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RESEARCH ARTICLE

Spatial and temporal variations in prehistoric human settlement and their influencing factors on the south bank of the Xar Moron River, Northeastern China

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Abstract The West Liao River Basin is the hub of ancient civilizations as well as the birthplace of rain-fed agriculture in Northern China. In the present study, based on 276 archaeological sites on the south bank of the Xar Moron River, Northeastern China, we trace the changes in prehistoric cultures as well as the shifts in the spatial and temporal patterns of human settlement in the West Liao River Basin. Location information for those sites was obtained from fieldwork. Factors such as climate change, landform evolution of the Horqin Dunefield, and subsistence strategies practiced at the sites were extracted via the meta-analysis of published literature. Our results show that the Holocene Optimum promoted the emergence of Neolithic Culture on the south bank of the Xar Moron River. Monsoon failure might have caused the periodic collapse or transformation of prehistoric cultures at (6.5, 4.7, 3.9, and 3.0) kyr B.P., leaving spaces for new cultural types to develop after these gaps. The rise and fall of different cultures was also determined by subsistence strategies. The Xiaoheyan Culture, with mixed modes of subsistence, weakened after 4.7 kyr B.P., whereas the Upper Xiajiadian Culture, supported by sheep breeding, expanded after 3.0 kyr B.P. Global positioning system data obtained from the archaeological sites reveal that cultures with different subsistence strategies occupied distinct geographic regions. Humans who subsisted on hunting and gathering resided at higher altitudes during the Paleolithic Age (1074 m a.s.l.). Mixed subsistence strategies led humans to settle down at 600–1000 m a.s.l. in the Neolithic Age. Agricultural activities caused humans to migrate to 400–800 m a.s.l. in the early Bronze Age, whereas livestock production shifted human activities to 800–1200 m a.s.l. in the late Bronze Age.

Keywords climate change, dunefield evolution, subsistence strategy, the Holocene, West Liao River Basin

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1 Introduction

With the rapid advancement of research on the impacts of global climate changes, human-environment interaction has attracted the attention of both scientists and the public (Lawler, 2007; Zhang et al., 2011; Chen et al., 2015a). It is particularly important to study climate change and its impact on prehistoric human settlements in ecologically fragile zones, as such knowledge may provide insights on how people in marginal areas can adapt to present day climate change. In human history, climatic fluctuations led to the expansion and collapse of prehistoric cultural types, the rise and fall of settlement sites, and changes in the intensity of human activities in the Holocene (Polyak and Asmerom, 2001; Lawler, 2007; Yancheva et al., 2007). Appropriate subsistence strategies were chosen by humans to adapt to climate change in the Neolithic-Bronze Age (Li et al., 2009; Jia et al., 2013, 2016; Li, 2013; Guedes et al., 2014; Chen et al., 2015b).

The West Liao River Basin, which is located in the western part of Northeastern China, is on the margin of the monsoon climate zone and at the eastern edge of the farming-pastoral eco-zone (Fig. 1). Its environmental conditions are extremely vulnerable to climatic changes. Monsoonal intensity influences the formation and movement of the Horqin Dunefield in the central part of the West

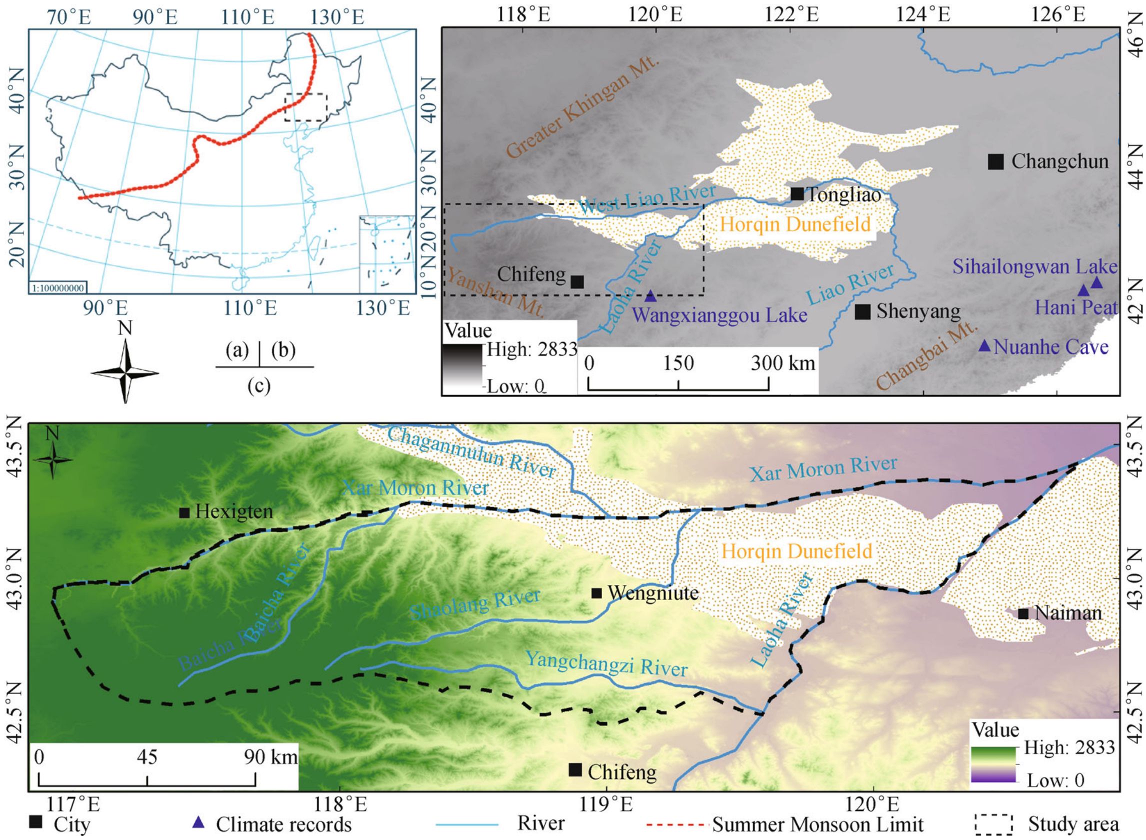

Fig. 1 Location of the south bank of the Xar Moron River, Northeastern China. (a) Map of China; (b) Map of West Liao River Basin; (c) Map of the south bank of the Xar Moron River.

Liao River Basin (Qiu, 1989; Yang et al., 2012), and in turn affects environmental conditions and human activities in this area (Xia et al., 2000; Li et al., 2006). As one of the hubs of Chinese civilizations (Drennan and Peterson, 2006; Peterson et al., 2010) as well as the birthplace of rain-fed agriculture in Northern China (Jones and Liu, 2009; Zhao, 2011, 2014), the West Liao River Basin has attracted much attention and interest (Xia et al., 2000; Li et al., 2006; Zhao et al., 2009, 2011). However, the lack of continuous climate records with accurate dating has made it extremely challenging to study the relationship between human activities and environmental changes in this region in prehistory.

Subsistence strategies (Lee et al., 2007; Guedes et al., 2014; Chen et al., 2015b) and geographic information system (GIS) analyses (Peterson et al., 2010; Wagner et al., 2013) have been used to explore the interrelationship between human activities and environmental changes in the Holocene. Although these methods have also been applied to unfold the human-environment nexus in the West Liao River Basin (Xia et al., 2000; Li et al., 2006), their application is largely constrained by the lack of geo-referenced location data of human settlement and accurate identification of plant and animal remains in the basin. In addition, the absence of precise dating for climate records in this region has made it more difficult to directly correlate human activity and climate records (Xu et al., 2002; Li et al., 2006).

In this study, we sought to address the above issues. We conducted an extensive survey of archaeological sites on the south bank of the Xar Moron River, a major tributary of the West Liao River, to trace the changes of prehistoric cultures as well as the shifting of spatial and temporal patterns of human settlement in the West Liao River Basin. Accurate location data of archaeological sites were collected using global positioning system (GPS) receivers during our field investigations. In unison, records of climate change and the evolution of the Horqin Dunefield during the Holocene were also extracted via the meta-analysis of published literature. These data were combined with additional geomorphologic data, subsistence strategy information, and spatial-temporal ranges of human activities, and were comprehensively analyzed to explore human-environment interactions.

2 Study area

Our study area is on the south bank of the Xar Moron River (42°25′–43°23′N, 116°50′–120°40′E), which covers an approximate area of 1.7×10^4 km^2 in Northern China (Fig. 1). The basin is located in the transition zone between the Inner Mongolia Plateau and the Songliao Plain. The river originates in the southwest of Hexigten County, Chifeng, Inner Mongolia. As the main tributary of the upper West Liao River, the Xar Moron River joins the upstream branches of the Baicha River, the Shaolang River, the Chaganmulun River, and the Laoha River, and flows into the Liao River and eventually to the Bohai Sea (Figs. 1(b) and 1(c)). The upper West Liao River Basin is divided by the Xar Moron River Fault. The uplift of Great Khingan Mountain resulted in the western part being higher in elevation than the eastern part on the south bank of the Xar Moron River. The average elevation drops from 2833 m a.s.l. in the west to 280 m a.s.l. in the east, with mountains gradually giving way to hills and eventually to plains. The Greater Khingan Mountains and the Yanshan Mountains dominate the western part of the study area. Loess hills are located in the central region, and the Horqin Dunefield lies on the eastern side. This area also contains extensive loess accumulations with loess tableland, loess hills, valleys, and other landform types.

The study area lies in the monsoon marginal zone, a transitional region between semi-humid and arid climate, with mean annual temperatures between 5°C–6.7°C, annual precipitation between 250–500 mm, and annual evaporation above 2100 mm in some regions. Precipitation is highest in the west and decreases toward the east. Land cover in the region consists of woodland and forest steppe in the western mountains, meadow steppe on the western plateau, steppe on the central low hills and plains, drifting and semi-drifting sand in the eastern Horqin Dunefield, and sporadic croplands in the loess accumulation area.

3 Materials and methods

In our extensive survey of archaeological sites on the south bank of the Xar Moron River, we found a large number of pottery shards on land surfaces and profiles. The relative age of a single site was verified according to those archaeological remains. All of the 276 prehistoric archaeological sites on the south bank of the Xar Moron River were investigated, and geo-referenced location data of these sites were collected by GPS (Fig. 2 and Table 1). Based on the above geo-referenced data, we further

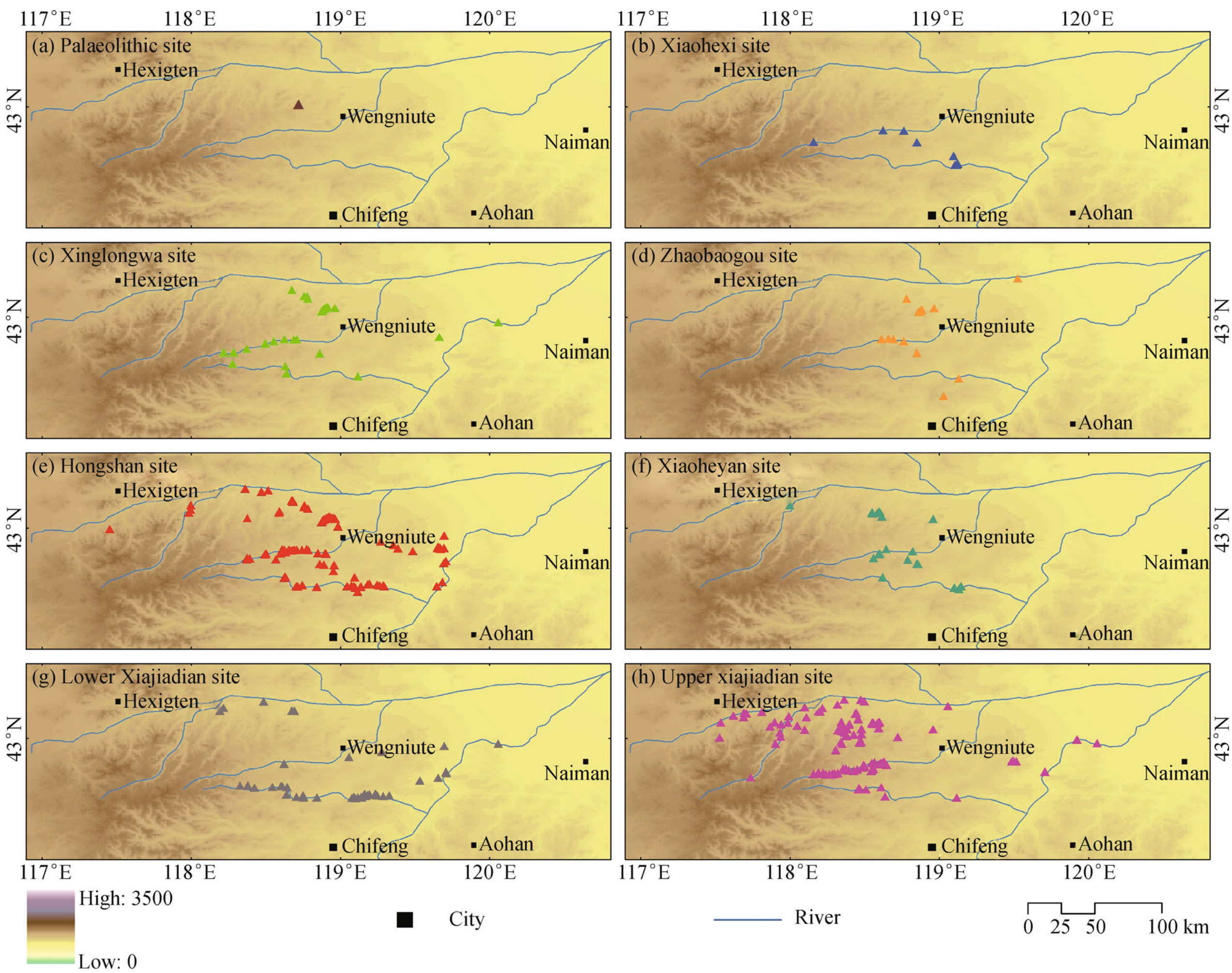

Fig. 2 Distribution of prehistoric sites on the south bank of the Xar Moron River, Northeastern China.

Table 1 The elevation distribution of the surveyed prehistoric sites on the south bank of the Xar Moron River, Northeastern China

Archaeological cultural types		Elevation distribution/(m a.s.l.)												Max.	Min.	Mean
		200–400		400–600		600–800		800–1000		1000–1200		1200–1400				
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%			
Paleolithic										1	100.00			1074	1074	1074
Neolithic Age	Xiaohexi					6	66.70	2	22.22	1	11.11			601	1170	764
	Xinglongwa	1	3.57	1	3.57	13	46.40	10	35.71	3	10.71			398	1159	774
	Zhaobaogou			1	7.14	8	57.10	5	35.71					512	951	741
	Hongshan			23	22.12	49	47.10	29	27.88	3	2.88			446	1145	712
	Xiaoheyan			1	4.76	5	23.80	14	66.67	1	4.76			591	1174	821
Bronze Age	Lower Xiajiadian	1	2.22	18	40.00	13	28.90	9	20.00	4	8.89			394	1101	697
	Upper Xiajiadian	1	0.79	6	4.76	7	5.56	68	53.97	41	32.54	3	2.38	398	1290	939

estimated the total occupied area of each culture type according to the distribution of pottery shards specific to that culture among our surveyed archaeological sites. Basic information about these sites is presented in Fig. 3, including the number of sites in each period and their mean, maximum, and total areas. The Xar Moron River was mainly down-cut by headward erosion during the Holocene (Xia et al., 2000; Yang et al., 2015), and its tributaries probably meandered little in the south bank of the river during that time. Hence, the major tributaries of the Xar Moron River were employed for calculating the nearest distances between these archaeological sites and the nearest river by using Arc GIS 9.2 (Fig. 4(b)).

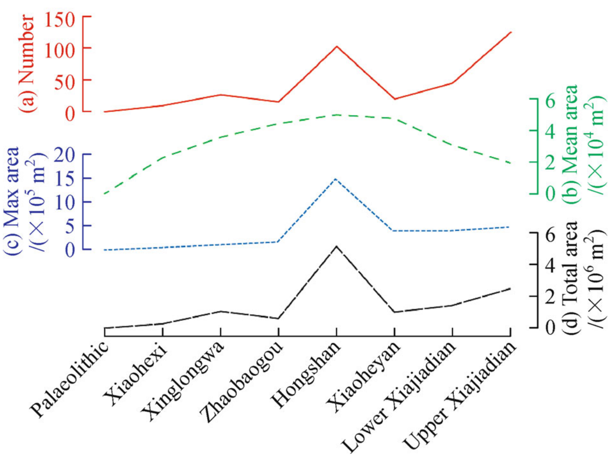

Fig. 3 The number and the occupied area of prehistoric sites located on the south bank of the Xar Moron River, Northeastern China. (a) Number of prehistoric sites. (b) Mean occupied area of prehistoric sites. (c) Occupied area of the largest prehistoric site. (d) Total occupied area of prehistoric sites.

The chronologies of all of the prehistoric cultures on the south bank of the Xar Moron River were established based on ^{14}C data (Supplementary material S1) corrected with tree-ring data. All ages reported were relative to AD 1950 (referred to as "cal. yr B.P."). The IntCal09 curve (Reimer et al., 2009) and the Libby half-life of 5568 years were used for calculating all dates with the Calib5.01 program (Ramsey, 2001). The established prehistoric culture sequence is: 8200–7200 cal. yr B.P. for the Xinglongwa Culture, 7000–6400 cal. yr B.P. for the Zhaobaogou Culture, 6600–4900 cal. yr B.P. for the Hongshan Culture, 4900–3600 cal. yr B.P. for the Xiaoheyan Culture, 3900–2800 cal. yr B.P. for the Lower Xiajiadian Culture, and 3100–2000 cal. yr B.P. for the Upper Xiajiadian Culture, based on the summed probability of radiocarbon dates (two sigma) from the prehistoric sites in the area. The Xiaohexi cultural layers were cut through by the Xinglongwa layers at the Baiyinchanghan sites on the north bank of the Xar Moron River. Therefore, the age of the Xiaohexi Culture is considered to be older than the Xinglongwa Culture and probably to be slightly older than 8.0 cal. kyr B.P..

Information about climate change in our study area was obtained from a variety of sources, including biogenic silica from Sihailongwan Lake in Jingyu County, Jilin Province (Schettler et al., 2006), $\delta^{13}C$ ‰ records from the Hani peat mire in Liuhe County, Jilin Province (Hong et al., 2005, 2009) and $\delta^{18}O$ ‰ records from stalagmites in Nuanhuo Cave, Hengren County, Liaoning Province (Wu et al., 2011, 2012). The expansion and contraction of the Horqin Dunefield was reconstructed using more than 50 profiles of sand and paleosol layers around the Horqin Dunefield from published papers (Supplementary material S2) (Fig. 5). Subsistence strategies were also established for these sites from the published literature.

4 Results

4.1 The number of human settlements and the total occupied area of various prehistoric cultural types

We identified and investigated 276 archaeological sites on the south bank of the Xar Moron River, including 1

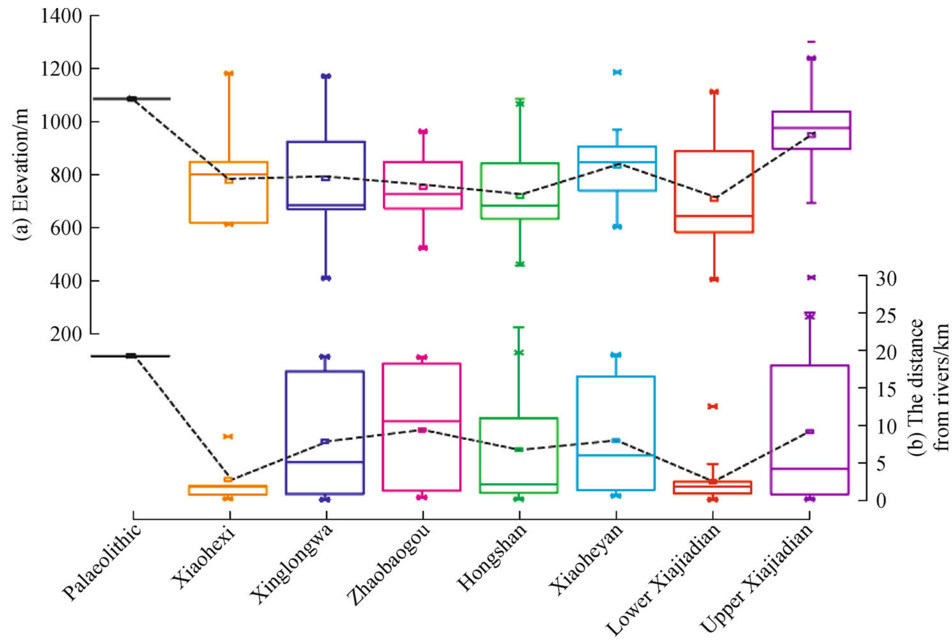

Fig. 4 The box plot of the elevation and the nearest distance to main rivers of prehistoric sites located on the south bank of the Xar Moron River, Northeastern China. (a) Elevation of prehistoric sites. (b) Nearest distance to main rivers of prehistoric sites. Black dashed line represents the mean of data.

Paleolithic site, 143 Neolithic sites, and 167 Bronze Age sites. 59 sites had two cultural types, and 7 sites had three. The Hongshan period of mid-Neolithic had the largest total site area (5,190,300 m^2), whereas the Upper Xiajiadian period of late-Bronze Age had the largest number of sites (126).

The earliest human activities with small-scale troglodytism in the study area were found in the Shangyao Cave site of the Paleolithic with an area of 60 m^2 (Figs. 2(a) and 3 (d)). Large-scale human activities appeared in the Neolithic and were found at 143 archaeological sites, including 9 Xiaohexi sites (Fig. 2(b)), 28 Xinglongwa sites (Fig. 2(c)), 14 Zhaobaogou sites (Fig. 2(d)), 104 Hongshan sites (Fig. 2(e)), and 21 Xiaoheyan sites (Fig. 2(f)). The total areas for each of these five cultural types were 205,200 m^2, 1,005,800 m^2, 622,600 m^2, 5,190,300 m^2, and 1,004,650 m^2, respectively (Fig. 3(d)). There were 167 Bronze Age sites, including 45 Lower Xiajiadian sites (Fig. 2(g)) and 126 Upper Xiajiadian sites (Fig. 2(h)). The total areas for each of these two cultural types were 1,399,300 m^2 and 2,474,697 m^2, respectively (Fig. 3(d)). After the Bronze Age in this area, human history passed into the Warring States period and entered the dawn of civilization.

4.2 Spatial and temporal change of human settlement pattern

It can be seen that after the occupation of the earliest site, Shangyao Cave (43°0.9′N, 118°43.3′E) in the Paleolithic (Fig. 2(a)), the range of human activity expanded slowly in the early Neolithic until it reached a maximum during the Hongshan period in the mid-Neolithic (42°34.3′–43°15.8′ N, 117°21.3′–119°42.6′E, Fig. 2(e)). Subsequently, it declined during the Xiaoheyan period in the late Neolithic (42°35.5′–43°09.2′N, 118°00.0′–119°16.6′E, Fig. 2(f)). Human activity expanded again during the Lower Xiajiadian period of the early Bronze Age (42°36.0′–43°14.9′N, 118°11.6′–120°3.5′E, Fig. 2(g)), but the majority of the sites were distributed along the Yangchangzi River in the southern part of this area. The largest range of prehistoric sites occurred in the Upper Xiajiadian period of the late Bronze Age, when the majority of the sites shifted westward (42°36.2′–43°15.8′N, 117°31.8′–120°3.6′E, Fig. 2(h)).

We also measured the elevation and the distance to the nearest river of all of our surveyed prehistoric sites. The results are summarized in Table 1 and Fig. 4. During the Paleolithic Age, humans resided at higher elevation sites (1074 m a.s.l.), which are also far away from rivers. In the Neolithic Age, most of the human settlements were located at lower elevations (600–1000 m a.s.l.). In the early Bronze Age, human settlements further concentrated at downhill locations (400–800 m a.s.l.), and those locations are also very close to rivers. In the late Bronze Age, settlements shifted back to higher elevation sites (800–1200 m a.s.l.).

5 Discussion

Given the above findings, we proceeded to discover the major driving forces for the changes in prehistoric cultures as well as the shifting of spatial and temporal patterns of human settlement in our study region during the Holocene.

5.1 Climate fluctuations and the evolution of prehistoric cultures during the Holocene

We compared our established ^{14}C sequence of the prehistoric cultures (Fig. 5(a)) with the records of the Horqin Dunefield evolution (Fig. 5(b)) and paleo-climate change (Figs. 5(c)–5(e)). The close match between the ^{14}C sequence and the paleo-climate records indicates that the Holocene Optimum might have promoted the emergence of Neolithic Cultures on the south bank of the Xar Moron River in general. Furthermore, the flourishing of cultures was also supported by the presence of a soil layer on the

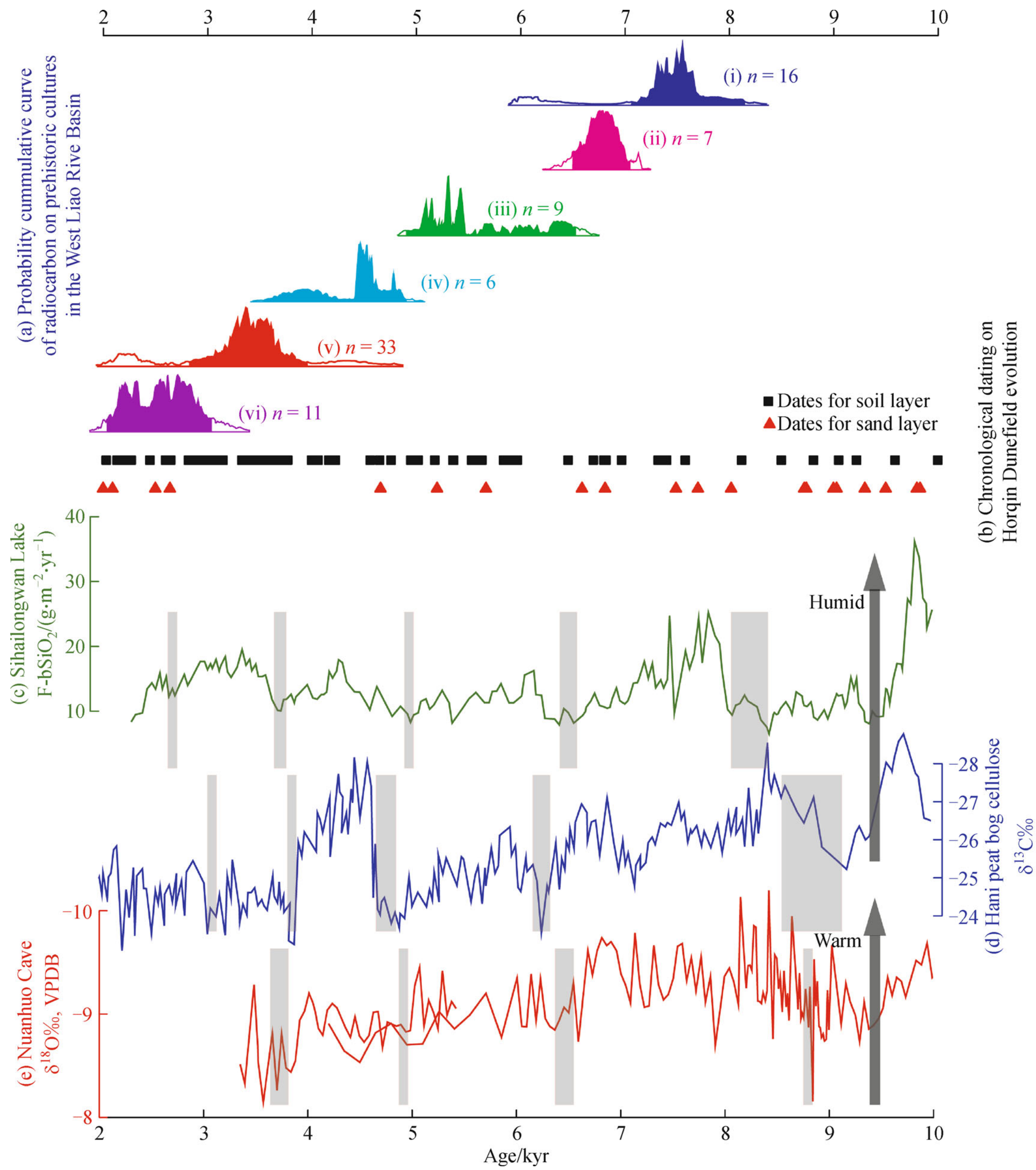

Fig. 5 Contrast between the ^{14}C sequence of prehistoric cultures on the south bank of the Xar Moron River with the evolution of the Horqin Dunefield and climate change. (a) Probalility cumulative curve of radiocarbon on prehistoric cultures on the south bank of Xar Moron River (S1): i, Xinglongwa Culture; ii, Zhaobaogou Culture; iii, Hongshan Culture; iv, Xiaoheyan Culture; v, Lower Xiajiadian; vi, Upper Xiajiadian Culture; (b) The chronological dating on Horqin Dunefield evolution (S2); (c) Biogenic silica from the Sihailongwan Lake in Jingyu County, Jilin Province (Schettler et al., 2006); (d) $\delta^{13}C$‰ records from Hani peat mire in Liuhe County, Jilin Province (Hong et al., 2005); (e) $\delta^{18}O$‰ records from stalagmites in the Nuanhuo Cave in Hengren County, Liaoning Province (Wu et al., 2011). The grey bands show arid or cold gaps.

Horqin Dunefield. The development of the soil layer was largely attributable to favourable climate (Qiu, 1989; Yang et al., 2012). And monsoon failure might cause the periodic collapse or transformation of prehistoric cultures at (6.5, 4.7, 3.9, and 3.0) kyr B.P., leaving spaces for new cultural types to develop after these gaps.

The single Paleolithic site has insufficient chronological data for its correlation with climate change and is therefore not discussed here. The Neolithic started to emerge with the Xiaohexi Culture at the beginning of the Holocene Optimum after the "8.2 kyr events" recorded in the biogenic silica from Sihailongwan Lake (Schettler et al., 2006) (Fig. 5(c)), $\delta^{13}C$ ‰ records from the Hani peat mire (Fig. 5(d)) (Hong et al., 2005), and $\delta^{18}O$ ‰ records from Nuanhe Cave (Fig. 5(e)) (Wu et al., 2011, 2012). During this period, the monsoon strengthened, which caused increased precipitation (Hong et al., 2005, 2009; Schettler et al., 2006; Wu et al., 2011, 2012) and the contraction of the Horqin Dunefield (Qiu, 1989). The favourable climate conditions facilitated the expansion of early Neolithic cultures, including the Xiaohexi, Xinglongwa, and Zhaobaogou Cultures. However, the possible weakening of the monsoon and reduction in precipitation approximately 6.4 kyr B.P. (Hong et al., 2005, 2009; Schettler et al., 2006; Wu et al., 2011) led to the gradual decline of the early Neolithic Cultures. The subsequent improvement in climate benefited the Hongshan Culture, which prospered in the Western Liao River Basin during the mid-Neolithic (Hong et al., 2005, 2009; Schettler et al., 2006; Wu et al., 2011). The Hongshan Culture gradually collapsed on the south bank of the Xar Moron River approximately 4.8 kyr B.P. when the monsoon weakened again (Hong et al., 2005, 2009; Schettler et al., 2006; Wu et al., 2011), although there is an alternative hypothesis that the collapse might be attributable to the sudden north-to-east hydrologic shift in the Hunshandake Dunefield ca. 4.2 kyr, resulting in groundwater table drawdown by sapping (Yang et al., 2015). The Xiaoheyan Culture of the late Neolithic gradually developed and replaced the Hongshan Culture in this area after 4.8 cal. kyr B.P., but gradually vanished approximately 3.9 kyr B.P. during a period of monsoon recession (Hong et al., 2005, 2009; Schettler et al., 2006; Wu et al., 2011).

Bronze Age Culture began to flourish in the study area after a dry gap approximately 3.9 kyr B.P.. The Lower Xiajiadian Culture enjoyed a high level of development similar to that of later societies at the early stage of Chinese civilization (Tian, 2006). Previous environmental archaeology studies showed that the warm and humid climate promoted the expansion of the Lower Xiajiadian Culture, whereas cold and dry climate limited the cultural development of the Upper Xiajiadian Culture (Xia et al., 2000; Li et al., 2006). However, biogenic silica from Sihailongwan Lake and the $\delta^{13}C$ ‰ record from the Hani peat mire all show that the entire Bronze Age was relatively warm and humid (Hong et al., 2005; Schettler et al., 2006). In addition, paleosol was found in the ADQ and KP profiles, suggesting a contraction of the Horqin Dunefield (Yang et al., 2012; Yi et al., 2013). It is possible that there was a brief period of temporary climatic deterioration and expansion of the Horqin Dunefield approximately 3.0 kyr B.P. (Schettler et al., 2006; Yang et al., 2012; Yi et al., 2013). This could have triggered the cultural transformation from the Lower Xiajiadian Culture to the Upper Xiajiadian Culture.

Even though the rise and fall of various prehistoric cultures was driven by climate fluctuations, the influence of contextual factors of those cultures should not be overlooked. For instance, the Xiaoheyan Culture with mixed modes of subsistence weakened after the climate deterioration at around 4.7 kyr B.P., whereas the Upper Xiajiadian Culture, dominated by sheep breeding, expanded after the climate deterioration at around 3.0 kyr B.P.. The same environmental phenomenon (i.e., climate deterioration) produced different social outcomes (i.e., rise and fall of cultures), revealing that subsistence strategies might be imperative in mediating the prehistoric human-environment nexus.

5.2 Human adaptation to climate and environmental changes in prehistory

Change of subsistence strategies could be an important means for humans to adapt to climate and environmental changes in prehistory (Li et al., 2009; Li, 2013; Jia et al., 2013, 2016; Chen et al., 2015b). It might have changed human settlement patterns in consequence (Li, 2013; Chen et al., 2015b). For instance, livestock production shifted human activities to higher elevations. Agricultural activities caused humans to settle at lower elevation sites. Mixed subsistence strategies led humans to reside somewhere in between, as shown in Fig. 4(a).

The Holocene Optimum promoted rain-fed agriculture in northern China (Crawford, 2009). Humans likely did not rely primarily on millet cultivation, but on hunting and collecting, for subsistence in the western Loess Plateau during the early Neolithic period (Barton et al., 2009). Flotation results suggest that rain-fed agriculture with broomcorn millet and foxtail millet as key crops began during the Xinglongwa period (Zhao, 2014). Hunting and collecting, which could not support dense human settlement, were also the primary subsistence strategy of early Neolithic Cultures on the south bank of the Xar Moron River region, including the Xinglongwa and Zhaobaogou Cultures (Figs. 2(b)–2(d)). Due to low agricultural output, humans had to engage in other subsistence strategies, such as fishing, hunting, and gathering. Fishing was confirmed by a variety of tools made from fish bones and mussels excavated from the Yushushan and Xiliang sites during the Xiaohexi period (Suo and Guo, 2004; Yang and Lin, 2009), the Xinglongwa and Xinglonggou sites during the Xinglongwa period (Yang and Zhu, 1985; Yang and Liu, 1997; Liu, 2004), and the Zhaobaogou and Xiaoshan sites during the Zhaobaogou period (Yang and Zhu, 1987; Liu and Zhu, 1988). Hunting tools were excavated from many of the same sites as above, and they included a mass of stone balls and projectiles. In addition, the bones of wild animals were identified from many sites, including horse and deer bones from the Shawozi site during the Xiaohexi period, deer bones from the Xinglongwa, Xinglonggou, and Nantaizi sites during Xinglongwa period, and the bones of deer, birds, bears, and badgers from the Zhaobaogou site during the Zhaobaogou period (Song and Chen, 2004). Gathering is indicated by seeds of *Juglans mandshurica Maxim.,* which were identified from the Xinglongwa site during the Xinglongwa period (Yang and Zhu, 1985) and Xiaoshan site during the Zhaobaogou period (Yang and Zhu, 1987). Stable isotopic analysis of carbon in human bones from the Xinglongwa and Xinglonggou sites also suggests that C3 plants, usually obtained by gathering, formed part of the diet at that time (Zhang et al., 2003; Liu et al., 2012). The relatively warm and humid climate conditions (Hong et al., 2005, 2009; Schettler et al., 2006; Wu et al., 2011) increased agricultural production during the early Neolithic period and strengthened human settlement in this area. There were 51 archaeological sites in this period, and the majority of the sites were located between 600–1000 m a.s.l. during the early Neolithic (Fig. 4(a) and Table 1). After initial development during the Xiaohexi period (Fig. 2(b)), humans began to occupy the central region of the south bank of the Xar Moron River during the Xinglongwa period, including the upper reaches of the Shaolang River and the area between the upper reaches of the Shaolang River and the Xar Moron River, extending as far as the western edge of the Horqin Dunefield (Fig. 2(c)).

Previous studies suggested that the Hongshan Culture flourished under favourable environmental conditions (Xia et al., 2000; Xu et al., 2002; Li et al., 2006). However, the monsoon was weaker during that time than in the early Neolithic (Hong et al., 2005, 2009; Schettler et al., 2006; Wu et al., 2011) (Figs. 5(c)–5(e)), and there were occasional expansions of desert (Qiu, 1989; Yi et al, 2013) (Fig. 5(b)). Climate stability during the mid-Neolithic (Hong et al., 2005, 2009; Schettler et al., 2006) probably enabled the Hongshan Culture to be sustained at a low production level for a long period of time. Although the climate was not humid enough for large-scale agricultural production, ancient humans depended on other subsistence strategies to survive. The stable isotopic analysis of carbon in human bones from the Caomaoshan and Xinglonggou sites suggests that ancient humans lived on a diet of both millet agriculture and C3 plants from gathering (Liu et al., 2012). The flotation results show that foxtail millet and broomcorn millet were the main crops during the Hongshan period in the West Liao River Basin (Sun, 2012; Sun and Zhao, 2013). Millet agriculture might have been the most important strategy during that time, and probably facilitated the flourishing of the Hongshan Culture. Vast numbers of fish bones (Sun and Zhao, 2013) and artifacts made from shells (Liu and Yang, 1982) were also excavated, indicating that fishing was an important part of subsistence. A mass of deer bones were identified at the Hongshan (56: 02II) and Baiyinchanghan sites, suggesting that hunting was a significant subsistence strategy (Song and Chen, 2004). Sporadic dog bones implied that livestock rearing also existed (Song and Chen, 2004). The diverse subsistence strategies dominated by fishing and hunting weakened human development. Therefore, the large area coverage and number of sites of the Hongshan Culture may not be an indication of its high level of development, but rather a result of its long duration (6600–4900 cal. yr B.P.). Therefore, further work is required to divide the Hongshan Culture into finer stages to examine the relationship between human activity and climate change.

In contrast to conclusions of some previous studies (Xia et al., 2000; Li et al., 2006), this study finds that the late Neolithic Xiaoheyan Culture (4900–3600 cal. yr B.P.) coincided with a relatively humid period. However, owing to the expansion of the Horqin Dunefield approximately 4.7 kyr B.P. (Yi et al., 2013) and its invasion into the low-lying area, humans had to settle at relatively high regions (66.67% of the sites are at 800–1000 m a.s.l.) (Fig. 4(a) and Table 1). The single isotope datum from the Xishan site in Aohan County indicates that humans lived on millet from agricultural production (Liu et al., 2012). However, the mixture of artifacts made from pottery, stone, bone, and shells shows diverse subsistence strategies, including agriculture, hunting, and fishing (Hexigten Museum, 1992; Liaoning Provincial Institute of Culture, Relics and Archaeology, Chifeng Museum, 1998). Humans living at higher elevations probably depended on hunting and collecting rather than agricultural production as main subsistence strategies during the late Neolithic. This is reflected in the patterns drawn on pottery, such as deer and birds on pottery from the Shipengshan Cemetery in Ongniud Banner (Li, 1982). In addition, a large amount of birch (*Betula spp.*) bark was recovered from the Shipengshan (Li, 1982) and Danangou Cemeteries (Zhao, 2005). Birch usually grows in humid conditions in the mountains, and this may also suggest that humans settled at the fringe of the mountainous regions.

The relatively humid climate in the Bronze Age (Hong et al., 2005, 2009; Schettler et al., 2006) facilitated the evolution of civilization. It promoted the development of the early Bronze Lower Xiajiadian Culture (Xia et al., 2000; Li et al., 2006). A large number of carbonized plant seeds of foxtail millet and broomcorn millet were identified using flotation in Chifeng (Zhao, 2004; Zhao et al., 2009; Jia et al., 2016). Pig bones comprised the majority of animal bones at the Nanshangen, Zhizhushan, and Dadianzi sites (Song and Chen, 2004), which suggests that agricultural production was sufficient not only for human consumption but also for raising livestock. Relatively high agricultural output promoted social development during the Lower Xiajiadian period and led to the emergence of civilization in the West Liao River Basin. Agriculture enabled humans to settle at lower altitudes during the Lower Xiajiadian period (Figs. 2(g) and 4(a)), and 68.89% of the sites are between 400 and 800 m a.s.l. (Table 1). The sites were located only 2.5 km on average from major rivers (Fig. 3(b)), making them suitable for agricultural production with easy access to water.

The late Bronze Upper Xiajiadian Culture (3100–2000 cal. yr B.P.) gradually emerged after a brief episode of monsoon weakening approximately 3.0 kyr B.P. (Hong et al., 2005, 2009; Schettler et al., 2006). The destruction of vegetation and soil from extensive agricultural production in the early Bronze Age (Zhao et al., 2011), combined with the invasion of the Horqin Dunefield in low lying regions because of the arid climate approximately 3.0 kyr B.P. (Hong et al., 2005, 2009; Schettler et al., 2006), forced humans to migrate to other regions and look for new subsistence strategies, such as animal husbandry. A large number of sheep bones were identified from archaeological sites during the Upper Xiajiadian period in the West Liao River Basin, including the Xiajiadian, Nanshangen, and Zhizhushan sites (Song and Chen, 2004). The adoption of stockbreeding strengthened the Upper Xiajiadian Culture and facilitated its expansion in the West Liao River Basin (Fig. 2(h)). There are more archaeological sites during the Upper Xiajiadian period than for any other cultures in the previous stages (Fig. 3(a)). Nevertheless, the mean site area is relatively small (Fig. 3(b)), which could be attributed to high mobility in a pastoral society. Meanwhile, the distribution of sites during the late Bronze Age expanded westward to 117°31.8′E (Fig. 2(h)), and the upper limit of the elevation range of human activities rose to 1290 m a.s.l. (Fig. 4(a)), with 86.51% of sites between 800 and 1200 m a.s.l. (Table 1).

6 Conclusions

Our results show that changes in prehistoric cultures, as well as the shifting of spatial and temporal patterns of human settlement, in the West Liao River Basin were probably driven by climate change. The Holocene Optimum promoted the emergence of Neolithic Cultures on the south bank of the Xar Moron River, weak monsoon episodes led to the collapse or transformation of prehistoric cultures approximately (6.5, 4.7, 3.9, and 3.0) kyr B.P., and new cultural types emerged after these gaps. The collapse of the Hongshan Culture and the Lower Xiajiadian Culture could be attributed to arid climate episodes at 4.7 kyr B.P. and 3.0 kyr B.P.. Subsequent human activities underwent significant changes. A mixture of fishing, hunting, gathering, and agriculture was adopted as a subsistence strategy during the Xiaoheyan period. However, the gradual adoption of livestock production as a dominant strategy caused the Upper Xiajiadian Culture to expand and flourish after migrating westward to higher elevation areas.

GPS data obtained from the archaeological sites and the preliminary study of subsistence strategies suggests that humans with different subsistence strategies occupied distinct spatial regions. Humans who survived on hunting and gathering resided at higher altitudes during the Paleolithic (1074 m a.s.l.). Mixed subsistence strategies with agricultural production, hunting, gathering, and fishing led humans to settle between 600 and 1000 m a.s.l. (including 88.89% of the Xiaohexi sites, 82.14% of the Xinglongwa sites, 92.85% of the Zhaobaogou sites, 75.00% of the Hongshan sites, and 90.49% of the Xiaoheyan sites). The domination of agricultural production caused humans to migrate to 400–800 m a.s.l. during the Lower Xiajiadian period (68.89% of the sites), whereas livestock production brought humans to 800–1200 m a.s.l. during the Upper Xiajiadian period (86.51% of the sites).

This study contributes to the literature by providing a fine-grained portrayal of the evolution of ancient civilizations and its driving forces in the West Liao River Basin, which is imperative for understanding the prehistoric human-environment nexus in Northeastern China.

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