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ENVIRONMENTAL HISTORY OF RICE PLANTATIONS IN THE EARLY MODERN OTTOMAN EMPIRE BETWEEN THE 15TH AND 19TH CENTURIES AND ITS POTENTIAL FOR CLIMATE RESEARCH

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Abstract

Historians readily discuss the effect of climate change on the 21st century, but Ottomanists rarely reference palaeoclimatology data. This research compares palaeoclimatological data with documentary evidence from institutionalized rice plantations in the Ottoman Empire. Between the 15th and 19th centuries, the empire employed a group of experts for the cultivation of rice in the vast region between the Tigris and the Danube. Extensive registers exist from this period in archives that give documentary evidence about the organization of plantations, yields, prices and destructive floods. The objective of the study, as presented in this article, is to find rice-related phenological data in Ottoman Archive registers. It utilizes a comparative analysis of the Old World Drought Atlas (OWDA) summer precipitation data reconstructed by Cook et al. (2015), temperature changes, documentary evidence about seasonal extremes and archival evidence. The comparison shows that palaeoclimatology proxies are important sources of information regarding changes in rice cultivation. It also indicates that the Ottoman archive is a valuable source of possible phenological data. Thus, research sources from nature and societies complement one another. The comparison also demonstrates that climate change during the Ottoman Empire's reign showed regional differences, and a local comparison of phenological data and palaeoclimatological data can explain more about the effects of the Little Ice Age (LIA) on the empire.

Keywords: Climate History, Environmental History, Ottoman History, Rice Farming, Phenology, Palaeoclimatology

INTRODUCTION

The climate extremes of the Little Ice Age were a trigger for the development of the modern state's institutional structure (Parker, 2013). After the so-called early-modern gunpowder revolution of the 16th century, anthropogenic intrusions into the environment grew significantly all over the world (Ágoston, 2009). New institutional bodies in absolutist states enforced the large-scale displacement of plants, animals, human beings and raw materials. Empires employed plant breeders, who experimented with new hybrid forms to increase crop yields and enhance variation. The early modern era was a period of agronomic challenges (Murphy, 2007). The appropriate location of plantations, using the right varieties, coordinating the workforce and ensuring sustainable production was a great institutional challenge at a time of climate change. Cash crops such as sugar cane, rice, coffee, cacao, tea and tobacco had a substantial social and environmental impact in the regions where they were planted. Rice was one of the products that transformed the socio-ecological landscapes in its foodway from China and India to the Middle East, Europe and the Americas. Sugar cane and rice were among those plants diffused westwards from South Asia to the Middle East and Europe during the Arab Agricultural Revolution between the 8th and 13th centuries (Watson, 1981; Canard, 1959). Rice, the main staple of Indian and Chinese cuisines, first entered the courts of Middle Eastern sultans on its way from Persia and the Mamluk Empire to Ottoman lands. The demand for rice as a luxury cash crop in growing local markets rose hand in hand with the increasing specialization of production activities in Ottoman cities. Although rice production was known in Southeast Europe before the 14th century, there was no extensive production before the Ottomans founded institutionalized rice plantations in the 14th and 15th centuries (İnalcık, 1982). The Ottoman Empire was one of the empires that introduced agronomic challenges and experienced fundamental institutional changes in the early modern era.

Rice plantations in the Ottoman Empire have drawn the attention of many scholars for their political and economic importance (Gökbilgin, 1952; Barkan, 1963; Beldiceanu et al., 1978; İnalcık, 1982; Arıkan, 1990; Venzke, 1992; Andreev et al., 2003; Karagöz, 2004, Evered et al., 2015; Amedosky, 2017; Kul, 2017). Promitzer (2010), Evered et al. (2015) and Gratien (2017) introduced an environmental perspective to the study of 19th and early 20th century rice plantations. Shopov (2020) draws attention to early modern intrusions on the landscape, deforestation and the societal effects of rice plantations in Plovdiv, Bulgaria. However, in the above studies, climate change has received little attention. Amedosky (2017) relates the fluctuations in rice harvests to the environmental conditions of the Little Ice Age in the Balkans. She refers to Tabak (2008), connecting the humid conditions of the Little Ice Age with the introduction of aquatic crops. Andreev et al. (2003) mention drought and revenue problems in the 17^{t}h and 18th centuries. In these studies, neither proxy data from archives of nature (i.e., tree rings) nor speleothem or pollen analysis have been used.

The present article aims to compare palaeoclimatology data with documentary evidence about institutionalized rice plantations of the Ottoman state, thus it is a first attempt to find rice-related phenological data in Ottoman sources as potential material for the identification of climate history. The study addresses the effect of climate variability on rice plantations. Available phenological data is compared with regional tree ring data. The June-July-August drought index (PDSI) reconstruction maps by Cook et al. (2015), research on temperature changes and historical data on climate extremes are compared with available yields, prices and other historical evidence about rice plantations.

STUDY AREA

Ottoman rice plantations were situated in the river valleys of the region between the Tigris and the Danube, between 30°–46° latitude and 19°–43° longitude, where temperatures were over 20 °C in the growing season and water scarcity was rare. Figure 1 shows the distribution of Ottoman rice plantations in relation to: a) May-June-July mean temperatures; and b) annual mean precipitation values. The location of plantations has been ascertained from studying documentary evidence in decrees, cadastres, rice tax office books and the rice paddy tax registers.

The survey mainly focuses on areas where both documentary evidence and palaeoclimatology data are sufficient; therefore, it includes the region of Anatolia and the Balkans but does not cover Iraq and Egypt.

This large study area has a variety of very different climatic conditions. The strong influence of the East Atlantic/Western Russia's seesaw teleconnection pattern is sometimes evident between Anatolia and the Balkans (Roberts et al., 2012). At times, while Central Anatolia is dry, Western Europe has higher precipitation rates. Constantinidou et al. (2019) define six climatic regions (Anatolia, Balkans, Western, Central and Eastern Mediterranean, and Mesopotamia) depending on the Radiative Index of Dryness, the Fuel Dryness Index and the Water-limited Yield of winter wheat. However, even in this differentiated regional model, both Anatolia and the Balkans have sub-climatic regions as shown below (Fig. 2).

Anatolia

While Central Anatolia is often hit by extreme drought, the Black Sea Region and the Aegean coasts of Western Anatolia are not influenced as much. The parallel mountain chains in the east-west direction of the Mediterranean and the Black Sea Region build a barrier, thus rain clouds transform humid air into rainfall on the slopes (Akkemik et al., 2005). Whereas the mean annual rainfall in continental Central Anatolia is only about 300 mm, the western and eastern Black Sea measures 1,000 mm and the western Mediterranean coasts 800 mm (Türkeş, 1996; Akkemik et al., 2005). Based on annual precipitation totals from 96 stations in Turkey, Türkeş et al. (2011) have defined seven rainfall regime regions in the country: the Black Sea, Marmara Transition, the Mediterranean, Mediterranean Transition, Continental Mediterranean, Continental Central Anatolia and Continental Eastern Anatolia. Moreover, by using spectral clustering of precipitation values, Türkeş et al. (2011) have defined 800 mm in eight resultant subregions: the Black Sea, Northwest Turkey, the Southern Aegean and Western Mediterranean, the Mediterranean, West Continental Central Anatolia, East Continental Central Anatolia, Continental Eastern and Southeastern Anatolia. Since the rainfall regime is very important across the breadth of this study, the simplified climate region definition derived by Türkeş et al. (2011) is considered an appropriate categorization tool.

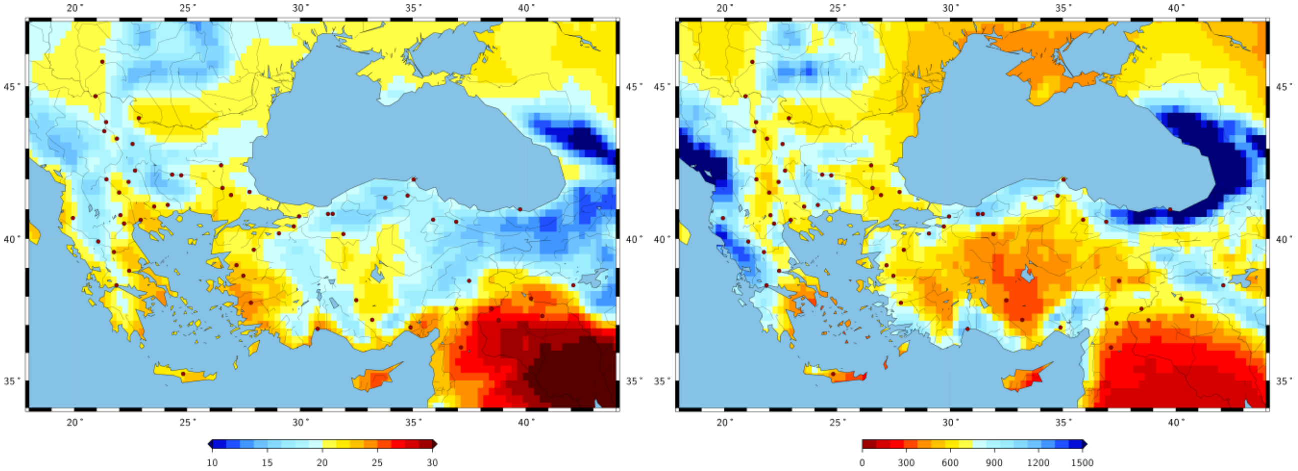

Fig. 1 Actual May-June-July mean temperatures [°C] (left) and annual mean precipitation [mm] (right) of the study area according to Hersbach et al. (2020) and the location of studied Ottoman plantations

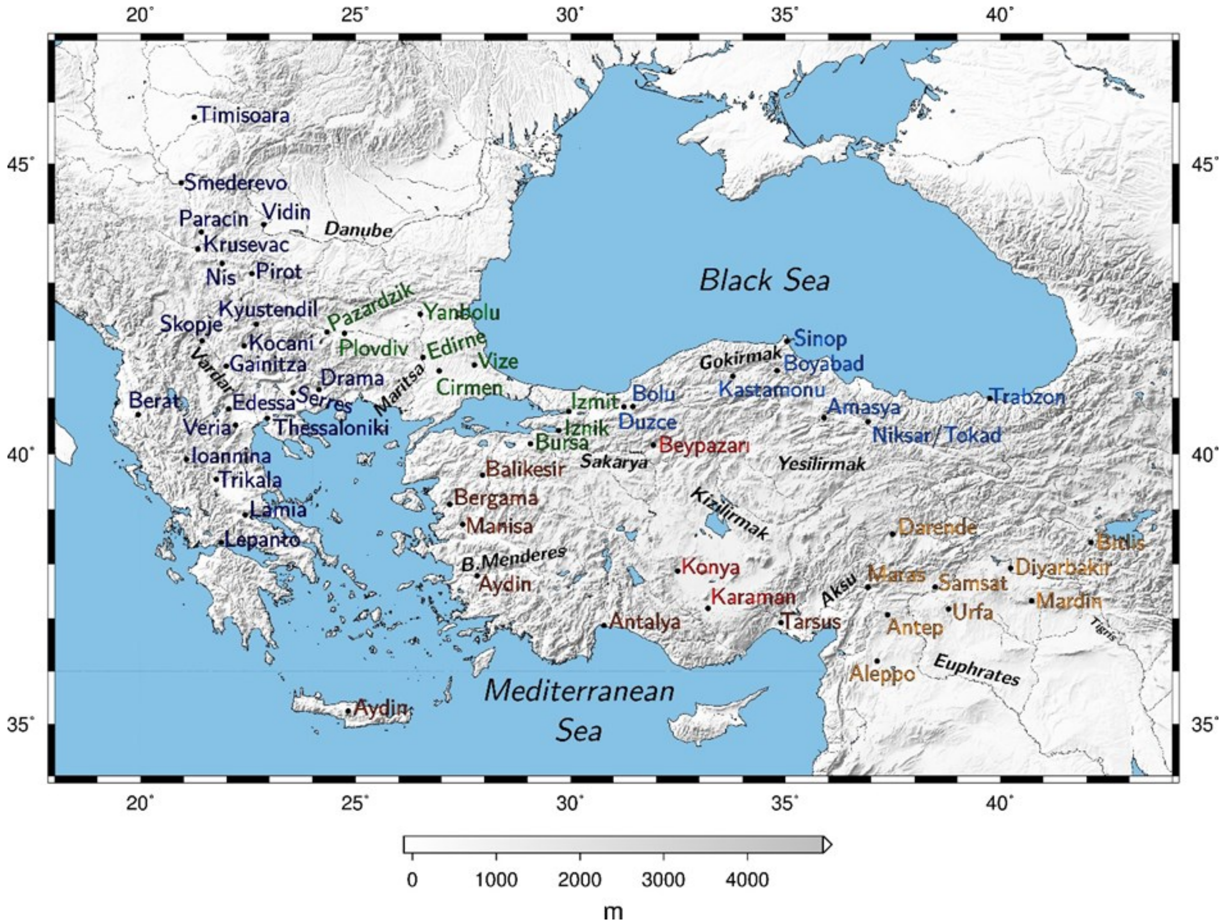

Fig. 2 Major rivers and locations discussed in the results section.
Colour coding of the locations: Continental Central Anatolia (red), the Black Sea Region (blue), the Mediterranean (burgundy), Southeastern Anatolia (orange), Southeastern Europe (navy blue) and Marmara Transition (green)

The Balkans

The Köppen-Geiger climate classification for the Balkans (Peel et al., 2007) is not sufficient to show the study area's regional climatic differences. The Balkans also have sub-climatic regions: Popov (2018), for example, modified the Köppen-Geiger classification for the Vardar, Struma and Mesta valleys. Similarly, using contemporary data and projections, Beck et al. (2018) drew a new Köppen-Geiger climate classification using a 1 km resolution map for 1980–2016. This map shows regional differences better than the Köppen map. Beck et al. (2018) also made another projection map for 2071–2100. The two maps show a great change in climate zones, which is a suitable warning against using current data for historical studies. In this study, the entire region is called Southeastern Europe.

The comparison of documentary evidence and palaeoclimatology data focuses on seven regions: Continental Central Anatolia, the Black Sea Region, the Mediterranean, Southeastern Anatolia, Southeastern Europe and Marmara Transition. The locations that have comparable data is restricted. Fig. 2 shows the major rivers and the locations discussed in the results section via a colour code. Since data that provide indications about annual yield and price variability are restricted, not all locations are discussed in the study.

DATA AND TERMINOLOGY

The Ottoman government gave particular importance to the production of rice as a cash crop. The administration of rice plantations required great organizational capacity for building canals and repairing them in case they were damaged by floods. New plantation areas were often allocated to *waqfs*, Islamic charitable foundations. In Southeastern Anatolia, the previous Mamluk system of rice growing was assimilated. The resultant Ottoman system was a challenging system that depended on waqfs to open new land for plantations. Waqfization also provided the cash flow that the gunpowder empire needed for its armies. High-ranking statesmen and affluent people donated income from revenue-generating sources to uphold the public good and simultaneously entrust their estates to family members. After Mehmed II's reign (1444–1446 and 1451–1481), the state employed a group of cultivation experts (*çeltikçi*) to implement and rehabilitate rice farming, organize the workforce and ensure sustainable production (İnalcık, 1982; Emecan, 1993). Waqfization went hand in hand with the spread of rice plantations in the Balkans (Shopov, 2020). The branches of the rivers were allocated to a tax farmers.

Each river and creek, which was used for rice production, were listed in registers.

The terminology in these registers gives an indication about the organizational principles that were used. To guarantee that correct varieties were used, the administration often supplied seeds to start plantations. Controlling the rice variety not only secured higher revenues but also prevented losses caused by planting mixed varieties. Controlling the varities was so important, that *tohum*, which literally means "seed", became a measurement unit for production lots. Rice plantations were so highly regarded by the state that there is an immense volume of data.

The use of archival data as historical evidence requires available documents to be classified and their potential analyzed.

Decrees

Important events, changes in production or changes in the organization of production were recorded in decrees called *Mühimme*. The data in these decrees provide evidence of weather extremes such as floods and droughts that resulted in reduced yield. The decrees also include information about geographical distribution. However, they are not useful for tracing gradual changes in rice production.

Cadastres

Cadastres (*Tapu Tahrir* and *İcmal* registers) are valuable because they give data about local production and the distribution of lots to tax farmers (*mukataa*) for 2–3 years. However, the data is not adequate enough to compare annual yields with climate variability.

Rice Tax Office Books

The Anatolian Fiscal Office kept separate registers for cash crops such as silk, tobacco, coffee and rice. The first Rice Tax Office Book (*Çeltik Rüsumu Kalemi or Vâridât-i Şikk-i Sânî Kalemi*) was started in 1524 and ended in 1532 defining the annual allocation of river branches to tax farmers (BOA D.ÇRS.D.25994). This book is valuable because it shows that the branches of the rivers were registered as early as the first half of the 16th century (Fig. 3).

Although these entries do not give data about the climate, similar register books could be beneficial for future land surveys. The documentation of each branch of the river from the 15th to 20th centuries is vast and the registers become more elaborate from the 16th century onwards.

The second Rice Tax Office Book dated up until 1551, which originated from Skopje (Üsküp), lists the allocation of lots (BOA D.ÇRS.D.25995). The third book is from Plovdiv (Filibe) and Pazardzhik (Tatarpazarı) (from now on modern names will be used). There are various entries from 1659, 1664–1665 and 1673. (BOA D.ÇRS.D.25996) The fourth register is also from Plovdiv and Pazardzhik for 1674 (BOA D.ÇRS.D.25997). The fifth is also from the same region and is dated 1684–1688 (D.ÇRS.D.25998). The sixth is from Pazardzhik and is dated up to 1780 (Karagöz, 2004; D.ÇRS.d.25999). The last book is from Düzce dated 1829 (BOA D.ÇRS.d.26000). The seventh Rice Tax Office Books show the allocation of river branches in Skopje on the Vardar River, Plovdiv and Pazardzhik on the Maritsa River, and Düzce on the Sakarya River in Anatolia (Fig. 2).

Rice Paddy Tax Register Documents

Rice Paddy Tax Register Documents (*Çeltik Rüsümu Evrakı*, Fig. 4) are records about the allocation of paddy fields, the changes to tax farmers' lots (*mukataa*) and their administration. There are four books, the first dating from 1688 to 1728 (BOA D.ÇRS.1), the second from 1734 to 1761 (BOA D.ÇRS.2), the third from 1762 to 1776 (BOA D.ÇRS.3) and the fourth from 1777 to 1792 (BOA D.ÇRS.4). All four books are related to the rice paddies in Pazardzhik and Plovdiv. The data are almost continuous from 1688 to 1792 covering more than 100 years of changes in the allocation of paddy lots on various river branches, except for five years between 1728 and 1734.

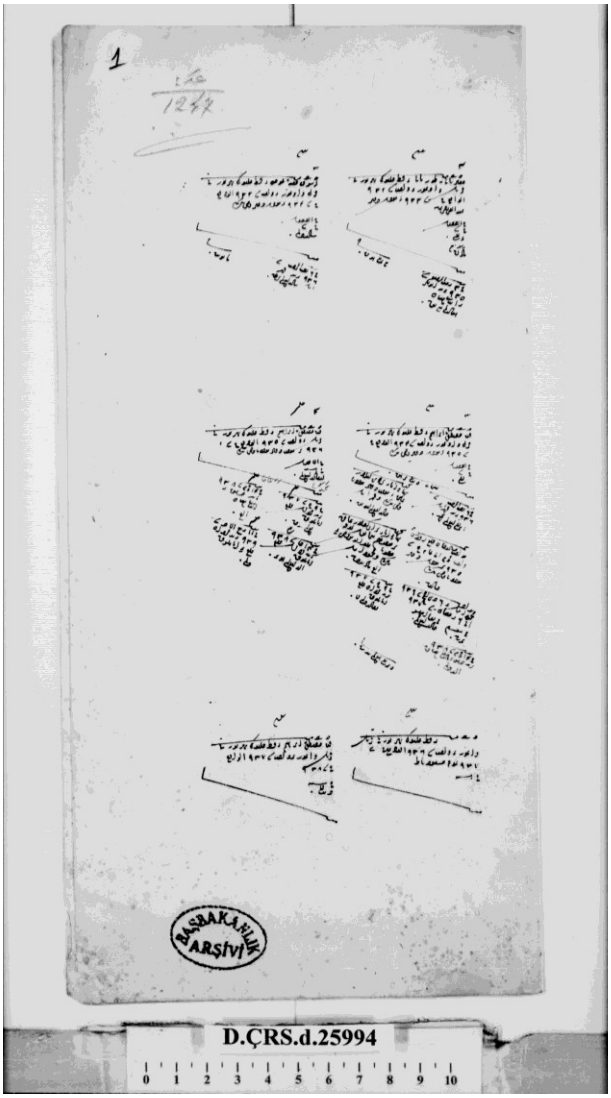

Fig. 3 Example of a Rice Tax Office Book from the first half of the 16th century (Image courtesy of the Prime Minister's Ottoman Archive, Istanbul, BOA D.ÇRS.D.25994)

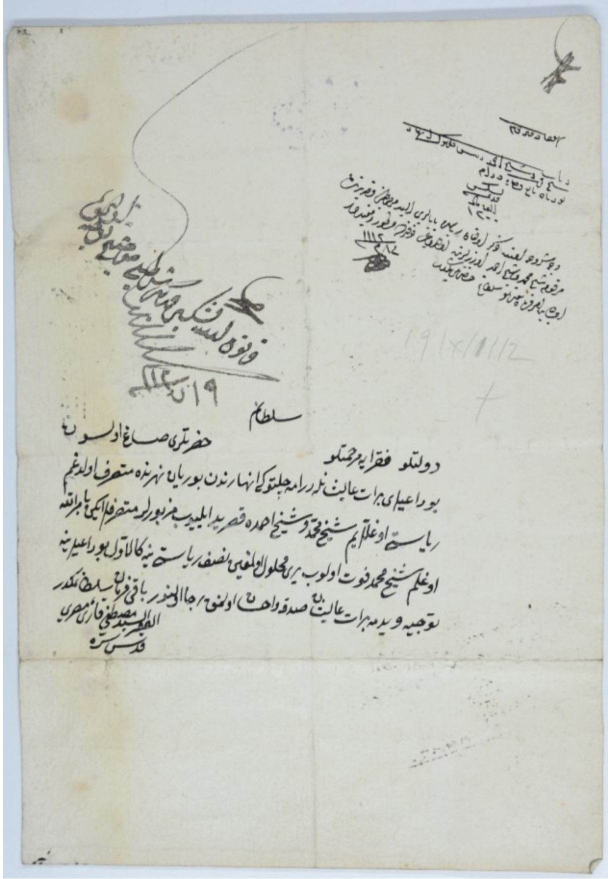

Fig. 4 Example of a Rice Paddy Tax Register Document from the early 18th century (Image courtesy of the Ottoman Archive, Istanbul, BOA D.ÇRS1, 29. ÇRS 1, 29)

The data about the allocation of the paddy fields is not adequate to compare yield quantity with climate variability, since they do not offer annual accounts. Despite these shortcomings, analysis of these documents may give important results about the anthropogenic intrusions on the land. When compared with the pollen data of rice in future studies, new perspectives may be gained.

Waqf Account Books

One critical type of regional document may help to provide evidence of climate variability and its effect on yield: the Waqf Account Books (*Vakıf Muhasebe Defterleri*) record yearly revenues from foundation budgets. Annual changes to the quantity of yield and price fluctuations are appropriate for a comparison with climate variability. However, the data are seldom continuous.

METHODS

Climate variability is not the only controlling factor of rice yield variability. Dry spells, changing cloud cover (and solar radiation), wind speed, seasonality and the timing of heat stress, water scarcity, pest and pathogen infestations, agronomic challenges, and economic and political or social factors can also affect yields. Among the many factors influencing rice production, yield fluctuations caused by climate variability can only be traced in high accuracy matches. This study offers a comparison of contemporary sources with regional climate data. It uses only contemporary sources that enable analysis of the change in rice yield. Since there is no one-to-one matching palaeoclimatology data for each plantation location, the definition of the regions is crucial to the analysis. The study defines regions which show similar climatic characteristics and uses the reconstruction of the June-July-August Palmer Drought Severity Index (JJA PDSI) series of the Old World Drought Atlas (OWDA) produced by Cook et al. (2015). Their OWDA reconstruction depends on data derived from tree rings and historical and archaeological data. It uses the point-by-point method, and yet, for some locations, the data's sensitivity is weak since it uses a proxy search radius of 1,000 km around each location. All in all, for this long-term review, the single year maps and decadal mean summer precipitation values show a regional differentiation in the distribution of droughts and are useful for understanding yield decreases caused by long-term drought and consequent water scarcity in the rice growing season.

Rice grows and matures in approximately 150 to 200 days. Seeds start to be planted as temperatures increase after April in South Anatolia, in early May in Thrace and in late May or early June in the north Balkan Peninsula. During the first 60 days, at the vegetative stage of germination, seedling and tillering, scorching temperatures and water deficits are detrimental to growth. The ideal temperature for germination is 20–35 °C (Maclean et al., 2013). Water scarcity in the crop-growing season reduces yield (Altinsoy et al. 2013) and the need for water in June and July increases, thus the reduced depths of water in rice fields decreased yield (Kara et al. 2013). Decadal droughts may cause water scarcity and lead to less water being allocated to the branch canals.

Phenological data from rice plantations in the Central Anatolian, Black Sea, Mediterranean, Southeastern Anatolian, Southeastern European and Marmara Transition regions will be compared with the reconstructed OWDA summer precipitation data (Cook et al. 2015), temperature changes and weather extremes. Important changes to the organization of plantations from decrees and revenue changes from cadasters offer partial comparison. Available yearly records of yield and rice price data in waqf account books provide year on year changes.

RESULTS

Central Anatolia, the Black Sea Region, the Mediterranean, Southeastern Anatolia, Southeastern Europe and Marmara Transition regions show dissimilar climatic characteristics. For each region, changes in summer PDSI values are indicated with yellow boxes and periods when the summer PDSI extremes increased with blue boxes.

Continental Central Anatolia

In Continental Central Anatolia, production was located in temperate lower regions (Fig. 1a). Three locations can be identified from archival evidence: Beypazarı, Konya and Karaman (BOA, MAD.d.10249, BOA, MAD.d.12168, BOA, MAD.d.3120; Coşkun 2010).

Although plantations in the Kızılırmak and Sakarya River valleys depended on irrigation, the annual mean precipitation values are very low and the region was vulnerable to decadal droughts. The tree ring-based hydroclimate reconstruction of the OWDA (Cook et al., 2015) shows that there were extreme drought years and an important decrease in the mean summer PDSI values by the end of the 16th century (Fig. 5). The small yellow box shows a short high precipitation era in the early 16th century. The long yellow box shows that the region had experienced a long low precipitation period, in which the mean JJA PDSI values were under -1. Nar Lake high-resolution data confirm that there was also a dry period between AD 1400–1950 (Jones et al., 2006).

The change in mean summer precipitation, and the length and intensity of the drought in these years may have caused water scarcity, resulting in an overall trend toward desiccation and decreased water depth in some paddy fields. For example, in Konya and Karaman, active plantations existed before the end of the 16th century. The Karaman pious foundations' regional revenue book from 1483 mentions two rice grinding mills (Coşkun, 2010). Historical evidence from Konya also shows that rice was planted there in the 16th century (Orbay, 2012). In both locations, the production of rice had decreased by the end of the century.

The account books of Selim II's and Mevlânâ Celâleddîn-i Rûmî's waqfs in the Konya region provide some annual comparable price data (Orbay, 2012). According to this data, rice was listed among both the revenues and expenditures of the foundation between 1594 and 1597; however, it had disappeared from revenues by 1597. This probably means that rice production in the lands that the foundation owned no longer returned revenues or production stopped.

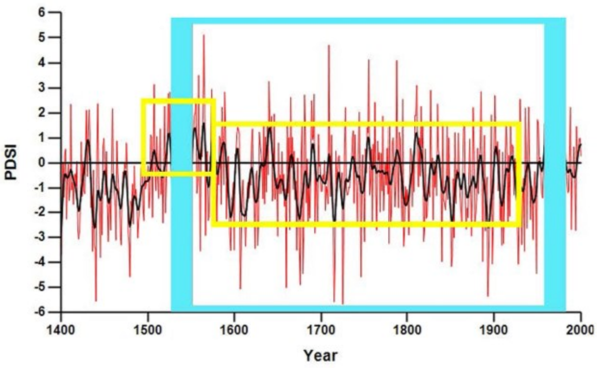

Fig. 5 Reconstructed June-July-August Palmer Drought Severity Index (PDSI) values of the OWDA (Cook et al., 2015) for Continental Central Anatolia between 1400–2000

Table 1 Rice prices in the account books of Selim II's and Mevlânâ Celâleddîn-i Rûmî's foundations (Orbay, 2012) and their comparison to reconstructed OWDA June-July-August Palmer Drought Severity Index (PDSI) values (Cook et al., 2015) for Continental Central Anatolia at Konya between 1594 and 1602.

Year	Reconstructed JJA		Selim II.'s Waqf		Mevlânâ Celâleddîn-i Rûmî's Waqf
	PDSI	10-Year Spline	Revenues	Expenditures	Expenditures
1594	-1,4054	-2,257	1,73	2,6	
1595	-2,8337	-2,339	2,3	3,18	
1596	-3,4746	-2,301	2,3	2,59	3,23
1597	-1,5316	-2,106		3,27	3,46
1598	-1,2798	-1,834		3,76	3,56
1599	-0,7683	-1,525		4,16	4,33
1600	-3,3649	-1,125		3,62	3,75
1601	0,2699	-0,545		3,42	4,33
1602	0,4688	0,112			4,79

A comparison with the reconstructed OWDA summer precipitation data (Cook et al., 2015) shows that this may be related to water scarcity. Table 1 compares rice prices in the account books of Selim II's and Mevlânâ Celâleddîn-i Rûmî's waqfs and reconstructed OWDA June-July-August PDSI values (Cook et al., 2015) between 1594 and 1602.

Ten-year spline summer PDSI values point to water scarcity in 1594, 1595 and 1596. The drought intensified from 1595 to 1596 and summer precipitation values fell from PDSI -2.8337 to -3.4746. In the same years, rice prices in the revenue section of the accounting book increase from 1.73 *akçes* to 2.3 *akçes*. After 1596, the rice revenue record was no longer in use and summer precipitation values were under zero.

Moreover, according to the Cook et al. OWDA reconstruction (2015), an extreme drought occurred in 1600. Rice prices listed as waqf expenses increased from 2.6 *akçes* in 1594 to 3.42 *akçes* in 1601. Although climate stress may not have been the only factor to cause such a price increase, this partial data shows a negative correlation between summer PDSI values and rice prices in waqfs revenues. Many other factors may have been causal in this decline and the disappearance of rice revenues, but dry June-July-August conditions are one probable trigger for this decline, as suggested by the OWDA reconstruction (Cook et al., 2015).

This fragmentary data from the revenue records reveals little in itself about water scarcity's effect on rice production. Therefore, it is highly important to find data more appropriate for comparison. Future studies may fill in the gaps and produce continuous results. Historical studies by Griswold (1993) and White (2011) relate peasant rebellions in Continental Central Anatolia to climate variability. There were also extreme fluctuations in the grain yield revenues of the region's waqfs. Orbay (2012) relates the financial difficulties of Sadreddîn-i Konevî and the Mevlevî waqf with June-July-August precipitation fluctuations in Southwestern Anatolia, as described by Touchan et al. (2005). More documentary evidence from the grain yield revenue registers of the account books can provide a better understanding of the effect of the Little Ice Age droughts in Central Anatolia by using palaeoclimatology data produced in the last decade.

Documentary evidence from the revenue books shows that northern parts of Central Anatolia were more active in production. The mean precipitation rates are slightly higher in the area (Fig. 1 right). According to an edict dating back to 1546, Beypazarı, a town northwest of Ankara, had rice fields on the Sakarya catchment (BOA, İE.ML.1/29). In 1580, a decree ordered villagers to give their tax revenue as hulled rice to bolster the Halil Paşa Waqf's revenue and avoid losses (BOA, A.DVNSMHM.d.41/1031). A decree dating back to 26 November 1609 states that those who worked the Hasan Paşa Waqf in Beypazarı but had left their village because of bandits should not experience problems returning to Beypazarı (BOA, A.DVNSMHM.d.78/2104). Two months later, another decree stated that new revenues from Bursa and Ankara should be added to the waqf's revenues. The decree book also mentions other security problems in the region (BOA, A.DVNSMHM.d.78/2104). At present, it is not possible to analyze the specific effect of the drought on the fields; production may have stopped because of bandits or drought, or both. In 1802, a decree ordered that rice from Beypazarı be sent to Hacı Bayram-ı Veli Order in Ankara (BOA, AE.SSLM.III/197, 11831). Thus, although there may have been ruptures in production by the end of the 19th century, rice production continued in areas north of Ankara. The blue box shows the period where precipitation extremes also occurred after the mid-16th century. Future phenological study may provide more data about the influence of these summer extremes.

According to the OWDA reconstruction (Cook et al., 2015), the low mean summer precipitation period started at the end of the 16th century and lasted until the late 20th century. In this four-hundred-year period, the mean precipitation rates during droughts were under -1 and the region experienced a significant change in its flora. Agricultural areas also suffered subsurface water problems and high salinization, as shown by the long yellow box in Figure 5. Some areas are still experiencing desertification today. Studying the early effects of droughts and previous conditions in the region makes the effect of climate change more evident. Water scarcity will likely be the most important issue to affect the region in the future (Sen et al., 2012).

Black Sea Region

There were once plantations on the Sakarya and Yeşilırmak Rivers at locations where temperatures were adequate. Other rice plantations were cultivated in Düzce, Kastamonu, Boyabad on the Gökırmak River, a tributary of the Sakarya River, and in Amasya within the Yeşilırmak River valley (BOA, AE.SSÜL.I.2; BOA, MAD.d.141; BOA, MAD.d.9507; BOA, İE.ML.1/29; BOA, İE.DH.2/109; BOA, İE.ML.12/1035; BOA, İE.ML.24/2327; BOA, AE.SMMD.IV.56/6501; BOA, İE.ML.16/1532; BOA, AE.SMMD.IV.101/11751; Evliya II, 98). The annual precipitation in the Black Sea Region is much higher than in other areas of Continental Central Anatolia (Fig. 1b). Türkeş (1996) and Akkemik et al. (2005) calculated 300 mm mean annual rainfall for Continental Central Anatolia and 1,000 mm for the Black Sea Region. The OWDA June-July-August PDSI values (Cook et al., 2015) also show that summer droughts were less effective in the Black Sea Region than in Continental Central Anatolia. Rice production in the Black Sea catchment of the Sakarya River continues to this day.

Historical evidence about revenue collection and security problems draws our attention to drought years and their possible impact. For example, according to the OWDA reconstruction (Cook et al., 2015), there was a drought in 1701 and subsequent problems with the collection of rice revenues, as recorded in March 1702 in Boyabad (BOA, A.DVNSMHM.d.112/6109). After the drought year of 1708, as shown by the OWDA reconstruction (Cook et al., 2015), another revenue collection and subsequent security problem occured (BOA, İE.ŞKRT.2/170). However, many other factors may play a role and better analysis would require the study of yearly yield data from the waqf account books.

Mediterranean Coastline

The west coasts of the Anatolian peninsula usually receive more precipitation than Continental Central Anatolia even in the scorching summers (Fig. 1 right). Rice production existed as early as 1480 in Aydın on the Büyük Menderes River (BOA, MAD.d.7387). The decrease in JJA PDSI after the 17th century did not fall below zero until the end of the 20th century (Fig. 6).

As seen in the second yellow box, JJA PDSI values declined at the end of the 16th century. The blue box shows an increase in the extreme values and also betterment in the low precipitation that started at the end of the 16th century and continued until the mid-17th century. After this betterment of precipitation value, mean JJA PDSI in the growing season did not fall below zero. However, as these data derive from the trees that lay higher in the mountains, they may not directly reflect the precipitation for lower agricultural regions. Historical evidence shows that rice production was undertaken sporadically due to water scarcity. For example, in Manisa, on some of the sultan's plantations, certain fields were left unfarmed for 10–15 years (Emecan, 1993). There are numerous registers, mentioning changes to tax farmer rice plantation lots. As in other locations, rice yield data may be found in single waqf account books and historical evidence about climatic extremes and their effect on plants may be documented.

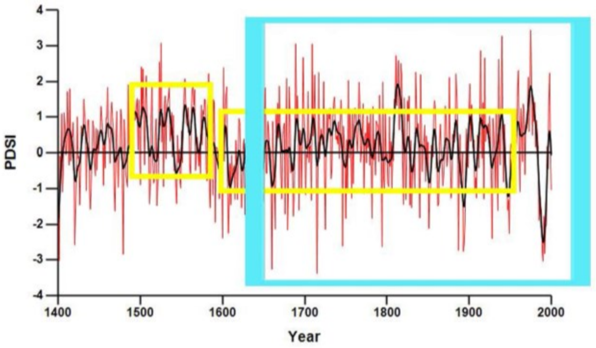

Fig. 6 June-July-August Palmer Drought Severity Index (PDSI) from the OWDA reconstruction (Cook et al., 2015) for the Mediterranean between 1400 and 2000

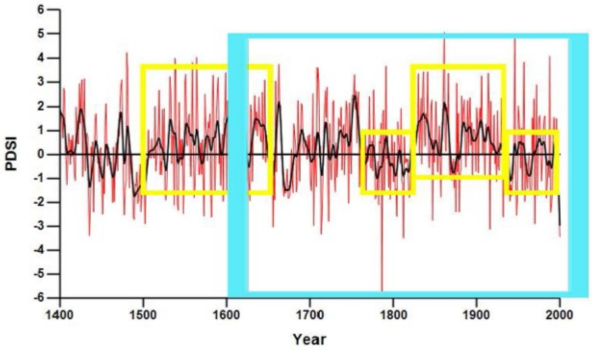

Fig. 7 June-July-August Palmer Drought Severity Index (PDSI) from the OWDA reconstruction (Cook et al., 2015) for Southeast Anatolia between 1400 and 2000

Southeastern Anatolia

There were rice plantations in Mardin, Urfa, Samsat and Darende on the Euphrates River (BOA, TS.MA.d4391), Bitlis and Siirt on the Tigris River (BOA, MAD.d.10280; Evliya III: 95, 97) and in the region between Maraş and Ayıntab on the Aksu River (Evliya III, 100). Registers were kept from 1519 about tax farmer changes in Darende on the Tohma River, a branch of the Euphrates (BOA, MAD.d.15450).

A decree dating back to 1595 informs about tax farmer changes in Diyarbakır (BOA, A.DVNS.MHM.d.73/33, 81). Unfortunately, the data do not include yearly yield or price data that would allow any comparison. Pehlivan (2020) provides documentary evidence on animal deaths, especially in the years of drought that followed extremely cold winters in the 19th century. JJA PDSI values are lower in years from the late 18th century (Fig. 7). Available proxy data show that there are two crucial decreased mean summer precipitation periods: one between the late 18th and early 19th centuries and a second that began in the early 20th century. Moreover, the region's summer precipitation extremes began in the middle of the 17th century, as shown within the blue box. Future regional studies may provide more data about the fluctuations of rice harvests and other effects of climate variability. Since proxy data from tree rings are also very rare for the region, the Cook et al. 2015 OWDA JJA PDSI mean values probably have low resolution. All in all, phenological data for this region would be very valuable.

Southeastern Europe

15th century censuses show that the Ottomans started cultivating rice in the Osum and Seman River Deltas even when JJA PDSI values were low. Rice tax was mentioned among the revenues of some villages near Berat, Albania, as early as 1432 in the area's first revenue registers (İnalcık, 1987). The Seman River Delta in present-day Albania is favorable for building rice paddies: the area's mean May-June-July temperatures are over 20ºC (Fig. 1 left) and the yearly mean precipitation is high (Fig. 1 right). According to Cook et al. (2015), JJA PDSI mean summer precipitation values were also high when the Ottomans organized plantations there in the 16th century (shown within the first yellow box in Figure 8).

Southeastern European river valleys in Macedonia, Thessaly and Thrace were also appropriate for rice farming. Other revenue registers show that in 1516 the area between Niš and Pirot (in present-day Serbia) and northern regions like Kruševac also had rice plantations (Amedosky, 2017). Drought data from the OWDA and historical evidence show that weather extremes started in the mid-16th century and ended in the mid-18th century. During these extreme weather conditions, floods disrupted some rice paddies in the 17th century. In Lamia, floods filled the paddies with stones in 1629 and 1630 (BOA, A.DVNSMHM.d.85/297). Between 1714 and 1718, very severe conditions affected the paddies in Thrace and, in 1716, floods ruined rice paddies on the Peloponnes, causing villagers to leave their homes (Amedosky, 2017). Weather extremes are especially relevant to cash crops like rice and sugar cane since they require mills in their production process, which are operated using water energy or working animals that are both stressed by extreme levels of water. Floods that damage mills also negatively impact rice production.

Rice production existed in Niš before the Ottomans arrived in the region, but production increased under their reign. The crop was one item among several doubling Niš' revenues from 1498 to 1516 (Amedosky, 2017). Temperatures fell in the 17th century (Luterbacher et al., 2004) and weather extremes started mid-century. By the 18th century, some Niš plantations became meadows and were used for animal farming (Amedosky, 2017). On 21 February 1739, a decree ordered rice to be sent from Plovdiv to Niš for the army (BOA, İE.ML.45/4373), which may indicate that production was not even enough for local use or the increased army needs in the region at the time.

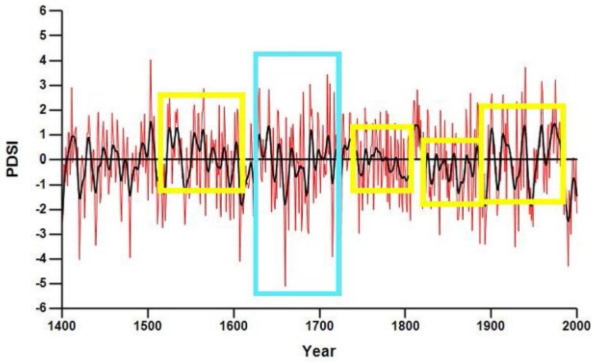

Fig. 8 June-July-August Palmer Drought Severity Index (PDSI) from the OWDA reconstruction (Cook et al., 2015) for Albania between 1400 and 2000

The effect of 18th century extremes changed crop preferences in the region. Since rice leaches the soil and makes it suitable for other crops (Maclean et al., 2013), people often substituted rice with less labour-intensive corn (Warman, 2003). The decline in rice production may have been due to insecurity, deteriorating workforce availability, energy problems, deteriorating climate conditions and/or the incompatibility of rice varieties.

The Ottomans started plantations at Timișoara, the most northern-known plantation location. Five decrees between 1572 and 1579 mentioned rice cultivation. The first, from 7 April 1572, regards a request for rice plantation experts (çeltikçis) (BOA, A.DVNSMHM.d.16/399; BOA, A.DVNSMHM.d. 16/400). The second, from 12 September 1573, mentions a decline in revenue (BOA A.DVNSMHM.d.22/683). On 25 June 1578, a decree ordered the administrators to check whether the region was appropriate for rice growing or not (BOA, A.DVNSMHM.d.35/33). In the following year, problems in the collection of rice revenues were mentioned again (BOA, A.DVNSMHM.d.36/577). European summer temperatures decreased in the 17th century (Luterbacher et al., 2004), which might have resulted in the reduction of rice plantations at the northern limit of the natural rice cultivation zone.

Historical evidence from Franciscan monastery chronicles mentioned by Mrgić (2011) shows that weather extremes influenced the region’s agriculture in the 17th and 18th centuries. While droughts were recorded in 1660, 1664 and from 1686 to 1687, heavy snowfall was also mentioned in 1683, 1687–1690, 1731, 1737–38, 1741, 1743, 1749–50, 1753, 1759–60, 1762, 1764–65, 1767, and 1769–70. These extreme weather years correspond to wars (Mrgić, 2011; 2018), including the Long War (1593–1606) in the Western Balkans, followed by the Morea War (1684–1699) in the south of the Balkan Peninsula and, finally, the War of the Holy League (1683–1699). Weather extremes and wars decreased the workforce and caused insecurity in plantation areas. In the Balkans, the number of *çeltikçis* had decreased by the beginning of the 18th century (Kul, 2017). But, as long as the workforce was available, the canals were repaired and there were still numerous paddies producing rice throughout the century. Evliya Çelebi mentions Serres, Thessaloniki, Crete, Lepanto and Ioannina as places where good rice was produced in the 17th century (Evliya VIII, 59, 73, 240-241, 271, 289). The influence of weather extremes both on the production process at mills and agriculture would be a very important topic for future studies.

Marmara Transition

The OWDA reconstruction (Cook et al., 2015) shows that the mean summer precipitation values in the Maritsa River catchment at Plovdiv were much higher than they are today. The yellow boxes in Figure 9 indicate periods of change in mean summer precipitation values. According to these values, the region experienced a two-step decrease in mean summer precipitation from the early 19th century. As a result of these gradual long-term decreases in precipitation and the high use of water sources for mass agricultural production, the region experiences significant water resource problems today.

In the Ottoman Plovdiv, rice paddies were registered as early as 1480 (Boykov et al., 2000). Plovdiv and Pazardzhik produced large amounts of rice (Shopov, 2020). This agricultural organization for large-scale production relied on the existence of large estates. These estates that fed Istanbul belonged to the waqfs of the sultans and high statesman. The organization of the workforce was the most critical factor for labour-intensive rice plantations. The number of workers known as *kürekçi*, involved in rice production, who were responsible for the technical organization of the canals, increased from 19 in 1480 to 55 in 1570–71 (Shopov, 2020).

The OWDA reconstruction (Cook et al., 2015) shows that the mean summer precipitation values decreased by the end of the 16th century, as seen in the second yellow box in Figure 9. Scorching summers and water stress meant harder conditions for workers and animals, and less water for the mills. Historical evidence shows that workers sometimes fled from hard working conditions in the fields and from malaria, which was rampant in rice fields. In 1583, a malaria outbreak was recorded (Sert, 2020a; Shopov, 2020; BOA, A.DVNSMHM.d.49/137). Conditions became harder by the end of the 16th century. In 1597, some villagers could not pay their taxes and fled (BOA, AE.SMMD.III.1/31). Commercial production continued in Eastern Europe despite reduced wages and worsening labour conditions (Wiesner, 2013); when workers left, new ones replaced them and production continued. Migrants supplied the labour-intensive workforce in the Plovdiv paddies. After extreme droughts and extraordinarily cold winters in the Crimean Peninsula that resulted in animals and people perishing, many moved to Ottoman lands in the 15th century and later in 1560 (Veinstein, 2001). Moreover, demographic studies (Stoianovich, 1992; Kiel, 1997) show that decreasing temperatures in the 17th century affected many people living in mountainous areas of the Balkans who moved to lower altitude settlements like Plovdiv.

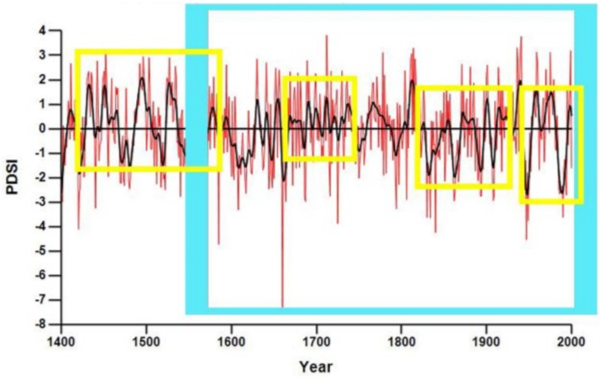

Fig. 9 June-July-August Palmer Drought Severity Index (PDSI) from the OWDA reconstruction (Cook et al., 2015) for Plovdiv between 1400 and 2000

Waqf account books published by Oruç et al. (2014) give a snapshot from five years between 1635 and 1641 and allows a comparison of yearly yield fluctuation with June-July-August PDSI changes. In Table 2 annual rice revenue entries of the Şahabeddin Paşa Waqf account books are compared with the June-July-August PDSI values from the OWDA.

Yield amounts show a negative correlation with OWDA summer precipitation values and decadal spline values. The approximate production amounts compared with June-July-August PDSI values show that PDSI values were -0.2539 in 1634, 0.0924 in 1635 and -0.6714 in 1636 and that production was approximately 456 kg (14 *müd*) in those years. It dropped to 391 kg (12 *müd*) in 1637 and 1638 when June-July-August PDSI decreased to -2.436 in 1637 and -2.2904 in 1638. There is no yield data for 1639 when the June-July-August PDSI was -1.4531. Although the June-July-August PDSI was 0.9276 in 1640, ten-year spline values were still negative. After the long dry years, yield dropped to 293 kg (9 müd). In 1641, the June-July-August PDSI increased to 2.084 and yield increased to 489 kg (15 *müd*) (Oruç et al., 2014). The same negative correlation was seen in Konya. However, a long series of data is needed to fully understand the influence of climate variability.

For Plovdiv, other revenue books of the Şehabeddin Paşa Waqf are available in the Sofia Archive for 1613–1614, 1672–1673 and 1679–1680, but the series of documents does not continue. The fluctuations of yields in other waqfs can also be a good source of information for determining climate history. Quite a few waqfs had rice plantations in Plovdiv. Even in low precipitation years such as in 1540 (Cook et al., 2015), the amount of rice carried by camel caravans from Plovdiv to Istanbul was around 513 tons (Shopov, 2020). This means that data regarding the Şahabeddin Paşa Waqf indicate only a very small part of the production. In future, the waqf account book series may show the relationship between yearly yield and precipitation changes for more extended periods.

All in all, droughts have been effective. Andreev et al. (2003) mention issues regarding rice revenues from 1698 to 1700 and water supply in 1708.

Table 2 Comparison of reconstructed OWDA June-July-August Palmer Drought Severity Index (PDSI) values (Cook et al., 2015) to the yield amounts according to Şahabeddin Paşa Waqf account books (Oruç et al. 2014) for the area of Plovdiv.

	Reconstructed JJA		Crop yield	
Year	PDSI	10-Year Spline	Production in kg	müd
1634	-0,2539	-0,176	456	14
1635	0,0924	-0,622	456	14
1636	-0,6714	-0,993	456	14
1637	-2,436	-1,176	391	12
1638	-2,2904	-1,04	391	12
1639	-1,4531	-0,607		
1640	0,9276	-0,085	293	9
1641	2,084	0,224	489	15

Moreover, historical evidence highlights the 1718 drought when villagers applied for a tax reduction and help to repair canals. However, officials declined their request and instead ordered them to pay 60 *akçes* for each kilo of rice they failed to deliver. People left their villages in Plovdiv and Pazarcık after this event (Andreev et al. 2003). Andreev et al. (2003) describe how the 1730s were even worse, whereby there was almost no rice revenue in 1735.

This coincides with accounts of Kelemen Mikes (1690–1761), the famous Hungarian essayist and political figure, who lived in exile with the Transylvanian Prince Ferenc Rákóczi in Tekirdagh. Kelemen Mikes described extraordinarily hot temperatures in March 1735 (Sert, 2007). As March is the germination period for rice seed and the ideal temperature for germination is 20–35ºC, scorching temperatures and water deficits would have been detrimental at this vegetative stage. This may be a reason why there were no rice revenues.

Kelemen Mikes mentions a significantly cold spell in 1740. That year, spring came late. It was even cold in May. In addition, December of the same year was extraordinarily hot. It was as if the seasons had changed place (Sert, 2007). There is a decree dating back to 27 March 1742 that includes the complaint that villagers did not seed their rice in March (BOA AE.SMHD.I.158/11923); since 1740's spring was so cold and farmers lost their seed, it is possible that they were behaving cautiously. Kelemen Mikes also mentions a devastating amount of snow, which started in October 1751 before the harvest of cotton and grapes (Sert, 2007).

According to Cook et al. (2015), the OWDA 19th century mean summer precipitation values fell and extreme drought years were experienced in 1806, 1830, 1832–1834, 1840, 1851, 1861–1863, 1887 and 1893–1894 (Fig. 9). Droughts probably made working conditions harder. In May 1844, the center sent help to rice workers (BOA, A.MKT.12/13, 01). Before this date, all relevant records refer to the punishment of workers who fled or peasants who did not pay their taxes. Perhaps conditions were more demanding and the workforce had diminished to such an extent after the long Balkan Wars that state authorities realized coercion might not work this time. This is the first mention of help being sent to workers so far identified by this study. In the course of the 19th century, the Ottoman Empire lost its plantations in the Balkans. The supply of rice decreased so much that demand in the Ottoman market could only be met with imported rice (Emecan, 1993). The state gave priority to resettling rice farmers who migrated from the Balkans to places that were convenient for rice farming in Anatolia, for example, and rice farmers from Plovdiv continued rice cultivation in Bursa.

DISCUSSION

The Little Ice Age was the period in which mean temperatures declined by up to 2°C. Like global warming today, the change in mean temperatures meant very hot and very cold extremes, floods and extreme seasonal changes. Its effects were divergent and showed regional differences. While in Continental Central Anatolia, the Little Ice Age brought drought years, which reduced agricultural production, and caused migration and rebellion (White, 2011), its effects on Europe were asynchronous and diverse.

Ottoman historians have asked (Griswold, 1993; Orbay, 2007; Sert, 2007, 2020b; White, 2011; Kolovos et al., 2018; Kuru, 2018) whether or not the Little Ice Age and other climate changes influenced the Ottoman Empire. To answer this question, institutional changes should be first mapped and then these changes should be related to the environmental and socio-economic conditions that the institutions faced. The present study shows partial effects of climate variability on rice yields, labour relations, rice mills, the health of inhabitants and population movements. The regional variability demonstrates the importance of using appropriate palaeoclimatology data in historical studies. Paleoclimatogic proxy data can advance discussions about the impact of climate variability in Ottoman historiography. Both the regional differences in climate variability and the influence of weather extremes are significant for discussions about the Little Ice Age in Ottoman history.

The Ottoman Empire experienced profound institutional changes after the second half of the 16th century (Kunt, 1983; Tezcan, 2010). An increase in the capacity of supplying food to cities and the capacity of intrusion into the environment draw some attention. However, the effect of climate is an underestimated topic in this anthropocentric historiography. The effects of the Little Ice Age have been introduced as a trigger for the decline of the Ottoman Empire (White, 2011) but have never been examined as a factor for institutional advancement even when the decline theory was rejected. The Little Ice Age droughts, which started at the end of the 16th century and continuing into the 17th century, were destructive in Central Anatolia. Due to the teleconnections of climate, an east-west bipolar climate seesaw operated in the Mediterranean. While Inner Anatolia was dry, West Europe and Western Anatolia had higher precipitation rates (Roberts et al., 2012). While in Continental Anatolia the Little Ice Age brought drought years, which decreased agricultural production and caused migration and rebellion in the 17th century (White, 2011), the Aegean islands and southern Balkans saw an increase in the olive harvest during the very same century (Kolovos et al., 2018). Likewise, in the coastal regions of Anatolia, where climate conditions were different, population movements and production conditions were not like those in Central Anatolia (Kuru, 2018). Due to these conflicting conditions, Ottoman scholars have discussed whether the Little Ice Age was effective on the Ottoman Empire at all. The present study asserts that a better acquaintance of the Ottomanist with palaeoclimatology data is vital to understand the teleconnections of climate and society.

Instead of focusing only on the destructive effects of the Little Ice Age, recognizing its institutional challenges may overcome dualistic discourse in this scholarly discussion. Orbay (2007) shows that waqfs undertook important institutional transformations to overcome the problems caused by increased food prices (e.g., waqfs introduced cash aid to students instead of providing free food from their kitchens). He highlights regional differences in the transportation of food from other regions, exemption of tax revenues and refutes the idea that the 17th century was a crisis era triggered by climate change that led to the empire’s decline. Although I agree with Orbay (2007) about the importance of institutional measures and organizational changes and agree with Kolovos et al. (2018) and Kuru (2018) that climate conditions were different in other regions, there was a regional crisis in Central Anatolia that started at the end of the 16th century and continued during the 17th century. Moreover, the effects of the Little Ice Age in the Balkans still needs to be studied, especially as this study and Mrgić (2018) show that the 18th century climate extremes influenced the region. Moreover, the effect of 19th century droughts were more influential than the 16th century in Istanbul (Sert, 2020b).

CONCLUSION

This study has introduced the importance of Ottoman rice plantations in the environmental reconstruction of the region between the Tigris and the Danube. It has classified available archival documents about plantations and compared palaeoclimatology data with archival evidence. This comparison shows partial historical evidence about the effects of precipitation and temperature variability and climate extremes on rice yields and the research potential of Ottoman archival documents for climate history.

Results show that decadal low summer PDSI values coincided with a decrease in rice yields or an increase in rice prices in Plovdiv and Central Anatolia. Weather extremes such as the cold May in 1740 resulted in a fatal decrease in yield in Plovdiv. The piecemeal information about the effects of climate variability prove that the account books of waqfs are an important source type that can give yearly yield data. Nature provides useful evidence to help understand the archives of societies (White et. al, 2018).

Questions about the influence of the Little Ice Age on the Ottoman Empire will find answers in line with an increase in palaeoclimatology data. In 2007, when Orbay (2007) was writing about grain yields and climate relation, available palaeoclimatology proxy data was limited. Future works on account books may answer some of the questions raised here if prices and yearly revenues are compared with palaeoclimatology proxy data. Moreover, a group of scholars in Paleo-Science and History at the Max Planck Institute for the Science of Human History in Jena, including Ottomanists Georgios Liakopoulus and Elias Kolovos, are working on phenological data about grain to reveal information about the relation between climate and institutional changes. The present study aims to contribute to the debate.

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BOA AE.SMMD.III.1/31; IV.56/6501; IV.101/11751.

BOA AE.SSLM.III/197, 11831.

BOA AE.SSÜL.I.2.

BOA, D.ÇRS.1; 2; 3; 4.

BOA, D.ÇRS.D.25994; 25995; 25996; 25997; 25998; 25999; 26000.

BOA İE.DH.2/109.

BOA İE.ML.1/29; 12/1035; 16/1532; 24/2327; 45/4373.

BOA İE.ŞKRT.2/170.

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