Spatial and Temporal Distribution of Ancient Settlements in the Salt Lake of Yuncheng City

Binhao Du [1, 2], Miaole Hou [1, 2], Zhenhua Gao [3, 4]

[1] School of Geomatics and Urban Spatial Informatics, Beijing University of Civil Engineering and Architecture, Beijing 102616, China - 2108570023076@stu.bucea.edu.cn, houmiaole@bucea.edu.cn
[2] Beijing Key Laboratory for Architectural Heritage Fine Reconstruction & Health Monitoring, No.15 Yongyuan Road, Daxing District, Beijing, China - 2108570023076@stu.bucea.edu.cn, houmiaole@bucea.edu.cn
[3] Shanxi Provincial Research Institute of Archaeology, Taiyuan, China - gzh1314@163.com
[4] Shanxi Key Laboratory of Scientific and Technological Archaeology, Taiyuan, China - gzh1314@163.com

Keywords: Hedong Salt, Ancient Settlements, Spatial Distribution.

Abstract

As one of the oldest salt lakes in China, the Hedong Salt Pond has accompanied the Chinese people through thousands of years of civilization accumulation and has an important influence on Chinese civilization. This study explores the spatial and temporal distribution of ancient settlements in Yuncheng City from the Neolithic Age to the Song, Yuan, Ming and Qing Dynasties, and evaluates their correlation with the natural environment using geographic information system (GIS) technology. The results show that: (1) the ancient settlements in different historical periods were mainly concentrated in Wenxi County and Jiang County in the northeastern part of Yuncheng City, and the center of gravity was mainly in the junction of Wenxi County, Xia County and Yanhu District. (2) Ancient settlements were mainly concentrated in areas with low elevation, low slope and sunny slope, which were not only suitable for production and life, but also convenient for transportation and salt trade. (3) The Salt Lake had a significant influence on the ancient settlements around it, showing the distribution characteristics of close - far - close again with the change of dynasties.

1. Introduction

Shanxi was a place where kings and capitals gathered in the early stages of Chinese civilization, with a long history and a unique natural and human environment. Yuncheng, the area of this study, is located in this important zone. Mr. Dai Xiangming once pointed out that "archaeologically, Yuncheng is a piece of treasure land, with mountains and rivers in its surface, and the Chinese civilization has left its mark here many times with heavy ink and color. ......(Li, 2022)" Yuncheng's two major resources were especially treasured by the ancients: one is the Zhongtiao Mountain vein, which is the most important copper ore source in northern China, and the other is the Zhongtiao Mountain vein. one of the most important copper ore sources in the north of China (Qin and Xue, 2003); and the second is the Hedong Salt Pond, one of the oldest salt lakes in China. Both are important strategic resources supporting the formation and development of Chinese civilization. Hedong Salt Pond is accompanied by the Chinese people through thousands of years of civilization precipitation, the Chinese civilization has an important impact, while after thousands of years of change around the salt lake formed a dense distribution of ancient settlements, ancient settlements as a class of immovable cultural relics, is an important part of cultural heritage, is the carrier of ancient human life and culture, they carry the unique historical information, has outstanding value, more Witnessing the profound influence of salt transportation and trade on the development of civilization in the Central Plains, the analysis of its spatial and temporal evolution characteristics helps to reveal the law of succession of human-land relations (Zhang and Wang 2012) .

In recent years, the ecological environment (Liu and Ma, 2019), spatial and temporal evolution (Wang, 2019), and the surrounding settlement (Wang, 2011) around the Hedong Salt Pond have attracted the attention of many scholars (Dai, 2021). However, most of the current studies rely on the analysis of historical information and lack substantial data analysis (Cai, 2019). Therefore, in order to reveal more clearly the spatial and temporal distribution characteristics of ancient settlements around the Salt Lake in different periods, the characteristics of settlement distribution and its relationship with the surrounding natural environment, this study collects data on the names, locations and ages of 1,912 ancient settlements in the third cultural relics census of Yuncheng, Shanxi, and utilizes multi-source information such as historical documentary information and digital elevation models (DEMs), and uses a variety of spatial analytical methods to explore the different Using multiple sources of data such as historical documents and digital elevation model (DEM), we use various spatial analysis methods to explore the spatial and temporal distribution patterns of ancient settlements in Yuncheng Yanchi during the historical period, and analyze the natural factors affecting the spatial and temporal distribution of ancient settlements, so as to reveal the change patterns of the ancient settlements in Yuncheng Yanchi.

2. Overview of the Study Area

The study area of this paper is Yuncheng City, Shanxi Province, as shown in Figure 1, located in the southwest of Shanxi Province, China. Yuncheng Salt Lake is also known as "Hedong Salt Pond" and "Jinnan Xiechi". In ancient times, the lack of sufficient surface runoff near the Salt Lake and the bitter and salty groundwater affected by the Salt Lake made it difficult to gather large numbers of people or develop large settlements in the area. To this day, the Yuncheng city district and neighboring villages and towns located on the north side of the Salt Lake rely mainly on external introduction of water for domestic use (Jiang and Tian, 2019). Yuncheng archaeologists have conducted several archaeological surveys of the Hedong Salt Pond and found that most of the settlements of the Shang and Zhou Dynasties and earlier periods were distributed in areas

This contribution has been peer-reviewed.
https://doi.org/10.5194/isprs-archives-XLVIII-M-9-2025-423-2025

beyond 5 kilometers from the Salt Lake (Zhao, 2014). Meanwhile, many mining and metallurgical generation settlements and copper smelting remains were found in the northern part of Zhongtiao Mountain (Zhao, 2017).

After thousands of years of civilization accumulation around the Yuncheng Salt Lake, a densely distributed cluster of ancient settlements was formed, and these ancient settlements carry unique historical information. Therefore, the study of the Salt Lake around Yuncheng can better reveal the profound influence of salt on the development of civilization in the Central Plains.

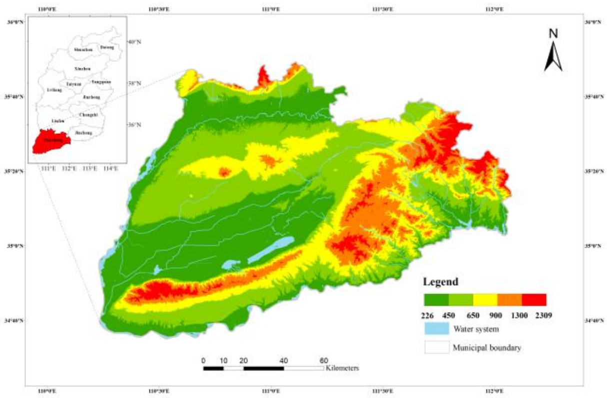

Figure 1. Location map of the study area.

3. Materials and Methods

3.1 Data Sources

The ancient settlement data and information of each period in this study mainly come from the third cultural relics census data of Yuncheng City, Shanxi Province, totaling 1,912 ancient settlement points. The GIS software used in this study is ArcMap10.7.1, and the DEM data are from Geospatial Data Cloud (http://www.gscloud.cn), the type of which is ASTER GDEMV3 30M-resolution digital elevation data, and the data of elevation and slope inclination of the study area are extracted from the DEM data. The water system data were taken from OSM map (https://www.openstreetmap.org).

Historical Period	Number of settlements	percentage share of total number
Paleolithic	154	6.17%
Neolithic	605	24.23%
Xia	74	2.96%
Shang	53	2.12%
Zhou	394	15.78%
Qin and Han	499	19.98%
Wei, Jin, Southern and Northern	26	1.04%
Five dynasties of the Sui and Tang	48	1.92%
Song, Yuan, Ming and Qing	644	25.79%

Table 1. Statistical table of the number of ancient settlements in Yuncheng City.

According to the statistics, since most ancient settlements span multiple periods, they were screened and organized, and finally 2947 ancient settlement data were obtained. In this study, the ancient settlements in Yuncheng Yanchi are divided into nine historical periods: Paleolithic, Neolithic, Xia, Shang, Zhou, Qin and Han, Wei, Jin, North and South Dynasties, Sui, Tang, and Five Dynasties, Song, Yuan, Ming, and Qing (Table.1), and the spatial and temporal dimensions are used to explore the spatial distribution characteristics of the ancient settlements in Yuncheng Salt Lake .

3.2 Research Methodology

For the spatial and temporal distribution characteristics of ancient settlements in Yuncheng Salt Lake, this study mainly uses mean nearest neighbor analysis, kernel density analysis, standard deviation ellipse and center of gravity migration trajectory analysis, and the total technical roadmap is shown in Figure 2.

3.2.1 Average Nearest Neighbor Analysis: The nearest neighbor index is a metric used in spatial statistics and pattern recognition to quantitatively reveal point data its spatial distribution pattern (Runze, 2017). Its calculation formula is as follows:

$$\text{Nearest neighbor index:} R = \frac{\frac{\sum_{i=1}^{n} d_i}{n}}{\frac{0.5}{\sqrt{n/A}}} \tag{1}$$

d_i is the distance between each element and his nearest element; n is the total number of features in the study area; A is the area of the study area; R is the nearest neighbor index.

3.2.2 Kernel Density Analysis: Kernel density analysis is used to evaluate the degree of aggregation of point data in a certain area, so as to understand the aggregation distribution of spatially discrete points. It is calculated as follows:

$$f(x) = \frac{1}{nh}\sum_{i=1}^{n} k\left(\frac{x - X_i}{h}\right) \tag{2}$$

$f(x)$ is the estimated kernel density at the valuation point; k denotes the kernel function; $x - X_i$ denotes the distance from the valuation point X_i; h is the bandwidth; n is the number of points within the bandwidth.

3.2.3 Standard Deviation Ellipse and Center of Gravity Migration Trajectory Analysis: Standard deviation ellipse analysis can identify the methods and distribution trends of a set of point data, interpreting their specific distributional characteristics. The center of gravity migration trajectory model can present the spatial and temporal evolution characteristics based on geographic elements, which can be used to assess the evolution trend of spatial objects in time (Jiang and Yue, 2001). The combination of the two methods can analyze the distribution characteristics and evolution trend of the data more significantly (Yang and Wei, 2023) Among them, the standard deviation ellipse is calculated as follows:

$$\text{Mean Center:} \begin{cases} \bar{X}_w = \frac{\sum_{i=1}^{n} x_i w_i}{\sum_{i=1}^{n} w_i} \\ \bar{Y}_w = \frac{\sum_{i=1}^{n} y_i w_i}{\sum_{i=1}^{n} w_i} \end{cases} \tag{3}$$

Azimuth:

$$\tan\theta = \frac{\sum_{i=1}^{n} \tilde{x}_i^2 w_i^2 - \sum_{i=1}^{n} \tilde{y}_i^2 w_i^2 + \sqrt{\left(\sum_{i=1}^{n} \tilde{x}_i^2 w_i^2 - \sum_{i=1}^{n} \tilde{y}_i^2 w_i^2\right)^2 + 4\sum_{i=1}^{n} \tilde{x}_i^2 \tilde{y}_i^2 w_i^2}}{2\sum_{i=1}^{n} w_i^2 \tilde{x}_i \tilde{y}_i} \tag{4}$$

(x_i, y_i) denotes the spatial location of the study object; $(\bar{X}_w, \bar{Y}_w)$ denotes the weighted mean center; w_i denotes the weight; θ is the ellipse azimuth, which denotes the angle formed by rotating clockwise to the long axis of the ellipse in the due north direction; $\bar{x}_i$ 、 $\bar{y}_i$ denote the coordinate deviation from the location of each study object to the mean center, respectively.

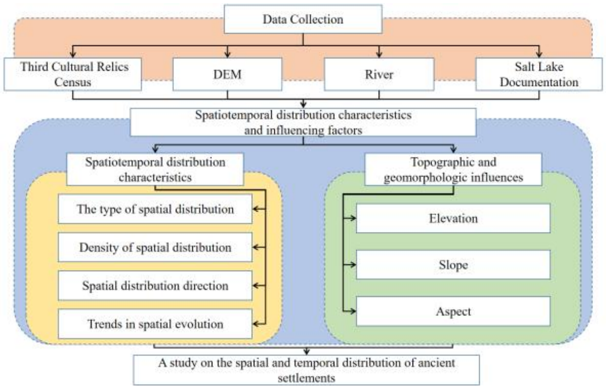

Figure 2. Technology roadmap in the paper.

4. Analysis of Results

4.1 Spatial and Temporal Distribution Characteristics of Ancient Settlements

4.1.1 Types of Spatial Distribution and Degree of Agglomeration of Ancient Settlements in Different Historical Periods: In this paper, the spatial distribution type and degree of agglomeration of ancient settlements in each period in the study area were analyzed by using the average nearest neighbor analysis method. The results are shown in Table 2, the nearest-neighbor index of ancient settlements in the Paleolithic and Wei, Jin, and North and South Dynasties periods is greater than 1, and the spatial distribution characteristics are discrete; the nearest-neighbor index of ancient settlements in the Sui, Tang, and Five Dynasties period is close to 1, and the spatial distribution characteristics are insignificant; the nearest-neighbor indices of ancient settlements in the rest of the periods are all less than 1, and the spatial distribution characteristics are agglomerated distribution. Although some periods belong to the same spatial distribution type, there are still large differences. Specifically, the proximity index of ancient settlements in the Paleolithic period is 12.68, with the highest degree of spatial dispersion; the proximity index of ancient settlements in the Neolithic period is 0.57, with the highest degree of spatial aggregation. On the whole, the ancient settlements show an aggregated distribution pattern.

Historical Period	Nearest neighbor index（R）	Spatial distribution Type
Paleolithic	12.68	discrete
Neolithic	0.57	congregate
Xia	0.79	congregate
Shang	0.76	congregate
Zhou	0.60	congregate
Qin and Han	0.67	congregate
Wei, Jin, Southern and Northern	1.17	discrete
Five dynasties of the Sui and Tang	0.92	——
Song, Yuan, Ming and Qing	0.63	congregate

Table 2. The results of the average nearest neighbor analysis of ancient sites in different historical periods.

4.1.2 Characteristics of Spatial Distribution Density of Ancient Settlements in Different Historical Periods: The kernel density analysis of the available ancient settlement data by period, as shown in Figure 3. shows that: the ancient settlements of the Paleolithic period were mainly concentrated in the southwest of Yuncheng City, in the present-day territory of Yuanqu County; from the Neolithic period to the Zhou Dynasty, the settlements were mainly concentrated in Wenshi and Jiangxian Counties; and the distribution of the ancient settlements during the Qin and Han Dynasties was more dispersed, with relatively little agglomeration of the settlements. During the Sui, Tang, and Five Dynasties and the Song, Yuan, Ming, and Qing Dynasties, the distribution of settlements was influenced by the location of the dynastic capitals: the capital of the Tang Dynasty was located in the southwestern part of Yuncheng, while the capital of the Ming Dynasty was located in the northeastern part of Yuncheng, and the ancient settlements during these two periods therefore clustered in a southwesterly and northeasterly direction, respectively.

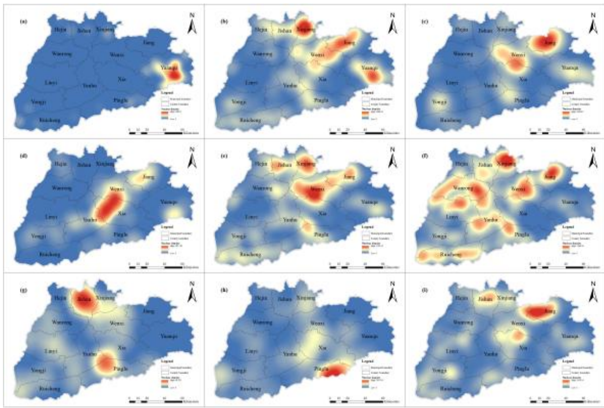

Figure 3. Kernel density analysis of ancient ruins in Yuncheng in different historical periods.

4.1.3 Distribution of Centers of Gravity and Spatial Evolution Trends of Ancient Settlements in Different Historical Periods: In this paper, we use the standard deviation ellipse tool to calculate the distribution direction and spatial distribution of the center of gravity of ancient settlements in different periods, and at the same time, we carry out the analysis of the center of gravity offset trajectory, as shown in Figure 4.

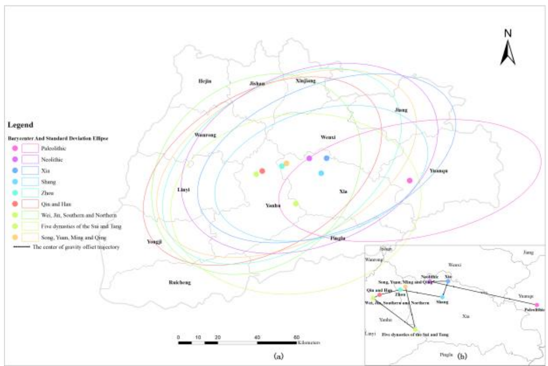

Figure 4. Analysis of the kernel density of ancient settlements in the Salt Lake of Yuncheng in different historical periods.

The results show that the center of gravity of ancient settlements is mainly concentrated in Xiaxian County and the northern part of Salt Lake District, with an overall northeast-southwest orientation, indicating that this direction is the main direction of the spatial distribution of ancient settlements in Yuncheng City, and that the degree of concentration is relatively high. From the standard deviation ellipse direction of each historical period, the rotation angle changes are relatively small, but the angle changes are more significant in the period from Wei, Jin, North and South Dynasties to Sui and Tang Dynasties, indicating that the ancient settlements in the period of Wei, Jin, North and South Dynasties are relatively uniformly distributed and less concentrated. In terms of the center of gravity offset in each period, the center of gravity of the ancient settlements in the Neolithic period was shifted by a larger distance, while that of the Wei, Jin, and North and South Dynasties period was smaller. The center of gravity trajectory shows an evolutionary pattern from east to northwest to northeast to southwest to northwest to southwest to southwest to southeast to northwest. In terms of the distribution range of ancient settlements in each historical period, the Neolithic period began to expand and then gradually narrowed, expanding again in the Zhou Dynasty until it began to shrink again in the Song, Yuan, Ming and Qing periods.

4.2 Spatial and Temporal Distribution of Ancient Settlements Topographic and Geomorphologic Influences

In this paper, by superimposing the ancient settlements in the study area with three geographic elements, namely, DEM data, slope, and slope direction, we obtained the proportion of ancient settlements in different elevations, slopes, and slope directions in different periods. According to the natural breakpoint method, the elevation is divided into five ranges: 226-450m, 450-650m, 650-900m, 900-1300m, and 1300-2309m; according to the steepness of the slope, the slope is divided into five grades: 0-5° (flat slope), 5-12° (gentle slope), 12-20° (slope), 20-30° (steep slope), and more than 30° (dangerous slope). These five levels; the slope level is divided according to the steepness of the slope into five areas: flat slope (-1-0°), shady slope (0-45° and 315-360°), semi-shady slope (45-135°), sunny slope (135-225°), and semi- sunny slope (225-315°）

Historical Period	Elevation (Meters)				
	226-450	450-650	650-900	900-1300	1300-2309
Paleolithic	44.16%	46.75%	5.19%	1.95%	1.95%
Neolithic	41.32%	40.00%	17.19%	1.16%	0.33%
Xia	31.08%	41.89%	27.03%	0%	0%
Shang	52.83%	35.85%	7.55%	3.77%	0%
Zhou	41.62%	38.32%	19.04%	0.76%	0.25%
Qin and Han	39.28%	42.08%	17.43%	1.00%	0.20%
Wei, Jin, Southern and Northern	38.46%	30.77%	23.08%	3.85%	3.85%
Five dynasties of the Sui and Tang	58.33%	22.92%	12.50%	4.17%	2.08%
Song, Yuan, Ming and Qing	35.25%	42.86%	18.79%	1.55%	1.55%

Table 3. Percentage of distribution of ancient settlements by elevation areas in different historical periods.

Historical Period	Slope (°)				
	5°or less	5°-12°	12°-20°	20°-30°	30°or more
Paleolithic	27.92%	49.35%	20.13%	2.60%	0%
Neolithic	43.47%	46.61%	7.77%	1.98%	0.17%
Xia	40.54%	50.00%	9.46%	0%	0%
Shang	50.94%	45.28%	1.89%	1.89%	0%
Zhou	47.21%	43.40%	8.12%	1.52%	0%
Qin and Han	56.51%	37.07%	4.41%	2.00%	0%
Wei, Jin, Southern and Northern	38.46%	46.15%	7.69%	3.85%	3.85%
Five dynasties of the Sui and Tang	35.42%	41.67%	8.33%	12.50%	2.08%
Song, Yuan, Ming and Qing	45.50%	42.39%	9.47%	2.02%	0.62%

Table 4. Percentage of distribution of ancient settlements by slope areas in different historical periods.

Historical Period	Aspect				
	Flat slope	Shady slope	Semi-shady slope	Sunny slope	Semi-sunny slope
Paleolithic	0%	16.88%	20.78%	40.91%	21.43%
Neolithic	1.98%	22.64%	23.21%	31.57%	20.50%
Xia	2.70%	27.03%	22.97%	28.38%	18.92%
Shang	0%	28.30%	22.64%	32.08%	16.98%
Zhou	1.27%	24.62%	22.34%	31.22%	20.56%
Qin and Han	1.40%	23.85%	23.45%	31.86%	19.44%
Wei, Jin, Southern and Northern	0%	15.38%	34.62%	42.31%	7.69%
Five dynasties of the Sui and Tang	4.17%	14.58%	31.25%	39.58%	10.42%
Song, Yuan, Ming and Qing	0.78%	24.22%	22.98%	30.12%	21.89%

Table 5. Percentage of distribution of ancient settlements by aspect areas in different historical periods.

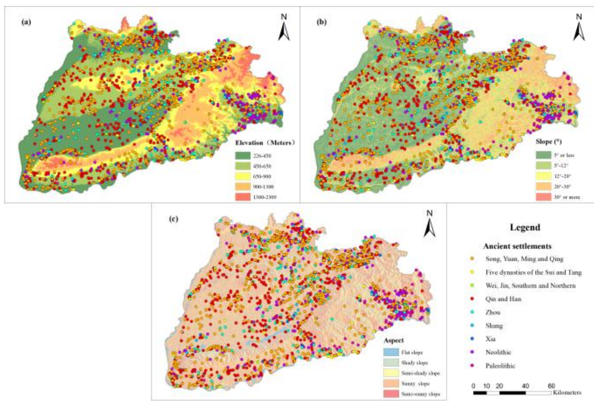

Figure 5. Distribution of elevation, slope, and aspect of ancient

settlements around Yuncheng Salt Lake in different historical periods.

As shown in Table 3, Table 4, Table 5 and Figure 5, in terms of elevation, people preferred areas with lower elevation for production and living, because these areas have favorable temperature and sufficient precipitation, which are suitable for human habitation and agricultural cultivation. In terms of slope, people preferred areas with lower slopes, but the number of settlements in sloping areas increased over time. Gently sloping areas are conducive to land development, drainage, and other productive and living activities, while areas with higher slopes have lower resource utilization and restricted living space, and thus fewer settlements are distributed. In terms of slope orientation, more settlements choose sunny slopes because of the abundant sunlight and higher temperatures, which provide good lighting conditions, are favorable for the growth of crops and vegetation, and are also more suitable for human life. Taken together, settlements are mostly distributed in areas with low elevation, low slope and sunny slope orientation, which are not only suitable for production and living, but also convenient for transportation and salt trade.

5. Discussion

5.1 Salt and Copper Resources and Settlement Change

Since the Paleolithic era, human beings have obtained salt by hunting animals, and with the development of agriculture, the importance of salt has gradually come to the fore. The Yuncheng Salt Lake was formed about 65 million years ago during the Himalayan tectonic movement, and its surrounding thousands of square kilometers became a zone of dense distribution of settlements in the Neolithic period. During the Xia and Shang Dynasties, Jinnan area became an important area for the Xia Dynasty due to its geographical proximity to the Yiluo Basin and its richness in products, especially strategic resources such as copper and salt (Chen et al, 2009). Emperor Shun once passed by the Salt Lake and recited the "Song of the South Wind", reflecting the relationship between the south wind blowing down from Zhongtiao Mountain during the high temperature in summer and the crystallization of salt in the Salt Lake. The Xia people conquered and exploited Jinnan in the course of their rise to power, initially to obtain salt resources, while the importance of copper mines gradually emerged as the national society was formed, and the Zhongtiao Mountain vein was thus exploited on a large scale (Liu and Zhao, 2000).

According to archaeological findings, there is a close correlation between the sitting of ancient settlements in the Salt Lake area around Yuncheng and the salt economy. Among them, the Dongxiafeng site in the Erlitou to Erligang period may be the earliest state-controlled salt distribution center around the Xiechi area, and its circular base site is highly consistent with the composition of modern salt ponds through soil testing, which is suspected to be the remains of salt warehouses (Zhao et al, 2010) ; while the Ruicheng Shili-Potou settlement in the Longshan period, although located in a remote area at the southern foot of the Zhongtiao Mountains, is located in the transportation hub of the Huanghe River crossing in the south of the Yuncheng Salt Lake. The formation of this "non-agricultural dominated" regional center probably originated from the control of the salt transport corridor (Wang and Xue, 2006), or the residence of the institutions that managed the salt trade, or the location of the interest groups that monopolized the salt transport (Xue, 2015). Together, these cases reveal that the spatial layout of the Salt Lake communities not only needs to satisfy the needs of life but also pays more attention to the strategic control of the salt trade corridor.

Other scholars' systematic investigation of the eastern region of the Yuncheng Basin found that the number and size of settlements dropped sharply from the Longshan to Erlitou periods, which may be related to the conquest of Jinnan by the Xia Dynasty. In the Erligang period, the number of settlements plummeted again, which was closely related to the replacement of the Xia Dynasty by the Shang Dynasty. During the Late Shang period, the number of settlements dropped precipitously, probably due to the depletion of copper oxide ore in the surface layer of Zhongtiao Mountain, and merchants turned to seek copper resources, resulting in large-scale migration of the population in Jinnan, and the formation of the phenomenon of "hollowing out" (Liu and Chen, 2002). From the results of the study, we can also see that the Neolithic period was a multi-core distribution of settlements, outward exploration; Xia and Shang period, the number of settlements decreased, the formation of a double-core distribution, Salt Lake and Zhongtiao Mountain around the settlement cluster. It can be seen that the decrease of the settlements is closely related to the conquest of Jinnan by the two Central Plains dynasties, both of which are inseparable from the acquisition of copper and salt resources.

After the establishment of feudal dynasties, salt lakes have been strictly controlled throughout the ages. During the Qin and Han Dynasties, Emperor Wu of the Han Dynasty implemented the policy of "Salt and Iron Official Management" to manage the production, transportation and sale of salt ponds; the Northern Wei and Sui Dynasties built aqueducts to protect salt ponds, safeguard salt production and provide drinking water for nearby residents; the Tang Dynasty invented the method of watering and sunning on cultivated borders and dug trenches and set up fences around the salt ponds; the Song Dynasty set up a Salt Officer --In the Song Dynasty, salt officials were set up; in the Yuan Dynasty, the Department of Salt Transit was set up; in the Ming Dynasty, the Department of Hedong Transit was set up; and in the Qing Dynasty, the Minister of Buzheng compiled and edited the "Preparation of Salt Laws of Hedong," which recorded the management of the salt affairs, etc. All these initiatives show that successive dynasties attached great importance to the management of salt resources. From the results of the study, we can also see that there were settlements around the salt lake in all periods, of which the Qin-Han period was the most significant, with settlements distributed around the salt lake, and the settlements in other periods, although also clustered around the salt lake, tended to converge in the direction of the king's capital of each dynasty. This is inextricably linked to the more systematic management of salt transportation trade in the later dynasties.

5.2 Critical Analysis

Although the current study has initially revealed the spatial and temporal distribution pattern of ancient settlements in the Salt Lake area of Yuncheng, there are still three obvious limitations: first, the research object mainly focuses on settlement sites, and has not yet covered multiple types such as ancient tombs; second, the existing analysis focuses on natural geographic elements such as topography and geomorphology, and in the future, it is necessary to carry out a comprehensive investigation by combining multidimensional environmental elements such as climatic changes, hydrological conditions, and patterns of livelihood; third, the study is biased towards the analysis of macro-scale spatial features. Third, the study favors the analysis of macro-scale spatial features, and we intend to explore the driving mechanism of core elements such as resource control and social organization on the distribution of settlements through micro-scale functional zoning of settlements and site location analysis, and try to construct a prediction model of ancient settlements in the Salt Lake area of Yuncheng to assist archaeological investigations.

6. Conclusion

This thesis is a milestone achievement of the project "Remote Sensing Archaeological Survey of Salt Lake in Yuncheng". By combining GIS spatial analysis with archaeological data, the interrelationship between the distribution of historical settlements in the Salt Lake of Yuncheng City and the neighboring natural factors has been deeply explored. The results of the study show that the distribution of settlements in Yuncheng City as a whole shows a state of aggregation, the distribution range is relatively stable, and the distribution of settlements is closely related to the surrounding natural environment. The three geomorphologic factors of elevation, slope, and slope direction all have a significant influence on the choice of settlement location. However, the combination of archaeological data and analysis results further shows that the salt pond in Hedong is the key factor influencing the distribution of ancient settlements around Yuncheng. The gathering of Yuncheng's settlements in the past generations is closely related to the Hedong Salt Pond, and the existence of the Salt Lake not only shaped the distribution pattern of the settlements, but also profoundly influenced the historical development of the region.

This research result provides important theoretical support and practical guidance for the subsequent archaeological discovery of Yuncheng Salt Lake. Through in-depth analysis of the distribution pattern of settlements and natural factors, we can better understand the interaction between ancient humans and the environment, and provide a scientific basis for the delineation of key areas for future archaeological work, and the protection and utilization of sites. At the same time, this study also lays a solid foundation for exploring the strategic position of the Salt Lake in the development of Chinese civilization and its long-term impact on the evolution of the surrounding settlements.

References

Li, D., 2022. "The footprints of my field archaeology have never left Yuncheng" [N]. Yuncheng Daily, 10.38235/n.cnki.nycbr.2022.001985.

Qin, Z., Xue, K., 2003.Geological characteristics and types of copper deposits in the Zhongtiao Mountain area[J]. Geological Survey and Research, (02):108-113.

Zhang, Y., Wang, B., 2012. Research on Environmental Evaluation Index System of Yuncheng Salt Lake Based on 3S Technology[J]. Western Exploration Engineering, (9):112-114.

Liu, C., Ma, C., 2019. Analysis of 30-year (1987-2017) changes in ecological indicators and driving forces in Yanhu District, Yuncheng City[C]//**Exchange materials for the 8th National Academic Conference on Land Reclamation and Ecological Rehabilitation in Mining Areas of the Professional Committee of Land Reclamation and Ecological Rehabilitation of Coal Society.

Wang, C., 2011.A study of the spatial and temporal evolution of the salt ponds in the eastern part of the river since the Northern Wei Dynasty[D]. Fudan University.

Dai, X., 2021.Salt resources in southern Jinnan and the growth of early civilization in the Central Plains: Problems and hypotheses[J]. Central Plains Cultural Relics, 4: 43-53.

Cai, Y., 2019.Survey and Research on Historical Sites around Xiechi[D]. Shanxi University.

Jiang, W., Tian, W., 2023. Research on the distribution range of salt ponds in Hedong during the period of Longshan-Erligang culture[J]. Central Plains Cultural Relics,89-95.

Zhao, Z., 2014. The formation process of ancient Chinese agriculture--evidence from flotation excavated plant remains［J］. Quaternary Research.

Zhao, Z.,2017. The Development of Farming Production and the Establishment of Agricultural Society in the Yangshao Culture Period--Analysis of Flotation Results from the Yuzhai Site［J］. Jianghan Archaeology.

Runze Y. 2023. A study on the spatial distribution and historical evolution of grotto heritage: a case study of Gansu Province, China[J]. Heritage Science, 11(1): 165.

Jianhua, Yue Wenze. 2001. Evolvement and comparative analysis of the population center gravity and the economy gravity center in recent twenty years in China. Scientia Geographica Sinica. 21(5):385-389.

Yang R, Wei W. 2023. GIS-based research on the spatial distribution and spatiotemporal evolution of grottoes along the Gansu section of the Silk Road[J].

Chen, X., Liu, L., Zhao, C., 2009. Unraveling salt and the formation of the early Chinese state [C] // Salt archaeology (II). Beijing: Science Press.

Liu, L., Zhao, C., 2000. City: control of natural resources during the Xia and Shang dynasties［J］. Southeast Culture, 2000 (3).

Zhao, C., Chen, X., Liu, L., 2010. Analysis of the chemical composition of the soil of the circular building at the Dongxiafeng site [C] // Archaeological Collected Works (18). Beijing: Science Press.

Wang, X., Xue, X., 2006. Several Issues Concerning the Graveyard of Qingliang Temple [J]. Chinese Cultural Relics, 2006(3).

Xue, X., 2015. The Qinglin's Cemetery in Ruicheng, Shanxi and the Early Export of Lu Salt［C］//Oriental Archaeology (12). Beijing: Science Press.

Liu, L., Chen, X., 2002. The Formation of the Early Chinese State - From the Relationship between the Center and the Margins in the Erlitou and Erligang Periods [C] // Ancient Civilization (1). Beijing: Cultural Relics Press.