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Exploratory Analysis on the Spatial Distribution and Influencing Factors of Beitang Landscape in the Shangzhuang Basin

Shangzhou Song [1], Shaohua Wang [2,3,*], Huichun Ye [3,4] and Yong Guan [5]

[1] College of Urban and Environmental Sciences, Peking University, Beijing 100871, China; songshangzhou@pku.edu.cn
[2] Key Laboratory of Digital Earth Science, Aerospace Information Research Institute, Chinese Academy of Sciences, Beijing 100094, China
[3] State Key Laboratory of Remote Sensing Science, Aerospace Information Research Institute, Chinese Academy of Sciences, Beijing 100094, China; yehc@aircas.ac.cn
[4] Key Laboratory of Earth Observation of Hainan Province, Hainan Research Institute, Aerospace Information Research Institute, Chinese Academy of Sciences, Sanya 572029, China
[5] Department of Information System and Technology, Claremont Graduate University, Claremont, CA 91711, USA; yong.guan@cgu.edu
* Correspondence: wangshaohua@aircas.ac.cn; Tel.: +86-010-82178178

Abstract: Beitang landscape is a production system and land use pattern that ancient people created to adapt to droughts and floods during a long traditional farming culture. It has a critical reference meaning for water resource use and water systems protection in modern cities. Taking the Shangzhuang Basin (China) as an example, this study used multi-source data, such as remote sensing images, Beitang vector dataset, land-use dataset, elevation, slope, river, road, and field survey, to investigate the spatial distribution and influencing factors Beitang landscape. Results showed that in a typical small watershed basin, an area of ponds accounted for 1.0%, about 12 ponds per square kilometer—the average area of ponds is 814 m^2, of which the vast majority is less than 1000 m^2. The study found that the spatial distribution of Beitang in the Shangzhuang Basin has cluster characteristics, influenced by elevation, slope, aspect, river, roads, villages, farmland, woodland, and other factors, all of which have closely related to the natural environment development and human activities. The upstream, middle, and downstream of three Beitang landscapes were coordinated to support the Beitang landscape system in the small watershed of the basin. Findings provided a model for protecting and utilizing natural water systems in rural areas during the construction of sponge cities.

Keywords: spatial distribution; influencing factors; landscape pattern; spatial analysis; Beitang landscape

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1. Introduction

The Beitang landscape, containing the art of survival [1], is the carrier of the relationship between the people and the land in the farming era [2]. The closer meaning of Beitang is also called pond, Shuitang in Chinese [1], usually a collective term for small artificial water bodies and natural water bodies. The study of the spatial layout and structural characteristics of the Beitang landscape, especially related work on adaptive characteristics of drought and flood, brings a deep understanding of the operation and adaptation mechanisms of the rural natural water system [1], then gets further rethought and puts forward an important reference on the urban and rural water environment management, flood control planning and land management along with a background in urbanization [3–5]. The Beitang landscape is a production system and land use pattern that ancient people created to adapt to droughts and floods during a long traditional farming culture [6]. The Beitang has a critical reference meaning for water resource use and water systems protection in modern cities [7]. The effects for rural area is essential for sustainable city research [8–13] and the Beitang landscape brings benefits for the rural area [14,15].

China's urbanization rate has exceeded 50% [16], and the natural water system in the countryside has been damaged [17]. Many farmland water conservancy facilities of small-scale Beitang weirs have been abandoned and landfilled [2]. On the one hand, the rural natural water system is damaged in the process of long-term changes to the water environment, which makes it difficult to perform modern functions; on the other hand, with instances of an extreme storm, the grey infrastructure such as drainage pipes in urban areas is weakened, which makes cities vulnerable to floods. Such problems have been constantly seen over the years. A study of functional changes of the Beitang landscape and its potential impact on water problems can establish the most affected area and the causes of spatial impact [18]. In particular, a quantitative study on the changes in the capacity of rain and flood regulation of Beitang can explain to what extent the large-scale reduction of the number of Beitang weakens the regional drought and flood adaptability, which attracts the attention of planners and government decision-makers [2,19,20]. It is essential to conduct a spatial analysis to consider multiple factors and the human environment in land research [21,22].

Beitang refers to small water bodies with semi-natural and artificial attributes other than large water bodies such as reservoirs and lakes, or to be exact, small water bodies formed by artificially intercepting natural runoff [3,23].

The related research questions in this study are:

(1) What are the structural characteristics of the Beitang landscape in Huizhou area? Under different landform types, soil types, and vegetation types, what kind of Beitang structure models have been adopted for adaption?
(2) Within a specific range, what are the spatial distribution characteristics of the Beitang landscape? What kind of structural model does this distribution feature correspond to? How does the Beitang landscape system composed of different structural models work?

Taking the Shangzhuang Basin as the study area and the Beitang landscape as the research object and using research methods such as spatial analysis in the Geographic Information Systems (GIS) and landscape ecology, the research is carried out from the following aspects:

(1) Study the spatial distribution and landscape characteristics of Beitang landscapes in hilly and mountainous regions and summarize the structural models of different types of Beitang landscapes.
(2) Take a small watershed in the Shangzhuang Basin as an example to quantitatively analyze the characteristics and structural patterns of the Beitang landscape in the study area.

The main motivation is to identify spatial characteristics and influence indicators for the Beitang landscape in the Shangzhuang Basin. The novelty of this study is that it generates the first-hand Beitang landscape dataset and performs spatial analytics between the natural environment development and human activities. The contribution of this study is using quantitative methods to show the Beitang characteristics.

In this paper, we propose an exploratory spatial analysis of the Beitang landscape. This paper is organized as follows: Section 2 introduces the related work, Section 3 shows the research dataset and methods, Section 4 describes the results, and the last sections are the discussion and the conclusion.

2. Related Work

Since the 20th century, the number of ponds in the agricultural landscape of Western Europe has begun to decline, and the land has gradually been used for residential and industrial development [24]. Similar trends have also been found in Japan, Brazil, North

America, and other places. With the drastic reduction in ponds, the habitats around the ponds are also disappearing, and European countries' attention to ponds stems from this. Different countries have established reservoir protection organizations and carried out related research. For example, the UK established a non-governmental organization, Pond Conservation, in 1986, which is responsible for the protection of ponds and freshwater ecological environment [25]. The organization initiated the National Pond Survey (NPS) in 1989 in order to provide essential data on ponds' biology, physics, and chemistry. The European Pond Conservation Network has also held Pond Workshops every two years since 2004 [25].

The size, spatial structure, and history of ponds and surrounding land use have been investigated [2,26]. For example, the decline in the number of ponds in Cheshire, North West England between 1870 and 1986 resulted in a reduction in the density and landscape connectivity of ponds throughout the county [27]; changes in the network connectivity of farm ponds in the suburban landscape [28]; and the essential cultural and biodiversity value of the ponds in the southeastern part of Northumberland, UK in the process of regional change [29]. A few scholars have studied the protective effect of the Beitang landscape on linear eroded slopes [30] and the influence of small ponds on the chemical characteristics of rivers [31].

Research on the network of ponds in hilly areas is concentrated in Southeast Asia. The ponds in Sri Lanka are called tanks, and the Tank Cascade System resembles the cascade irrigation system in ancient China. Some scholars have studied the network of irrigation ponds in Sri Lanka from an ecological perspective [32]. From the perspective of landscape urbanism, the scholars have analyzed how Sri Lanka's local pond network system organizes the distribution of settlements, human use, and the process of urbanization, and pointed out the productive, religious, and engineering nature of the pond system (controlling floods and droughts) and the urbanization process hand in hand [33]. For the Hassan District, Karnataka, India (Hassan District, Karnataka, India), the watershed development based on the farm–pond network was evaluated and it was pointed out that the network provides drinking water and agricultural water but also promotes orchards development. The development of agriculture and forestry has increased agricultural production and provided local employment opportunities [34]. Blayac T et al. used the method of landscape perception to study the evaluation of the ecological service value of pond fish culture by four groups of people (fishers, economic stakeholders, pond users, and pond villagers). They found that the value perception varies with the types of people. The influence of education level is relatively essential [35]. Studies have also focused on the ecological–social transformation of urban wetlands in Colombo, Sri Lanka since the colonial period and pointed out that the urbanization of watersheds and the transformation of ecosystem utilization have become the main reasons for the transformation of wetlands (hydrology–soil–vegetation relationship) [36].

Overall, the developed countries in Europe and the United States have paid attention to ponds when the urbanization process was completed and suburbanization was prevalent. Attention to ponds and farming ponds since the 20th century was a topic that began after urbanization was completed. During this period, Europe and the United States paid more attention to environmental protection and further improved the ecosystem service functions of natural resources through scientific research and practice.

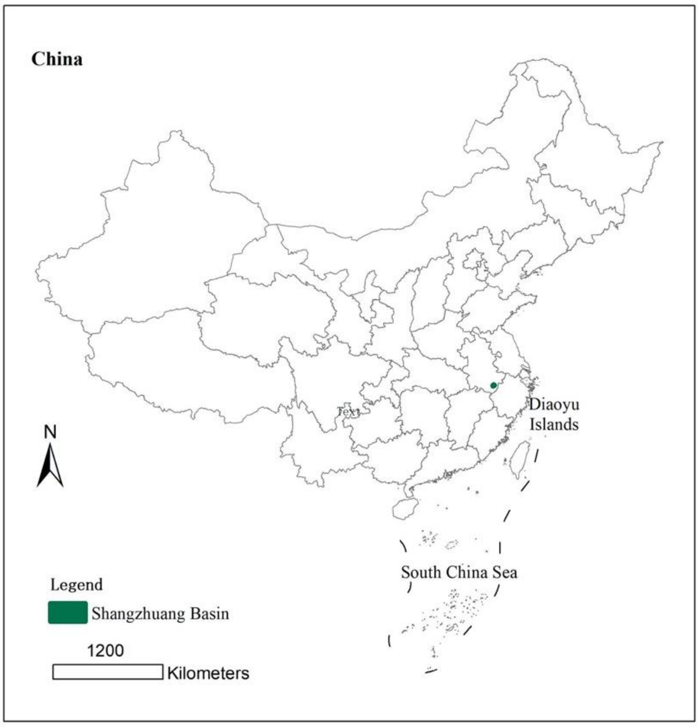
The initial research on ponds was mostly to monitor ponds' physical, chemical, and biological characteristics and to evaluate pond ecosystems. The importance of landscape heterogeneity of pond networks and pond types has been emphasized for pond protection [37,38], as well as the importance of socio-ecological values [39]. The focus shifted from individual monitoring and protection to building a network for overall monitoring and protection, from individual functions to functions in changing landscapes and socio-economic development.

Understanding the relationship between natural indicators and the watershed basin is essential [40]. The GIS-based methods characterized the descriptive parameters of a hydrographic basin [41]. Most qualitative and quantitative studies on ponds focus on the macro characteristics, morphology, features, and measurement [1]. Spatial analysis to discover multiple factors between natural and human environments should be considered for extensive research. Our study will conduct research to identify spatial characteristics and influence indicators for the Beitang landscape in the Shangzhuang Basin.

3. Materials and Methods

3.1. Study Area

The study area is located in Jixi County, Xuancheng City, Anhui Province, China and a small watershed of Shangzhuang Basin (Figure 1). It is bounded by Shangzhuang Town and some areas of Chang'an Town.



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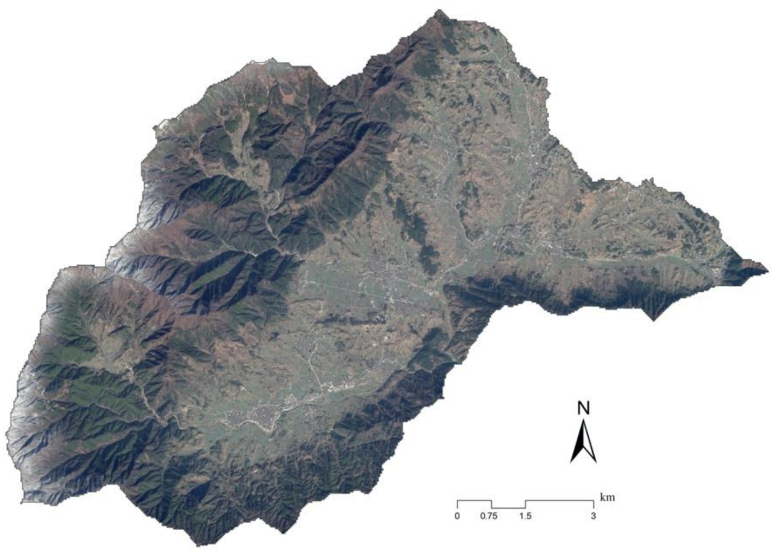


(**b**)

Figure 1. The study area. (**a**) The study area location; (**b**) Shangzhuang Basin.

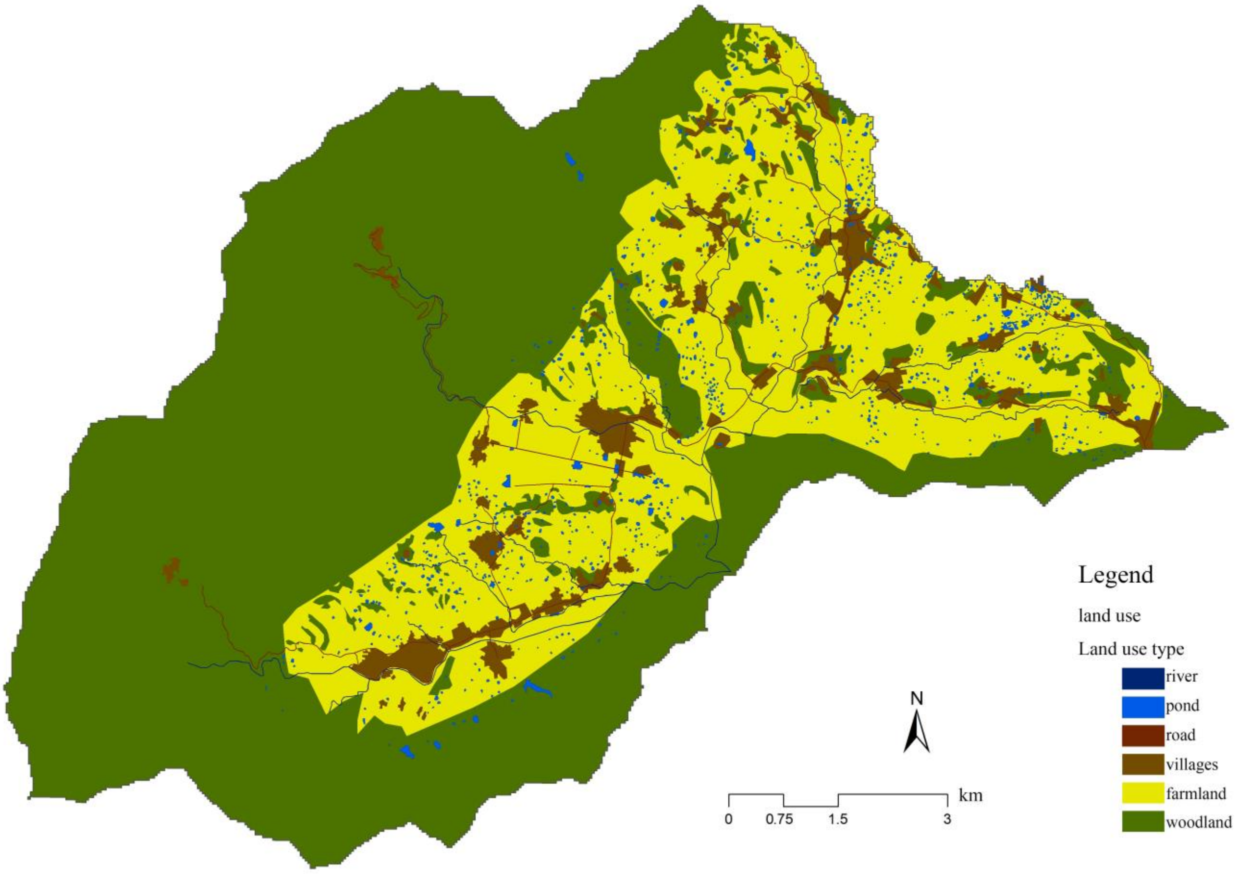
There are several reasons for choosing the Shangzhuang Basin as our study area. First, the intermountain basin is a typical geographical structure of the Jixi County, and the small watershed of the basin is a relatively independent geographical subunit. Second, there are multiple Beitang landscapes in a small basin watershed, and the vast majority of the population in the Huizhou area is concentrated in the small watershed of the basin. Third, this area is a relatively typical small watershed of basin. Fourth, the study area is dominated by traditional agricultural production, and the Beitang landscape is well preserved.

This study used multi-source data such as remote sensing images, Beitang vector dataset, land-use dataset, elevation, slope, river, road, and field survey, to investigate the spatial distribution and influencing factors of Beitang landscape in Shangzhuang Basin. We used Google Earth remote sensing images in February 2019 referred to ENVI 5.0 supervision classification to interpret the land use types in the study area manually. As shown in Figure 2a, the land-use types are divided into six categories: rivers, ponds, roads, villages, farmland, and woodland, with a total area of 100.6 km^2, of which woodland and farmland have the most proportion. The ArcMap 10.3 was used to create a first-hand Beitang dataset in Shangzhuang Basin and conduct spatial analysis. We used an on-the-spot investigation and field survey dataset—the coverage of the survey dataset in the whole study area is 80%.

In the small watershed area of the Shangzhuang Basin, the water systems are all formed within this area, which belongs to the upper reaches of the Changxi River. Only the area near the village on the mainstream of the Changxi River will intercept the vast water surface through the weir, and the rivers in the remaining sections exist in the mode of small streams with a width of less than 3 m. In order to coordinate the irrigation of farmland, the stream at the end of the runoff often exists ditches, combined with the ridge trails, which are full of twists around the field. Figure 2b shows the distribution of rivers based on manual interpretation of remote sensing images.

With the Soil and Water Assessment Tool (SWAT) model and a 30-m DEM map, the small watershed of Shangzhuang Basin is divided into eight sub-basins, and five levels of surface runoff are simulated simultaneously. The basin watershed division and surface runoff are simulated according to the DEM map, consisting of current runoff, but there are still some discrepancies. The main reason is that while building terraced fields, there are many artificial diversions of the current runoff; the simulated runoff is the original that is completely simulated based on natural topography, reflecting the original state.

As shown in Figure 3, the runoff in the small watershed of the Shangzhuang Basin, a fan-shaped radial pattern, is distributed based on the mouth of the southeast valley. Comparatively speaking, the sub-basins 1, 3, 5, 7, and 8 are in the upper reaches of the small area of the basin, sub-basins 2, 4, and 6 are located in the lower reaches, and sub-basins 1, 3 are located in the mountainous area.



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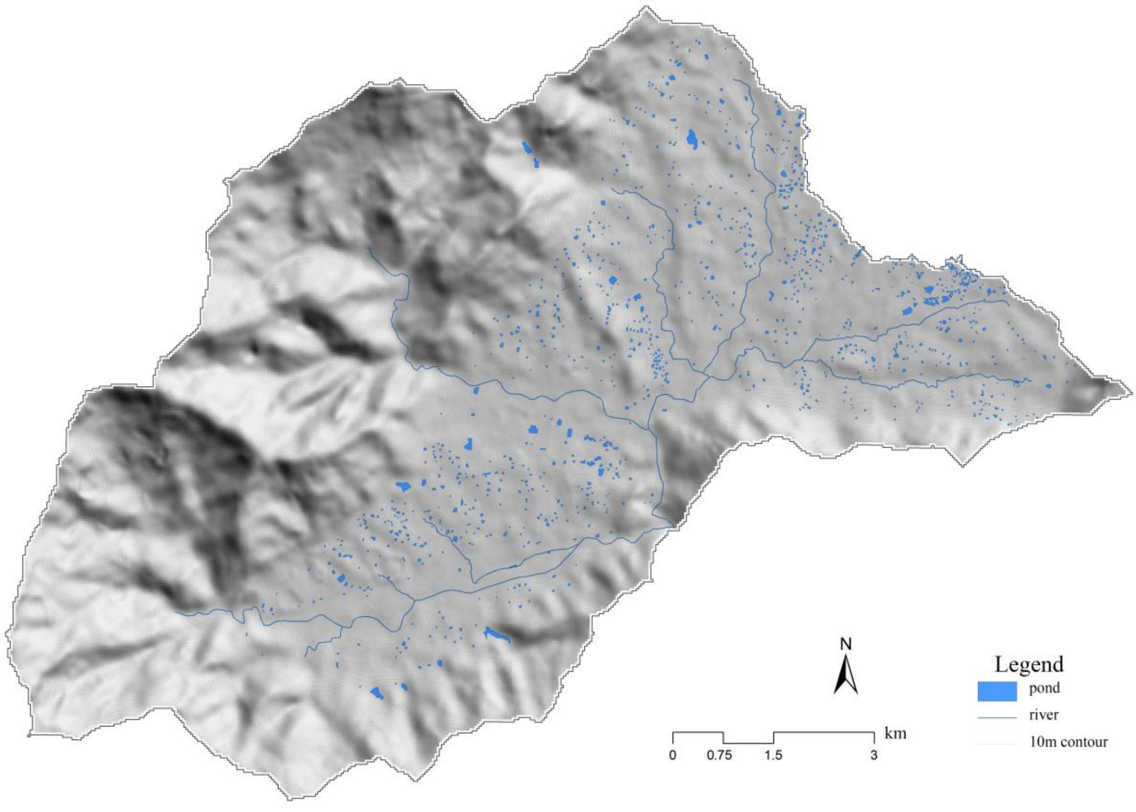

(**b**)

Figure 2. (**a**) Land-use dataset; (**b**) The river dataset.

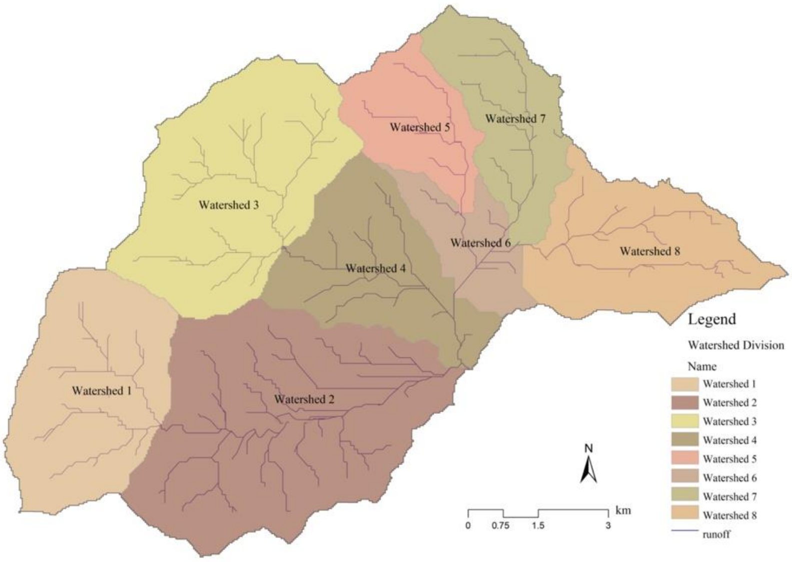

Figure 3. The small watershed of the Shangzhuang Basin.

We summarize the landscape pattern in Huizhou area as four types: source model, upstream, midstream, and downstream model (Figure 4).

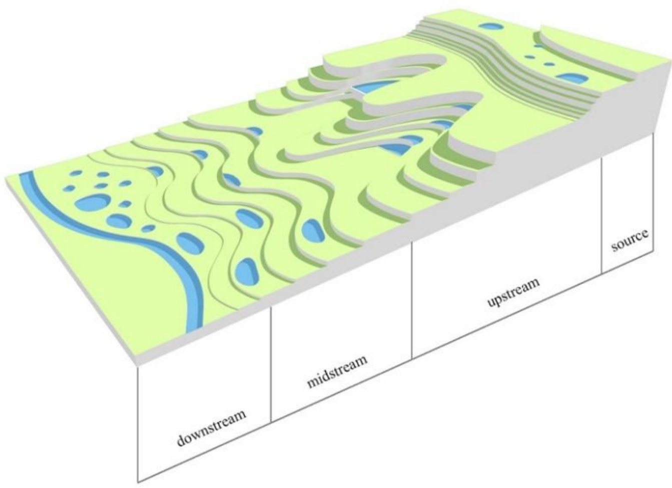

Figure 4. The landscape pattern in Huizhou.

3.2. Methods

3.2.1. Average Nearest Neighbor Index

We use the Average Nearest Neighbor index (ANN) to determine whether the spatial distribution of Beitang sites is a random occurrence or a clustering effect. We compare the average distance between the center of a Beitang site and its nearest neighboring Beitang to the expected average distance for a hypothesized random distribution and calculate the ratio of the two, which is its average nearest neighbor index R_n. It can be defined as the following equation:

$$R_n = \frac{\overline{D}_O}{\overline{D}_E} = \frac{2\sqrt{n/A}}{n} \sum_{i=1}^{n} d_i \tag{1}$$

where $\overline{D}_O$ is the average distance between the Beitang and its nearest neighboring Beitang; $\overline{D}_E$ is the average distance in the condition of a random distribution of Beitang locations. d_i is the distance between Beitang site i to its nearest neighboring Beitang; n is the number of

Beitang, and A is the area of the entire study area. If $R_n < 1$, then the distribution of the Beitang tends to be clustered; if $R_n > 1$, the distribution of the Beitang tends to be dispersed.

3.2.2. Kernel Density Estimation

The Kernel Density Estimation (KDE) is a method for estimating the density of point or line grids that use a moving cell [42]. For observation $x_1, x_2, \ldots, x_n$, the kernel density can be estimated by the following formulation:

$$\hat{f}_h(x) = \frac{1}{nh} \sum_{i=1}^{n} K\left(\frac{x - x_i}{h}\right) \quad (2)$$

where x_i is the coordinate of point i $(i = 1, 2, \ldots, n)$; n is the number of points; h is called the bandwidth of kernel density; the kernel function K is a weight function. Its form and value domain control the number of data points that will be utilized to estimate the value of $\hat{f}_h(x)$ at the point x. Intuitively, the benefit of kernel density estimation is determined by the choice of kernel function and bandwidth h [43]. In this study, we compute the kernel density of the Beitang landscape in a watershed basin and find the clustering areas in spatial distribution to determine their spatial pattern.

3.2.3. GeoDetector

GeoDetector is a set of statistical tools to identify spatial heterogeneity and help understand the mechanisms [44,45]. Its factor detection tools can be used to examine the influence of natural and human factors on the distribution of Beitang landscape. The technique of factor detection is used to investigate the extent to which factor X explains the spatial heterogeneity of an attribute Y. It is defined as the q-value and can be calculated as follows:

$$q = 1 - \frac{\sum_{h=1}^{L} N_h \sigma_h^2}{N\sigma^2} = 1 - \frac{SSW}{SST} \quad (3)$$

where $h = 1, \ldots, L$ is the strata of variable Y or factor X; N_h and N represent the number of units in the strata h and the whole study area, respectively; σ_h^2 and σ^2 represent the variance of variable Y and the overall area, respectively; SSW and SST denote the sum of variance within strata and the total variance of the overall region, respectively. The value domain of q is [0, 1], and the greater value of q, the more consistent the spatial distribution of X and Y is, and the stronger the explanation of the independent variable X on attribute Y is. In contrast, the smaller the value of q, the more inconsistent the spatial distribution of X and Y is and the weaker the explanation.

4. Results

4.1. Spatial Distribution Characteristics

The number of Beitang in the small watershed of Shangzhuang Basin is 1179, and there are about 12 Beitangs per square kilometer. The total area of Beitang is about 96.0 hm^2 (1440 mu), which accounts for about 1.0% of the entire area (100.6 km^2). The smallest Beitang in the area, the largest area, the average area accordingly is about 40 m^2, 25,317 m^2, 814 m^2.

As shown in Figure 5. The ANN result for the Beitang in Shangzhuang Basin is clustered pattern. The observed mean distance is 84.88 m, the expected average distance is 141.1794 m. The nearest neighbor ratio equals 0.601207, the z-score is −26.251501, and the p-value equals 0.

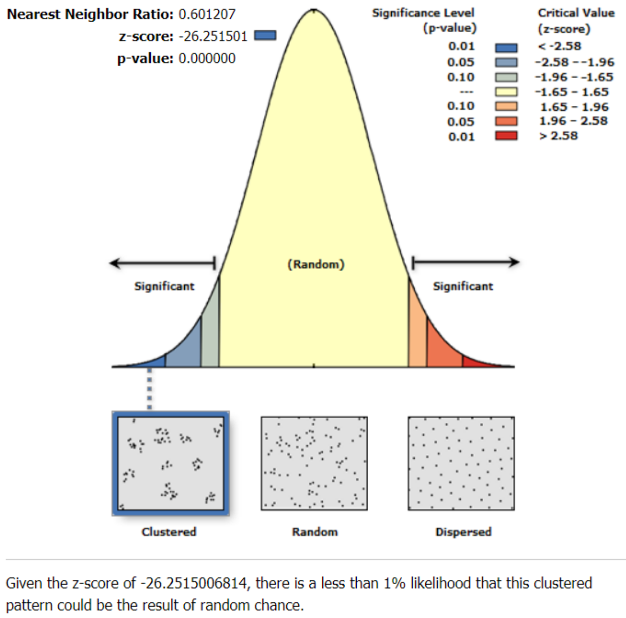

Figure 5. The ANN result for the Beitang landscape in Shangzhuang Basin.

As shown in Table 1 for the area distribution of Beitang, the majority (82%) of Beitangs smaller than 1000 m^2 was homogeneously distributed; the number of Beitangs larger than 2000 m^2 was significantly reduced with 59 in total and accounted for 5%.

Table 1. Statistical result for the area of the Beitang.

Area of the Beitang (m^2)	Number of Beitangs
<1000	972
1000–2000	148
2000–5000	39
5000–10,000	13
>10,000	7

As shown in Figure 6, the kernel density map of Beitang has apparent aggregation, which is affected by certain factors. The influence of factors is not random. The two sub-basins in the northwest have no Beitang distribution, while the two sub-basins in the northeast are concentrated.

4.2. Influencing Factors

4.2.1. Elevation, Slope, and Aspect

(1) Elevation

Figure 7 shows the elevation of the study area.

The number and area distribution proportion of the Beitangs within an altitude of 276–300 m accounts for 33/km^2 and 2.4%, respectively, which are much higher than the average of 12/km^2 and 1.0%. In total, about half of the Beitangs are distributed in this elevation. This area is the most widely distributed (18.4%) in the agricultural area, in which the terraces and slopes adjacent to the periphery of the valley depressions in the basin.

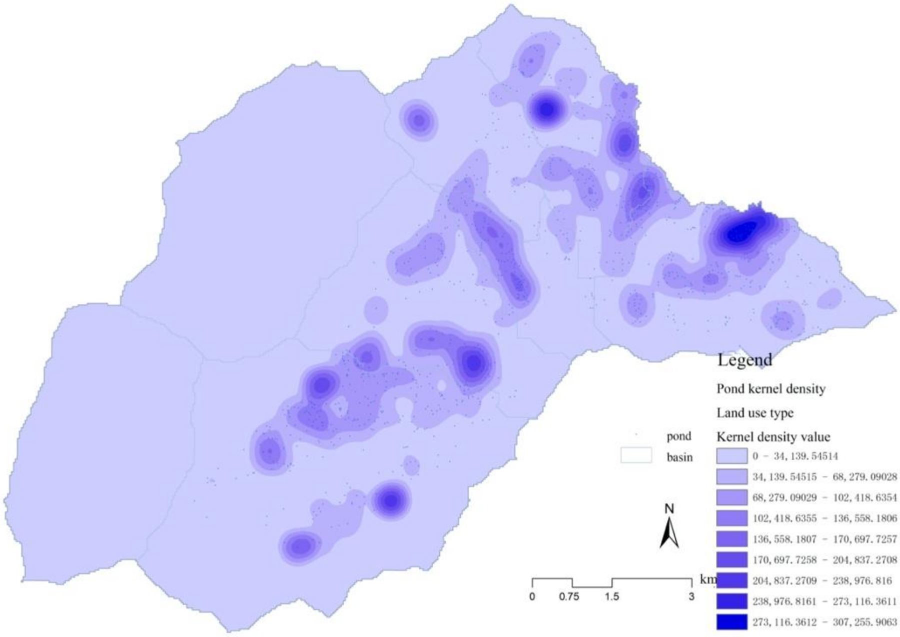

Figure 6. The density map for the Beitang landscape.

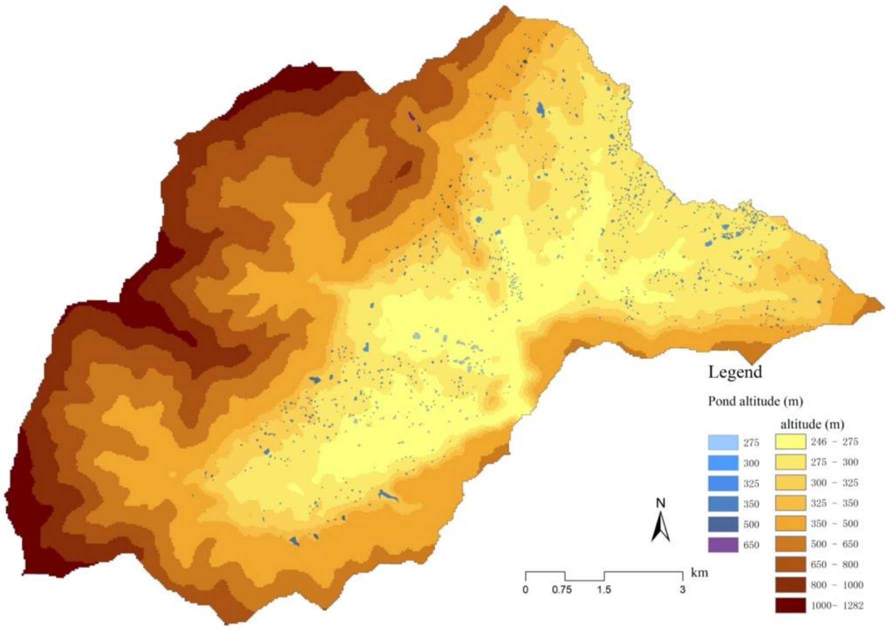

Figure 7. The altitude of the Beitang landscape.

The number and area distribution proportion of Beitangs in other areas at 350 m is relatively even, accounting for 17/km^2 and 1.5% or more, respectively, higher than the average of 12/km^2 and 1.0%. This area is the primary human activity and farming area. The area and distribution value of Beitang can better reflect the distribution level of the farming area. However, due to the existence of large mountain forests in the entire area, the proportion of the distribution of Beitang is diluted. This value mainly reflects the average level of the whole region and is even representative of the Huizhou area.

The average area of Beitang within an altitude of 326–350 m is 1134 km^2, which is higher than the average of 814 km^2. This area is the intersection between the piedmont slope and the shallow mountain area. Beitangs in this area are primarily micro-mountain ponds with dams, so the average area is relatively large. The average area of Beitang is within an altitude of 351–500 m is 673 km^2, which is less than the average of 814 km^2. This area is a shallow mountainous area. Beitangs are mostly located in mountain valleys, and the topography is narrow. Therefore, the area of Beitangs is small, with no great difference. There are only two Beitangs above 500 m, both of which are surrounded by mountains.

(2) Slope

According to the grading method of the cultivated land slope, the area is divided into five grades of $\leq 2°$, 2–6°, 6–15°, 15–25°, >25° (upper and lower excluding), among which the slope is $\leq 2°$ is regarded as flat ground (Figure 8).

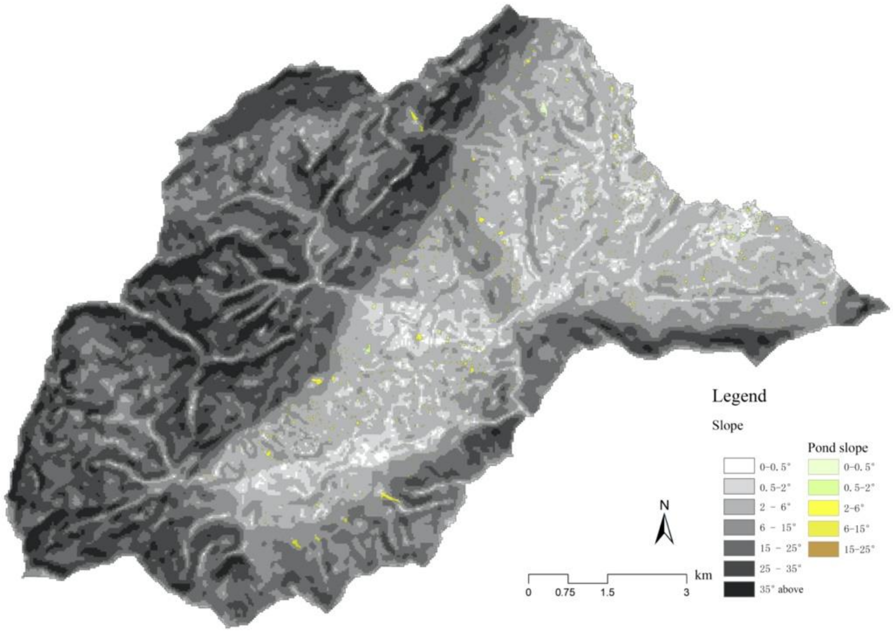

Figure 8. The slope for the Beitang landscape.

Overall, the lower the slope, the more numbers and area of Beitang. This regular has two related aspects. One is related elevation, where the slope is low at low altitude, and the distribution density of Beitang is high; the other is that Beitang is more likely to be distributed in the valleys and low-lying areas of hills and mountains.

There are 23 Beitangs in total within 15–25°, the number and area of which are only 1 per km^2 and account for 0.1%, respectively. The average Beitang area is 452 km^2, and the standard deviation is 207, far lower than the average value. It shows that the area with a large slope is not suitable for the construction of Beitang but only for small ponds.

(3) Aspect

The aspect of the study area is shown in Figure 9.

Although the area of the flat area is small, the area accounts for only 0.4%, but the number and area of Beitang are 43/km^2 and 2.7%, respectively, which are much higher than the average. The average area of Beitang is 478 km^2, and the largest Beitang is also only 933 km^2, with a standard deviation of 206. It shows that the area with no obvious slope direction (the slope is close to zero) is densely distributed, and most of them are small-sized ponds, which is also consistent with the slope analysis.

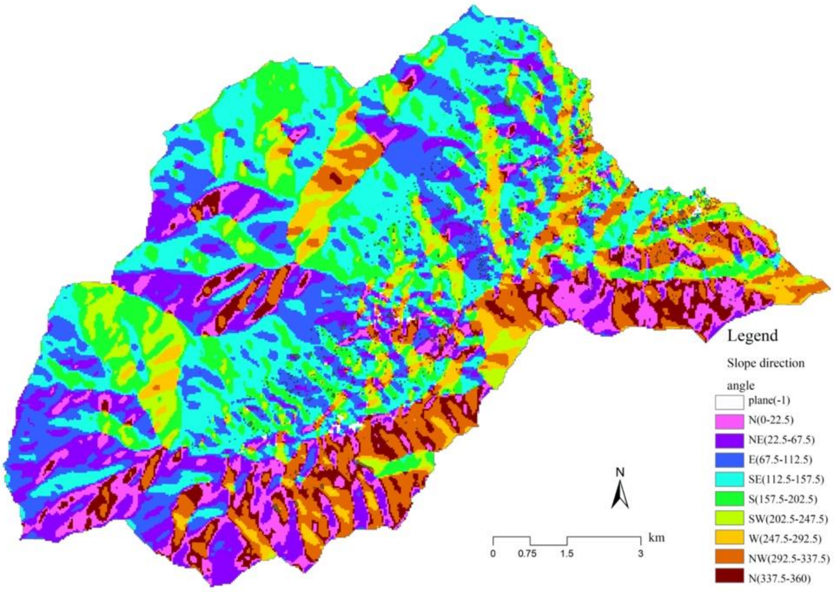

Figure 9. The aspect of the Shangzhuang Basin.

The number and area of Beitang in the north and northeast slopes are lower than the average. It shows that the possibility of choosing a site for Beitang on the northern slope is low. The main reason may be that the northern slope has less sunlight, which is not suitable for farming, and there are fewer Beitangs.

The number and area of Beitang in the east and west slopes are slightly higher than the average.

4.2.2. Rivers, Watersheds, and Runoff

(1) Rivers

Figure 10 shows the river buffer dataset.

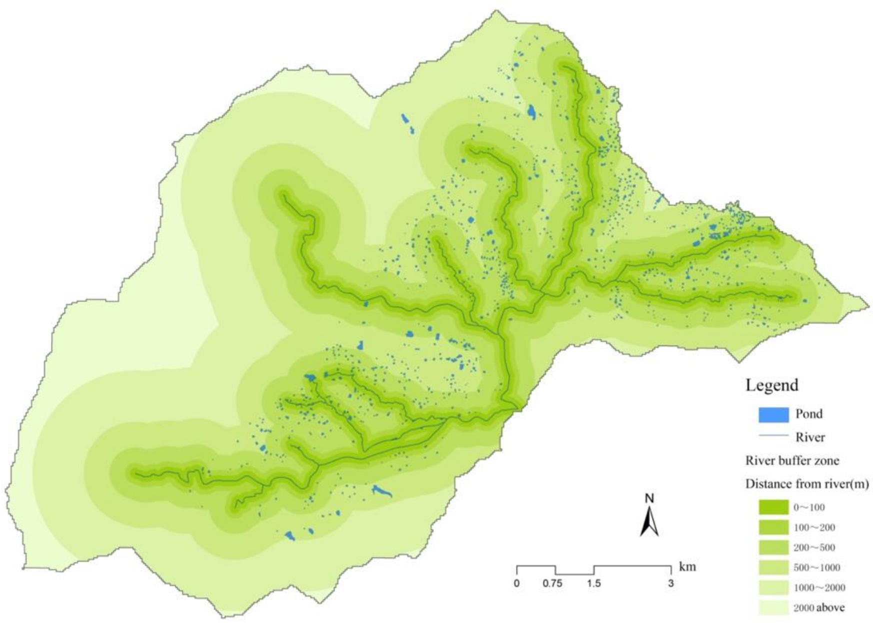

Figure 10. The river buffer dataset.

The number and area of Beitang within 200–500 m are 24/km^2 and 1.8%, respectively, both of which are the highest values. According to the trend, it is estimated that the area with the highest distribution density of Beitang is about 250–350 m from the river.

The number of Beitangs within 0–100 m is 12 per km^2, which is an average level, but the area accounts for only 0.7%, which is lower than the average level of 1%. The average Beitang area is still at an average level of 830 km^2. Some Beitangs are only within 100 m from the river at the edge, and most areas are more than 100 m away from the river. Based on the above analysis, it can be concluded that the distribution density of Beitangs in areas too close to the river is relatively low.

There are only 32 Beitangs above 1000 m, with an average of less than 1 per square kilometer. It shows that most of the Beitangs are located within 1000 m of the river.

(2) Watersheds

Figure 11 shows the watersheds dataset.

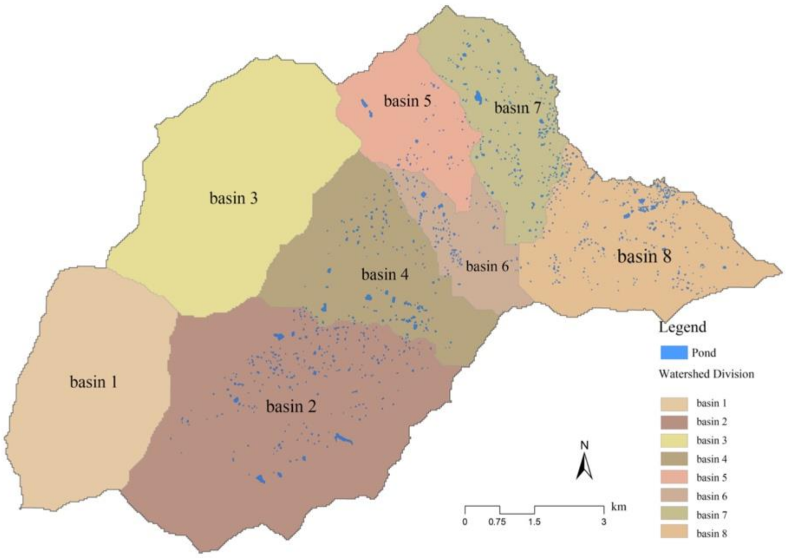

Figure 11. The watersheds result for the Shangzhuang Basin.

There are no Beitangs in basins 1 and 3. These two sub-watersheds are in the upper reaches of the small watersheds of the entire basin. Most of them are mountainous and forests. Only a few villages are located in the valleys, and a small amount of farmland has been reclaimed around the villages. There are no Beitangs in these two sub-basins. On the one hand, the terrain is steep, and it is challenging to build Beitang; on the other hand, it is sparsely populated, and the demand for water storage is small.

The number and area ratio of Ponds in basins 7 and 8 is 48/km^2, 4.1% and 42/km^2, 2.8%, which are much higher than the average. There are three reasons. First, the sub-basin is free of mountains, the terrain is relatively flat, suitable for farming, and the demand for water storage in Beitang is excellent. Second, there are many depressions in the sub-basin, which tend to form Beitang naturally; third, the end of the sub-basin. The mountain's more miniature woodland requires rainwater and flood regulation to conserve water sources. The distribution of Beitang in the remaining sub-watersheds is relatively even.

(3) Runoff

Figure 12 shows the runoff in the study area.

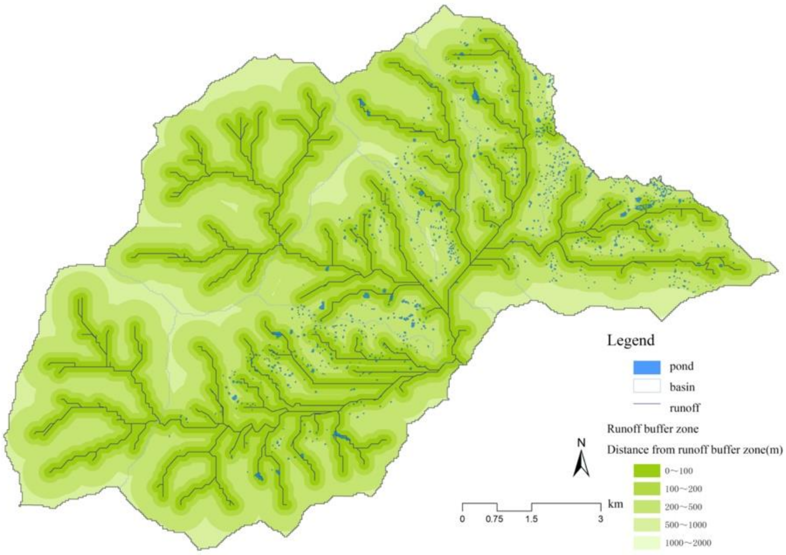

Figure 12. The runoff result for the Beitang landscape.

Compared with actual rivers, simulated runoff can reflect potential surface runoff, the distribution of terminal without channelization, and water catchment trends, which are also useful for reference.

The distribution trends in Beitang are similar to that of rivers, except that the peak interval is advanced from 200–500 m to 100–200 m. This is the main reason the simulated runoff density is higher than that of the current river. According to the analysis of neighbors, the average distance between Beitang and the river is 410 m. The average distance to runoff is only 229 m.

The density of Beitang within 0–100 m is lower than that within 100–200 m, or even less than that within 200–500 m, indicating that the density of Beitang distribution is not higher as it is closer to the runoff. This is because the areas close to the runoff often have stable surface runoff and do not need to store water in Beitang. Second, because the area approaching runoff is low-lying, the potential energy is lower in stored Beitang, and the gravity irrigation area is smaller.

The density of Beitang above 500 m has dropped significantly. The number and area of Beitang are only 1 per km^2 and 0.1%, respectively, indicating that source areas such as mountain tops and hills are not suitable or need to be built Beitang.

As shown in Figure 13, there are often ponds at the end of the first-level runoff. These ponds are generally mountain ponds with dams, and these ponds are in the best location for source management. Overall, the Beitangs are more inclined to be distributed in the vicinity of the 1, 2 and 3 levels of runoff, while the 4 and 5 levels of runoff are scattered on both sides of the Beitang.

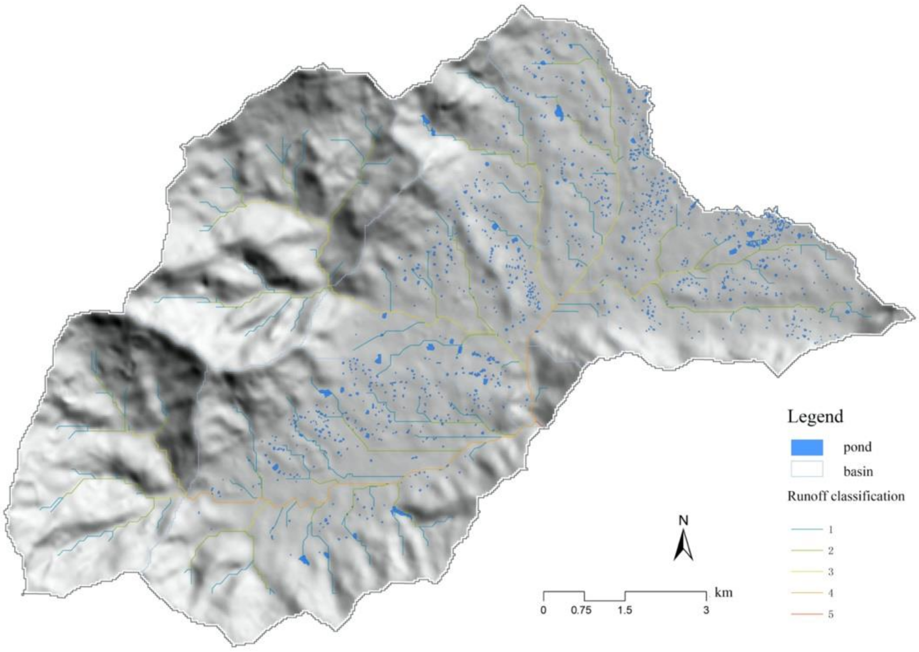

Figure 13. The runoff classification result for the Beitang landscape.

4.2.3. Roads and Villages

(1) Roads

Figure 14 shows the road buffer in the study area.

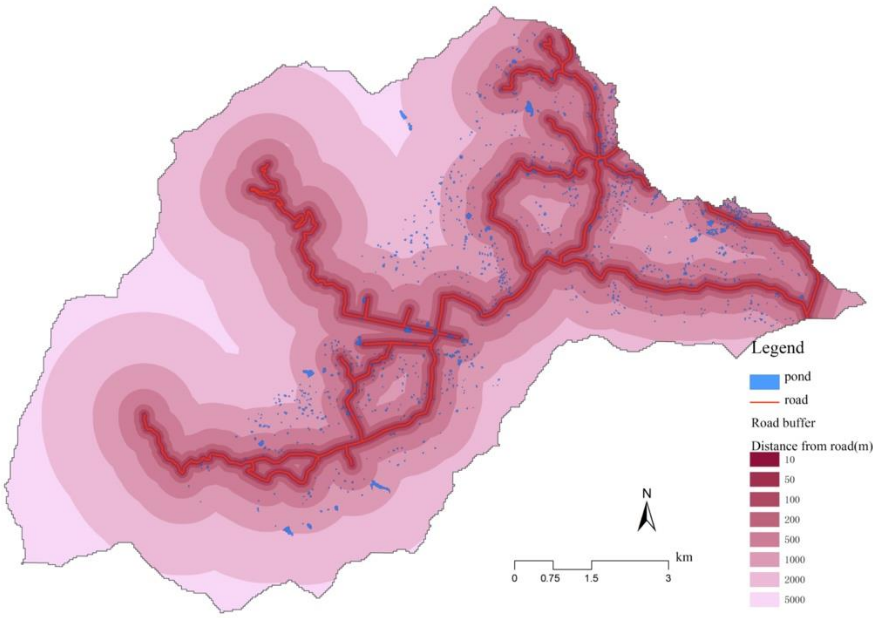

Figure 14. The road buffer result.

The number of Beitangs within 10 m accounted for 33/km^2, while the area of Beitangs accounted for only 0.6%. This is caused by the statistical method. The proportion of the number of Beitang refers to the area covering 0–10 m and the proportion of the area of the Beitang within 0–10 m. There is no contradiction but a more meaningful area proportion here. It shows that the construction of roads (vehicle roads) is generally selected far away from Beitang.

The distribution of Beitang within 10–500 m is relatively even, and there is no apparent relationship.

The distribution density of Beitang above 500 m is significantly reduced.

(2) Villages

Figure 15 shows the distance from villages.

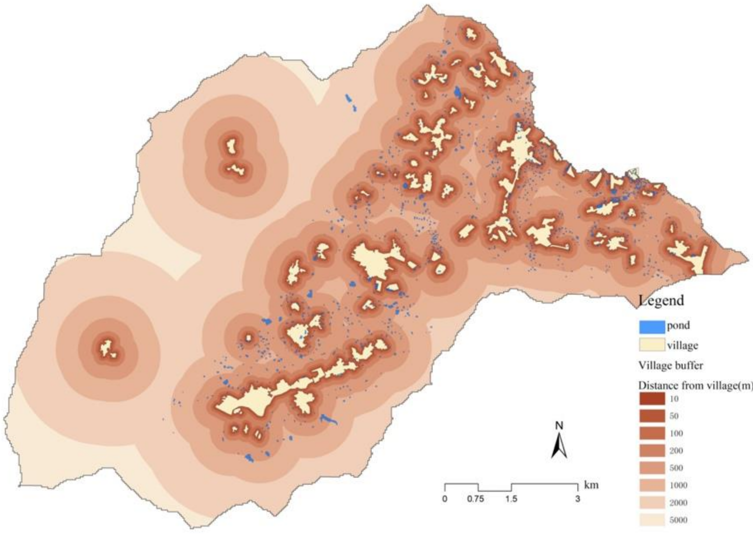

Figure 15. The distance from villages.

The area within 10 m accounts for 5.7%. Considering the accuracy of remote sensing interpretation and the blurring of the village boundary, the study area is the scope of the village land, and it can be regarded as an impervious area. The Beitang within this range can also be regarded as Beitang in the village. The area of Beitang in this range accounts for 1.0%, which is the same as the average value in the entire region.

The proportion of the number and area of Beitang within 10–100 m is much higher than the average. After 100 m, the density of Beitang continues to decrease. After 500 m, it drops sharply, and after 1000 m, it is almost zero. It shows that Beitang tends to be distributed in the area closer to the village, and the activity radius of 500 m is an area that is easier for farmers to reach.

4.2.4. Farmland and Woodland

(1) Farmland

Figure 16 shows the farmland in the study area.

The remote sensing interpretation shows that the total farmland area is 3108.9 km^2, accounting for 30.9% of the total area (100.6 km^2). The total area of Beitang within the farmland area is 77.6 km^2, accounting for 80.8% of the total area of Beitang (96.0 km^2). It shows that the farmland in the Shangzhuang Basin accounts for about 30%, and the Beitang located in the farmland accounts for about 80%.

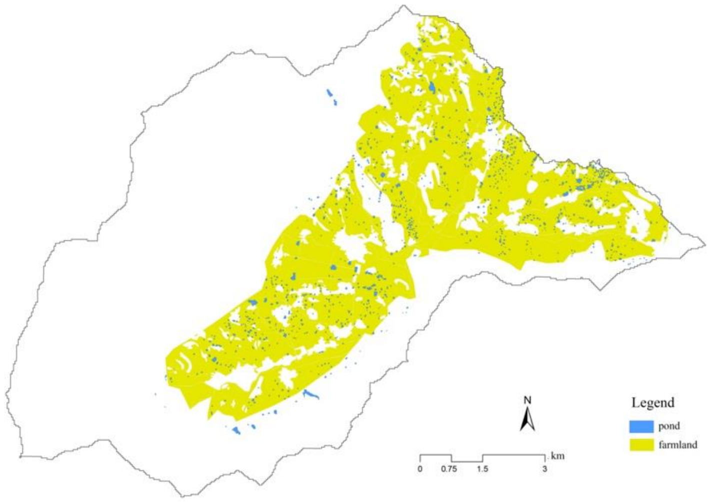

Figure 16. The farmland dataset.

The area of the pond in the farmland accounts for 2.5%, that is, the ratio of the pond to the field is 1:39, which is lower than the ratio of 1:10 to 1:20 proposed by some scholars, and it is far lower than the area of ponds proposed that the ratio of 1:4 to the irrigated area by the ancients. There are three main reasons. First is that the above proportion refers to the pure irrigation proportion of Beitang rice fields, but there are various types of farmlands in this area, not only rice fields. Second, the above proportion refers to the proportion of in-situ water storage irrigation in Beitang. In this area, many farmlands are irrigated by mountain ponds, which are not included in the scope of farmland. Third, the area uses another way to irrigate the farmland through the canal network from the main river, which reduces the demand for Beitang.

(2) Woodland

Figure 17 shows woodland buffer.

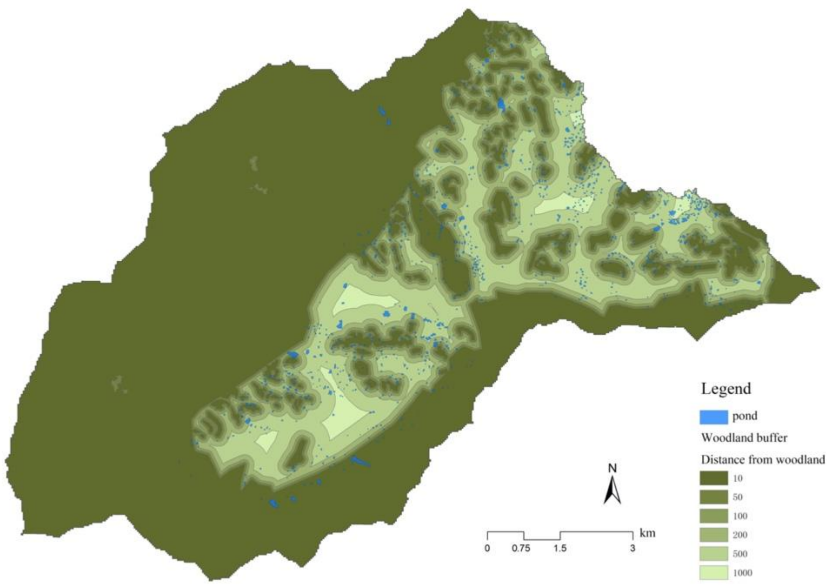

Figure 17. The woodland buffer.

The number and area of Beitang in the area within 10 m are $3/m^2$ and 0.2%, respectively, which are far below the average level, indicating that the density of Beitang in the woodland is low.

The proportion of Beitangs in the range of 10–50 m is 24/km^2, which is less than the proportion of Beitangs in all areas above 50 m; the proportion is as high as 2.9%, which is larger than the proportion of Beitangs in all areas above 50 m. The average area of Beitang in this range is as high as 1002 km^2. This is mainly because this area can be considered close to forest land. On the one hand, water conservation forests tend to be distributed around Beitang, and on the other hand, mountain ponds are mostly distributed in valleys close to forest land.

The proportion of the number and area of the Beitang within a range of 50 m is relatively balanced, indicating that after a certain distance, the correlation between the distribution density of the woodland and the Beitang is very small, and the location of the Beitang is not affected by the distance to the woodland.

4.3. Landscape Pattern

Based on the spatial analysis of remote sensing images and elevation maps, combined with the actual situation obtained from the field survey, the 1179 Beitangs in the area are divided into three modes: upstream mode, midstream mode, and downstream mode (Figure 18).

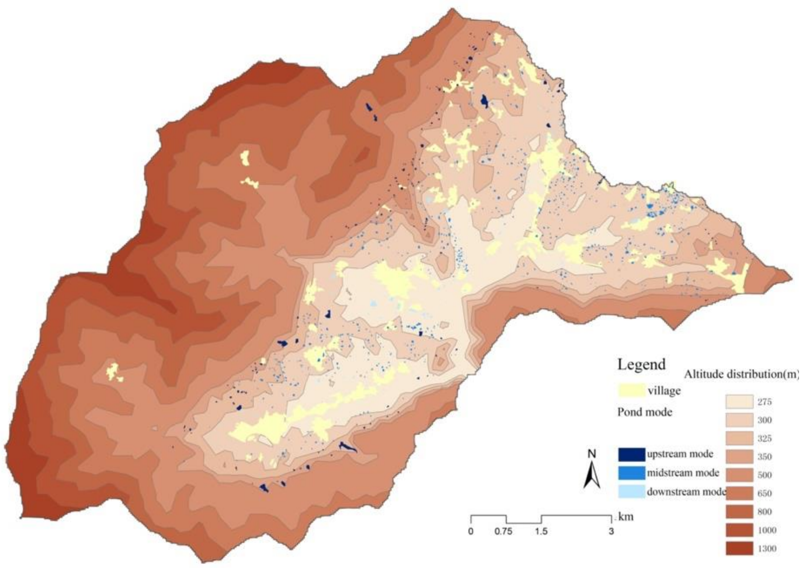

Figure 18. The landscape pattern.

There is no settlement in the top area of the mountain in the small watersheds of the basin, so there is no source pattern in this area.

The upstream mode is mainly distributed on the edge of the shallow mountainous area of the basin, with an altitude of about 500 m. The specific structural model is mainly the mountain surrounding pond model, and the shaping pond model and the valley gully model are supplemented. As the "first pass," the high mountain surrounding the basin, the collection of runoff serves as a guarantee for agricultural water use in the entire basin, as well as the first guarantee for the retention of floodwater.

The midstream mode is mainly distributed in the slope area with an altitude of about 350 m. the gullies and terraces are the main models and the edge of the basin. The undulating hills in the basin are mainly the gentle slope terraces. The water from the mountain pond flows into the terraces and the ponds through the ditches.

The downstream mode is mainly distributed in the flat area within 300 m above sea level. In the river valley village model, the farmland of the villages is distributed along the river. On the one hand, it continues to receive water from mountain ponds, and on the other hand, weirs are set up on the river to divert water through the channel network to meet a large amount of water demand. In the flat area of the basin, there is also a plain canal network model, which is responsible for the irrigation of plain paddy fields.

All the above three modes cooperate to form a basin system that supports the Beitang landscape system of the entire basin.

5. Discussions

GeoDetector was used to examine the influence of natural and human factors on the distribution of BeiTang landscape. The GeoDetector was used to determine the *X*-axis according to altitude, slope, aspect, distance from rivers, and distance from roads, villages and farmland. Discretization is performed, and single-factor detection is performed separately. The degree of determination of the kernel density distribution of Beitangs by each influencing factor was calculated in descending order: altitude > distance from farmland > distance from rivers > distance from roads > distance from villages > slope > aspect, and the p-values of each influencing factor passed the 0.01 level—significance test (Table 2).

Table 2. Single-factor detection results of influence factors.

Factors	Aspect	Slope	Distance from Villages	Distance from Roads	Distance from Rivers	Distance of Farmland	Altitude
q value	0.0532	0.0839	0.1914	0.2189	0.2763	0.3105	0.3657
p value	0	0	0	0	0	0	0

The small watershed area of the Shangzhuang Basin has a long history and numerous celebrities. It is one of the birthplaces of Huizhou culture. It has a close relationship with the development of local agriculture. The rural natural water system with Beitang plays the main guarantee role for the development of agriculture. The drought and flood adaptability of the Beitang landscape in this area can be summarized as the following three points:

(1) Open up paddy field in the lowland of hilly country, reserve space for flood discharge

Open up paddy field in the lowland of the hilly country along the mountain recesses and layout along with the runoff at the end, reserve space for flood discharge. The soil on the hillside is eroded by rain, and the scoured sediment is deposited in the depression to form a soil siltation area. The geomorphological process of the upward erosion and lower deposition forms paddy soil with rich soil nutrients and better water retention performance in the gully deposition. Because the piedmont valley receives much rainwater from the surface of the highlands, this area is prone to waterlog and is seriously troubled by drainage problems. Fortunately, the positive impact formed by the natural process is used to cultivate the paddy field, and sufficient space is reserved for flood discharge and to prevent the settlements on the hillside and the top of the hill from the hazards of mountain floods. Layers of ridges are mostly earthy dams, which retain rainwater and mitigate flood peaks. The planting of rice increased the roughness of the ground and played a role in delaying flood peaks.

(2) Maximize the rain-collecting area and make rain and floodwater resources

The Beitang system makes full use of the mountainous terrain to maximize the rainwater collection irrigated area. The system can be built in the upper, middle, and lower reaches. The top ponds are built to collect rainwater for agricultural irrigation. Ponds are built in key locations in the middle and lower reaches to alleviate the harm of drought and floods to the downstream farmland. The Beitang system is a critical flood drainage system in mountainous rural areas and a decentralized source water storage management system. The valley is in the lowland, which can take full advantage of the terrain for gravity irrigation and solve the problem of irrigation power. In the case of mountainous land resources being in short supply, opening up fields in nature valleys is an effective way to conform to nature and efficiently use water and soil resources.

(3) Select high places for settlement layout to avoid flood hazards

The residential sites are mostly located in the middle and upper part of the Beitang system, in areas with sunny and open terrain such as slopes and flat dams. There are many woodlands around the settlement, which can effectively conserve water and regulate the microclimate. Beitang is built in the middle of the settlement, and rainwater runoff flows along the eaves into the drainage ditch in the settlement and then flows into the Beitang in the settlement, effectively collecting rainwater, acting as a source of retention, and reducing the damage of floods.

6. Conclusions

The main objective of this work was to identify spatial characteristics and influence indicators for the Beitang landscape in Shangzhuang Basin. The Shangzhuang Basin(China) was selected as the study area to investigate the spatial distribution and factors influencing the Beitang landscape. This study used multi-source data, such as remote sensing images, Beitang vector dataset, land-use dataset, elevation, slope, river, road, and field survey. The ANN, KDE, and GeoDetecor were used to get spatial analytics. Results showed that in a typical small watershed basin, an area of ponds accounted for 1.0%, accounting for the number of 12/km^2; the average area of ponds is 814 m^2, of which the vast majority (82%) of less than 1000 m^2. The study found that the spatial distribution of Beitang in Shangzhuang Basin has cluster characteristics, influenced by elevation, slope, aspect, river, roads, villages, farmland, woodland, and other factors, all of which have a close relationship with the natural environment development and human activities. The drought and flood adaptability characteristics are mainly manifested in opening up paddy fields in the lowland of the hilly country along the mountain recesses and reserved flood drainage space, maximizing the rain collection area to recycle rainwater and floods, and choosing high places for settlements to avoid flood hazards. Findings provided a model for protecting and utilizing natural water systems in rural areas during the construction of sponge cities. The contribution of this study is to show the extensive Beitang characteristics with quantitative methods and the obtained research findings corroborate the ideas, methods, and conclusions proposed in similar studies [1,46].

There are two limitations to this study. The first limitation is that we only used a one-year dataset during the study. The second limitation is that we did use the temporal human activities dataset to perform the extensive study; historical events and human trajectories are essential to conducting research. We will use the spatial-temporal dataset to explore the spatiotemporal patterns in future research. We also will use machine learning methods to detect the Beitang landscape in a large area and conduct extensive geospatial analytics.

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