Spatiotemporal Distribution Characteristics of Ancient Settlement Sites in Shandong Province Since the Neolithic Period

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Abstract: Using ArcGIS10.2, a spatial database was constructed for 8.5-2.2 ka historical and cultural sites in Shandong Province. Using a combination of statistical and superposition analysis, the spatial and temporal distribution of ancient settlement sites in Shandong Province since the Neolithic period was studied, and the factors influencing their spatial and temporal distribution were investigated. The study found that as human civilisation has evolved since the Neolithic, the number of ancient settlement culture sites in Shandong province has also been changing, going through four periods: rising, surging, declining and rising. In the HouLi culture period, the settlement sites were mostly concentrated in the plain area in front of the mountains in Luzhong; in the Beixin culture period, Luzhong was the main settlement area of the settlement; in the Dawenkou culture period, there were settlement sites in Luzhong and southeast Luzhong; in the Longshan culture period, there were settlement sites in Luzhong and northwest Luzhong; in the Yueshi culture period, the distribution scale of the settlement sites was obviously reduced and scattered in the plain in front of the mountains. During the Shang culture period, the distribution of settlement sites increased, mostly in the central, southern and northwestern Lu areas; during the Zhou culture period, the distribution of settlement sites increased sharply, mostly in the central, southern and northwestern Lu and Jiaozhou peninsula areas. 8.5-7.5 ka B.P., in general, the natural climate during this time period was warm and humid, with good natural resources, and the Houli from 7.0 to 4.0 ka B.P., climatic conditions remained generally mild, with minor fluctuations but a steady general trend, and the Beixin, Dawenkou and Longshan cultures developed sequentially under stable, excellent climatic conditions during this time period. The Longshan culture gradually declined, and after a more stable period the Yueshi culture emerged. Changes in the overall climatic environment had a great impact on social, cultural and economic development, and the formation and development of Early Neolithic culture is strongly linked to climate, but the influence of many factors, including social productivity, led to spatial changes.

Key words: Shandong Province; Neolithic Age; Ancient settlement site ;settlement factor; distribution characteristics

1 Introduction

The relationship between humans and natural ecosystems, along with the evolution of the ecological environment since the Holocene, has been a subject of ongoing concern [1-4]. Ancient settlement sites are the products of human-nature interactions and reflect the processes of social development and natural evolution [5-7]. The scale of ancient settlement sites often corresponds to factors such as population size and hierarchical levels [8-9]. Current research on ancient settlement sites primarily focuses on their spatiotemporal distribution, distribution characteristics, and their relationship

with environmental evolution, as well as the driving forces behind their spatiotemporal evolution [10]. However, studies on the spatiotemporal distribution characteristics of these sites remain relatively limited.

In Shandong Province, research on the spatial and temporal distribution of ancient settlement sites since the Neolithic period is relatively underdeveloped, lacking a comprehensive research framework and conclusive results. Investigating the spatiotemporal distribution characteristics of these sites can enhance our understanding of human-environment relationships and provide valuable insights for promoting sustainable ecological development in modern society. Studying ancient settlement sites in Shandong Province is particularly significant for deepening our understanding of the long-term human-environment interactions in the region and can offer references and lessons for current and future ecological sustainability efforts [10-11].

Current research on the spatiotemporal distribution characteristics of ancient settlement sites since the Neolithic period primarily utilizes ArcGIS technology to construct digital elevation models (DEMs). By overlaying DEMs with site locations, researchers have generated elevation distribution maps of cultural relics in the region, analyzing their distribution from the perspective of elevation. Additionally, the distribution of ancient settlement sites has been overlaid with hydrological systems to explore the relationship between site locations and water systems. Furthermore, studies have examined the spatiotemporal distribution characteristics and driving factors of these sites by analyzing mid-Holocene climate evolution and extreme climatic events.

This paper focuses on Shandong Province as the study area and employs the ArcGIS 10.2 platform to analyze the spatiotemporal distribution characteristics of ancient settlement sites since the Neolithic period. Through comparative overlay analysis, statistical methods, and other approaches, the study aims to explore the spatiotemporal distribution patterns of these sites and systematically summarize the driving factors and influences affecting their distribution.

2 Overview of the Study Area and Research Methodology

2.1 Overview of the study area

Shandong Province is located in the southeastern part of the North China Plain, along the eastern coast of China, spanning longitudes from 114°36' to 122°43' E and latitudes from 34°25' to 38°23' N. It experiences a temperate continental monsoon climate, with an average annual temperature ranging from 11 to 14 °C and annual precipitation between 550 and 950 mm. The study area features a central uplift, with low-lying terrain in the southwest and northwest, while the eastern region is characterized by undulating hills and an interwoven network of plains and basins. The topography of the study area is relatively complex and can be broadly categorized into nine types: medium mountains, low mountains, hills, terraces, basins, piedmont plains, the Yellow River alluvial fan, the Yellow River plain, and the Yellow River delta. The central-southern mountainous region and the Jiaodong mountainous area are dominated by prominent peaks. The Yellow River and the Grand Canal traverse the province from north to south, while the Huai River system is primarily distributed in the northern part of Shandong. The province is densely intersected by small rivers, each forming its own hydrological network (Figure 1).

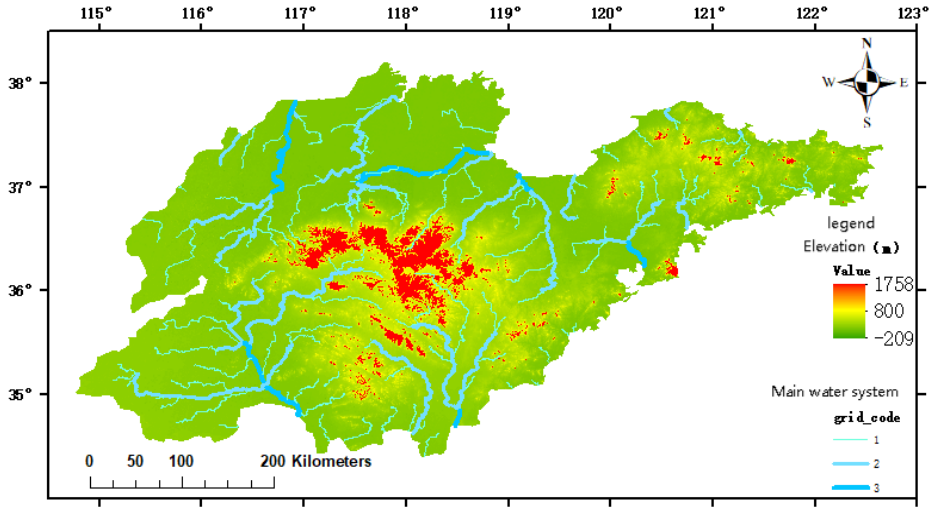


Figure 1. Overview of the study area in Shandong Province

2.2 Data sources and research methods

This study incorporates data from 7,133 ancient settlement sites, a Digital Elevation Model (DEM) of Shandong Province, vector graphic (shp) data of Shandong Province, distribution data of major water systems in Shandong Province, and topographic slope data of Shandong Province. The data for the 7,134 ancient settlement sites in Shandong Province analyzed in this study were sourced from provincial site maps published in the Atlas of Chinese Cultural Relics. Using mapping software, dynamic analysis was conducted to extract, digitize, and correlate archaeological data, revealing a total of 7,134 archaeological sites spanning from the early Neolithic period to the early Bronze Age (approximately 6500–600 BCE), with spatial coverage across the entire Shandong Province. From the collected data of 7,134 ancient settlement sites in Shandong Province, spatial distribution databases were established for seven cultural periods: Houli, Beixin, Dawenkou, Longshan, Yueshi, Shang, and Zhou. The DEM data and vector graphic (shp) data of Shandong Province were obtained from the Geospatial Data Cloud platform, with a resolution of 30 m × 30 m, comprising 31 ASTER GDEM elevation datasets. Using the raster processing tools in ArcMap 10.2, the 31 elevation datasets were merged and clipped with the Shandong Province vector graphic (shp) to generate the DEM map of Shandong Province.

The distribution map of major water systems in Shandong Province was derived from the DEM data. Within the ArcMap 10.2 environment, key hydrological information was extracted using methods such as filling sinks, calculating flow direction, determining flow accumulation, generating river networks, and classifying river hierarchies. The resulting data were then converted into vector format and smoothed. The topographic slope data of Shandong Province were also derived from the DEM data. Using the raster surface analysis tools in ArcMap 10.2, slope data were extracted to create the slope distribution map.

Finally, ArcGIS 10.2 was utilized to perform overlay analysis of the DEM map, water system distribution map, and topographic slope map with the spatiotemporal distribution database of ancient settlement sites in Shandong Province since the Neolithic period. This analysis yielded elevation distribution maps, major water system distribution maps, and slope distribution maps of the ancient settlement sites. The study investigated the temporal and spatial distribution characteristics of these sites and analyzed the driving forces behind their formation.

3 Cultural Sequence and Spatiotemporal Distribution Characteristics in Shandong Province Since the Neolithic Period

3.1 Cultural Sequence in Shandong Province Since the Neolithic Period

Shandong Province boasts a long and independent cultural lineage, spanning from the Houli Culture over 8,500 years ago, through the Beixin, Dawenkou, and Longshan Cultures, to the Yueshi Culture more than 4,000 years ago. Additionally, the Zhou Culture emerged around 3,600 years ago, marking a transitional period between the late Neolithic and early Bronze Age, followed by the Shang Culture approximately 3,000 years ago.

After compilation, this study ultimately utilized data from 7,134 sites (Table 1). Archaeological excavations in Shandong Province have uncovered numerous ancient settlement sites. Through systematic organization, it was determined that the ancient cultures in Shandong since the Neolithic period include the Houli, Beixin, Dawenkou, Longshan, Yueshi, Shang, and Zhou Cultures. The Houli Culture, the earliest Neolithic culture identified in the study area, exhibited relatively low levels of agricultural development and dates back to 8.5–7.5 ka BP. The Beixin Culture, belonging to the early and middle Neolithic periods, was primarily distributed in the Taiyi Mountain range and southwestern Shandong, with a timeframe of 7.0–6.1 ka BP. The Dawenkou Culture, which flourished during the middle to late Neolithic period, was centered in the lower Yellow River region and dates to 6.1–4.6 ka BP. The Longshan Culture, a late Neolithic culture characterized by advanced agricultural practices, existed between 4.6 and 3.9 ka BP. The Yueshi Culture, distinct from its predecessors, represents a Bronze Age culture dating to approximately 3.9–3.5 ka BP [12].

The Neolithic period began around 10,000 years ago and ended between 5,000 and 2,000 years ago. The Erlitou Culture, recognized as an early Bronze Age culture in China, has been dated to around 2000 BCE (approximately 4,000 years ago) based on radiocarbon (14C) dating. The Shang and Zhou Cultures in Shandong Province represent a transitional phase between the late Neolithic and early Bronze Age. The Shang Culture, emerging after the Yueshi Culture, was a Bronze Age culture primarily based on agricultural economy, with highly developed handicrafts and bronze metallurgy, dating to approximately 3.6–3.3 ka BP. The Zhou Culture, belonging to the late Neolithic and early Bronze Age, succeeded the Shang Culture and is dated to around 3.6–3.3 ka BP.

Based on the historical development stages and level of civilization in Shandong Province, the ancient settlement cultures after the Neolithic period are divided into seven sequential phases: the Houli Culture period (8.5–7.5 ka BP), the Beixin Culture period (7.0–6.1 ka BP), the Dawenkou Culture period (6.1–4.6 ka BP), the Longshan Culture period (4.6–3.9 ka BP), the Yueshi Culture period (3.9–3.5 ka BP), the Shang Culture period (3.6–3.3 ka BP), and the Zhou Culture period (3.0–2.6 ka BP) (see Table 1) [13].

Table 1 Cultural sequences and number of sites of each culture type since the Neolithic in Shandong Province

	Culture type							
	Houli Culture	Beixin Culture	Dawenkou Culture	Longshan Culture	Yueshi Culture	Shang Culture	Zhou Culture	Total
Cultural period(ka)	8.5-7.5	7.0-6.1	6.1-4.6	4.6-3.9	3.9-3.5	3.6-3.3	3.0-2.6	8.5-2.6
Number of sites	11	26	563	1409	314	1334	3477	7134

Percentage(100%)	0.15	0.36	7.89	19.75	4.40	18.70	48.75	100

3.2 Spatiotemporal Distribution Patterns of Cultures in Shandong Province Since the Neolithic Period

The distribution of ancient settlement sites across different periods is illustrated by changes in the number of sites in each period (Table 1). Starting with 11 sites during the Houli Culture period, the number increased to 26 sites in the Beixin Culture period, further rose to 563 sites in the Dawenkou Culture period, and then significantly expanded to 1,409 sites in the Longshan Culture period. However, during the Yueshi Culture period, the number declined to 314 sites, marking a minor peak. During the transition from the Neolithic to the Bronze Age, the number of cultural sites surged dramatically, starting with 314 sites in the Yueshi Culture period, increasing sharply to 1,334 sites in the Shang Culture period, and reaching a peak of 3,477 sites in the subsequent Zhou Culture period. Overall, since the Neolithic period, the number of ancient settlement sites in Shandong Province has undergone significant fluctuations, experiencing four main phases: initial growth, rapid expansion, decline, and subsequent resurgence (Figure 2).

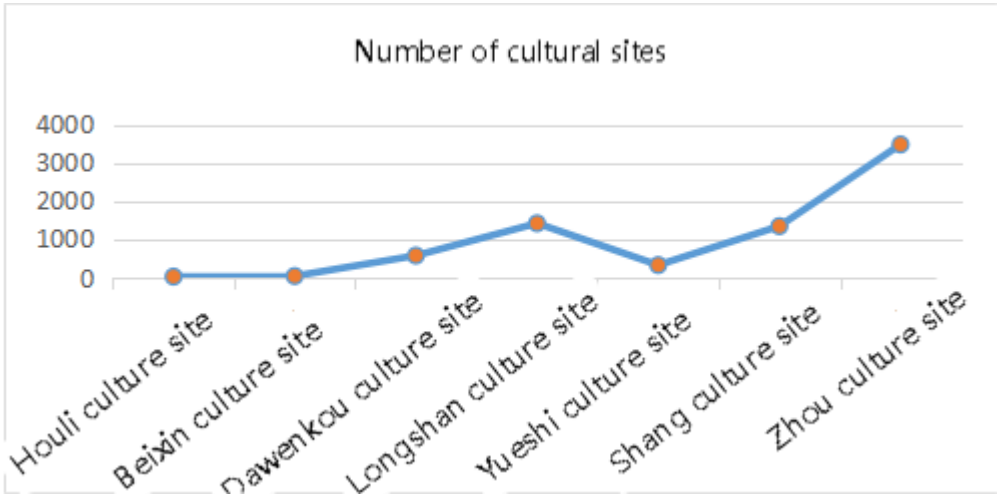


Figure 2 Changes in the number of site locations of each culture type since the Neolithic in Shandong Province

During the Houli Culture period, ancient settlement sites were primarily distributed in low-altitude plain areas, mainly concentrated in the central mountainous region of Shandong, particularly in the alluvial fan plains north of the Taiyi Mountains (Figure 3a). In the Beixin Culture period, the sites remained predominantly located in the Taiyi Mountain range, but their distribution began to gradually expand, with a focus on the central mountainous region and piedmont plains of Shandong [14] (Figure 3b). During the Dawenkou Culture period, due to increased population density, the distribution of settlement sites became more widespread, concentrating in the southeastern and central regions of Shandong (Figure 3c). In the Longshan Culture period, the density of settlements significantly increased, and their distribution expanded further, covering the central, northwestern, and central-southern regions of Shandong (Figure 3d). During the Yueshi Culture period, both the number and scale of ancient settlement sites were considerably smaller compared to the Longshan Culture period, with sites dispersed across plains and piedmont alluvial plains (Figure 3e).

In the Shang Culture period, the number of settlement sites increased dramatically compared to the Yueshi Culture period, expanding in both scale and quantity. The number of sites was roughly comparable to that of the Longshan Culture period, but their distribution shifted, primarily located in the central, central-southern, and northwestern regions of Shandong (Figure 3f). During the Zhou Culture period, the number of settlement sites surged further, reaching its peak. The scale and quantity of sites continued to expand, with their distribution extending to the central, central-southern, northwestern regions, and the Jiaodong Peninsula. Settlement sites began to spread extensively into the central mountainous areas of Shandong, resulting in increased cultural site density and a total of 3,477 sites (Figure 3g), marking the zenith of their distribution.

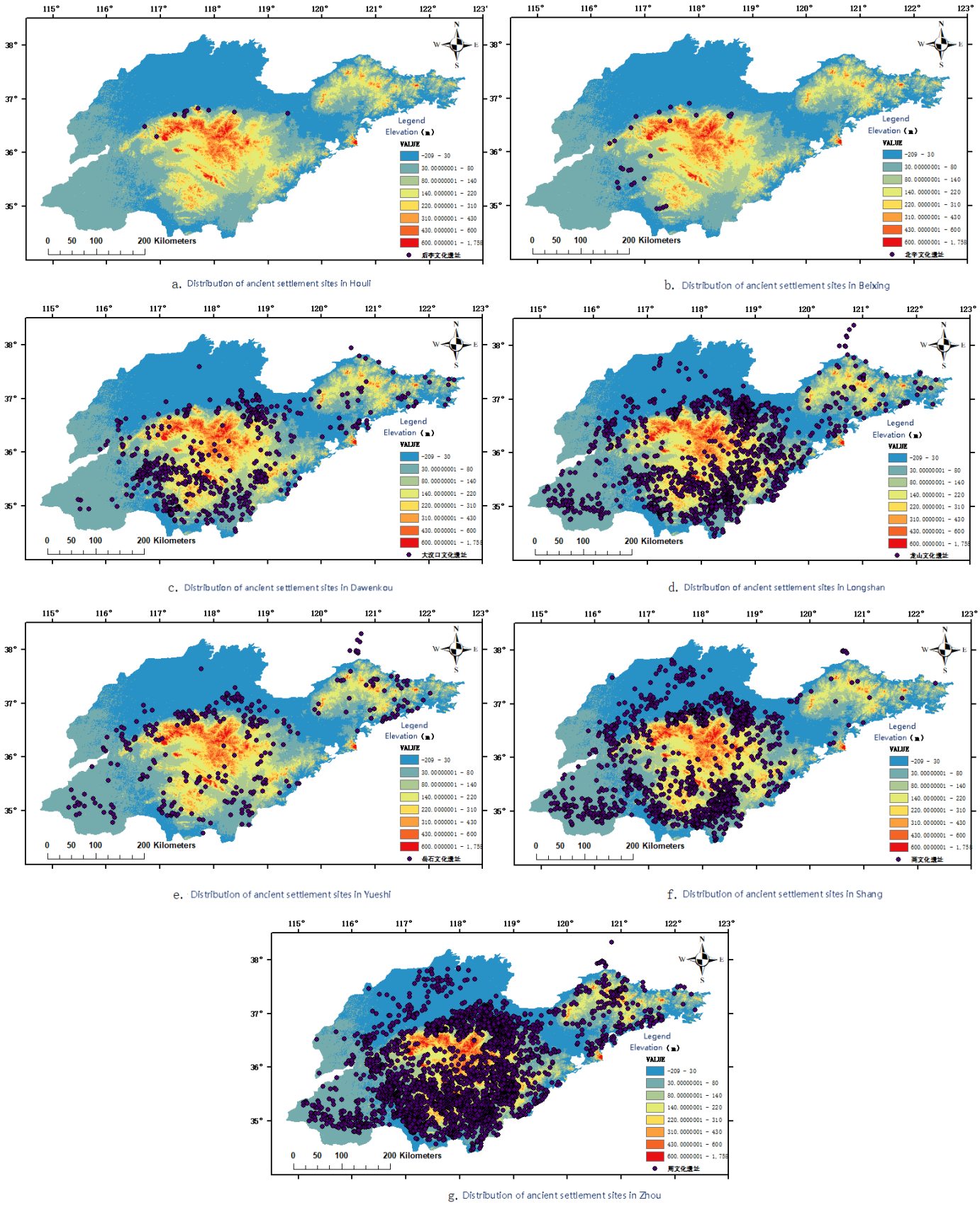
4Driving Factors Influencing Human Distribution Patterns in Shandong Province During the Neolithic Period

4.1 Geomorphological Variations in Settlement Distribution in Shandong Province Since the Neolithic Period

The spatiotemporal distribution characteristics of ancient settlements in Shandong Province are closely related to factors such as human activities, geomorphology, and climatic environments. Therefore, a comprehensive analysis of their geographical patterns is essential [15].

Since the Neolithic period, the elevation and topographic distribution of ancient settlement sites have exhibited distinct characteristics across different cultural periods. During the Houli Culture period, ancient settlement sites were predominantly concentrated on river terraces in the northern part of the Taiyi Mountains in central Shandong, with an average elevation ranging from 20 to 80 meters. These river terraces were primarily located in alluvial fan plains, characterized by relatively flat terrain (Figure 3a). In the Beixin Culture period, the elevation range of ancient settlement sites began to expand, with most sites maintaining elevations similar to those of the Houli Culture period. However, a small number of sites were distributed in areas with elevations between 80 and 140 meters, extending into the southwestern region of Shandong (Figure 3b). During the Dawenkou Culture period, the density of ancient settlement sites increased, and their elevation range expanded further, reaching up to 410 meters. A few sites were even found at elevations above 410 meters (Figure 3c). In the Longshan Culture period, the number of ancient settlement sites continued to grow, with most new sites concentrated in the central-southern and southeastern regions of Shandong at elevations below 310 meters. The number of sites above 410 meters saw only a slight increase compared to the Dawenkou Culture period, remaining largely unchanged (Figure 3d). By the Yueshi Culture period, the number of ancient settlement sites decreased sharply, and their distribution density diminished. Sites at higher elevations became less common, with the majority of settlements located below 310 meters (Figure 3e).

During the Shang Culture period, the number of ancient settlement sites began to increase again, with their distribution expanding into higher elevation areas. Sites above 600 meters appeared, and the density of settlements in lower elevation regions further increased (Figure 1f). In the Zhou Culture period, the expansion of ancient settlement sites continued. Settlements below 140 meters became densely concentrated, while those between 140 and 300 meters increased significantly. Sites above 600 meters also emerged, and apart from the higher elevation areas, the distribution of ancient settlements became notably denser (Figure 3g).



a. Distribution of ancient settlement sites in Houli

b. Distribution of ancient settlement sites in Beixing

c. Distribution of ancient settlement sites in Dawenkou

d. Distribution of ancient settlement sites in Longshan

e. Distribution of ancient settlement sites in Yueshi

f. Distribution of ancient settlement sites in Shang

g. Distribution of ancient settlement sites in Zhou

Figure 3 Distribution of ancient settlement sites in Shandong Province since the Neolithic period

Since the Neolithic period, the elevation distribution of ancient settlement sites in the study area has exhibited variations across different cultural periods. However, the slope distribution of these sites shows little difference over time. From the Houli Culture to the Zhou Culture periods, the slopes of ancient settlement sites consistently fall below 30°, with the majority concentrated between 10° and 30°. No ancient settlement sites are found on slopes ranging from 60° to 90° (Figure 4). This pattern aligns with the characteristics of ancient settlement site selection, which favored low elevations and gentle slopes.

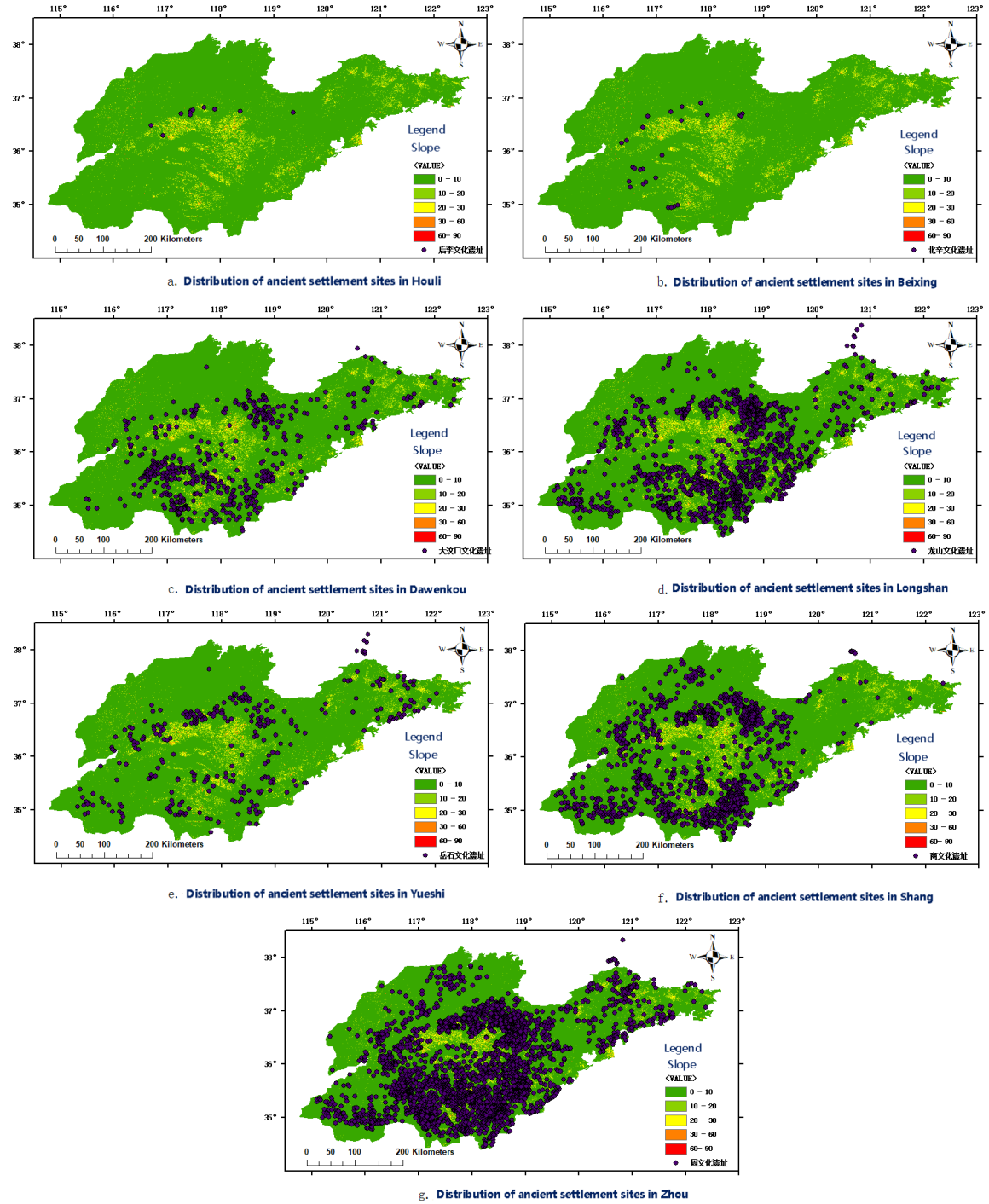


Fig. 4 Slope distribution of each ancient settlement site point since the Neolithic in Shandong Province

During the early Neolithic period, ancient humans relied on fishing, hunting, and gathering as their primary means of subsistence. As a result, settlement sites were often located near mountains and rivers, which provided convenient access to these resources. This marked the gradual development of the Houli Culture. Due to limited production capabilities and resources, coupled with increasing population and human demands, people began to seek warmer and more humid climates with abundant resources, leading to a shift toward low-elevation areas along rivers. Field investigations have revealed that since the Neolithic period, settlement site selection in Shandong Province has favored plains and piedmont alluvial fan plains, characterized by relatively low elevations and gentle slopes. Flat terrains were more conducive to agricultural development and the expansion of cultural sites.

In summary, the geomorphological preferences of ancient settlement sites in Shandong Province since the Neolithic period evolved from piedmont alluvial fan plains to plains. With population growth and technological advancements in later periods, humans' ability to conquer natural environments strengthened, leading to a gradual expansion into mountainous regions.

4.2 Hydrological Influences on Settlement Distribution in Shandong Province Since the Neolithic Period

The primary river systems in Shandong Province are the Yellow River and the Huai River systems. During the early Neolithic period, human production capabilities were limited, and ancient settlement sites were predominantly located near rivers to access abundant resources for fishing, hunting, and gathering, as well as flat and habitable areas. Influenced by the climate of the early to mid-Holocene and the 4.2-kiloyear cooling event [16-18], the downstream regions of rivers experienced more significant tectonic uplift compared to erosion and lateral accretion, resulting in more stable hydrological systems. The piedmont lowlands, less affected by tectonic activity, were primarily characterized by subsidence, lower kinetic energy, and higher river accumulation and network density, making them more sensitive to climate change. The piedmont alluvial plains featured crisscrossing river channels but sparse settlements. During the Houli and Beixin Culture periods, ancient settlements were mostly distributed in the upper reaches of rivers.

As time progressed and multiple factors came into play, the number of ancient settlement sites near rivers increased significantly during the Dawenkou Culture period. By the late Longshan Culture period, the climate became cooler and drier, leading to enhanced river sedimentation, reduced water surfaces, and increased arable land. Consequently, the number of ancient settlement sites near rivers grew rapidly [19]. Although the number of ancient settlement sites decreased substantially during the Yueshi Culture period, their distribution remained closely tied to river systems. Similarly, during the Shang and Zhou Culture periods, ancient settlements were primarily distributed along rivers. However, due to limited space near rivers and the continuous increase in the number of settlements, ancient sites expanded from areas immediately adjacent to rivers to nearby regions, maintaining their distribution trend along river systems (Figure 5).

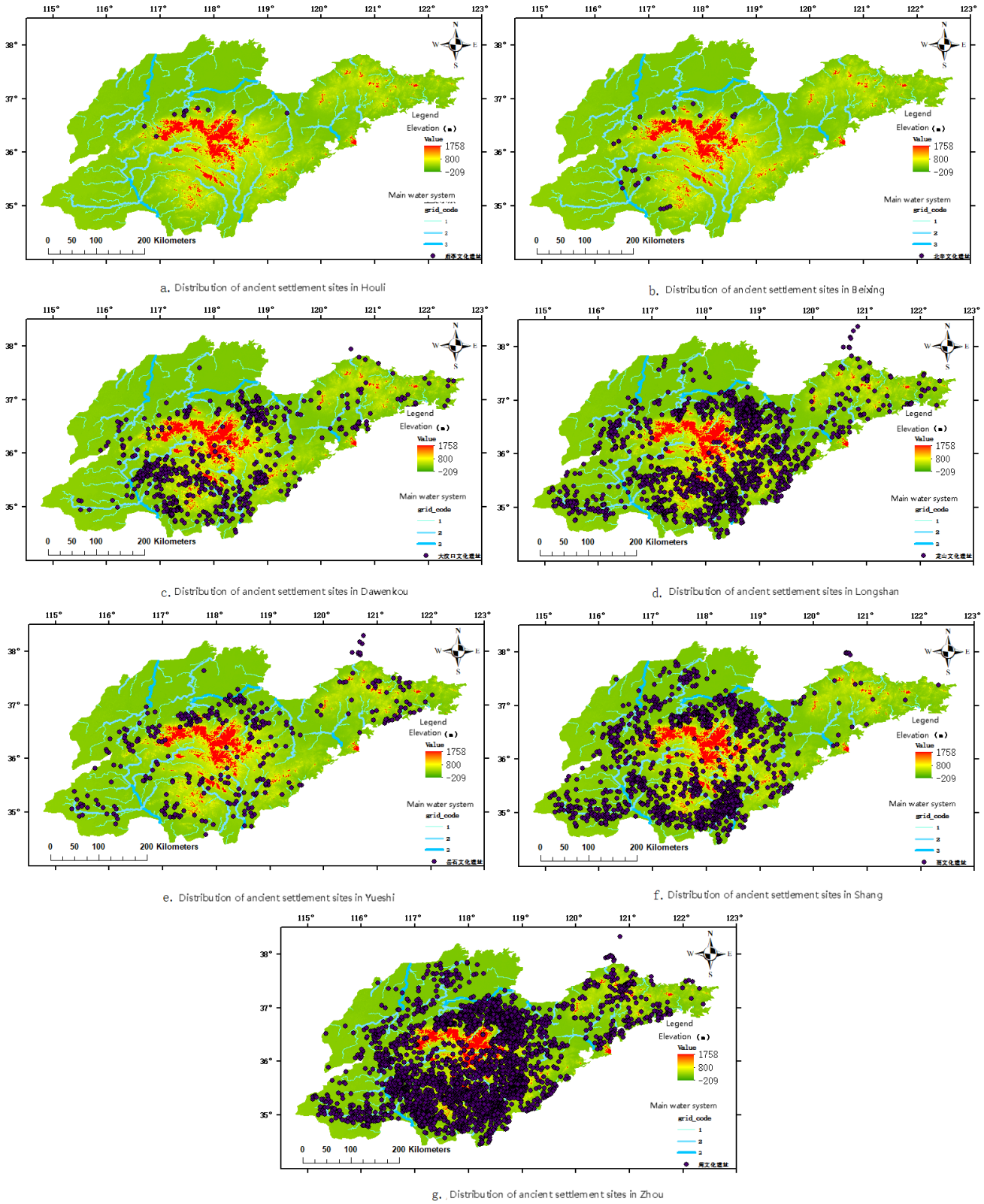


Figure 5. Distribution of water systems at various ancient settlement sites in Shandong Province since the Neolithic Age

4.3 Impacts of Mid-Holocene Climatic Evolution on the Distribution of Settlement Sites in Shandong Province Since the Neolithic Period

The Neolithic cultures in Shandong Province experienced a period of flourishing development due to the warmer and more humid climate during the mid-Holocene. According to studies by Zhu Kezhen and Ding Min, among others, the period from 8.5 to 2.6 ka BP was characterized by higher temperatures and a warmer, more humid climate compared to today. Although climatic conditions began to shift toward aridity and reduced precipitation starting around 3.1 ka BP, the average temperature during this interval remained approximately 2–3°C higher than present levels [20-21]. Additionally, the climate in Shandong Province underwent significant fluctuations during the Holocene, with five major climatic oscillations identified. Among these, cooling events occurred at 8.2, 5.5–5.0, and 4.2 ka BP [12], which contributed to the decline of ancient settlement cultures. Notably, the cooling event at 4.2 ka BP was particularly severe [22]. Around this time, extreme precipitation events became frequent in mid- to low-latitude regions [23], coinciding with the Younger Dryas event and North Atlantic cooling events [24-26]. Xia Zhengkai et al. [27] analyzed abnormal flood activities in the Yellow River region, suggesting a high likelihood of unusual floods around 4.0 ka BP. Several abnormal floods in the Yellow River region were also linked to the 4.2 ka BP cooling event, primarily driven by increased rainfall and humidity due to climatic cooling.

Climatic changes significantly influenced human production and livelihoods. Suitable temperatures and precipitation provided favorable conditions for the emergence of ancient settlement sites. By examining the distribution characteristics of ancient settlement sites in Shandong Province since the Neolithic period and the climatic evolution of the Holocene, this study explores the relationship between the spatiotemporal distribution of these sites and climatic changes. During 8.5–7.5 ka BP, the global climate was warm and humid, with temperatures approximately 2°C higher than today and abundant precipitation, creating ideal conditions for the survival and reproduction of flora and fauna. This period saw relatively rich material resources, providing better conditions for the survival and development of ancient communities. Although agriculture and animal husbandry were gradually developing, fishing and hunting remained the primary subsistence strategies, leading to a preference for settling near rivers. The Houli Culture emerged and developed under these conditions.

During 7.0–6.1 ka BP, the Beixin Culture emerged and flourished. The climate during this period generally followed the warm and humid trend of the preceding era. Although several climatic fluctuations occurred, they did not significantly hinder the development of cultural sites, as overall climatic and natural conditions remained favorable. As a result, the number of Beixin Culture sites increased from 11 during the Houli period to 26.

The Dawenkou Culture emerged and expanded during 6.1–4.6 ka BP, a period with average temperatures 2–3°C higher than today. This era marked the early stages of agricultural development, with significant improvements in agricultural productivity, population growth, and an increase in the number of ancient settlement sites, reaching 563. Around 5.0 ka BP, a sudden cooling event led to the decline of the Dawenkou Culture in eastern Shandong while simultaneously promoting the development of ancient settlement sites in central Shandong.

By 4.6 ka BP, the Longshan Culture period represented the peak of Neolithic settlement site development. The climate remained warm and humid, with lush vegetation and excellent natural conditions. Advances in productivity and social progress facilitated further agricultural development, leading to significant improvements in agricultural tools and the

emergence of harvesting tools and rice cultivation, as evidenced by archaeological findings [28-29]. These advancements contributed to population growth and the expansion of settlement sites, with the number of Longshan Culture sites reaching a peak of 1,409.

Around 4.2 ka BP, global ancient civilizations were severely impacted by extreme droughts and cooling events, leading to the gradual decline and collapse of ancient settlement cultures. By approximately 3.9 ka BP, frequent extreme climatic events, including floods, caused significant environmental instability, resulting in natural disasters, sharp temperature drops, and reduced precipitation. These changes exceeded human adaptive capacity, leading to the decline of the Longshan Culture in Shandong.

As the climate stabilized, temperatures gradually rose, and precipitation increased, creating favorable conditions for the rise of the Yueshi Culture. However, due to the lingering effects of previous climatic events and limited human productivity and adaptability, the number, density, and scale of Yueshi Culture sites drastically decreased to 314.

By 3.6 ka BP, the climate transitioned from instability to relative stability, facilitating the expansion of Shang Culture settlement sites. This period saw an increase in the number and scale of sites, with a total of 1,334 sites. Over time, the climate became even more stable, warm, and humid, supporting further development of ancient settlement cultures. The number of sites reached its peak during the Zhou Culture period, totaling 3,477. Overall, humans sought warmer, more humid, and resource-rich regions for better development and survival.

4.4 4.2The impact of the ka event on the distribution of Neolithic settlement sites

Around 4,200 years ago, civilizations worldwide experienced a sudden and severe drought and cooling event [30-31]. In many regions across the globe, the development of agricultural civilizations was impacted by nearly 200 years of arid and cold climatic changes. Areas such as Egypt, Greece, Syria, Palestine, Mesopotamia, the Indus Valley, and the Yangtze River Basin in China were all affected by this event, which led to the decline of civilizations and human migrations. During this period, various mid-to-late Neolithic cultures in China also began to decline. For example, the Qijia Culture in the Gansu-Qinghai region, the Liangzhu Culture in the middle and lower reaches of the Yangtze River, and the Shijiahe Culture in the Hunan-Hubei region all weakened and eventually disappeared due to this extreme climatic event.

During the mid-Holocene, China experienced five major periods of drought and flooding [32], which had significant impacts on the development of human civilizations. The 4.2 ka BP event stands out because it coincided with the end of the Longshan Culture. This period was characterized by unusual floods in the north, the southward shift of the lower Yellow River, and a dramatic deterioration of the natural environment. The northern region of Shandong, through which the lower Yellow River flows, was severely affected by flooding. As a major distribution area of Longshan Culture settlement sites, this region suffered significant disasters that greatly impacted agricultural development. Farmlands were permanently submerged, rendering them uncultivable for extended periods. Simultaneously, temperatures dropped sharply, and the excess of natural resources exceeded the adaptive capacity of the population to the climatic conditions at the time, leading to the gradual decline of the Longshan Culture [33].

4.5 Productivity and economic patterns in relation to the distribution of Neolithic settlements

Productivity and economic forms serve as the material and resource foundations for cultural development. Across

different historical stages, various cultures exhibit significant differences in productivity and economic forms. For instance, the invention of pottery long dominated human life, with distinct types and decorative patterns emerging in different regions. During the Houli Culture period, pottery was relatively uniform, predominantly consisting of reddish-brown ceramics. In the Beixin Culture period, yellowish-brown sandy pottery was more common. The Dawenkou Culture period was characterized by wheel-made black and gray pottery, while the Longshan Culture period featured black pottery as its most distinctive type, along with the emergence of white pottery. During the Yueshi Culture period, most pottery consisted of fine-paste gray-bodied black-surfaced ceramics and sandy reddish-brown pottery. Additionally, a small number of bronze artifacts were unearthed in Shandong Province during the Yueshi Culture period, with bronze and iron artifacts becoming more prevalent in the Shang and Zhou Culture periods. The development of productivity progressed gradually, transitioning from rudimentary agriculture in the Houli Culture period to improved agricultural practices in the Dawenkou Culture period. By the Longshan Culture period, handicrafts had separated from agriculture and achieved significant development, leading to increased productivity and a corresponding rise in the number and scale of ancient settlement sites.

In summary, while climatic changes have a certain influence on cultural development, they do not dictate its direction. After the Holocene, frequent climatic changes led to the decline of certain cultures and shifts in their distribution patterns. However, overall, the development of human civilization continued to progress.

Through an analysis of the factors influencing the spatial and temporal distribution of Neolithic settlement sites, it is evident that the primary reason for early human settlement was the climatic environment. Climate is a major factor affecting cultural development, but it is not the only one. Other factors, such as production methods, productivity, and social structures, also play significant roles. During the Neolithic period, the formation and development of early cultures were closely linked to climate, while in later periods, the influence of other factors, such as productivity, became more pronounced.

5 Conclusion

1）Since the Neolithic period, the cultural sequence in Shandong Province can be divided into seven stages: Houli, Beixin, Dawenkou, Longshan, Yueshi, Shang, and Zhou. The number of ancient settlement sites experienced four phases: initial growth, rapid expansion, decline, and resurgence.

2)The Houli Culture was primarily distributed in the piedmont plains of central Shandong, while the Beixin Culture was concentrated in the Taiyi Mountains. By the Dawenkou period, settlements extended further into southeastern Shandong. The Longshan Culture was mainly distributed in central, western, and central-southern Shandong. The Yueshi Culture saw a decline, with settlements scattered across plains. During the Shang and Zhou periods, settlements continued to expand and became increasingly dense.

3) During the Houli and Beixin Culture periods, ancient settlements were predominantly located in the upper reaches of rivers. In the Dawenkou period, the number of settlements near rivers increased significantly. By the late Longshan period, the climate became cooler and drier, leading to enhanced river sedimentation and a rapid increase in the number of settlements near rivers. This trend continued into the Zhou period, with most settlements distributed along river systems.

4)During the Houli, Beixin, and Dawenkou Culture periods, the climate was relatively warm and humid, with average temperatures approximately 2°C higher than today. Although temperature fluctuations occurred, the overall climate was favorable, providing a conducive environment for the development of ancient settlement cultures. The Longshan period

marked the peak of Neolithic cultural development.

5)Around 4.2 ka BP, extreme cooling, declining temperatures, reduced precipitation, and deteriorating climate conditions exceeded the adaptive capacity of humans at the time, leading to the decline of the Longshan Culture. Abnormal climatic conditions and extreme weather events contributed to the collapse of this culture.

6)Climatic and environmental changes significantly influenced cultural development. The origins of early cultures were closely linked to climate, but in later stages, other factors, such as productivity, played an increasingly important role in the development of ancient settlement cultures.

Data sharing agreement

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Declaration of Conflicting Interests

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