

Article

The Distribution Model and Spatial Structure of Market Towns in the Pearl River Delta during the Ming, Qing, and Min-Guo Periods: A Case Study of Taishan County

Shuyin Feng ^{1,2}, Qi Lu ^{1,3,*}, Zhaohui Wu ⁴ and Zihui Guo ^{1,2}
¹ School of Architecture, South China University of Technology, Guangzhou 510641, China

² Guangzhou Municipal Key Laboratory of Landscape Architecture, Guangzhou 510641, China

³ State Key Laboratory of Subtropical Building Science, Guangzhou 510641, China

⁴ Architectural Design and Research Institute of SCUT Co., Ltd., Guangzhou 510641, China

* Correspondence: luqi@scut.edu.cn

Abstract: Previous studies have clarified that there are certain regularities in the spatial organization of traditional Chinese rural market towns as viewed from the perspective of the economic geography and local society. Nevertheless, the results of some studies concerning distribution patterns and factors influencing these patterns are contradictory, and there are few comprehensive analyses of the influence of interconnected variables. Taishan County in the Pearl River Delta of Guangdong Province is used as an example, and the results of the identification of the distribution pattern of market towns within this county are determined as clustered by using the Voronoi method and the calculated coefficients of variation (Cv). The correlation between the market towns and the physical and social environment is quantified and illustrated through Geographic Information Systems (GIS), logistic regression analysis, and graphic methods, and the application of nuclear density change rates clarifies the development trajectory, which explains the phenomenon of market town clustering with ecological and cultural significance. Overall, the results indicate traditional preferences for sites characterized by low elevation, little slope, proximity to water, and productive agricultural land, while at the local scale, the spatial-temporal arrangement of market towns reflects partitioning and interactions between distinct clans. Further integrating the perspective of environmental history, we propose that the structural relationships of natural ecology, subsistence mode, and social organization crucially constitute the site selection and layout logic of market towns.

Keywords: market town; distribution model; spatial patterns; eco-cultural structure; quantitative identification; environmental history



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1. Introduction

Chinese rural market towns, as concentrating places for rural commercial trade and social and cultural activities, exhibit almost all the characteristics of rural peasant society [1], which is a concrete, micro, and widespread social space composition [2]. The majority of market towns in southern China can be classified as rural commercial settlements, in which the front half of the traditional building unit serves as a store and the back half as a residence, combining commerce and housing [3]. It is worth noting that the Pearl River Delta of Guangdong Province's dense distribution of market towns was far ahead of other regions of China in the traditional period, according to pertinent statistics [4].

The spatial pattern is a fundamental aspect of studying market towns, since it reflects the social and economic circulation system [5] and is an important indicator for examining social processes. It has long been a major topic in this research area. The characteristics, quantity, density, and growth evolution of market towns have received plenty of discussion. However, fewer conclusions have been drawn regarding the spatial organization patterns

and formation mechanisms of market towns; furthermore, researchers differ in their opinions regarding these findings. On the other hand, several current studies have identified the influence of geographical, ecological, economic, and social factors on the distribution of market towns and compiled a comprehensive list of potential variables. However, there is still a lack of understanding of their relationship and the difference in the degree of their influence [6]. It is a significant challenge to integrate environmental and cultural variables into the analysis of market town locations and to distinguish between them empirically.

In this study, we carried out an empirical study in the Pearl River Delta region's Taishan County, establishing a database for modeling the market towns during the Ming, Qing, and Republican Dynasties and quantitatively assessing the types of distribution patterns of market towns at the global and local scale levels. Referring to the potential factors provided by earlier studies, we searched extensively for accessible data information that met the requirements of the study, including elevation, slope, water system, soil, clan information, and village location. Using GIS, regression analysis, and graphical methods, the correlations between these factor variables and market town locations and the degree of influence were effectively examined and compared. We also integrate existing evidence from historical studies of environmental history and socioeconomic history to further reveal how market town layout intersected with rural economic life through the relations based on the interaction with the local environment. This study can contribute to clarifying the mixed results derived from previous studies in the area and provide more comprehensive insights into this research topic.

The analytical content and results are organized into five sections: (i) Literature review of traditional market towns and the factors driving the spatial distribution. (ii) Description of the study area situation, materials, data collection process, and analysis methods and techniques. (iii) Preliminary results include an assessment of the types of spatial distribution patterns of market towns, spatial relationships between market towns and physical and social environmental factors, and spatial and temporal evolution. (iv) The discussion section is an integrated analysis and further systematic consideration of the preliminary results presented. (v) Conclusion section, which is a summary and reflection of the entire study, pointing out the limitations and future directions for improvement.

2. Literature Review

The previous studies on the distribution of market towns and influencing factors can generally be classified into three categories:

(i) Those that highlighted the efficiency of market economies as the dominant factor and aimed to abstract a universally applicable model for the market town distribution. These studies share the common feature that they are significantly affected by the central place theory [7]. In these theoretical models, market towns have a unique centrality in a specific economic regional unit, and the size of the regional hinterland units of market towns are all nearly equal, thus deducing that the morphological characteristics of market towns tend to a distributed equilibrium.

G. William Skinner's research has received the most attention and discussion. He drew upon the central place model [7] and the ideal market town area structure [8] to propose the "hexagonal model". His theory presents an abstract account of the hierarchical structures and the tendency of market towns to be uniformly distributed. It also suggests that the extensive, routine economic activities undertaken by market towns led to the formation of basic rural communities [1]. Hayashi employed Skinner's method to conduct an analysis of Shanghai and presented a regional town distribution model. He notes in his research that various factors such as population size, waterway, landway, and postal networks are associated with the distribution of market towns. However, the final model and hierarchy he proposed remain a reference to the methods of Skinner's and central place theories. The geometric relationship between the market towns is based on calculating the proportion of settlements at each level, and the location of market towns is determined by a modified abstraction based on the principle of centrality [9]. Similarly, Chen carried out a research

study in Fujian Province with reference to Skinner's methodology and outlined a regional model, even though he found that topographical, positional, and social factors differentiate the spatial network of market towns from the "hexagonal model" [10].

The results of these models appear to have the theoretical value of describing simplicity and generalization. However, they also have the limitation of single-factor determinism, as reality does not always follow the assumption of an equilibrium distribution of economic and material factors.

(ii) Influences related to the social environment have been the focus of existing sociological and ethnographic research. Many potential influences have been mentioned, and the social factors identified by different researchers have been recognized mutually. However, most studies have only employed qualitative analyses to illustrate the effects. Few studies have compared these factors and their relative levels of influence, and they have not been established by any testable results.

Research results on social factors can be divided into two categories: one relates to farm households' life patterns and livelihood maintenance. The need for commodities, farmers' side businesses, and economic security contributed to a close communication between rural market towns and farm households [11]. Song proposed that the low commercial trade in the countryside, the lack of trade information, and the acquaintance mode of social interaction led to the market towns being spatially dispersed, and the calendar system has an organized cycle [12]. In a study specifically on the plains, it was suggested that dispersed rural settlement patterns, resulting from migrant societies and the topography of the plains, contributed to the tendency of market towns to be distributed evenly, thus allowing market services to be available to an expanded range of people and villages [13].

Other studies have focused on the influence of clan organization and their culture. Several researchers have noted that in the traditional Chinese market town, the order is not only governed by economic rules but also by regional politics and social customs [14–17]. The construction and control of market towns are related to the competition for resources and interests and power struggles within social groups [18,19]. In southern China, where clan culture is well-developed, market towns are usually the property of local clans [20–22]. Only powerful clans with certain cultural reputations and local political influence were qualified to establish and manage the market town [23]. It is commonly difficult to adhere to objective economic regulation due to market town social orientation, which social groups dominate [16].

It is evident from these studies that there can be a climate of monopoly, competition, or exclusion in market towns as a result of the complex social relations and subjective factors of clan groups. Some of these findings contradict the argument that market economic efficiency is primarily responsible for uniform spatial distribution. However, most social factors have been analyzed only by individual examples. They have not been explored at the more macro level of the market town group or network system in terms of their influence extent.

(iii) The physical environment has been discussed in varying degrees in most studies, including transportation, settlements, topography, water systems, arable land, and commercial crops.

Natural environmental resources, agricultural development, and arable land size correlate positively with market town distribution density [4,20]. The rapid growth in food and cash crop production in the Guangdong region after the Qing Dynasty led to the development of a commercial agricultural economy and supported the prosperity of market towns [24]. Providing easy access to water and land transportation in the plains of the water network area was a favorable condition for socio-economic development, and the proximity to waterways was a pivotal consideration in locating market towns [25,26]. Additionally, morphologically, there is a similarity between the distribution pattern of market towns and the water transport routes [5].

Although several studies have identified possible influences of physical environment factors, spatial and quantitative analysis has been the most effective in establishing the

relationship between market town locations and particular environmental features. In reality, however, it is no longer possible to establish a complete database of historical social and environmental information. Thus, it is not easy to perform an ideal quantitative analysis [6]. Such specialized analyses have been relatively rare. Huang employed GIS to determine the distribution characteristics of market towns with roads, water systems and residences in Chengdu [27]. Chen examined the correlation between waterways, roadways, population scale, financial income, and the distribution of market towns in Guangdong using a geographically weighted regression analysis [28]. These two studies provided an excellent example of an empirical experiment involving a variety of factors. However, they failed to identify the emergence of market towns in different historical periods and also confused traditional elements with modern elements, which is likely to be out of the historical context and lead to the obscuring of the original factors and fundamental mechanisms behind the formation of rural market towns' distribution patterns.

According to the existing findings and the lack of clarity, it is possible to formulate a hypothesis that the distribution pattern of market towns is structurally characterized, the site selection is influenced by a particular environmental characteristic factor or group of factors, and that the performance and effects of the influencing factors are relative. Literature review also indicates a need to advance research directions and methods; thus, regionalized studies, interdisciplinary approaches [6], big data analysis [14], and the use of multilevel perspective methods [29] are desirable. This study combines quantitative and qualitative analysis, examines at the local and global levels, and observes historical evolutionary processes, which provide a framework for testing the hypotheses from multiple perspectives.

3. Materials and Methods

3.1. Study Area

Our study area, Taishan County, is located on the southwestern edge of the Pearl River Delta in Guangdong Province (Figure 1). Towards the Qing Dynasty, Taishan County had the second greatest number of market towns after Guangzhou and Foshan, the economic centers of the Pearl River Delta [20]. While Taishan was an agricultural county, it was different from Guangzhou and Foshan, which carried out central regional economic functions, and the marketplaces in their rural areas were heavily influenced by the political environment and high-level commercial trade [5]. The main stem of the Tam River in the north and the mountains in the east and west composed the basis for the boundaries of relatively independent geographical units and administrative county areas. As a result of the mountain ranges in the county, the county is divided into three distinct regions: the north, southeast, and southwest. The county has a dense network of rivers, with rivers in the north flowing northward and feeding into the mainstream of the Tam River, and all rivers in the south flowing southward and feeding into the South China Sea. The geomorphic type in the north is characterized by alluvial plains, terraces, and low hills, whereas the type in the south is characterized by low coastal hills and marine plains. Taishan experiences high temperatures and humidity throughout the year, so the duration of plant and animal growth, as well as the maturation of cash crops, is relatively short [30].

Taishan is a suitable case for the study because it not only has the general characteristics of the geographical environment of the Pearl River Delta, but it also retains the traditional cultural features of the township society of the Pearl River Delta, which was a universal clan system. Therefore, the Taishan case can accommodate the required variables and factors for this investigation.

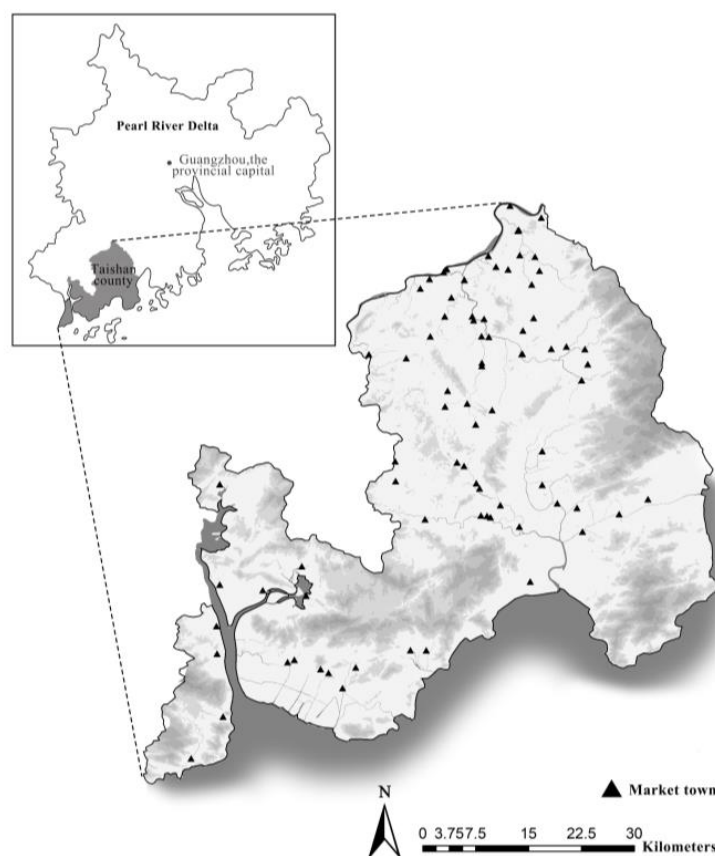


Figure 1. Geographical location of Taishan County in the Pearl River Delta Region of Guangdong Province.

3.2. Data Sources

This study employed informational data that can be categorized into three types: (i) The first type consists of historical materials and local archives, including text-based data about the establishment date, distribution location, and related social events of the market towns, which were collected and compiled from local histories, gazetteers, ancient maps, and ethnographies of the Ming, Qing, and Min-Guo periods. (ii) The second type consists of data obtained from field surveys, including historical land rights, social identities, and precise locations of market towns and related villages, and cross-referencing the field survey results with historical documents and local chronicles. Eventually, a sample of 80 market towns could be identified and included in this study [31–33]. The geographic coordinates of the market towns and villages were collected from Google Earth. (iii) Digital elevation model (DEM) data with a horizontal accuracy of 30 m are available at the ASF Data Search website. Local soil data for 1980 were obtained by submitting an application to China’s National Earth System Science Data Center.

3.3. Study Methods

3.3.1. Voronoi Method and Coefficient of Variation

The Voronoi method and coefficient of variation (Cv) were used in this study to quantitatively determine the pattern type of the spatial distribution of market towns. A Voronoi diagram divides a space plane into polyhedrons associated with sample points within that region. The polyhedron is defined as the region consisting of points that are closer to that sample point than to any other [34]. Because global Voronoi analysis may obscure characteristics at the local scale, subregional analyses are also required. Due to the distribution of mountainous areas, Taishan County can be roughly divided into three physical geographical regions: the north, the southeast, and the southwest. We also calculated the Cv of each region independently based on this division. GIS was used to

perform the Voronoi diagram analysis, and the segmented area values were exported and then calculated in Excel. The formula for the Cv is as follows:

$$R = \sqrt{\frac{\sum (S_i - S)^2}{n}} \quad (i = 1, 2, \dots, n) \quad (1)$$

$$Cv = R/S \quad (2)$$

3.3.2. Spatial Relationship Analysis and Logistic Regression

The correlation characteristics of elevation, slope, water system, and soil at the locations of market town sample points were analyzed based on the DEM and soil distribution map. In addition, a logistic regression analysis was conducted on the spatial distribution of market towns and variable factors to determine their statistical correlation. The random samples in the logistic regression analysis were created using the CreateRandom-Points tool on the GIS command line. There were as many random points as there were sample points from market towns.

For the examination of the social factors of the market town, we chose to conduct a detailed survey at the local area level, including three towns in the southern region of Taishan—Duanfen, Chonglou, and Doufu. The data of local clans' surnames, market towns, and settlements, as well as their geographical locations, were gathered during a historical materials investigation and fieldwork, inputted into the GIS to map the distribution, and supplemented with graphic analysis.

3.3.3. The Rate of Density Fluctuations

The rate of kernel density fluctuations method is widely employed in the analysis of spatial distribution dynamics. This method effectively describes the changes in density values and morphological information of the factor distribution and intuitively reflects the evolution process. [35,36]. Using the GIS software platform, we carried out the map algebra calculation based on the kernel density raster data of market towns in three historical periods: the Song Dynasty to Ming Jiajing, the Ming Dynasty to 1909 in the late Qing Dynasty, and 1909 to 1931 in the Min-Guo period. Historical literature can only give an approximation of market towns' build times, so the analysis of the change in market town distribution is only a rough estimate. The year 1909 was chosen as the dividing line between the two phases because the completion of the Xinning Railway in Taishan in that year provided a direct boost to the socioeconomic and market town development, and the market town development entered a new phase [37].

4. Results

4.1. Determination of Spatial Distribution Pattern Types of Market Towns Based on the Voronoi Method

The Voronoi diagram (Figure 2) shows the results of the spatial area partitioning of the market towns, and Table 1 shows the measurements of the Cv. Following the suggestions of existing studies, the sample points were distributed in clusters when $Cv > 0.64$ (the sample points were distributed uniformly when $Cv < 0.33$; the sample points were distributed randomly when $0.33 < Cv < 0.64$) [38]. These results of the Cv indicate that the distribution patterns of market towns are clustered at both the global and local scales, which does not conform to the hypothesis put forth by some researchers that the market town tends to be uniformly distributed [1,9,10].

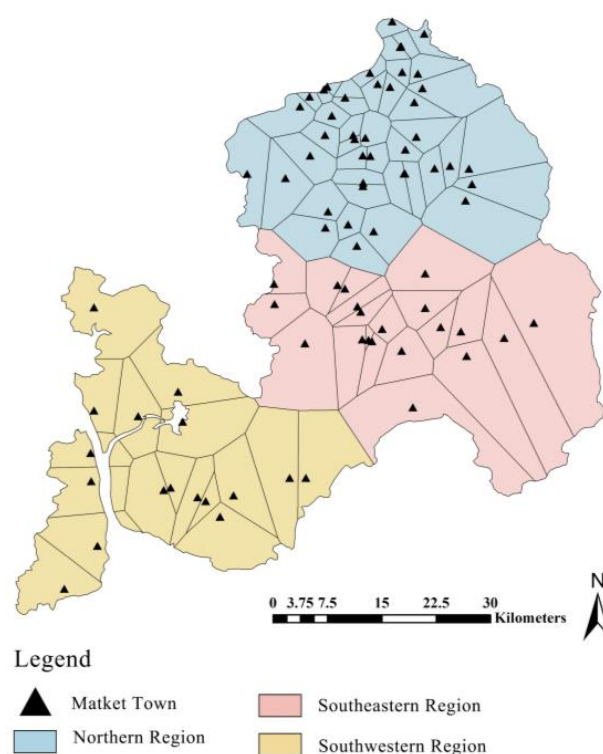


Figure 2. A Voronoi diagram showing the distribution of market towns in Taishan. Light blue part indicates the northern region, light red part indicates the southeastern region, and light green part indicates the southwestern region.

Table 1. Summary of the measurements of the Cv.

	Global Scale of Taishan County	Northern Region	Southeast Region	Southwest Region
Standard Deviation	36.26	19.76	54.27	23.70
Mean Value	36.86	21.30	54.45	33.00
Cv	0.98	0.93	0.99	0.72

4.2. Correlation Analysis and Quantitative Identification of Physical Geographic Environmental Factors and Spatial Distribution of Market Towns

The market town sample points were correlated with elevation (Figure 3a), slope (Figure 3b), and water buffer maps (Figure 3c). We divided these environmental factors into levels to better show the siting characteristics of market towns (Table 2). The market towns in Taishan are mainly distributed in areas where the elevation height is below 0 m, accounting for 60% of the total number. Within the altitudinal range of 0–15 m, the number of market towns accounts for 38.75% of the total number; there are only 1.25% of the market towns located in the area of 15–30 m elevation, while no market towns are located in the area above 30 m elevation. A total of 50% of the market towns are distributed on slopes with a gradient range of 0°–3°, and the other 50% are distributed on slopes with a gradient range of 3°–10°. Taishan's river networks are widespread, and most of the market towns are situated along the water. Using the buffer creation function of the GIS software platform, we graded the distance of the market from the water system. The proportion of market towns that are distributed less than 500 m away from the main rivers is as high as 73.75% of the total number. The market towns located in the area of 500–1500 m from the water system account for 18.75% of the total, while the remaining 5% and 2.5% of the market towns are located 1500–3000 m away and more than 3000 m away from the water system, respectively.

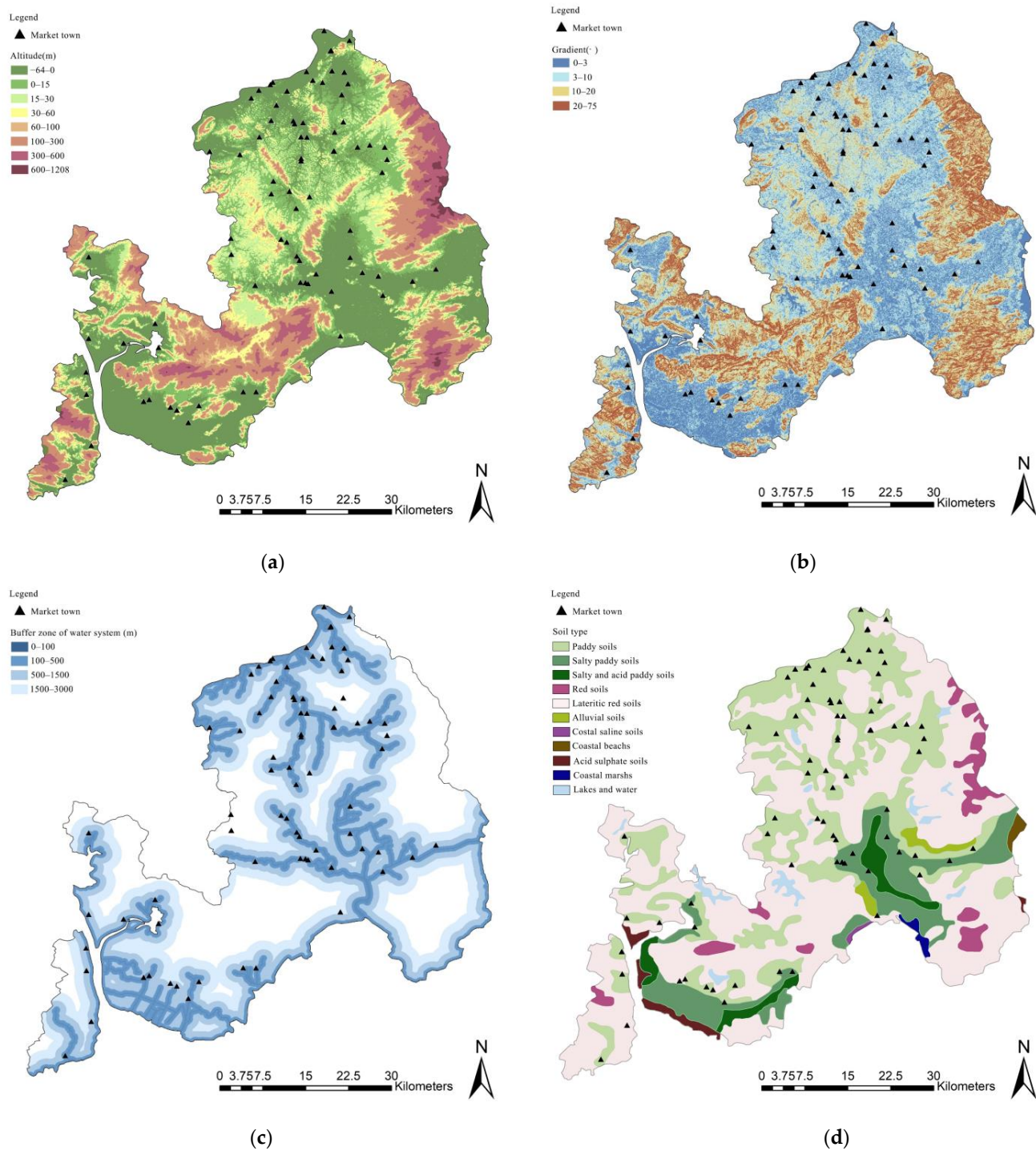


Figure 3. Physical environmental factors and market town distribution. (a) Elevation classifications; (b) slope classifications; (c) water system buffer zone classifications; (d) soil classifications.

Table 2. Statistics of market towns in different classifications of elevation, slope, and water buffer zones in Taishan.

	Elevation (m)			Slope (°)			Water Buffer Zone			
Range of Value	<0	0–15	15–30	0–3	3–10	>10	0–500	500–1500	1500–3000	>3000
Quantity	48	31	1	40	40	0	59	15	4	2
Percentage (%)	60.00	38.75	1.25	50.00	50.00	0.00	73.75	18.75	5.00	2.50

Figure 3d depicts the distribution of different types of soil, and Table 3 [39,40] lists the main types of soil used in traditional production, where they are found, and what kinds of cash crops can be grown in them. According to local agricultural records, paddy soils and salty paddy soils are the primary soil types utilized for agricultural production in Taishan. Paddy soils are suitable for numerous agricultural cash crops, and their soil parent material is river alluvium, which is widely distributed in the alluvial plains of the Tam River in the north and along the banks of freshwater rivers in the southeast and southwest regions. Salty paddy soils are mainly distributed in the southeast and southwest regions, and their parent material is littoral sedimentary soils, the salinity of which needs to be reduced to be better utilized in agricultural production. Lateritic red soils are found primarily in the low mountains and hills of each part of the prefecture and are suitable for growing dry crops [39].

Table 3. The main types of soil utilized for production and economic crop.

Region	Types of Terrain	The Main Types of Soil Utilized for Production	Main Cash Crop
North and northwest	Tam River Plain	Paddy soils	Paddy, peanut, fruit, vegetable, and silkworm
	Hilly areas	Lateritic red soils	Dry crop, potato, peanut, and sugarcane, tea
Southeast	Coastal Plain	Salty paddy soils, salty and acid paddy soils	Paddy, potato, fishery product, salt
	Upstream river alluvial plain	Paddy soils	Paddy, peanut, fruit, and vegetable
Southwest	Coastal Plain	Paddy soils, lateritic red soils area	Paddy, potato, fishery product, and salt
Mountainous areas in each part of the prefecture		Lateritic red soils and red soils	Tea and peanut

The overlay analysis of soil mapping and the distribution of the market town sample points show that the majority of market towns are located in the paddy soil areas. It can be seen from the statistical results that 65% of the market towns are located in the paddy soil areas, while 17.5% of the market towns are located in the salty paddy soil areas, and the remaining 17.5% of the market towns are located in the lateritic red soil areas. There are no market towns located in the rest of the soil-type areas with low agricultural productivity. These results support what local records and previous studies have shown: agriculture had the highest economic returns in Taishan County during the traditional period, followed by fishing and salt. Paddy was the most important cash crop, fundamentally supporting the development of a commodity-based agricultural economy in the Pearl River Delta and creating the prerequisites for the emergence of a large number of market towns [24].

On the basis of a preliminary examination of the characteristics of the spatial distribution of market towns, logistic regression was then used to identify the influencing factors and influence degrees of the spatial distribution of market towns in a statistical sense. Logistic regression analysis is a statistical measure of the variables of two distinct groups of individuals. In function, P represents the appearance probability of the spatial distribution of market towns. Using the Create Random-Points tool in GIS software, as many random points as the number of market towns were created to represent the non-appearance of market towns.

Due to the limitations of the availability of local historical data, this study mainly focused on the basic physical environmental factors. Four factors were selected: water buffer distance (X_1), gradient (X_2), classification of soils (X_3), and elevation (X_4). After the preliminary processing of the original data set, the Pearce correlation coefficients of the independent variable factors were calculated before logistic regression. The correlation coefficient between X_2 and X_4 was 0.63, which was greater than 0.5, indicating a linear

correlation between the two variables. Therefore, only the X_4 variable, whose p -value passed the significance test and whose p -value was small, was retained in the logistic regression model. The logistic regression results are summarized in Table 4.

Table 4. The logistic regression summary of the dependent variables of market town sites.

Logistic Regression Model ¹		Unstandardized Coefficient	Standardized Coefficient	p -Value (Significance Test)
AIC ² = 109.5	AUC ³ Estimation of Roc Curve = 0.86			
	X_1	−0.0008332	−0.48818035	0.00197
	X_3	−0.0324848	−0.04342646	0.00141
	X_4	−0.0644039	−1.822550178	0.00296

¹ Since X_2 did not pass the significance test ($p = 0.879 > 0.05$) in the modeling process, it was eliminated. ² AIC is the Akaike Information Criterion. ³ AUC is the area under curve, which is defined as the area under the receiver operating characteristic curve (ROC).

According to the results, there is a significant correlation between X_1 , X_3 , and X_4 and market town distribution. The AUC estimation of the ROC curve is 0.86, indicating that the model predicts well (the AUC ranges from 0.5 to 1.0; the closer the AUC value is to 1.0, the better the model's prediction). The logistic regression model between the spatial distribution of market towns in Taishan and the influencing factors is shown as follows:

$$\log\left(\frac{P}{1-P}\right) = -0.488X_1 - 0.043X_2 - 1.822X_3 + 3.882 \quad (3)$$

Additionally, the collinearity between X_2 and X_4 may have caused X_2 to not pass the significance test of 0.05 in the modeling process. In order to examine the relationship between X_2 and the dependent variable, we also carried out logistic regression analysis with X_1 , X_2 , and X_3 as independent variables to compare with the previous model. The regression coefficients of the X_1 , X_2 , X_3 variables all passed the significance test, and the X_2 regression coefficient was 0.576 ($p < 0.05$). However, the AIC value of this model was 118.2, which was higher than the AIC value of the previous model, indicating that the goodness of fit of this model was not as good as that of the previous model, and it was therefore not selected. In brief, although not included in the logistic regression model of this study, the slope factor (X_2) has a certain correlation with the market town distribution.

It can be seen from the regression results that elevation, slope, distance from the water system, and the poorly arable soil type all present a negative correlation with the distribution of market towns. The spatial distribution of market towns in Taishan has a location preference for low altitude, gentle slope, adjacent water systems, and highly productive soil areas. The spatial distribution of market towns in Taishan has a location preference for low altitude, gentle slope, adjacent water systems, and highly productive soil areas. These characteristics have also been proposed and discussed separately in previous studies [4,5,25]. This quantitative result of the inclination of market towns to specific physical environments can effectively explain the formation of the clustered distribution of market towns derived from the assessment of the Voronoi method in the preceding subsection.

4.3. Association Analysis of the Local Social Environment and Spatial Distribution of Market Towns

In the analysis of the social factors, we focused our research on the southern Taishan Water Network Plain region. This section presents the results of the mapping of the socio-spatial pattern of market towns and explores the site organization and market day arrangement of market towns on a local scale and their relation to inter-clan interaction and clan distribution features. Based on an extensive investigation of village sites and surname information, this region was found to contain both villages of residents with different surnames living together and villages of clansmen with the same surname.

Generally, villagers in single-name villages have close blood ties, they descend from the same ancestors, jointly develop and occupy properties and farmlands, and assemble clan organizations with blood, geographical, and productive economic ties [41]. Most of the villager families with different surnames fail to form organized clan groups due to their small and dispersed family populations. Their impact on rural society is less significant than that of clan-based village communities.

About 189 villages with single surnames reside in this area, and they belong to 25 distinct clans [42]. Figure 4 depicts the distribution of these clan villages. The Mei, Chen, Ruan, Liang, Wu, Zhao, and Li families are the eight largest clan groups in this rural area; they occupy continuous land and have built adjacent settlements, as well as having built their market towns as collective places for commerce and social activities. Twelve of the sixteen market towns in this area were built and are controlled by the eight largest clans, while only four are operated by small families.

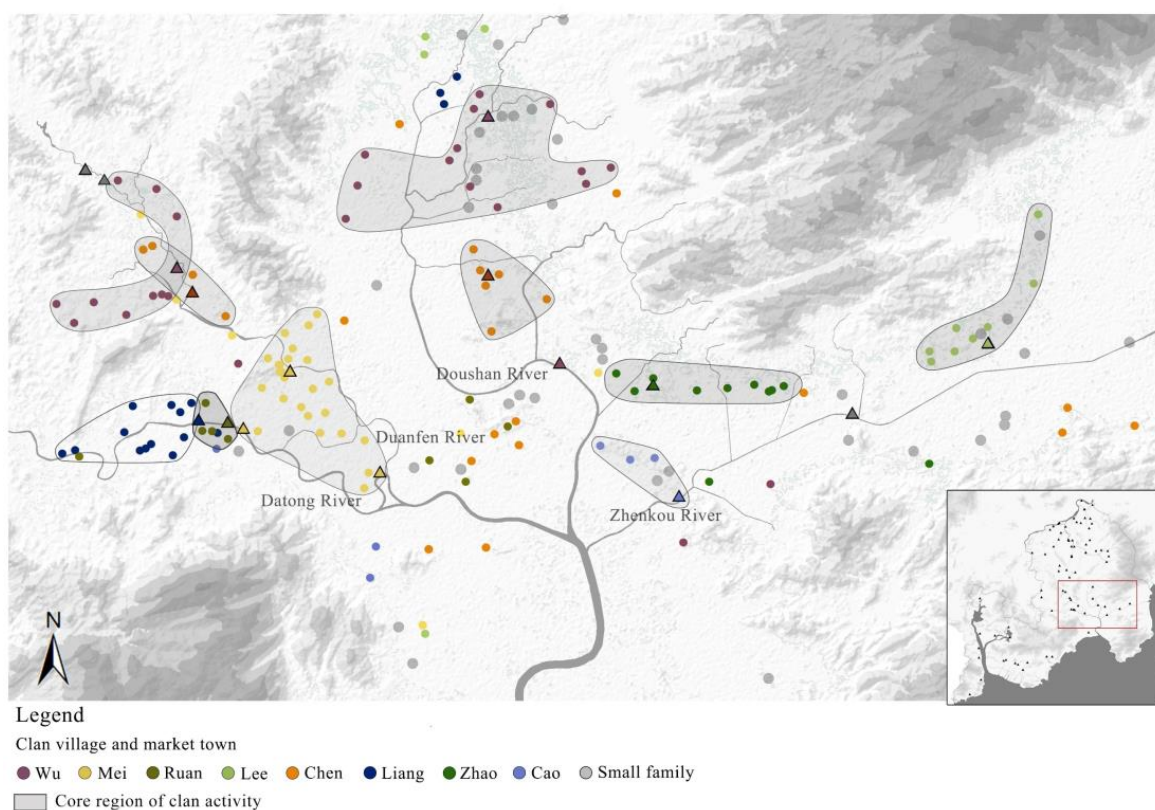


Figure 4. Distribution of clan villages and market towns in the southern area. The triangles of different colors represent different clan market towns, and the dots of different colors represent different clan villages.

Upon further inspection, it was discovered that there are two phenomena in this area that can be compared and analyzed: one occurs in the region between the Duanfen River and Datong River, and the other occurs in the region between the Doushan River and Zhenkou River. Though both of these regions are predominated by clan culture and the market towns are governed by clan organizations, market towns in the former are arranged spatially and temporally at an unusual density, while market towns in the latter maintain regular intervals.

As shown in Figure 5a, in the region between the Datong and Duanfen Rivers, the settlement domain of the four large clans is in close proximity, the market towns are only a short distance apart, and the market day arrangements frequently overlap (Figure 5b, Table 5) [43], which is contrary to the general principles that the trade days of each market town in the village commercial system form a cyclical, periodic rhythm. These config-

urations of market towns are inconsistent with the rules of rational economic interests and express challenging and competitive intentions. This is similar to the phenomenon described by Liu in his study of the Fujian case [16] and by Baker in his investigation of the Hong Kong case [19], where their findings suggest that such phenomena are indicative of economic competition and power struggles between clans.

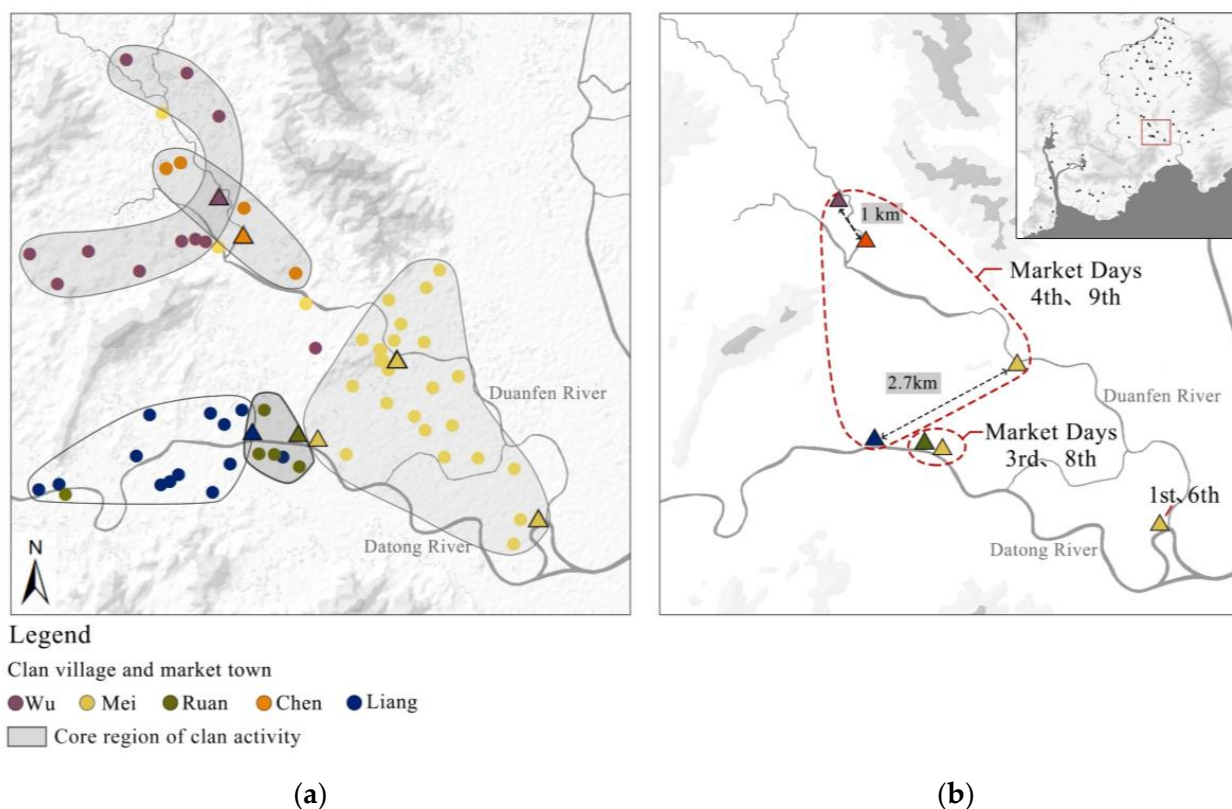


Figure 5. Diagram of the region between the Duanfen River and the Datong River. The different color triangles represent different clan market towns, and the different color dots represent different clan villages. (a) Illustrates the density of the different clans' territories; (b) Illustrates the close proximity of different clans' markets and the conflicting market days.

Table 5. Summary of the market days of market towns in the region between the Duanfen River and the Datong River.

Clan	Market Town Name	Market Days of Every Ten Days					
		1st	3rd	4th	6th	8th	9th
Mei	Haikou	✓					
	Duanfen				✓		
	Tingjiang			✓			✓
Ruan	Datong		✓			✓	
Liang	Xiguo		✓			✓	
Chen	Shangze			✓			✓
Wu	Chengwu			✓			✓

It should be noted, however, that the operations of the different market towns established by the same clan in this region are characterized by a coordinated relationship; for instance, the three market towns of the Mei clan do not only maintain a certain distance from each other, but in addition, their market days do not conflict but form a cycle of service time. Referring to the case of the Mei clan market towns, coordination relationships are generally formed within the clan as opposed to a situation of competition and exclusion between different clans.

In a review of historical records and existing ethnographic studies, we explored the possible reasons for this competitive socio-spatial relationship. Historically, disputes between different clan groups in this region frequently arose over water irrigation, local politics, or rural commerce. The Chen clan, for example, believed they were the earliest to settle in the community, conducted trading activities as early as the Song Dynasty, and therefore were entitled to control the Shangze Market Town. However, even the Wu clan, which held comparable clan force and settled nearby, was restricted in market activities due to the Chen clan's management, so they had to establish another market town. In addition, conflicts also existed between the Chen and Mei clans, both of whom relied upon the Duanfen River as their main source of water, and in the past, they would often disagree over the scheduling of water. This discordant social relationship also had a negative influence on rural commercial activity, as the Mei clan shifted the location of the market town several times due to the Chen clan's interference. Similar situations were also witnessed in communities along the Datong River, in which the Ruan clan intervened in the activity of other clans in Datong Market Town, while the Mei clan developed their own market town nearby and used the same market days as Datong Market Town in an attempt to compete with it [44].

The distribution of clans between the Doushan and Zhenkou Rivers is significantly different from that between the Duanfen and Datong Rivers. The domains of different clans here are kept at buffer distances from each other (Figure 6a), thereby reducing resource competition, social friction, and interest competition among the clans. The market towns here are kept at reasonable interval distances from each other, with no conflicting market days (Figure 6b, Table 6 [43]). Such a spatial distribution and the schedule of market towns display the normalization of rational rural trade rules, reflecting the intention of the clans managing the market towns to coexist without interfering with one another.

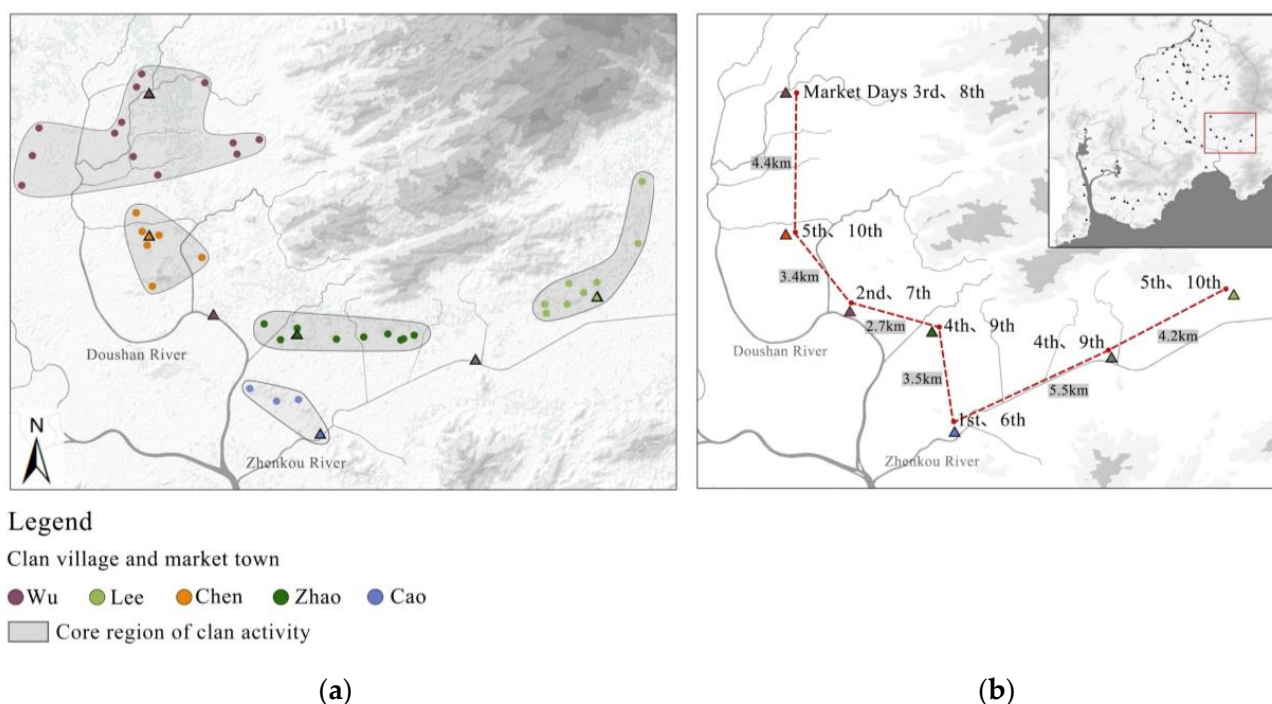


Figure 6. Diagram of the region between the Duanfen River and the Datong River. The different color triangles represent different clan market towns, and the different color dots represent different clan villages. (a) Illustrates the different clans' territories maintain normal intervals; (b) This figure illustrates the spatial and temporal distribution of normal intervals between market towns.

Table 6. Summary of the market days of market towns in the region between the Doushan River and the Zhenkou River.

Clan	Market Town Name	Market Days of Every Ten Days									
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Wu	Chonglou			✓					✓		
Chen	Doushan		✓					✓			
Zhao	Shatan					✓					✓
Fushi					✓					✓	
Cao	Zhenkou										
Nushan		✓					✓				
Dufu					✓					✓	

A comparison of the two phenomena above reveals that in the agrarian society dominated by kinship culture, there was a strong influence of clan groups behind the market, with the organization of the market town influenced by complex factors such as domain distributions and social interactions.

4.4. Analysis of the Spatial Distribution Evolution of Market Towns Based on the Change Rate of Kernel Density

The rate of density fluctuations in market towns can visually represent their spatial-temporal variation characteristics over time.

Until the Jiajing period of the Ming Dynasty, the market towns in Taishan were still in the initial stage of development, with the highest rate of nuclear density fluctuations at about 0.17‰ per annum, and market towns patches were mainly distributed in the southwest and north (Figure 7a).

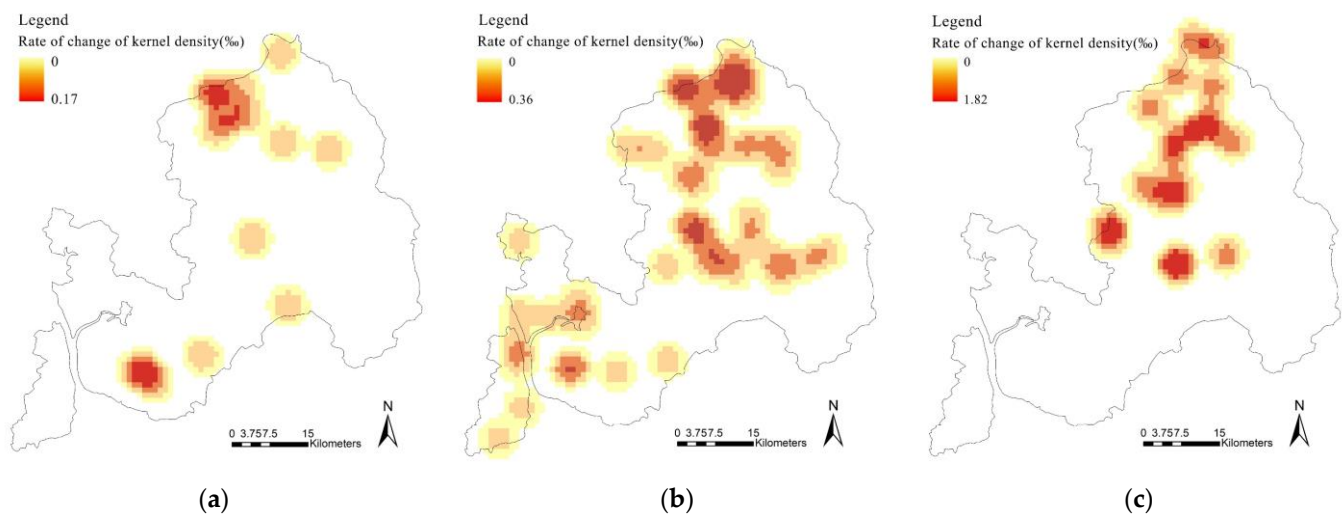


Figure 7. The change rate of the market town kernel density. (a) Song Dynasty to the years of Jiajing in the Ming Dynasty; (b) the years of Jiajing in the Ming Dynasty to the late Qing Dynasty in 1909; (c) 1909 in the late Qing Dynasty to 1931 in the Min-Guo Period.

The Ming court built a guarded town for coastal defense in the region of the southern coastal plain in Taishan and established an inspection agency in the town of Haiyan, which was in the region of the southwestern coastal plain, as well as a berth for tribute ships and merchant ships to park, replenish, and trade [45]. Additionally, Haiyan is also the location of one of the major saltern and salt distribution centers in Guangdong [46]. However, the number of market towns in the north is slightly higher than that in the southwest and south, owing to the fact that the Tam River network plain in the north has more easily exploitable soil and water conditions, and that the administrative center of Taishan County was situated along the major tributaries in this region. These factors contributed to the economic development and growth of market towns to a certain extent.

In the Qing dynasty, the three major plain areas of Taishan experienced different levels of market town density growth, which reflected the rural market towns' entry into an overall development stage (Figure 7b). The highest rate of change in market town density during this time period was 0.36% per annum, exceeding that of the Ming Dynasty. The development of the market towns in Taishan County has been greatly improved in this crucial period of agricultural economic expansion, which is analogous to the situation in other regions of the Pearl River Delta in Ye 's statistical analysis [20]. Stronger growth was observed in the north along the main stem of the Tam River and its tributary water network areas, displaying a continuation of the development advantage achieved in the Ming Dynasty. There was also a significant increase in the southeastern coastal sedimentary plain, related to the reclamation of farmland, construction of water conservancy facilities, development of commercial agriculture, and expansion of maritime transportation under the Qing Dynasty [24,40], and yet, the incremental intensity in the southwest was significantly lower than that in the northeast and southeast regions.

Since 1909, the overall expansion range of the market town has been reduced compared to the Qing Dynasty, whereas the growth intensity has increased greatly, with a maximum rate of density fluctuations of 1.82% per year, which are mainly concentrated in the northern river network region and the southeastern river network region, while the expansion of market towns in the southwestern coastal region has stopped (Figure 7c).

A railroad line known as the Xinning Railway, which commenced operation in 1909, connected Taishan County to Jiangmen Port, an important trading port in the Xijiang River basin, which contributed greatly to the development of urban and rural commerce along the route (Figure 8 [47]). Furthermore, nearby cities, such as Hong Kong, Guangzhou, and Jiangmen, had their ports opened for international trade, stimulating Taishan's economy from the outside [37].

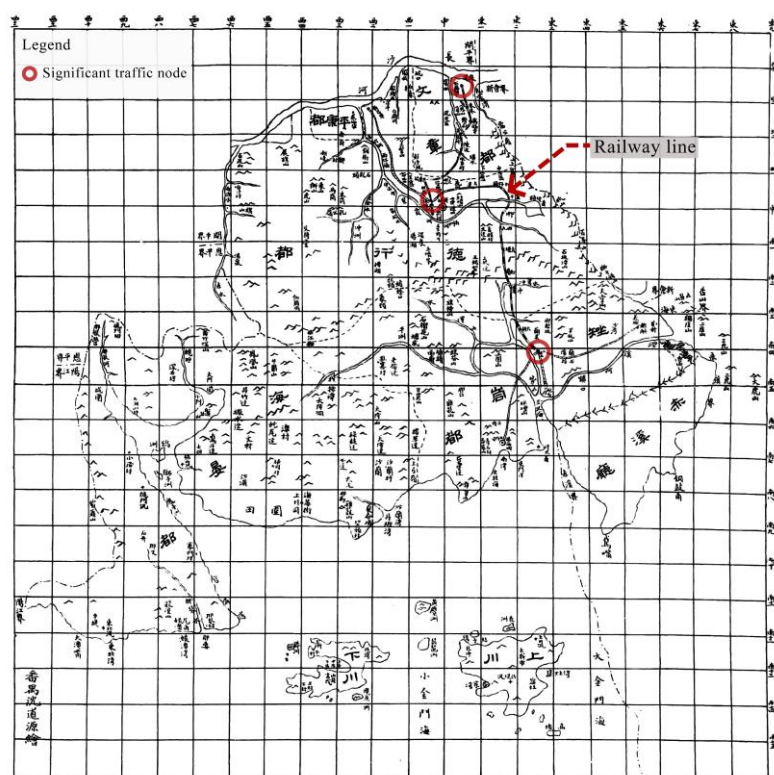


Figure 8. The Xinning Railway drawn on a map of Taishan County made during the years of Xuantong in the Qing Dynasty.

5. Discussion

5.1. Distribution Model of Market Towns

According to the respective theoretical approaches, the suggestions regarding whether the distribution of market towns tends to be regular or clustered provided by current studies were conflicting [1,16], while Voronoi tessellation and the coefficient of variation are plausible approaches to help determine the type of characterization of the spatial distribution. The results show that the distribution of market towns in Taishan is clustered at both the global county scale and the local regional scale. The application of the Voronoi method also simplifies some specific problems in reality, such as the topographic conditions, and it is unable to accurately represent the real economic area when utilizing the administrative county as a calculation range. Nevertheless, this method is effective in avoiding potential biases caused by different theoretical perspectives.

Logistic regression analysis of the spatial distribution of market towns and geographical factors revealed the main reasons for the formation of market town clustering patterns, which are generally concentrated in areas of low elevation, little slope, near water, and productive agricultural land. With the use of the GIS, the geographical distribution characteristics of market towns were visualized, which are concentrically distributed in the coastal plains of the Tam River system in the north and the coastal plains of the rivers in the south and west. This could be due to the particular need for low economic and labor costs as well as efficient and rapid transportation for the market town and its economic activities. The topography of the plains environment presents few barriers to economic activity, and the river network waterways can provide waterway corridors that facilitate the expansion of trade [5].

Furthermore, the geographical characteristics of the spatial distribution of the market towns mentioned above include much more than the factors of the transportation environment; there are also significant advantages in terms of soil resources. Researchers have mostly focused on the relationships among the size of arable land, commercial crops and population aggregation, and market town development [4,20], but so far there has been little discussion of soil properties as the fundamental conditions for cash crop production.

In the Pearl River Delta, due to the regional characteristics of the soil distribution, the soils in the water network plains areas are typically the types of soils with high agricultural productivity [48]. Our counting results indicate that there were more market towns found earlier in the river alluvial plain areas where paddy soils are widely disseminated, followed by the coastal sedimentary plain areas where saline paddy soils are distributed, and the hilly areas with lateritic red soils. The soil parent materials of paddy soils in Taishan are mainly river alluvial sediments and valley floor deluvial materials [39], which are suited to cultivating higher-value cash crops and can be cultivated with a minimal amount of intervention and reclamation. Until the years of Jiajing in the Ming Dynasty, the coastal sedimentary plain area had a smaller number of market towns than the northern alluvial plain area. Throughout the Ming and Qing dynasties, the southern coastal plain was gradually formed and developed, while this coastal saline land required artificial improvements, for example, by diverting fresh water to reduce salinity and acidity so as to improve the soil's arable properties. Until the middle and late Qing dynasties, with the development and improvement of the southern coastal plain and the continuous development of agriculture, the number of market towns in this area grew rapidly. In brief, a high proportion of market towns emerged in productive soil environments suitable for agriculture, especially in paddy-producing areas. Their growth dynamics are also characterized by both a spatial and temporal correlation with the evolution of agricultural land.

Geographical and land environments have a comprehensive and dominant influence on the distribution of market towns, though, as many studies have pointed out, market towns are also affected by local forces and social organizations [23,49]. It was found in our survey that almost all of the market towns in Taishan are the property of communal clan organizations, and most of them belong to large local clans, with smaller clans holding only a small number of them. Our findings also support what some researchers have

stated [16,18,19] that the monopolistic control and exclusionary behavior of clans in commercial management lead to the high density of market towns and market day conflicts. We also provide supplementary explanations for the reasons for the different phenomena by comparing the examples of the Duanfen and Doushan regions. Even within the same clan social culture, the spatial organization of market towns and the scheduling of market days in different communities vary significantly. The emergence of unreasonable market town gatherings and unenviable competition were likely to occur in a specific social context, which is probably the close proximity of different clans' settlements, the intersection of their production spheres, or a conflict in social life, leading to an antagonistic relationship between them, and thereby affecting the market town arrangement.

A pattern of regular spatial structuring of market towns related to plain topography, water availability, production areas, and clan domains can be derived by integrating several attributes of the distribution of market towns discussed above (Figure 9).

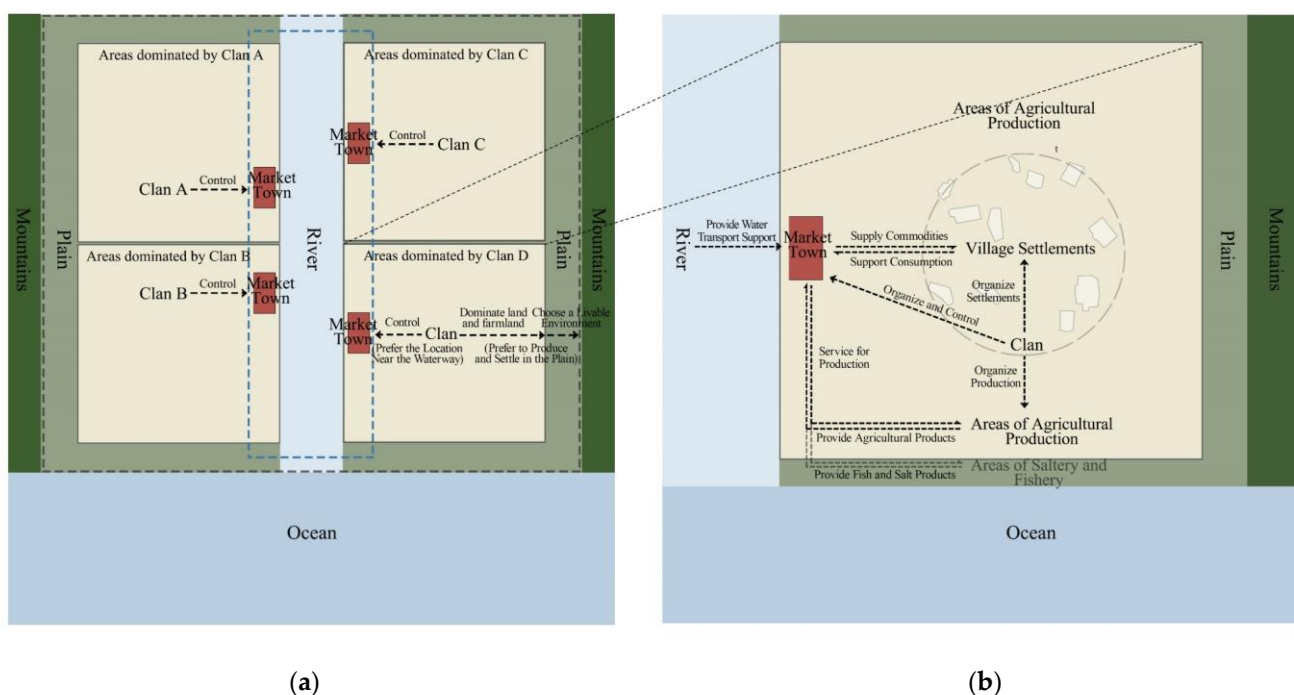


Figure 9. Spatial structure pattern of market towns associated with plains, waterways, and clan villages. (a) Clans' respective domain units and market towns; (b) the spatial pattern of the market town and environmental factors is essentially a reflection of the functioning mechanisms of rural trade, production, and settlement.

5.2. Developmental Trajectories of Market Towns

The results of nuclear density change rate analysis show different evolutionary paths in the spatial distribution of market towns in three historical stages:

(i) The early stage of development, from approximately the Song Dynasty to the years of Jiajing in the Ming Dynasty, shows a bipolar distribution pattern, with market towns emerging first in the northern and southwestern regions. There were considerable ecological conditions along the north Tam River alluvial plain, and it has been highlighted for its leading status at this stage, while the southwest region had certain clusters of market towns due to military settlements and the salt trade.

(ii) The period from the years of Jiajing to the late Qing Dynasty saw the overall development of market towns, which expanded along the water transportation corridors and on the agricultural polder land, forming a wider distribution across the river network plain. Furthermore, the nucleus of the market town gathering in the northern river network area was strengthened. The growth rate of the market towns' distribution density in-

creased in the southeastern and southwestern coastal plains as the soil and land production environment improved and developed.

(iii) The period from 1909 in the late Qing Dynasty to 1931 in the Min-Guo period was the post-development stage. The level of agglomeration in the northern river network area intensified, and market town expansion mainly occurred around the locations of rail–water terminals, while the growth of market towns in the southwestern coastal plains ceased entirely. Modern economic factors became the new driving force of commercial trade in Taishan County. The Tam River ports and Xinning Railway stations served as important nodes for cross-city transportation and long-distance trade in the Pearl River Delta, facilitating regional market town development.

The trajectories imply that the development of market towns was unbalanced among regions in the long term. Regions with superior natural and ecological conditions not only developed market towns earlier and gained an advantage of forwardness, but also maintained a sustainable growth trend in the subsequent phase and even achieved a cumulative effect of continually stimulating the growth process of market towns. Additionally, variations in the transportation status of the region, ports, or military settlements in different periods may have also influenced the changes in the growth of market towns.

5.3. Multiple Structures of Market Towns and Natural Ecology, Livelihood Strategy, and Social Model

Considerable studies have noted the association between market town distribution and a variety of factors, mainly including geography, transportation, agriculture, and social organization. However, there is a lack of a holistic perspective to relate these factors to the market town pattern distribution as a composite system [6,50]. As rural life is governed by the natural environment, rural issues should take into consideration the interrelationship between ecological conditions and socioeconomic factors [51]. The adaptation and exploitation of environments are the basis for the formation of cultural characteristics in which productive activities and economic arrangements are associated, which also play an important role in the formation of livelihood strategies, as well as social organization modes [52]. For the Pearl River Delta region, the focus of this study, its natural ecology was characterized by dense water networks, silty riverine silt plains, and shallow beaches that constantly stretch outward, forming the available conditions for local livelihoods. From the Song Dynasty onwards, a large number of migrants from the north utilized manpower to manage the lowlands, construct water conservation facilities, and reclaim tideland for cultivation based on such ecological circumstances [24]. Agricultural activities and land occupation required large numbers of laborers to work together, which led to families developing a clan system to organize themselves. They developed into a social group, combining labor cooperation, settlement, and economic integration. The clan form of organization acted as an important institution within the agricultural societies of the Pearl River Delta in supporting subsistence, which included not only basic production activities, such as irrigation agriculture and water facility maintenance, but also rural commerce strategies. Clan associations dominate the commercial earnings of rural markets and manage their operation in the chain of the agricultural commodity economy. Ecosystems and societies do not simply interact unidirectionally, but also display a dynamic process of regional ecology–economy–society–cultural structuring [53]. The clan model was constructed as a customary cultural and institutional tool through which workforce and financial resources are effectively pooled and acted as an intervenor in the Shatin polder in a socially collective manner, thus promoting arable land expansion, agricultural commercialization [21,49,50], and growth in the number of market towns.

To summarize the above analysis, it can be suggested that there is a relationship of mutual construction between the layout of the market towns, the adaptation, and transformation of the river network plains, the reclamation of polder fields, irrigated agricultural production, and the clan system construction; that is, the multiple relationships

among ecology, livelihood patterns, and social organization are important components in the logical chain of market town distribution (Figure 10).

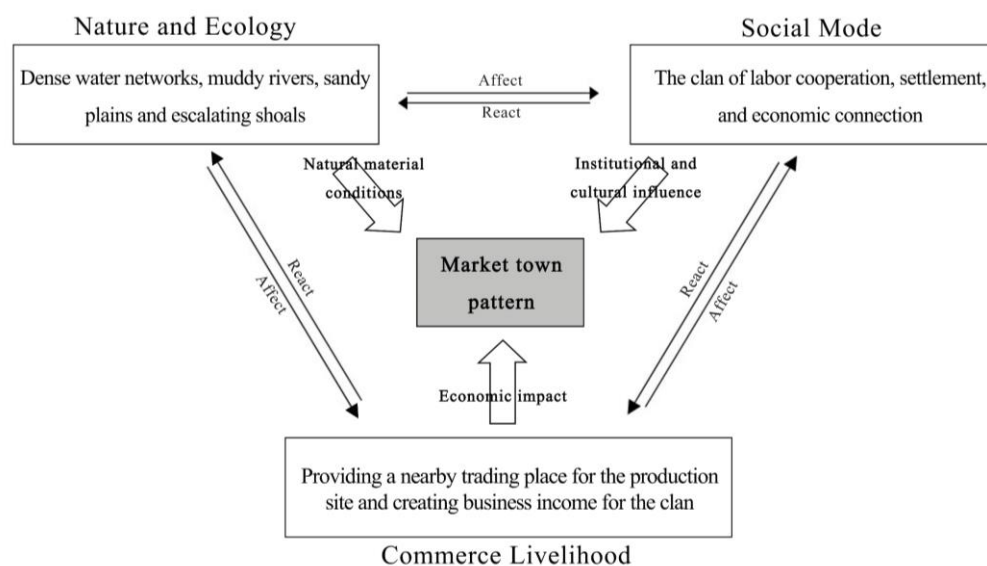


Figure 10. The relationships among ecological environment, social organization, and business livelihood patterns and their correlation with market town patterns.

6. Conclusions

The combination of GIS spatial analysis, quantitative statistics, and local historical materials research is an effective approach to further understand the formation of market town distribution patterns. This study demonstrates that the distribution of market towns in Taishan is clustered and that the clustered pattern is mainly a result of site selection being influenced by geographical, ecological, and social factors, as well as having a non-equilibrium dynamic evolution. Market towns, waterways, plains, productive low-lying paddy fields, and clan domains form an interdependent spatial configuration. Furthermore, in the material spatial dimension, the logic of the distribution pattern of market towns associated with the ecological and cultural environment is essentially a projection of the system of regional agricultural commercialization in the rural areas.

Amidst the ecological conditions of the estuarine alluvial plain and the clannish social system, the villages' traditional commercial livelihoods were based on irrigated agriculture and food cash crop production, while the rural commercial order was regulated by the local clan cultural model. The results of the quantitative identification of the distribution characterization and environmental variables of market towns in this study validate some empirical insights from existing studies. In addition, the abstracted spatial patterns of market town associations with the physical and social environment differ from existing theoretical models that only address the structure between market towns. Nevertheless, there are some potentially relevant factors that are difficult to include in the analysis due to the dearth of relevant historical data and archaeological records. Even though future research is required to conduct empirical studies in other areas of the Pearl River Delta region, as well as to further explore other possible variable factors, basic spatial relationships have been identified, and this database and research framework are primed for further, more complex, and comprehensive analyses.

The results of this study offer a comprehensive understanding of the functioning of traditional market town systems and their interaction with vernacular settlements and local ecology. In addition, it facilitates the exploration of the traditional connotation and cultural significance of agriculture economy and rural commerce in history, as well as providing historical references and knowledge support for the practice of living preservation and sustainable development of market town heritage. The continuing goal of this research is to develop a regional model of market town distribution and its types and systems.

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