SCIENCE CHINA
Earth Sciences

• PROGRESS •

December 2013 Vol.56 No.12: 2027–2036
doi: 10.1007/s11430-013-4758-3

New progress in the Holocene climate and agriculture research in China

LI XiaoQiang*

Key Laboratory of Vertebrate Evolution and Human Origins of Chinese Academy of Sciences, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing 100044, China

Received July 15, 2013; accepted October 21, 2013; published online November 5, 2013

Global climate change and its possible ecological consequences have become the focused issue (IPCC, 2007; Mann et al., 2008; Ding et al., 2009). The Holocene contains the analogous characteristic of future climatic change and the continuous agriculture activity, providing the ideal "similar pattern" for studying the climate change and human adaption and impact in the future. Based on the recent studies of stalagmite, ice core, ocean, and lake etc., the paper introduces the new progress in the Holocene climate and agriculture research in China as follows: (1) Discuss the variability, amplitude, and unstable characteristic of climate, as well as the abrupt events and mechanisms of climate. (2) Analyze the botanical index records for studying the early agriculture. (3) Review the agricultural origin, expanding, and development. (4) Reveal the style and intensity of early agriculture and understand the agricultural impact and adaption to the environmental changes. (5) Introduce ongoing research projects in China and emphasize the significance of increasing the dating precision and the indicative effectiveness of proxies. (6) Realize how the ecosystem and environmental factors respond to the increasing temperature process, understand how the human adapt to the rapid climate change, and provide the scientific basis for assessing the effects of climate change and the human adaption in the future.

China, Holocene, climate change, agriculture activity, new progress

Citation: Li X Q. New progress in the Holocene climate and agriculture research in China. Science China: Earth Sciences, 2013, 56: 2027−2036, doi: 10.1007/s11430-013-4758-3

Global warming as the core of global climate change and its possible ecological consequence have become the focused issue in the scientific community and general public (IPCC, 2007; Mann et al., 2008; Ding et al., 2009). As is known to all, it is a key but difficult task to accurately evaluate the environmental effects of the future climate changes and understand the relationship between human activity and global climate changes. An ideal way to overcome above problems is to choose a geological epoch with similar climatic features as those in the future, reconstruct the climate change history and the environmental pattern, and then recognize the characteristics of human activity and its relationships with environment. All these findings will provide a scientific basis for evaluating the effect of future climate changes and human impact and adaption.

Modern environmental systems result from the climate changes in different time scales and the profound impact of human activity in the past. The Holocene represents the latest geological epoch, whose climate experienced increased temperature of the early Holocene, warm and humid mid-Holocene, and cooling trend of the late Holocene (Wang et al., 2005). The Holocene climate is characterized by the occurrence of millennial-century scale climatic changes and abrupt climate events (Bond et al., 2001; Kleiven et al., 2008). Marcott et al. (2013) suggested that

*Corresponding author (email: lixiaoqiang@ivpp.ac.cn)

temperatures during the early Holocene (10–5 ka) was 0.7°C warmer than the middle to late Holocene (<5000 years ago) based on 73 globally distributed records. The Holocene Megathermal occurred in mid-Holocene, and the climate around 6 ka BP is similar with the scene of 1–2°C average increase of global temperature (Shi et al., 1992; IPCC, 2007).

The climatic transition from the Pleistocene to Holocene changed the activity characteristics and life style of ancient people. The human society has undergone revolutionary changes from hunting-gathering to agriculture (Bellwood, 2005). The agriculture became a major economic activity by which human adapted to the environment during the Holocene (Cavalli-Sforza et al., 1993). Agriculture provided the material foundation for birth of civilization and formation of modern society and promoted an increase in population and intensity of human activity (Ruddiman et al., 2008; Li X Q et al., 2012), which has had a lasting and profound impact on the environment. Therefore, the study on the Holocene climate and agricultural activity not only is a vital path to distinguish the natural and anthropogenic impact on the climate changes, but also offers an ideal historical analog for evaluating the future climate change and human adaption.

At present, a series of important findings of the Holocene climate on the variability, amplitude, abrupt events, and mechanisms have been obtained in China, based on the high resolution records from stalagmite, ice core, ocean, and lake. On the other hand, it has made some breakthroughs in the research on the origin, spread, and impact of agriculture by studying the agriculture index. Here, we summarize chiefly the new research progress in the Holocene climate change in China, review the agricultural origin, expanding, and development, reveal the style and intensity of early agriculture, and understand the agriculture impact and adaption to the environment changes.

1 Recent progress of the Holocene climate research

The Holocene climate is not only controlled by orbital parameter change, but also influenced by climatic instability and abrupt events dominated by non-orbit factor. The key research of Holocene climate is to trace the climate variability on different time scale, reveal the characteristics and cause of rapid cooling and warming up events, discover the early signal of predictability, and offer a referable historical analog based on the high resolution geological-biological records. The climate in China is influenced by various climate systems such as East Asian monsoon, southwest monsoon, and westerlies, all of which are important parts of the global climate systems. Therefore, China has been a key region for studying the Holocene climate.

In recent years, Chinese scientists confirm the link of climate instability between East Asia and high latitude areas in the Northern Hemisphere (Yuan et al., 2004; Tan et al., 2006; Wang et al., 2008) using the stalagmite records, which have the advantage of continuation, high resolution, and precise dating (Stuiver et al., 1995). They found that the Holocene monsoon climate was strongly correlated with solar activity in the decades-century scales, and most events of weak Asia monsoon were synchronous with the cold event in the North Atlantic (Figure 1) (Stuiver et al., 1995; Wang et al., 2005). The teleconnections of Holocene warm-wet climate between Asia and North Atlantic ocean were also put forward (Liu et al., 2013).

Ice sheets and ice caps are the important material for studying global change (Yao et al., 2009). The $\delta^{18}O$ records from Dunde ice core indicate the Holocene Megathermal appeared in 6–8 ka, which is roughly identical to the record of Guliya ice core showing the warmest period occurred in 6–7 ka.

The $\delta^{18}O$ records decreased sharply in ca. 5 ka that marked the climate transition during the Holocene (Thompson et al., 1995). The records of oxygen isotope from Puruo-gangri ice core indicated that the Tibetan Plateau climate was strongly unstable since 7.5 ka, during which there were several large climatic fluctuations and cold climate events, which correspond to the advance of the Tibetan Plateau glacier (Figure 1) (Thompson et al., 2006). Eight warm periods and seven cold periods are also identified from the Guliya ice core for the last 2 ka (Yao et al., 2001).

Lake sediment record is an ideal archive for the past global climate change research (Shen et al., 2004). The record from the Erlongwan Maar Lake in Northeast China indicated the entire Holocene climate development (from 11.4 ka BP to present) exhibited an increasing temperature trend, although rapid cooling climate events occurred repeatedly (You et al., 2012). The high resolution pollen record from the Huguangyan Maar Lake demonstrated the Holocene optimum period occurred in 9.5 ka in low latitude areas (Wang et al., 2007). The study on diatom-winter monsoon index discovered that the strength of the East Asian winter monsoon shifted by the strong to the weak from the early to late Holocene, which was in-phase with the East Asian summer monsoon on orbital time scales during the Holocene (Wang et al., 2012). A similar trend was revealed in the rate of SST (sea surface temperature) changes in east-west and south-north directions (Huang et al., 1997), and the clay sediment in the South China Sea (Hu et al., 2012). The high resolution sediment records from the Qinghai Lake suggested that the Holocene climate changes were dominated by Asian monsoon, and linked with orbital forcing, North Atlantic abrupt events, and solar activity changes (Figure 1) (Ji et al., 2005; An et al., 2012).

Based on the multi-proxies of pollen, foraminifera, and alkenone paleothermometry from the Okinawa trench, East China Sea, the terrestrial and oceanic sequences suggested that the deglacial warming in East Asia land lagged behind

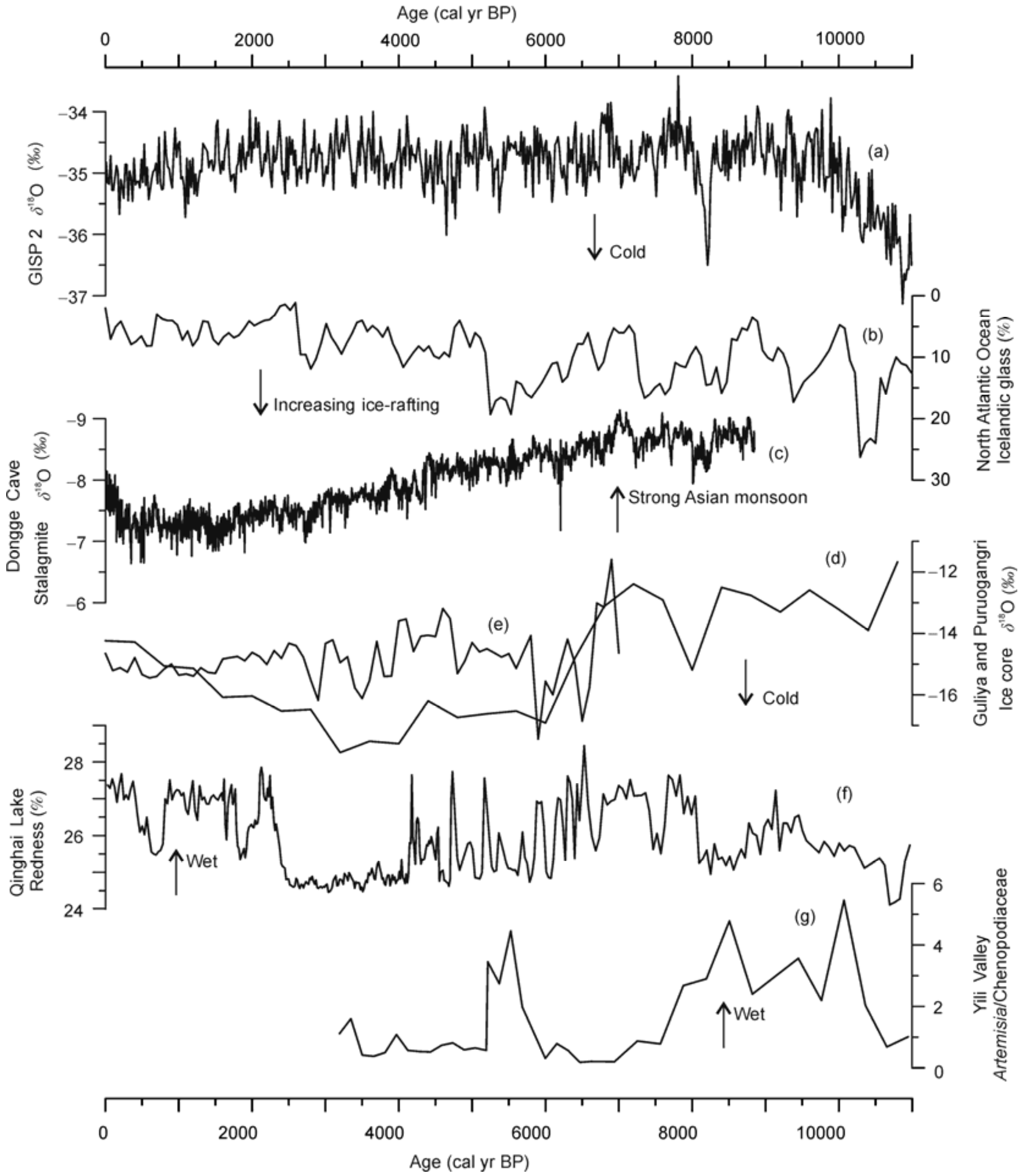

Figure 1 Comparative diagram of high-resolution climate records in China, Greenland ice core, and North Atlantic Ocean during the Holocene. (a) Oxygen isotope record in Greenland ice core 2 (GISP2) (Stuiver et al., 1995); (b) percentage of glass debris in the core of the North Atlantic MC52-V29191 in the North Atlantic Ocean (Bond et al., 2001); (c) oxygen isotope record of stalagmite in Dongge cave (Wang et al., 2005); (d) oxygen isotope record of ice core in Guliya (Wu et al., 2004); (e) oxygen isotope record of ice core in Puruo-gangri (Thompson et al., 2006); (f) red degree from the sediment in the Qinghai Lake (Ji et al., 2005); (g) ratio of *Artemisia* and Chenopodiaceae (*A*/C) (Li et al., 2011).

adjacent oceans changes by ca. 3–4 ka for the last 40 ka, and the high-latitude Northern Hemisphere and low-latitude ocean climate changes drove the asynchronous warming between marine and land (Xu et al., 2013). The drought events were synchronous with the cold event occurring in the Greenland ice core, and there are effective teleconnections of the atmosphere between the Asian monsoon area and the North Atlantic Ocean during the Holocene warm period (Liu et al., 2013).

New research progress of the Holocene climate has been obtained in arid central Asia dominated by the westerlies. Chen et al. (2008) suggested that the Holocene moisture changes in arid central Asia were controlled by the westerlies, most wet climate occurred in mid- to late Holocene, and the effective moisture history is out-of-phase with that in monsoonal Asia. The high resolution record of moisture changes revealed that the climate was dry during the Medieval Warm Period (MWP), whereas the climate was wet during the Little Ice Age (LIA) in arid central Asia (Chen et al., 2010). The effective moisture changes also showed an out-of-phase relationship with that in monsoon area over the past 1000 years (Chen et al., 2010). High resolution pollen records from the Yili Valley indicated that the climate was dominated by warm-wet and cold-dry pattern since 15 ka. The climate was controlled by westerlies and SST in the North Atlantic Ocean, and the moisture changes in the Yili Valley are similar with monsoon area (Figure 1) (Li et al., 2011).

At present, four warmest periods and two coldest periods were revealed during 350–1000 AD from the tree ring records in the east Tibetan Plateau. The warmest period was probably in AD 1970–2000 for the past 1000 years (Liu et al., 2009). The history literature also indicates that there exist four warm periods and three cold periods for the past 2000 years, and the Song-Yuan Dynasty is consistent with the Medieval warm period (MWP, 900–1300 AD), whereas the Ming-Qing Dynasty corresponds to the Little Ice Age (LIA, 1550–1850 AD) (Ge et al., 2012). The latest research shows that the LIA was the coldest time during the Holocene, and the average temperature declined 2°C in the north Atlantic region (Marcott et al., 2013). The high resolution records of climate change showed that many dynasty collapses possibly corresponded to the cold events in the China history (Yancheva et al., 2007; Zhang et al., 2008; Liu et al., 2009).

Although the high-resolution studies of the climatic records, events, and processes during the Holocene have made some substantial progresses, it remains unclear that the method and mechanism of different climate subsystem responded to the global change, and it still lacks core evidence on the performance and inducing factor of mutation events in different climate subsystem. Therefore, it becomes urgent how to obtain the high-precision proxies and climatic sequences and be integrated with the modern climate records and measurement data, not only to explore the external factor of climate change but to understand the internal driving mechanism of climate system. Moreover, what changes will happen in different regions under the background of different warming range? What kind of response of the ecological environment will emerge in global warming or cooling process and what is its positive and negative side? All are important subjects to be tracked and explored.

2 The plant proxies of early agriculture

Agricultural research based on the records of plant proxies mainly uses archaeological plant remains (including seeds, fruits, pollen, charcoal, phytolith, starch, leaves, stems, tree trunk, foot, bark, and resin etc) to identify plant types and vegetation characteristics, reconstruct regional climate and environment, restore human's food pattern, understand human ability and behavior in obtaining and utilizing the natural resources, and reveal the social-economic formation of ancient society. At present, many new approaches and methods have been developed to analyze and identify plant indicators (Lu et al., 2009a; Yang et al., 2009; Yang et al., 2011; Sun and Li, 2012) and widely accepted by majority of scholars.

The breakthrough of phytolith morphological identification from the lemma of foxtail and common millet (Lu et al., 2009b) has provided a reliable solution to the origin and spread of rain-fed agriculture of millet (Fuller et al., 2009). The organ morphology of megafossil plants, such as carbonized kernel and rachilla, cell morphology of microfossils, including phytolith, starch, pollen, molecular structure of fossil, and the DNA characteristics of the genetic material (Dickau et al., 2007; Allaby et al., 2008) have gradually shown their potential to interpret the domestication, the genetic relationships, and evolution succession on the cultivated crops.

The taxonomic identification of wood through the anatomical characters of fossil charcoal is almost identical to that of the original wood, which offers improved precision at the levels of genus and species (Scott, 2010). Therefore, the fossil charcoal provides the significant potential for determining the plant types and the regional vegetation (Shackleton and Prins, 1992), reconstructing the terrestrial environment (Newton, 2005; Sun et al., 2013), and investigating the early human activity on the selected use of wood (Willcox, 2002; Li X Q et al., 2012). Charcoal as a direct product of fire has the unparalleled advantages on interpreting the "slash and burn" mode of early agriculture, reconstructing the intensity of agricultural activity, and exploring the impact of human activity of fire on vegetation and environment (Shen et al., 2006; Li et al., 2009b).

Pollen not only is an important indicator for vegetation and environmental reconstruction, but also has a significant role in discriminating crop types by precision analysis of pollen morphology (Li et al., 2009a; Mao and Yang, 2011). The pollen changes of Poaceae plants (such as wheat, rice, common millet, and foxtail millet) in agricultural area can indicate crop cover changes (Li et al., 2007a, 2007b; Zong et al., 2007). Comparative study on pollen and charcoal records has a distinctive significance for promulgating the intensity of land use (Wick et al., 2003). The analysis of plant starch, playing an important role in distinguishing crops especially tuber plants, has become an effective index in interpretation of diet type of early human, plant utilization, and crop structure (Yang and Jiang, 2010; Wan et al., 2012).

Comprehensive studies on plant records of agricultural activity that promotes the early agriculture no longer remain simple analysis and speculation, but obtain more evidence for in-depth exploration and thinking. Significantly, the high-precision dating of AMS^{14}C has been extraordinarily developed and become the perfect match with agricultural megafossil in chronological scope and dating material. Not only can the dating establish timescales of agricultural activity, but also reflect the regions of agricultural activity in different times according to the distribution of ^{14}C age data. Simultaneously, depending on the unified timescale, the effective and reliable comparative research can be carried out between early agriculture and climatic change to promote the research of agriculture origin, development, and its driving mechanism.

3 Research progress of early agriculture in China

Agriculture originated mainly from three centers of West Asia, East Asia, and Central America (Bellwood, 2005). China is the origin and development centers of rain-fed millet (Zhao, 1998; Lu et al., 2009b) and cultivated rice (Crawford, 2006; Yan, 1997). Continued agricultural activity has ongoing and profound impact on vegetation and ecological environment. Therefore, the research of early agriculture has become the key point and breakthrough for human activity and its relationship with environmental change during the Holocene, and stepped into multidisciplinary and integrated research stage. In recent years, it has become an important scientific topic for studying the origin, expanding and spread of agriculture based on the systematical records of early agriculture, investigating the mode and intensity of agricultural activity, and revealing the agricultural impact and adaption on the environment.

The expanding and spread of agriculture going outward from the center led to widespread dissemination and exchange of agriculture (Belfer-Cohen, 2011) and also promoted the maturity of agricultural technology, the complexity of agriculture structure, and the occurrence of agricultural diversification. Wheat, barley, and various legumes were domesticated in the "Fertile Crescent" region of West Asia at around 12 ka and gave birth to Mesopotamia civilization (Bellwood, 2005). In China, the rain-fed agriculture in the middle valley of the Yellow River and the rice agriculture in the middle and lower valley of the Yangtze River were the birthplaces of oriental civilization (Jiang and Liu, 2006; Lu et al., 2009b; Fuller et al., 2009). The "old world" of Eurasia is the "heartland" of the culture and civilization development (Figure 2). Referred to the origin region of agriculture in the East and West Asia, this raises the intriguing questions on how the flourishing culture based on agriculture was exchanged in "old world". Also, how did the routes through which the Neolithic farmers moved and transferred material cultural between East and West Eurasia spread and expand? All of these are important and challenging issues and need to be addressed.

Researches on diffusion and dissemination of wheat farming in West Asia to South Asia, Central Asia, North Africa, and Europe were more in-depth with comparatively adequate evidence (Yan, 1997; Jared and Bellwood, 2003). Early wheat remains in China emerged mainly in the Tarim Basin in Xinjiang (Zhao et al., 2013), the Hexi Corridor (Flad et al., 2010; Dodson et al., 2013), and the Tianshui Basin (Li et al., 2007c), and the Liangchengzhen site of Shandong and Erlitou site of Henan (Thornton and Schurr,

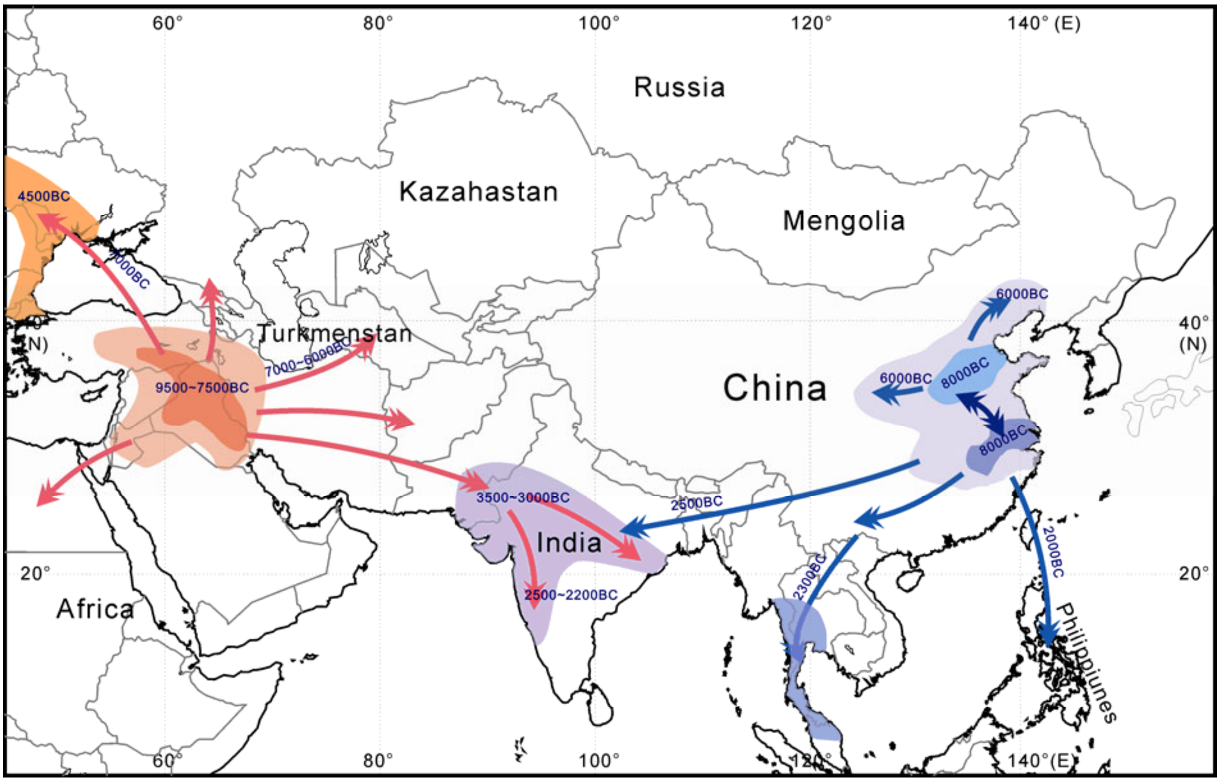

Figure 2 The expanding and spread of early wheat and rice agriculture.

2004), dated at roughly around 4000 a BP. Currently, the disseminative time and path of wheat agriculture from West Asia to East Asia are still in dispute, mainly due to the lack of sufficient, precise dating evidence of wheat farming. Recently, Dodson et al. (2013) suggested that the spreading route of early wheat was mainly from West Asia through the Russian steppes and then the Gansu Corridor to China based on 37 direct AMS^{14}C datings of wheat seeds in China (Figure 2).

At present, more consistent perspective has come on the spread and expanding route of rice agriculture. The cultivated rice centered in the middle-lower Yangtze River (Zhao, 1998), and expanded northward into Shangdong Province in North China around 8 ka (Jin et al., 2007), and then introduced to the Korean peninsula through the Liaodong peninsula, landed in Japan at roughly 2 ka (You, 1995; Crawford, 2006). Around 5 ka, the cultivated rice spread southwardly to Southeast Asia and the Indian subcontinent through Guangdong and Yunnan provinces (Yan, 1997). The rice spread westward into the Guanzhong Basin in the south Loess Plateau during Yangshao period (Zhang et al., 2010), and the most westward record of cultivated rice was found in the Tianshui Basin in the southwestern Loess Plateau around 5 ka BP (Li et al., 2007a) (Figure 2).

Rain-fed agriculture was distributed mainly in the Yellow River valley in North China (Barton et al., 2009; Lu et al., 2009b; Zhang et al., 2010) and the common millet first appeared around 10 ka and the foxtail millet came later (Lu et al., 2009b). The rain-fed agriculture appeared in the Xinglongwa site in Northeast China around 8 ka (Zhao, 2004), and southwardly extended to the Huaihe River valley and formed a mixed agriculture with cultivated rice (Fang et al., 1998). At about 5 ka, rain-fed agriculture emerged in the arid area of Northwest China such as the Hexi Corridor and southeast of the Tibetan Plateau, and possibly went into Xinjiang and other inland arid regions of Asia around 4 ka (Xie, 2002; Wang, 2005). Although the common millet dated at 7 ka BP was discovered from west bank of the Black Sea to Eastern Europe, Central Europe (Hunt et al., 2008) and some scholars speculated that the rain-fed agriculture between east and west Asia may have certain possible link (Jones and Liu, 2009), it is still in need of support with more plant archaeological evidence and accurate dating data.

An important form of early agriculture development was the continual adjustment of agricultural planting structure for improving the adaptive capacity to environmental change. The Eastern Mediterranean ancestors coped with climate variability and land salinization through restructuring the plant structure of wheat and barley (Cullen et al., 2008). The ancestors in the Andean desert frequently changed crop species to respond to the drought climate (Dillehay and Kolata, 2004). The planting proportion of rain-fed agriculture in the western Loess Plateau has bearings on the climate change during the Holocene. The common millet accounted for a higher proportion in the early and middle Yangshao Culture, but then the foxtail millet had a dramatic rise in the planting structure (Liu et al., 2008; Zhou et al., 2011).

Continuous technologic innovation is an important indicator of agricultural development. The first stone or bone tools of agricultural production emerged in North China before Yangshao Culture period (Chen, 2005). The ancestors had used fire for managing the cultivated field in the middle-lower areas of the Yangtze River at around 7 ka (Zong et al., 2007) and had yet developed paddy irrigation systems during Majiabang Culture and Qujialing culture (Ding, 2004). The diversity of early agriculture in the late Neolithic in the southwest Loess Plateau was the result of technology exchange and integration of agriculture planting, cultivation, and field management, which improved agricultural scale and land-carrying capacity and enhanced the agriculture adaptability to the environmental change (Li et al., 2007b).

As the change of global climate possibly has a strong impact on mankind, it has become the crucial question as how to response to the global change and formulate the corresponding countermeasures. The human adaptation has been raised to a new level in the research of global change. Through the in-depth analysis of archaeological material and human remains together with the high-resolution records of climate change, we can recover the characteristics of human adaptation against the background of different amplitude of warming in different regions, uncover the relation between the human evolution, agriculture origin, ancient culture, ancient civilization, and the climate change, and provide the scientific basis for understanding and evaluating the human adaptation under the climate change in the future.

4 Impact of early agriculture

Human activity must be considered as an important geologic force while the change process of earth system is cognized (Crutzen, 2002). Some important issues in the research of "past global change" are as follows: (1) Studying the characteristic of human activity and its process and mechanism on interfering with or driving earth system; (2) discussing the laws of interaction between human and nature and their functioning; (3) protecting and improving the sustainable environment relied on by the human. Therefore, some research topic should focus on how to combine various means and methods to extract the environmental effects of human, distinguish the natural and anthropogenic impact on vegetation and environment, and reveal the relationship between the regional environment and global climate change.

Some scholars held that environment was strongly impacted by human mainly after the industrial revolution

(Crutzen, 2002), but some scientists suggested that the early land use based on the agriculture activities may have begun to impact profoundly on the global environment as early as 8000 years ago (Cavalli-Sforza et al., 1993; Ruddiman et al., 2008; Li et al., 2009b). The progressive enhancement of the Holocene agriculture impacted on the global and regional ecological environment profoundly by way of the water cycle, photosynthesis, and land use. Based on the concentration abnormity of CO_2 around 8 ka and CH_4 around 5.2 ka, Ruddiman suggested the Hypothesis of "Anthropogenic Impact" on the climate change during the Holocene (Ruddiman et al., 2008), which has drawn much attention in the academic community.

The early agriculture of "slash and burn" and extensive pattern land use, as well as the settlement construction and ritual activities etc., exerted a strong and far-reaching transformation on the landscape (Kirch, 2005). The vegetation within ruins periphery approximately 3 kilometers in Levant region of West Asia was suffered transformation by agricultural activities in the early Holocene (Rollefson and Kohler-Rollefson, 1992). Massive farmland reclamation has substantially reduced forest distribution acreage in Mesopotamia and most areas of Middle East since 5 ka (Miller, 1997). Spruce forest located on the Loess Plateau and the surrounding area has been significantly reduced since around 4 ka and the disappearance of spruce forest since around 2 ka was caused mainly by the intensifying human activity (Zhou and Li, 2011).

The study of early agriculture activities in the Guanzhong Basin indicates that the vegetation has been influenced significantly since 4.7 ka due to rapidly increasing agriculture activities (Li et al., 2009b). The study on the utilization pattern and effect process of agriculture activity to forest in Xishanping, Tianshui Basin, reveals that the spruce trees suffered extensively selective cutting and utilization by the ancestors since 4.6 ka, which had a significant impact on mixed conifer and broadleaved forest with the long growth cycle and led to the invasion of secondary bamboo forest with a short growth cycle (Zhou and Li, 2011; Li et al., 2013). The agriculture diffusion and rapid growth of population have greatly enhanced the impact intensity of human and extended influencing range since 5 ka BP, which has already had a wide range of regional characteristics (Ruddiman et al., 2008). The agriculture study in arid area of the Hexi Corridor shows that the land use had a significant influence on soil and vegetation during the late Bronze Age (about 3.5 ka) and the agriculture decline was the result of joint action from the human activity and climate change (Zhou et al., 2012).

Yu et al. (2012) found the spatial distribution of land use patterns around 5 ka was similar to modern days in the Yiluohe River valley (central area of early agriculture) by applying land use scale models (PLUM, short for Paleo-Land Use Model) to simulate land use area and spatial-temporal characteristics per thousand years between 8 ka and 4 ka, based on the analysis of sites distribution as well as the climatic, geological, and geographic parameters. He et al. (2006) analyzed the relationship between sediment change of the modern Yellow River and human activities as well as environmental change using the decoupling theory and its index system, and established the relationships between soil erosion and agricultural activity for the last 2.5 ka and Holocene respectively. Zhou and Li (2013) proposed that a significant increase of population and arable land in the Guanzhong Basin may be the main reasons for the disappearance of the Luyang Lake (the biggest lake in the Loess Plateau) in the modern time.

If the early human activities focus on regional scale, continued agriculture activities were bound to impact on the vegetation and landscape. Therefore, the studies on the process and strength of early agriculture can be considered as the breakthrough of human impact during the Holocene for reconstructing the impact of agriculture (especially the process of land use) on the environment, and then analyzing and probing the possible influence of human activity to the atmospheric elements as well as carbon cycle, and closely linking to the early human impact and the research of global change.

5 Research prospect

In recent years, the high-resolution researches on the geological and biological records (Zhu et al., 2008; Wu et al., 2010; Zhao et al., 2012; Li et al., 2013), early human activity (Huo et al., 2008; Li M Q et al., 2012), and numerical model (Li et al., 2010) during the Holocene in China have advanced rapidly, enriched the contents on the climatic instability and abrupt events during the Holocene, improved the acquaintance on the responding mechanism to the change of orbital force in the internal process of climate system, deepened the understanding on the human activities and its possible impact on the orbital climate variability, and driven the study progress of past global change. At the same time, it put forward a series of profound scientific problems.

At present, the "National Basic Research Program of China" designed the project on "The changes of climatic environment and human impact and adaption in China", whose main target is on how the gradual change of global temperature, and rapid increasing/decreasing temperature impact the climate in monsoon and westerly region in China, and promulgate the internal process of climatic system and its induce mechanism on the abrupt events, distinguish how the rapid increasing of temperature and human activity impact on the environment in arid and semi-arid region during the Holocene. The CAS Strategic Priority Research Program on the "The Environment pattern in China of Holocene Megathermal" aims to reconstruct the climatic and ecological pattern during the Holocene Megathermal based on the geological-biological records, confirm the distribution of carbon density and carbon reserve in the terrestrial ecosystem, and predicate the change of biological diversity in the process of increasing temperature. The project of "human adaption under the climate change" will focus on the two important scientific issues on origin of modern human and agriculture, understand the characteristic, mode and intensity of early human activity especially the agriculture in Holocene and the relationship with the climate change, and reveal the pattern and mechanism on how the human adapt to the climate change.

Climate and environment changes cause the prodigious temporal and spatial difference (Fu and Ma, 2008). The fifth report of IPCC focuses on the regional evaluation and considers what the advantage or disadvantage is under the background of warm up in difference region and scope. Based on the technology of precise dating, the research on the Holocene climate and human adaption still need to improve the precision of climate proxies and the indicative effectiveness of human activity. We still need to realize how the ecosystem and environmental factors respond to the increasing temperature process, understand how the human adapt to the rapid climate change, and combine the geological-biological records and numerical modeling. It is an important goal to provide the scientific basis for assessing the environmental effects of climate change and the human impact and adaption in the future.

The research is supported by the CAS Strategic Priority Research Program (Grant No. XDA01020304), National Natural Science Foundation of China (Grant No. 41172161), and National Basic Research Program of China (Grant No. 2010CB950204). Many thanks for the helps for Dr Zhou Xinying, Dr Zhao Keliang, Dr Yang Qing, and Dr Sun Nan from the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences.

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