Journal of
Climate Change Research

2020, 1(4): 35-47
DOI: 10.30488/CCR.2020.244327.1017

Holocene climatic events in Iran

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Keywords
Holocene
Climatic Event
Paleoclimate Research
Drought
Archaeology

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Article history
Received: May, 3
Revised: September, 3
Accepted: September, 28

Abstract

Climate change is significantly affecting the livelihoods and health of human societies. During the Holocene, climatic events have occurred repeatedly. These events typically have affected large regions between 100 and 600 years. Paleoclimate studies of the Northern Hemisphere have identified climatic events of 9.2, 8.2, 5.2, 4.2, 3.2 ka BP, Roman warming, the early medieval cooling, medieval warming, and Little Ice Age. Also, by adapting the archaeological studies and the paleoclimate research of Iran, other periods of climate change such as 7.5, 7, 6.2 and 4.8 ka BP can be introduced. Due to the vastness and geographical diversity of Iran, the impact of each of these events in different parts of the country has been different, but, in general, during droughts related to climate change, semi-arid to arid regions of Iran have been more vulnerable, and therefore, people were using a variety of strategies to resilience and adapt, such as changing subsistence patterns, managing water resources, and migrating. However, in some periods of climate change, the effects of climatic hazards have been such that it has led to the cultural, socio-economic and political decline of societies.

Introduction

Palaeoclimatology is the study of past climate, from decades to millions of years ago, based on indirect evidence, which can be quantified from proxies to reconstruct (Ouellet-Bernier and de Vernal, 2018). Evidence of past climatic conditions is commonly preserved in marine and lacustrine sediments, erosional features, Aeolian deposits, paleosols, loess, ice, glacial deposits, speleothems, subfossil biological material, biota in lake sediments, tree rings, pollen, plant macrofossils, corals, written records of environmental indicators, etc. (Bradley 2015:6, Tab. 1.1). Paleoclimate research not only clarifies many ambiguities about past climate change, but also guides future climate change (Azizi and Davoudi 2019). Climate variations happen on all time scales, as well as on all spatial scales, from the regional and continental to the global (Chiotis 2018).

Past climate and environmental change is of longstanding and fundamental interest to archaeologists (Jones et al. 2011). Although the high power of adaptation in Homo sapience has allowed him to make fundamental changes in the subsistence system and the organization of technology (Jajarmi et al. 2015), however, during the Holocene, southwest Asia witnessed the rise and decline of many agricultural-based communities due to abrupt climate change (Staubwasser and Weiss 2006; Weiss 2017).

Due to its special geographical location and the effect of air circulation system and subtropical high pressure and other factors, there is a relatively dry climate and desert environment in most parts of Iran (Kardavani 1988). The country has experienced repeatedly cooling and warming climate changes during the Holocene. The effectiveness of these courses has been different in each region of Iran. Addressing the issue of climate change in ancient times in order to understand their consequences has been less considered by Iranian archaeologists and only in a few studies can be seen the relationship between archaeology and palaeoclimatology (Schmidt et al. 2011; Djamali et al. 2009; 2016; Johns et al. 2015; Sharifi et al. 2015; Shaikh Baikloo et al. 2016, 2018, 2019; Shaikh Baikloo and Chaychi 2019). In this research, based on paleoclimate research and archaeological studies, known Holocene climatic events in Iran are studied and also a number of climatic events that were not previously identified are introduced.

Please cite this article as Shaikh Baikloo Islam B (2020). Holocene climatic events in Iran. Journal of Climate Change Research. 1(4): 35-47.

Methodology

This study focuses on paleoclimate research in Iran, but global studies have also been used to strengthen the discussion. Here, the periods of climate change and how they affect are examined. Paleoclimate research in Iran has been conducted with different resolutions, but most of them have low resolutions. Some of the climate change mentioned in this research are well-known events in the paleoclimate literature and others have been introduced by the author. The Central Greenland Temperature Change (GCTC) diagram (Fig 1) based on Greenland ice core sheet project 2 (GISP2), with high resolution (Alley 2004), has been used as a valid basis for indicating cold and warm periods. The Iranian paleoclimate studies used in this article include Lake Zeribar in Kurdistan province (Stevens et al. 2001 for diagram; Wasylikowa et al. 2006), Lake Mirabad in Luristan p. (Stevens et al. 2006), Maharlou in Fars p. (Brisset et al. 2019), Lake Neor in Ardebil p. (Sharifi et al. 2015), Lake Urmia (Sharifi et al. 2019), Lake Kongor in Gorgan p. (Shumilovskikh et al. 2016), the Konar Sandal site of Jiroft in Kerman p. (Safaierad et al. 2020 for diagram; Gurjazkaite et al. 2018 for the 3.2 ka BP event), Jazmurian Playa in Kerman p. (Vaezi et al. 2019), Lake Hamoun in Sistan and Baluchistan p. (Hamzeh et al. 2017), Katalekhor Cave in Zanjan p. (Andrews et al. 2020), Gole Zard Cave in Mazandaran p. (Carolin et al. 2018), Caspian Sea (Leroy et al. 2014) and Nimbluk lakebed in North Khorasan p. (Fattahi and Walker 2015) (Figs 2, 3). References to these studies are not written in the text to avoid repeat.

The Holocene Age

The Holocene, the second phase of the Quaternary, from 11.7 ka BP has been witnessing environmental processes which have continued to the present day; Processes such as soil formation, plant succession, lake ontogeny and faunal migration (Roberts, 2013). This age is divided into three stages: Early Holocene/ Greenlandian 11.7–8.2 ka BP, Mid-Holocene/ Northgrippian 8.2–4.2 ka BP and Late Holocene/ Meghalayan 4.2 ka BP to now (Cohen et al. 2013). The Holocene stratigraphic record contains details of many climatic, environmental, vegetation and animal changes (Walker et al. 2009).

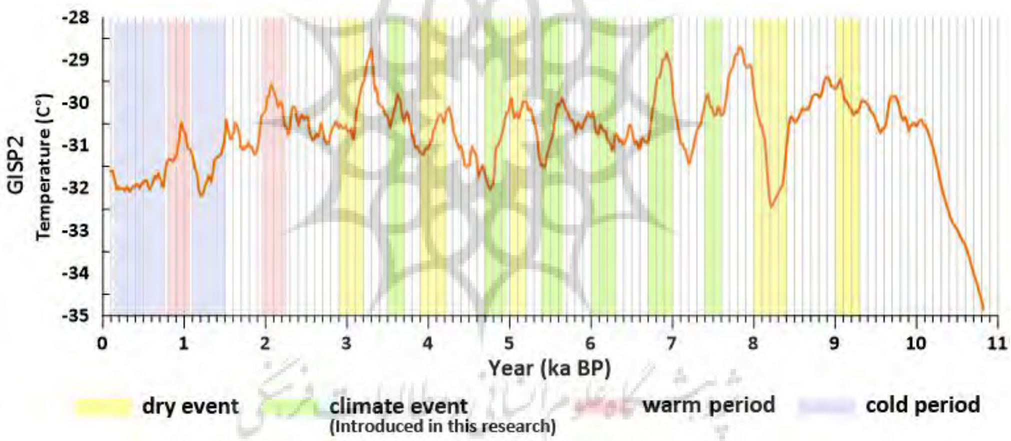

Figure 1. The Central Greenland Temperature Change diagram (GISP2) (Alley 2004).

The Early Holocene

The studies of Dye3 ice core in Greenland shows that at the beginning of the Holocene, the average annual temperature increased by about 7° C within maximum of 50 years (Dansgaard et al. 1989). The GISP2 research also show a gradual increase in temperature until ca. 10 ka BP (Figure 1). In the first warm phase of this period, forest vegetation spread rapidly in the glacial regions within half a century or less, and tundra-steppe cover was dominated by shrubs, and open forests replaced the grassland cover of the Younger Dryas (Bos et al. 2007). Reduction of dry conditions and increase in humidity in studies of Zaribar, Mirabad, Neor and Urmia Lakes, Jazmurian Playa, the Konar Sandal site and the Nimbluk lakebed are visible (Figs 2, 3). It is worth noting that oak appeared in Mirabad about 10 ka BP, 2000 years earlier than Zaribar, indicating that there was a more severe drought in the North Zagros during the early Holocene (Wright 1993). Studies of Lake Van in eastern Turkey indicate a rapid increase in humidity about 11 ka BP (Wick et al. 2003). In the eastern Mediterranean region, studies of sea level changes show a wet period between 10 and 8.6 ka BP (Migowski et al. 2006). This result confirms by examining the speleothems of Soreq cave in the west of Jerusalem (Bar-Matthews et al. 1999). Archaeologically, the early Holocene overlaps with the Neolithic Age in Near East, the period of the domestication of plants and animals, sedentary, the formation of villages, as well as the invention of pottery.

The 9.2 ka BP event

This event has led to a series of climatic anomalies, such as cooling in the northern and middle latitudes and drought in the northern tropics (Fleitmann et al. 2008). During this period, the southeastern region of Iran, probably due to the weakening of the Indian monsoons, experienced severe tension. Because of the relatively short duration of this event, only high-resolution research is able to demonstrate it (Flohr et al. 2016). According to studies of the Hoti and Qunf caves in Oman and the Dongge Cave in China, the event is dated to 9210±80 BP (Fleitmann et al. 2007, 2003; Neff et al. 2001; Dykoski et al. 2005), and based on studies of ice cores and the record of tree rings in Bamberg, Germany, it is dated to 9250 BP (Spurk et al. 2002; Vinther et al. 2006). The lacustrine record from Norway shows the date of 9390-9145 BP (Hormes et al. 2009). Geenland ice cores have been dated from 9300 (+10, -20) to 9190 (+30, -10) (Rasmussen et al. 2014). In Iran, evidence of this climatic event has been found in Lake Urmia and the Konar Sandal (Fig 2).

The Mid-Holocene

The Mid-Holocene climate was generally warm. Several climatic events have occurred during this 4000-year period, which can be seen in the results of paleoclimate research. During this period, human societies gradually entered the stage of advanced ruralization from the early rural stage. Pottery production technology was upgraded and irrigation canals led to agricultural development. From the late sixth millennium BC, new belief systems probably emerged based on new climatic-environmental and living conditions. These beliefs led to the construction of temples and the formation of the clergy in rural communities. In the fourth millennium BC, when the climate was generally arid and unfavorable, cities, urban control systems, and the early writing system for economic exchanges emerged. These innovations, in the early third millennium BC, led to the formation of early powerful governments.

The 8.2 ka BP event

The occurrence of this event marks the transition from the early- to the Mid-Holocene. During the event (ca. 8.4 – 8 ka BP), cold and dry climates prevailed in most parts of the Northern Hemisphere. Evidence of 8.2 ka comes from Greenland (Alley et al. 1997; Alley and Ágústsdóttir, 2005), North Atlantic (Bond et al. 1997), Europe (Jalut et al. 2000; Rosén et al. 2001; Davis et al. 2003; Seppä et al. 2007), North America (Hu et al. 1999; Barber et al. 1999; Seppä et al. 2003), Africa (Gasse, 2000) and Asia (excluding Iran) (van Campo and Gasse 1993; Wick et al. 2003; Bar-Matthews et al. 1999; de Menocal et al. 2001; Neff et al. 2001; Liu et al. 2003; Staubwasser et al. 2002; Fleitmann et al. 2003; Gupta et al. 2003; Parker et al. 2006; Cheng et al. 2009).

According to some Asian paleoclimate evidence, it is likely that this event was part of a longer anomaly that lasted 400 to 600 years (Rohling and Pälike 2005). According to CGTC, the event, which had about half the power of the Younger Dryas and caused temperatures to drop to a maximum of 6±2˚ C, occurred between 8.4 and 8 ka BP (Alley et al. 1997, 2004) (Fig 1). Signs of this abrupt climate change, with evidence of increasing climatic dryness and dust flux, from Lake Neor, Lake Urmia, Lake Hamoun, Jazmurian Playa and the Konar Sandal have been reported (Figs 2, 3). Both the change in solar activity (Bos et al. 2007) and the change in the thermohaline cycle (Clark et al. 2002) have been suggested as the cause of this event.

During the 8.2 ka BP event, many societies in the N. Hemisphere, especially in Near East, declined or were forced to migrate and change their subsistence patterns to adapt to abrupt climate change (Shaikh Baikloo et al. 2018; Staubwasser and Weiss 2006; Weninger et al. 2006). Significant population decline in these regions has probably been linked to migration and increased mortality due to severe droughts, frequent dust storms, famine, malnutrition, and the spread of deadly diseases. It should be noted that the prevalence of epidemics such as plague, cholera, smallpox and dysentery in the historical period was mostly related to climatic cooling periods such as the early medieval cooling and Little Ice Age (McMichael et al. 2012; Büntgen et al. 2016; Schmid et al. 2015; Appleby 1980).

The 7.5 ka BP event

Paleoclimate researches of Neor, Urmia and Mirabad Lakes, and Jazmurian Playa clearly show the increase in dryness between 7.6 and 7.4 ka BP (Fig 2). Researches in Lake Awafi, Saudi Arabia (Parker et al. 2006), Hoti Cave, Oman (Neff et al. 2001) and the Faynan Oasis, Jordan Valley (Hunt et al. 2004) also confirm the dry conditions of this time. Therefore, given the speed and magnitude of this climate change, it can perhaps be called a climatic event (at least on a regional scale). Apparently, these arid climates were associated with the occurrence of a short cooling period, which may have changed regional precipitation patterns and reduced annual rainfall in the tropics.

According to CGTC (Fig 1), this dry period is linked to the 8.2 ka BP event by a warm and dry period that occurred ca. 7.8 ka BP (Alley 2004). Thus, in general, dry climatic conditions (possibly with short-term fluctuations in climate improvement) prevailed from ca. 8.4 to 7.4 ka BP. Lacustrine records in northern Sweden also show cold periods in ca. 8.5, 8.2 and 7.6 ka BP and a warm period in ca. 7.7 ka BP (Rosén et al. 2001). This arid condition is confirmed by the study of Holocene climate change along the shoreline of southeastern France to southeastern Spain (Jalut et al. 2000).

The beginning of the cultural flourishing period and a significant increase in the number of villages with irrigated agriculture in Iran and Mesopotamia is related to the second half of the sixth millennium BC (Matthews 2000; Gillmore et al. 2009). The small abundance of archaeological sites in the arid and semi-arid region of North Central Iran during the mentioned millennium (6400 – 5400 BC) can confirm the difficult living conditions due to unfavorable climatic conditions for agriculture (Shaikh Baikloo et al. 2018). It is also possible that in order to adapt, the subsistence system of some communities have changed from sedentary-farming to pastoral nomadism.

The 7 ka BP event

The GISP2 Diagram shows a dramatic increase in temperature from ca. 7 to 6.7 ka BP (Fig 1). In Iran, studies of Neor, Urmia and Zaribar Lakes determine the dry climatic conditions (Figure 2). During this climate change, the first phase of the Cheshmeh Ali cultural period in North Central Iran declined (Shaikh Baikloo and Chaychi 2019).

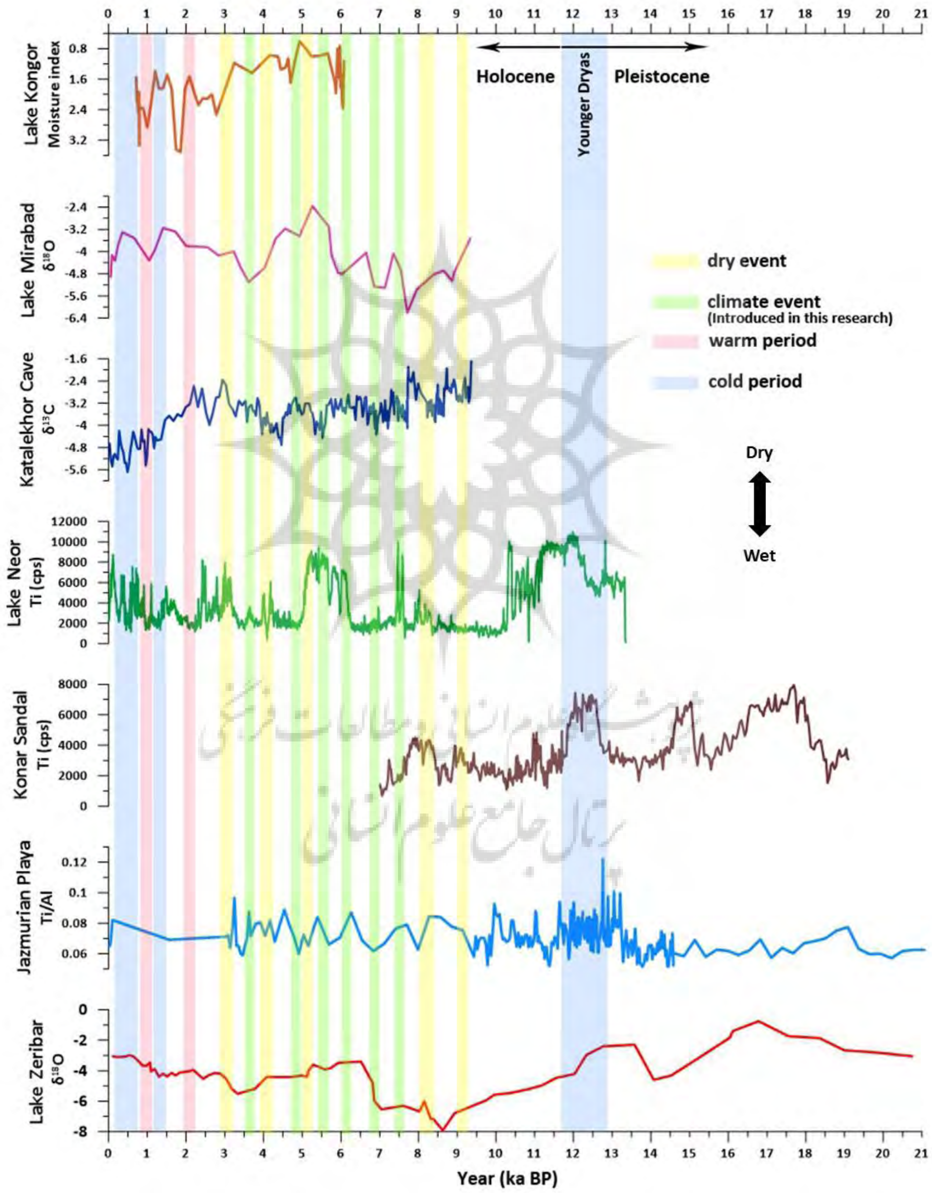

Figure 2. Paleoclimate research in Iran.

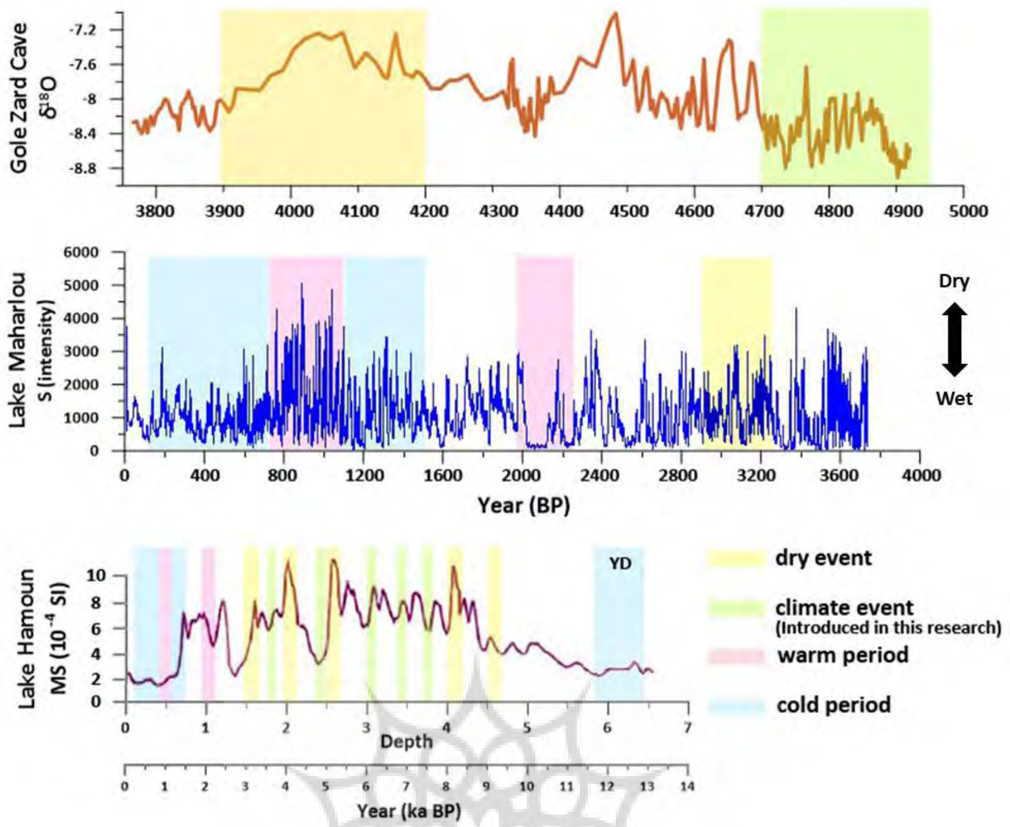

Figure 3. Paleoclimate research in Iran.

The 6.2 ka BP event

Many proxies in the Middle East represent arid climatic conditions between 6.4 and 6 ka BP. This long-term drought has been reported in studies of Lake Zaribar, Lake Neor, Lake Urmia, Lake Hamoun, Jazmurian Playa, Katalekhor Cave (Figs 2, 3), Soreq Cave (Bar-Matthews and Ayalon 2011), Lake Zazari in Greece (Cavallari and Rosenmeier 2007), Jeita Cave in Lebanon (Verheyden et al. 2008) and the North African Sahara (Petit-Maire and Guo 1996). Given that the peak of dry conditions during this period occurred betweem ca. 6.25 and 6.15 ka BP, so, here, this climate change is called the 6.2 ka BP event.

According to radiocarbon dating, the decline of the Cheshmeh Ali culture occurred between about 4300 and 4200 BC, and after that, the Sialk III culture did not appear in a flourishing state, but due to the lack of architectural remains belonging to the Sialk III_{1-2}, it seems, until about 4000 BC, sedentary-agricultural life in this area has been disrupting (Shaikh Baikloo and Chaychi 2019; Shaikh Baikloo et al. 2019).

The 6 – 5 ka BP dry climate

Proxies of Neor, Urmia, Zaribar, Mirabad, Hamoun and Kongor Lakes, and Katalekhor Cave, during the fourth millennium BC, in general, show dry conditions (with fluctuations) (Figs 2, 3) which was probably associated with the occurrence of a cold period that reduced the temperature of the North Atlantic surface waters and then weakened the Mediterranean system (Bar-Matthews et al. 1997; Migowski et al. 2006). Studies of 50 proxies around the world also confirm the cold and dry climate in warm regions during this millennium (Mayewski et al. 2004). Paleoclimate research in North Atlantic indicate the occurrence of the 5.9 ka BP cold event (the 4th Bond event[1]) (Bond et al. 1997). Studies of the Sahara Desert in North Africa determine a dry period in 5.9–5.76 ka BP (Cremaschi et al. 2006) and in Soreq cave characterizing two very dry periods in 5.7 – 5.6 and 5.25–5.17 ka BP (Bar-Matthews and Ayalon 2011). The transformation of North Africa into a vast desert due to climate change in the middle of the fourth millennium BC has led to the mass migration of nomadic pastoral communities from different parts of the Nile Valley, which was probably the main reason for the emergence of civilization in Egypt (Malville et al. 1998).

1.This is actually the 5th Bond event, but since the first event has been introduced with the number 0, this event is known as the 4th event.

The 5.2 ka BP event

This climatic event in the late fourth millennium BC, covering ca. 5.3 to 5 ka BP, in studies of Neor, Hamoun, and Mirabad Lakes, and Katalekhor Cave in Iran, Shari Playa in central Iraq (Jassim et al. 2007), Lake Van (Wick et al. 2003) and Lake Tecer in Turkey (Kuzucuoğlu et al. 2011), the Gulf of Oman sediments (Cullen et al. 2000), Soreq cave (Bar-Matthews and Ayalon, 2011) and Lake Zazari (Cavallari and Rosenmeier 2007) has been reported. During the arid climate, the Uruk civilization in Mesopotamia declined, leading to the collapse of towns affected by Uruk culture or Uruk colonies. At the same time, almost the entire cultural region of North Central Iran has experienced a cultural decline that lasted during the Bronze Age (ca. 3–1.5 ka BP) (Shaikh Baikloo et al. 2016).

The 4.8 ka BP event

According to CGTC (Fig 1), immediately after the 5.2 ka BP event, a dramatic drop in temperature occurred with a peak of 4.8 ka BP (Alley et al. 2004). Identification of this temperature drop has also been obtained in studies of Soreq Cave (Bar-Matthews et al. 1999). The research on changes in solar outputs shows a decrease at the same time, as well (Steinhilber et al. 2012). Undoubtedly, this abrupt cooling after the 5.2 ka, could have exacerbated the disturbances in the living system and the quality of human health. It is also not unexpected that the spread of various infectious epidemics along with famine and malnutrition, has led to an increase in mortality. This climate change at the beginning of the Bronze Age seems to have put great stress on the inhabitants of vulnerable environments. Research in Katalekhor and Gole Zard Caves (Carolin et al. 2018) and Lake Kongor, unlike other sites, shows dry conditions during this period (Figs 2, 3).

The Late Holocene

During this period, especially from the beginning of the first millennium BC, the trend of temperature changes tended to cool (Figure 1). Therefore, the main reason for the current global warming can be considered human activities and rapid population growth since the second half of the nineteenth century.

3.3.1. The 4.2 ka BP event

This climatic event (ca. 4.2–3.9 ka BP) is known as the 3rd Bond cooling event in the North Atlantic (Bond et al. 1997). Evidence of the event in climatic archives of Neor, Urmia, Hamoun and Kongor Lakes, Jazmurian Playa, the Konar Sandal site, Gole Zard Cave and Caspian Sea have been identified (Figs 2, 3). Also, paleoclimate researches of the Gulf of Oman (deMenocal 2001; Cullen et al. 2000), the Indus River Delta (Staubwasser et al. 2003), the Nile River Delta (Stanley et al. 2003), Red Sea (Arz et al. 2006), Soreq Cave (Bar- Matthews and Ayalon 2011) and Lake Tecer (Kuzucuoğlu et al. 2011) confirm the occurrence of this event. This event probably occurred in two pulses and apparently in the southern hemisphere, in contrast to the northern hemisphere, was associated with warming, increasing humidity and strengthening the monsoons (Railsback et al. 2018). The slowing of the North Atlantic thermohaline circulation seems to have caused this cold and dry period in the Northern Hemisphere, so that both western cyclones and monsoons have been weakened (Nakamura et al. 2016; Staubwasser et al. 2003).

The devastating effects of this abrupt climate change can be seen in most of the ancient textures of the Near East. The fall of the Akkadian Empire in Mesopotamia after about 150 years probably occurred due to the 4.2 ka. This civilization, despite having an advanced irrigation system and grain warehouses, could not withstand the consequences of this dry event. Archaeological evidence indicates that the Habur Plain was abandoned due to severe droughts from about 2200 to 1900 BC. The migration to the southern Mesopotamia was occurring at a time when southern irrigation agriculture was suffering from reduced flow of the Euphrates. Thus, in such circumstances, the economic balance in Mesopotamia was disturbed (Weiss 2017; Weiss et al. 1993). Also, the occurrence of the first Intermediate period in Egypt due to decrease in Nile floods and increase in sand and dust storms (Hamdan et al. 2016) and the decline of civilizations along the Indus valley (Staubwasser et al. 2003) and in central and southeastern Iran such as Tepe Hissar and Shahr-i Soukhteh (Voigt and Dyson 1992: 128, Tab.1) related to the 4.2 ka can be explained.

The 3.2 ka BP event

The CGTC diagram shows a significant increase in temperature from ca. 3.4 with a peak of 3.3 ka BP and then a sharp drop in temperature with a peak of ca. 3.1 ka BP (Fig 1) (Alley 2004). Proxies of Neor, Maharlou, Zaribar, Mirabad Lakes, the Konar Sandal site and Katalekhor Cave determine the increase in dryness from ca. 3.2 to 2.9 ka BP (Figs 2, 3). Also, the study of water fluctuations in the Tigris and Euphrates rivers indicates the minimum flow of these rivers between ca. 3.15 and 2.95 ka BP (Kay and Johnson 1981). Evidence of this event in climatic archives of the Eastern Mediterranean region (Kaniewski et al. 2010; 2013b; Neumann et al. 2007; Migowski et al. 2006; Verheyden et al. 2008), Egypt (Bernhardt et al. 2012; Baioumy et al. 2010) and Turkey (Wick et al. 2003; Roberts et al. 2001; Eastwood et al. 2007; Göktürk et al. 2011) have been identified, as well.

The overthrow of the kingdom of Ugarit in western Syria (eastern Mediterranean) in 1190-1192 BC by the Sea People was probably due to the weakness caused by drought, famine and economic pressure throughout the kingdom, which began around 1200 BC (Kaniewski et al. 2011, 2013a, 2015). Also, the outbreak of famine, economic crisis, civil war and weakening of political power in Egypt, especially from the time of Ramesses IV (1155 – 1149 BC) to the third Intermediate period (Shaw 2000: 525), may have been related to the 3.2 ka. In addition, during this event, the Hittites fell with the Assyrian invasions around 1178 BC and The Kassites with the invasions of the Elamites in 1155 BC. This period also coincided with widespread Indo-European migrations (Frachetti, 2011).

Roman Warming

According to CGTC (Fig 1), this warming period occurred from about 250 BC to 50 AD (Alley 2004). The effects of this climate change in the form of humidity reduction in proxies of Kongor, Urmia and Mirabad Lakes, and Katalekhor Cave, and increased humidity in Neor and Maharlou Lakes has been found (Fig 2, 3). It should be noted that, according to GISP2, after this event, the temperature decreased from 50 to 300 AD and increased from 300 to 500 AD (Fig 1). These temperature oscillations have been associated with increasing humidity in Kongor Lake and with reduced humidity in Hamoun, Neor, Mirabad and Urmia Lakes, and Katalekhor Cave (Figs 2, 3).

Early Medieval cooling

CGTC indicate a sharp drop in temperature during the 6th to 9th century AD (Fig 1) (Alley, 2004). According to North Atlantic studies, a period of climatic cooling occurred 1.4 ka BP, which is known as the first Bond cooling event (Bond et al. 1997). Studies of tree rings have shown a cooling period from 536 to 660 AD, due to repeated volcanic eruptions, leading to a widespread outbreak of plague (Büntgen et al. 2016; Sigl et al. 2015). Also, it is very likely that the reforms of the Roman emperor Justinian and the Sassanid King Khosrow Anushirvan can be attributed to the socio-economic problems caused by this natural event. Evidence and effects of this climate change in the form of increased humidity in Neor, Urmia, Mirabad, Kongor and Hamoun Lakes and Katalekhor Cave have been found. However, high-resolution studies show a relatively sharp increase in arid conditions from the late 5th to the middle 6th century AD (Figs 2, 3).

According to Futuh al-Buldan, in the year 6th or 7th AH (AD 628), the Tigris and Euphrates overflowed. Following this great and devastating flood, the plague spread in the western regions of Iran and throughout the Middle East, killing thousands of people, elders and apparently even the king of Iran, Ghobad II. Thus, the conditions were prepared for the Arab invasion and the fall of the Sassanid Empire. (Al-Baladhuri 1958: 414-415).

Medieval Warming

This warming period, from about 900 to 1250 AD, is clearly seen in CGTC (Figure 1) (Alley 2004) and Antarctica (Khim et al. 2002). Reasons for this climatic event include increased solar activity, reduced volcanic eruptions, and changes in the thermohaline cycle (Mann et al. 2009). Evidence of this warming period in Iran in the form of increased dryness in climatic archives of Neor, Urmia and Maharlou Lakes, and Katalekhor Cave has been observed (Figs 2, 3).

Little Ice Age

Although the drop in temperature during this cooling period was not as severe as the Ice Age, it has been termed the Ice Age (Matthes 1939). This climate change lasted from about 1300 to 1870 AD (Matthews and Briffa, 2005). The climatic proxies of Greenland (Fig 1) (Alley 2004), North Atlantic, as the 0 Bond cooling event in 500 BP (Bond et al. 1997), and Antarctica (Kreutz et al. 1997) clearly show this period. The end of this period is connected to the beginning of the global warming period. According to NASA, three maxima occurred during this cooling period: the first around 1650, the second around 1770, and the last around 1850. There have been relatively warm intervals between these periods. Several reasons have been suggested for this event, which can include a decrease in solar activity, an increase in volcanic activity, a change in the thermohalin cycle, a change in the axis and orbit of the earth (Mann et al. 2009).

Some consequences of Little Ice Age include climate hazards such as torrential rains and severe droughts, widespread famines (especially in 1315–1317 AD), social conflicts, plague outbreaks, and the death of one-third of Europian people (Parker 2013; McMichael 2012; Behringer 2005). Evidence of this period has been observed in the form of increasing dry conditions in Zaribar, Mirabad and Urmia Lakes. However, proxies of Lake Neor and Katalekhor Cave have determined a wet fluctuation between about 1400 and 1600 AD. Lake Maharlou studies also show wet and dry oscillations during this period (Figs 2, 3).

Current Global Warming

The Earth's current climate change, due to the widespread use of fossil fuels and the human subsistence system, occurs at a time when, given the decline in solar activity during the Late Holocene, we should probably see the continuation of Little Ice Age. Although the exploitation of fossil fuels using coal for Iron melting began in 1709 (Mott 1957), global warming accelerated with oil extraction in Pennsylvania from 1859 (Titusville 1896) and then, other countries. Extensive use of fossil fuels has increased greenhouse gas emissions (such as CO_2, CH_4, O_3, NO, water vapor etc.). Agricultural, livestock and industrial activities (especially petrochemicals and metallurgy), large-scale forest fires, deforestation for agriculture or construction, increasing vehicles with fossil fuels and population growth are the most important factors increasing atmospheric greenhouse gas emissions (Casper 2010). It should be noted that the human population of the earth has increased about 8 times in the last 150 years due to medical and lifestyle advances. Population growth leads to the production and emission of more carbon dioxide and methane. The effect of methane gas, which is most produced in paddy and animal husbandry, is estimated to be about 25 times that of carbon dioxide in global warming (Keppler et al. 2006). Therefore, it can be said with high probability that this climate change has been mostly the result of human activities, although the effects of natural factors in general cannot be ignored.

Conclusion

According to paleoclimate research and archaeological evidence of Southwest Asia, especially Iran, several climatic events occurred during the Holocene. These climate changes, both heating and cooling, have exacerbated extreme weather events such as droughts, dust storms and torrential rains, and have challenged the livelihoods and health systems of human communities. Due to the vastness and diversity of Iran's geography, the effects of these events have varied in different parts of the country, but, in general, in droughts related to climate change, many parts of Iran with semi-arid to arid climates have been more vulnerable. Resilience and adaptation strategies of human societies during periods of climate change have mainly included changing subsistence patterns, managing water resources and migrating to more favorable regions. In many cases, these strategies have ensured the survival of societies, but in some periods, the effects of climatic hazards have been such that they have led to the cultural, socio-economic and political collapse of societies.

Acknowledgement

I would like to thank Dr. A. Sharifi, Dr. M. Djamali, Dr. R. Safaierad, Dr. A. Vaezi, Dr. M. Hamzeh, Dr. L.S. Shumilovskikh, Dr. J.E. Andrews and Dr. S.A. Carolin for sharing their research data with me. Also, I sincerely thank Dr. Safaierd for all the time he has spent advising the author.

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