Quaternary International xxx (2015) 1–12

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

The Late-Holocene climate change, vegetation dynamics, lake-level changes and anthropogenic impacts in the Lake Urmia region, NW Iran

Taravat Talebi [a], Elias Ramezani [b,*], Morteza Djamali [c], Hamid Alizadeh Ketek Lahijani [d], Alireza Naqinezhad [e], Kamaleddin Alizadeh [f], Valérie Andrieu-Ponel [c]

[a] Urmia University, Urmia, Iran
[b] Department of Forestry, Faculty of Natural Resources, Urmia University, Urmia, Iran
[c] IMBE, Aix-Marseille Université, CNRS, IRD, Avignon Université, Europôle Méditerranéen de l'Arbois, BP 80, F-13545 Aix-en-Provence cedex 04, France
[d] Iranian National Institute for Oceanography and Atmospheric Science (INIOAS), Tehran, Iran
[e] Faculty of Sciences, University of Mazandaran, Babolsar, Mazandaran, Iran
[f] Department of Palynology and Climate Dynamics, University of Göttingen, Göttingen, Germany

ARTICLE INFO

Article history:
Available online xxx

Keywords:
Holocene
Rapid climatic changes
Anthropogenic activities
Vegetation history
Riella
Lake Urmia

ABSTRACT

Two short (100 and 175 cm-long) sediment cores from the southwestern corner of Lake Urmia provide a record of vegetation dynamics, lake-level changes and the role of climate and humans in shaping the landscape around Lake Urmia over the last 2550 years. Relatively low values of arboreal pollen (AP), and substantial values of *Artemisia* pollen from 2550 to 1500 cal BP indicate the prevalence of steppe vegetation and relatively arid climate in the area. However, a prominent peak of *Riella* spores may indicate a short-lived lake-level rise for the period 1900–2000 cal BP. The next period, 1500–550 cal BP, is characterized by substantial rise in AP, particularly *Quercus*, and a sharp decline of *Artemisia*, Chenopodiaceae/Amaranthaceae and wetland pollen types, suggesting the expansion of oak forests under a rather moist climate and/or a decline in agro-sylvo-pastoral practices in the area. Agricultural activity in the area can be inferred from sporadic occurrences of *Vitis*, *Ricinus* and *Juglans* pollen from the beginning of the record. The rise of saline habitat pollen types between 1100 and 800 cal BP, along with increased values of magnetic susceptibility and organic matter, suggest a lower water level and the subaerial exposure of saline mud flats, which could favour the re-colonization of chenopods and other halophytes around the margins of the lake. Thus, the Medieval Climatic Anomaly seems to be warmer-than-present in the Lake Urmia region. From 450 to 150 cal BP, the decline in *Quercus* and high values of *Artemisia*, along with higher lake levels and high magnetic susceptibility values, could be associated with the Little Ice Age. Since 500 cal BP, *Quercus* and *Riella* steadily decline and fade out towards the surface of the core, whereas pollen types attributable to steppe and desert vegetation increase. A prominent increase in organic matter in the uppermost part of the record could be associated with a lower lake level and the expansion of wetland vegetation in the recent past. Our findings suggest that the regional forest coverage in the highlands of Zagros and Azerbaijan has reached its minimum during recent decades, while Urmia's lake level dropped dramatically (increasing its water salinity) most likely as a function of extensive anthropogenic activities and general climate aridification.

1. Introduction

Southwest Asia, especially the Eastern Mediterranean and the Middle East, have a long history of human settlements and agro-pastoral economies (Robinson et al., 2006; Shackley, 2006; Klinge and Fall, 2010; Katkar, 2011; Tsanova, 2013). Climate variability is considered to have played an important role in socio-cultural and socio-economic changes of early societies in the Middle East. The

* Corresponding author.
E-mail addresses: valinor2000@yahoo.com (T. Talebi), e.ramezani@urmia.ac.ir, elias.ramezani@gmail.com (E. Ramezani), morteza.djamali@imbe.fr (M. Djamali), lahijani@inio.ac.ir (H.A.K. Lahijani), A.Naqinezhad@umz.ac.ir, anaqinezhad@gmail.com (A. Naqinezhad), kamal.alizadeh@biologie.uni-goettingen.de, kamal.alizadeh@gmail.com (K. Alizadeh), valerie.andrieu-ponel@imbe.fr (V. Andrieu-Ponel).

http://dx.doi.org/10.1016/j.quaint.2015.11.070
1040-6182/

impact of climate on the collapse and renaissance of early civilizations has been discussed by several investigators (e.g. Manzanilla, 1997; Cullen et al., 2000; Robinson et al., 2006; Issar et al., 2012; Leroy, 2013). Many studies have explored Late-Quaternary and Holocene environmental changes in Southwest Asia, including the Eastern Mediterranean and the Middle East (e.g. Wick et al., 2003; Djamali et al., 2008a; Kuzucuoğlu et al., 2011; Woodbridge and Roberts, 2011; Ponel et al., 2013; Litt et al., 2014; Tudryn et al., 2013). Almost all palaeoclimatic records from the region are in agreement over the pronounced changes in climate after the Younger Dryas to a warm Early-Holocene around 10,000 cal BP (e.g. Snyder et al., 2001; Wick et al., 2003; Wasylikowa, 2005; Robinson et al., 2006; Stevens et al., 2012). Several records reveal that an arid early Holocene transitioned to more humid and warmer climatic conditions at *ca*. 8000 BP, when trees started to expand across the surrounding uplands in Eastern Mediterranean and Anatolia towards 6500 BP (Bottema, 1986; Griffiths et al., 2001; Wick et al., 2003; Wasylikowa, 2005; Messager et al., 2013; Joannin et al., 2014). Since high-resolution multi-proxy Late-Holocene records for this region are scarce, synchronizing a single climatic event across the available palaeoclimate data is challenging. Messager et al. (2013) and Kuzucuoğlu et al. (2011) suggest that an arid phase occurred around 3000 cal BP at Lake Paravani in Georgia and Lake Tecer in central Anatolia, while Wick et al. (2003) showed this phase was established in the Lake Van area after 4000 cal BP. Palaeoclimatic records inferred from several investigations in the Eastern Mediterranean (Kaniewski et al., 2011; Kuzucuoğlu et al., 2011; Woodbridge and Roberts, 2011; Roberts et al., 2012) and northern Iran (Ramezani et al., 2008) suggest a shift towards warmer and/or wetter period during the Medieval Climate Anomaly (MCA) from 1100 to 750 BP (cf. Bradley et al., 2003). Subsequently evidence of a relatively wet and cold climate can be detected in the Eastern Mediterranean and northern and northwestern Iran between 800 and 150 BP, coincident with the Little Ice Age (LIA) (Ramezani et al., 2008; Djamali et al., 2009a; Kuzucuoğlu et al., 2011; Leroy et al., 2011; Woodbridge and Roberts, 2011; Naderi Beni et al., 2013).

As the first palynological study on Lake Urmia, Bottema (1986) attempted to reconstruct the Late-Pleistocene vegetation and climate history of northwestern Iran. However, this study suffered from relatively high chronological uncertainty. More recently, Djamali et al. (2008a) provided a 200,000-year-long record of environmental changes around Lake Urmia from marine isotope stage 7a (MIS-7a) to the Early-Holocene, based on pollen assemblages from two long cores. This study shows that the Late Glacial to Early-Holocene was dominated by general aridity (Djamali et al., 2008a), partly as a result of the intensification of subtropical anticyclonic system over Iranian plateau, which, in turn, indirectly controlled the early Holocene intensification of the Indian monsoon (Djamali et al., 2010). Mid-Late Holocene investigations in northwestern Iran suffer from low-resolution and/or insufficient dating, which hamper the accurate reconstruction of vegetation history and climatic changes (Djamali et al., 2008a).

The aims of this paper are to: 1) reconstruct the Late-Holocene climate of the Urmia Basin; 2) assess the extent of anthropogenic modification of the basin's vegetation through time; 3) track changes in wetland and halophyte vegetation under the influence of changing lake levels.

2. Materials and methods

2.1. Physical settings

Lake Urmia (Fig.1), *ca*. 1273 m asl (AghaKouchak et al., 2015), is the largest Iranian internal water body and one of the world's largest hypersaline lakes. It was designated as a National Park in 1975 and is a Biosphere Reserve protected by the Ramsar Convention (Ramsar Sites Information Service (RSIS), 2015). Earlier investigations (e.g. Kelts and Shahrabi, 1986) report an average area of more than 5000 km^2 for the lake and 52,700 km^2 for its basin, comprising 3.25% of the total land area of Iran. Recent data, however, show a progressive decline in the lake's surface area since 1995, e.g. 2366 km^2 in August of 2011 (Anonymous, 2012), to *ca*. 1750 km^2 in spring 2015 (Personal communication, Dr. Naser Agh, Urmia Lake Research Institute, Urmia University). This has resulted in a progressively decreasing water depth, from 8 to 12 m in the 1980s (Kelts and Shahrabi, 1986) to 1.5 m, its springtime maximum in recent years (Dr. Naser Agh, pers. comm.). At the same time its salinity has increased from 217 to more than 300 g per litre (Anonymous, 2012; AghaKouchak et al., 2015).

Geologically, the lake has formed in a depression made by interaction of Tabriz Fault and the Great Zagros Fault (Shahrabi, 1994). The geology of the lake basin is very diverse and includes Precambrian-Paleozoic metamorphic rocks, Cretaceous limestone, Tertiary volcanics and volcaniclastics and Miocene marine limestones (Kelts and Shahrabi, 1986; Shahrabi, 1994). This shallow lake is surrounded by a range of high mountains, particularly the Sahand complex. Almost 60 permanent and seasonal rivers and streams, as well as many underground springs feed the lake (AghaKouchak et al., 2015). Since 1995, the natural environment of the lake has been threatened by rapid decline in water inflow to the lake. While some groups blame climate change for recent water scarcity, the issue seems to predominantly attributed to extensive anthropogenic activities, such as the construction of the Shahid Kalantari Causeway across the lake and 56 reservoir dams in the lake's watershed area, as well as excessive exploitation of the groundwater (Sima and Tajrishy, 2013; AghaKouchak et al., 2015, Iran Water Resources Management (WRM), 2015).

2.2. Climate and vegetation

According to the Köppen climate classification, most parts of the Lake Urmia basin are under a semi-arid climate and experience cold winters, hot-dry summers and chilly autumns (Nourani and Sayyah Fard, 2012). The 60-year averages of annual temperature and precipitation recorded at Urmia weather station, located 10 km west of Lake Urmia, are 11.6 °C and 339 mm, respectively. Precipitation occurs mostly in winter and spring (Islamic Republic of Iran Meteorological Organization (IRIMO), 2015).

Based on available literature (Zehzad, 1989; Asri and Ghorbanli, 1997; Asri, 1999; Asem et al., 2014) and our own floristic surveys (2010, 2011), approximately 300 vascular plant taxa occur on the islands of the lake and in the lake's surroundings. The vegetation of the Lake Urmia area is chiefly composed of halophytic and halo-tolerant vegetation, dominated by Amaranthaceae species and halophytic grasses as the most prominent part of its flora. This type of vegetation constitutes the first zone of vegetation surrounding the lake and its islands. The delimitation of plant communities and detailed zonation within this vegetation type is difficult and a complex of factors – such as salinity, soil moisture, topography, stream water inflow, the relationship between groundwater and lake shore, interspecies competition and the human interference and grazing – all affect the distribution of plant communities and their establishment (Kelts and Shahrabi, 1986; Asri, 1999; Djamali et al., 2008b). Nevertheless, a total of 30 different plant communities are grouped into ten main physiognomical/ecological categories (Asri and Ghorbanli, 1997; Djamali et al., 2008b) in the halophytic and halo-tolerant vegetation zone: