unpreparedness for even minor droughts could result in conflict between water users, with potentially serious socio-economic consequences. By investigating drought

impacts during this critical period in the development of modern water supply systems, the study also contextualizes challenges in current water management in countries confronting anthropogenic warming.

Erfurt et al. (2019) investigate historical drought events in southwestern Germany since the early nineteenth century to assess continuing hazards arising from anthropogenic change and climate variability. Written descriptions and statistics of historical crop yields are used to investigate historical drought impacts and responses. This analysis reveals that the propagation of droughts and their types of impacts remained similar over time, although modern livelihoods have changed.

A third study of modern Europe, by Metzger and Jacob-Rousseau (2020), focuses on historical droughts in Alsace (eastern France) during the mid-nineteenth century. It presents a study of the 1857–1858 dry spell as well as its climatological, hydrological, and socio-political consequences. By unravelling the spatial and temporal distribution of precipitation based on available instrumental measurements, the paper highlights the importance of the drought on a regional scale. The authors contend that drought impacts were related to the economic situation on a local and national scale. This study illustrates how droughts, both and present, were partly defined by their social context.

Pribyl et al. (2019) propose an original analysis of a drought-driven ecological crisis in southeastern Africa during the second half of the 1890s. Using records previously unexploited for climate and climate impact research, which cover the area from modern-day Zimbabwe and Botswana to eastern South Africa, this study explores the complexity of this crisis. It analyses the spatial extent, duration, and severity of the regional drought and its associated socio-economic and environmental repercussions. This paper shows how drought triggered a cascade of responses from harvest failure to famine with enduring historical consequences.

The last two articles deal with historical droughts in northern China during the modern period. Lee (2019) presents a large-N statistical approach to reports of cannibalism and potential triggering factors in pre-industrial northern China. He analyzes 1194 cannibalism incidents during 1470–1911 alongside fine-grained paleoclimate and historical war datasets to identify potential causal factors. The paper demonstrates that reports of cannibalism in historical northern China are primarily associated with drought and war. However, the relationships among these variables are non-stationary and mediated by environmental and socio-political contexts.

A final paper by Fei et al. (2021) reconstructs water level changes of Lake Nansi on annual and decadal scales over the past 300 years, based on premodern water level observations and historical documentary records. It discusses their relationship with precipitation and the flooding of the Yellow

River. It identifies a significant correlation between lake level changes and a dryness/wetness index of in its drainage basin, indicating that precipitation has been a dominant factor regulating the water level.

This collection emphasizes regional-scale interdisciplinary studies combining reconstructions of drought episodes with analysis of environmental and societal impacts and adaptations, including agricultural and land use changes, famine, migration, and conflict. These studies also demonstrate information in natural and human archives can be integrated to reconstruct drought events and patterns in historical droughts, as well as their social and economic consequences. Taken together, these articles illustrate the significance of drought in human history, from ancient to modern times and in regions across the globe. In addition to their value for historical and paleoclimate research, it is hoped these historical studies can assist decision makers to identify strategies to recognize and prepare for future droughts.

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