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The Relationship between the Development of Settlements and Wells on Xiaoliuqiu Island

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ABSTRACT. *Water is a critical resource required for the development of settlements, and the presence of a water source is a key factor to be considered when choosing the location of a settlement. Xiaoliuqiu Island is a coral reef island that suffers from a lack of surface water. Before the construction of water pipelines, connecting the main island of Taiwan with Xiaoliuqiu, the primary water sources on the island were collected rainwater and wells constructed to access groundwater. There are numerous wells spread across the island, providing water for residential use and cultivation. The wells are closely associated with the development of settlements on the island. For this study, a number of older residents on the island were interviewed, and literature from different time periods was reviewed to investigate settlement distribution, demographic changes, and the development of streets on the island. The resulting data were then compared with the location of wells on the island. The study aimed to analyze Xiaoliuqiu's terrain, geology, climate, and culture to assess the correlation between the distribution of wells and the development of settlements on the island. A smartphone was used to triangulate the locations of roughly 80 wells that remain on the island, as well as collect historical and current data relating to the depth, level, and quality of water in the wells. Subsequently, an overlay analysis using a geographic information system (GIS) was conducted to determine the correlation between the development of wells and the island's geological characteristics, the evolutionary correlation between wells and settlement development, and the role of wells in the development of settlement cultures. A comparison of equidistant influence diagrams indicated that a significant correlation existed between the development of settlements and well distribution on Xiaoliuqiu. The study's findings also provided insights relating to the association between the development of settlements on the island and the underlying local customs relating to each well, as well as evidence of demographic change. The results of the study all indicate that wells played a critical role in the development of settlements on Xiaoliuqiu.*

Keywords: *Surface water, wells, demographic changes, settlement development, geographic information system (GIS)*

1. Introduction

Water is fundamental for life. A review of history shows that the origins and development of human civilizations have been closely associated with the acquisition of water. Undoubtedly, water is essential in people's lives. Before the availability of running water, people settled near water sources, river banks, or springs. Settlements can be described as establishments of groups of people. Thus, research on settlements largely focuses on social relationships and organizations of human groups and on the physical locations where people reside (Guo, 1998). Settlement geography is a branch of cultural geography that studies populations, settlements, transportation, and the economy. Rogers, P.D. and Edmiston, S.M.,(2013)explores the historical background of the Gila River Indian Community and its claim to water rights, the evolution of tribal water rights laws that culminated in the historicsettlement, and the consequences of the act on water resource management in the region. Lei, Jun ,Dong, Wen and Yang,Yu,(2012)analyses the coupling characteristics and spatio-temporal variations for oasis urban development and water-land resources at the northern slopes of the Tianshan Mountains by principal component analysis and a coupling degree model. The result shows that the degree and change in regional use of water and land resources are different among the studied cities/counties during their development. The study reflects that the urban development in arid and semi-arid regions is limited by oasis areas.

Madaleno,I. M.(2007) focuses on the ecological and socio-economic aspects of water legislation in Chile. Following legislation that effectively privatised water in the desert and mountain fringes of northern Chile, local farmers that relied upon traditional methods of water management were seriously disadvantaged by legislation that allowed the allocation of scarce water resources to large mining companies. In the Tonle Sap Lake Region, Cambodia, the interconnections between migration, environment and all water resources are apparent. These interconnections have not been widely studied in Cambodia, even though the study of water related migration could yield important socioeconomic information for the development aims of the Mekong Basin, the urbanization trends, and the future problems in the poor settlements of Phnom Penh(Heinonen,2006). The challenges facing water resources world-wide stem from a multitude of factors, including the steady increase in population, urbanization, environmental degradation, and industrialization. Those challenges are compounding water shortages, and in turn, resulting in steadily increasing international disputes over water Such disputes are getting more complex and novel, involving not only states, but also legal entities, corporations, and individuals against other states(Salman, 2006).

In recent years, research on settlements has gradually extended beyond natural geospatial research and historical reviews, demonstrating a shift in focus toward the humanities. Recent

studies have diverged from conventional settlement research, combining the humanities and studies of local spatial implications and landscapes to present findings of novel spatial significance.

Xiaoliuqiu, also known as the "Marine Garden," is Taiwan's only coral island. The island, which covers an area of 6.8 km2, is situated approximately 15 km off the coast of Donggang. It is pear-shaped, narrowing toward the south. The entire island is divided into four terraces by two intersecting grabens. One of these runs from the northeast to the southwest and the other runs from the northwest to the southeast, forming a network of trenches at the island's center that is currently used as the primary transportation channel. Information on Xiaoliuqiu's wells is included in the "Records of Inquiries in Fengshan County," a record of accounts authored by De-Chia Lu, during the Ching Dynasty. This notes that:

> *In 1765, Chu-Hou Hong of Qianzhou Prefecture, Jinjian County, sent 17 descendants to the eastern section of the island near Jianshan. They were primarily anglers. The area offered 'a spring with two outlets that remained plentiful in times of drought.' Because of the abundance of drinking water, an increased number of settlers arrived in this region, consequently establishing a settlement named Daliao. Another small settlement is located roughly 700–800 meters south of Jianshan. This settlement was established around an old well called 'Jingzikou.' The well, which was over 20 meters deep, was located in front of the Fu'an Temple. It is said that the well was dug by the ancestors of the Lin family during the reign of Emperor Jiaqing. The water supply in the well remained plentiful, even in times of drought. Thus, locals praised this well as being 'the well of the gods.'*

Success or failure relating to the construction of a well was influenced by the island's geological conditions. An immense amount of labor, materials, money, and time are required for constructing wells. Improper site selection often resulted in failure to access water, eventually leading to the abandonment of the construction project. Thus, our ancestors were challenged with selecting the ideal site for constructing water wells. The earliest record of a well on Xiaoliuqiu Island dates back to approximately 300 years ago. Extensive experience in well construction led locals to exercise considerable caution when engaging in construction projects. Consequently, they rarely failed in such endeavors.

Farming on Xiaoliuqiu is extremely difficult because of coral reefs extending up to the surface from the ocean floor as well as concentrated summer rainfall. However, the island has an abundant supply of marine resources. Xiaoliuqiu's inhabitants rely heavily on wells to overcome water scarcity during the drought season. Therefore, the early phase of Xiaoliuqiu's development was highly correlated with its distribution of wells. However, water scarcity and poor water quality have plagued Xiaoliuqiu. These are also key factors limiting the development of farming on Xiaoliuqiu. Concentrated summer rainfall and the terrain, which is composed of limestone, are

extremely unfavorable for preparing paddy fields. Hence, dry farming is practiced on the majority of island's fields. Historically, farming on Xiaoliuqiu has centered on upland crops grown on rain-fed paddy fields. Thus, in the past, the livelihoods of Xiaoliuqiu's inhabitants were strongly linked to the construction and distribution of water wells. The present study aimed to analyze the terrain, geology, climate, and culture of Xiaoliuqiu to elucidate the correlation between well distribution and settlement development on the island. A smartphone was used to triangulate the locations of approximately 80 wells that remain on the island and to collect historical and current data concerning the depth, level, and quality of water in the wells. Subsequently, a geographic information system (GIS)-based overlay analysis was conducted to determine the correlation between the development of the wells and the island's geological characteristics, the evolutionary correlation between wells and settlement development, and the functions of wells in relation to the development of settlement cultures.

2. Concepts and Methods

Settlements are the product of human-land interactions. The conduct of settlement research enables scholars to identify regional features. Taiwan has withstood a number of political changes, spanning the periods of early Dutch colonial rule, the regimes of the Zheng and Qing Dynasties, and of Japan, up to the later period of democracy that followed World War II. These have resulted in the unique regional characteristics of different areas of Taiwan. Settlements emerged following human-land interactions, with the locations of these settlements being predominantly determined by the natural environment. Settlement development research focuses on the interaction between vertical temporal issues and horizontal spatial issues, entailing an interweaving of space and time within a dynamic process of settlement development (Wu, 2008). This study adopted reclamation organization (as opposed to water abstraction) as a research perspective for studying original settlement organizations, with climate, terrain, and hydrology considered as irregular factors. The method of subsistence was considered a direct factor used to determine the effects of these factors on continuous development trends and on the magnitude of settlement organizations.

To determine the development of settlements prior to Japanese rule it was necessary to first elucidate how various factors, including the natural environment, as well as water abstraction, and reclamation approaches used by Han immigrants, interacted with each other on the island to shape subsistence methods and settlement patterns. In other words, because the environment is people's primary consideration in relation to settlement, the basic factors to be examined include the geology and terrain, hydrological conditions, natural resource distribution, and other economic factors (Lin, 2008).

Prior to the establishment of running water facilities, wells, as well as trapped rainwater, were the common sources of water used for washing and irrigation on Xiaoliuqiu. Mountain springs such as the springs of the Beauty Cave, Lobster Cave, and Biyun Temple comprised a

secondary water source. Water for cooling processes is not required on the island. Apart from its use in several restaurants and stores, most of the water is used for general purposes. Xiaoliuqiu's annual average rainfall is 1,000 mm, which is far less than the amount of rainfall on the main island. This highlights the importance of wells as a water source. To understand why Xiaoliuqiu's inhabitants chose certain locations for constructing wells, we conducted a field survey for each of the well locations. These locations were then overlaid on to a settlement distribution chart to compare settlement/demographic changes and well distribution conditions, and consequently to estimate settlement development trends. Lastly, Xiaoliuqiu's terrain and geology were analyzed to determine its residents' selection of well locations. Historical literature, discourses, and statistical data were compiled and examined to elucidate the characteristics of the natural and cultural environments of the study areas, the history of Xiaoliuqiu prior to Japanese rule, and factors relating to the natural environment (e.g., terrain, climate, and hydrology) influencing the construction of wells.

In terms of the methods, applied in the study, the positioning function of a commonly used smartphone enabled a field survey to be performed and the locations of the wells to be determined. The researchers endeavored to explain the meanings of Xiaoliuqiu's settlements and wells, in relation to the composition and structures of historical societies, using the GIS tool as a research platform, coupled with concepts pertaining to human-land relationships. The positioning data were then depicted on a distribution chart and the structural data and well supply circles were analyzed. Moreover, older residents on the island were interviewed to understand the origins and history of the wells. The research methodology and the smartphone/GIS field survey procedures were implemented by following the steps discussed below.

1. Set up the smartphone (Figure 1)

The location services and geotagging function of a smartphone, equipped with a positioning system, were activated. These functions enabled satellite images to be stored on the smartphone. The global positioning system (GPS) on the smartphone was enabled through the activation of mobile data.

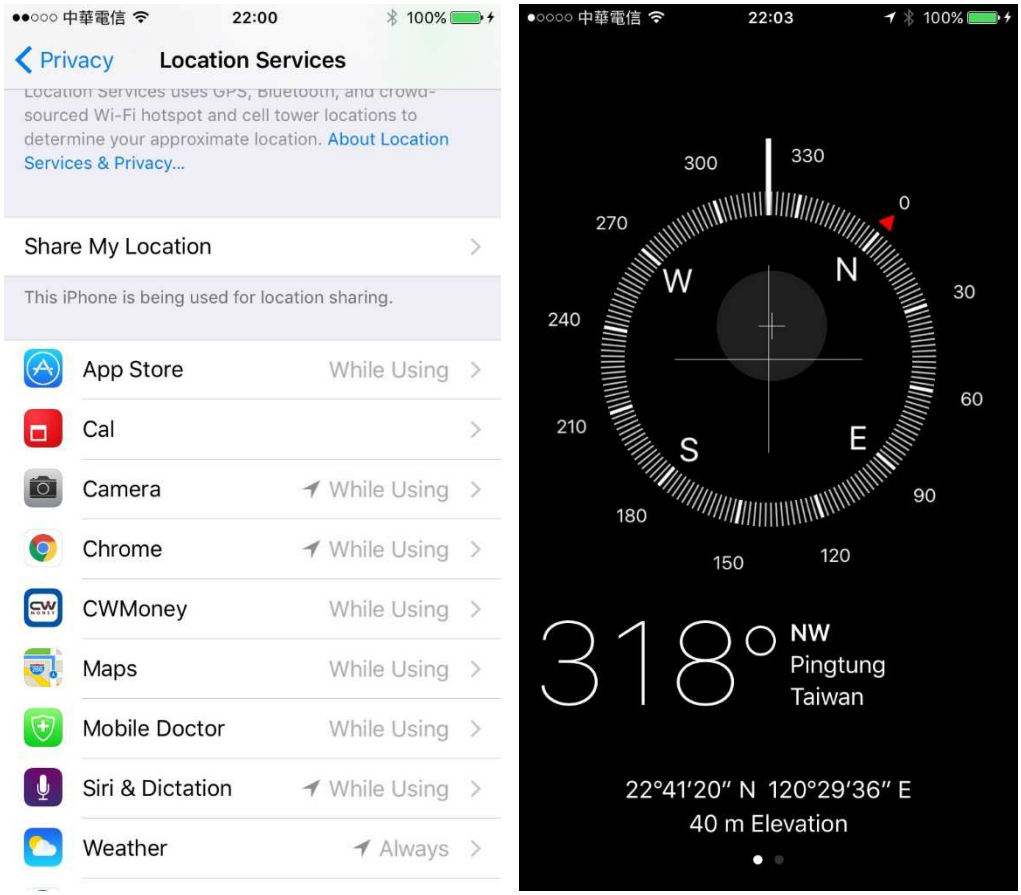

Figure 1. The Compass and GPS Settings of the Smartphone

2. Use the mobile APP to set the coordinates
3. Convert the survey data into the ESRI shapefile format
4. Ensure that the survey coordinates are accurate; if necessary, return to locations with errors to recapture the coordinates.
5. Import field survey data into the target coordinate file to create a complete target coordinate database (see Appendix)

It should be noted that although this study attempted to comprehensively represent the association between wells and settlements on Xiaoliuqiu, temporal and spatial changes have resulted in many of the traces of ancestral settlements and wells on the island having been replaced by jungle. Each historical well tells its own unique story. Unfortunately, however, many of these stories have been forgotten over time. The bulk of well construction occurred during the period of Japanese rule. The field survey conducted among older members of the population only yielded inherited data, with the history of the wells not being recorded in many cases. This is an unavoidable limitation of the study (Figure 2).

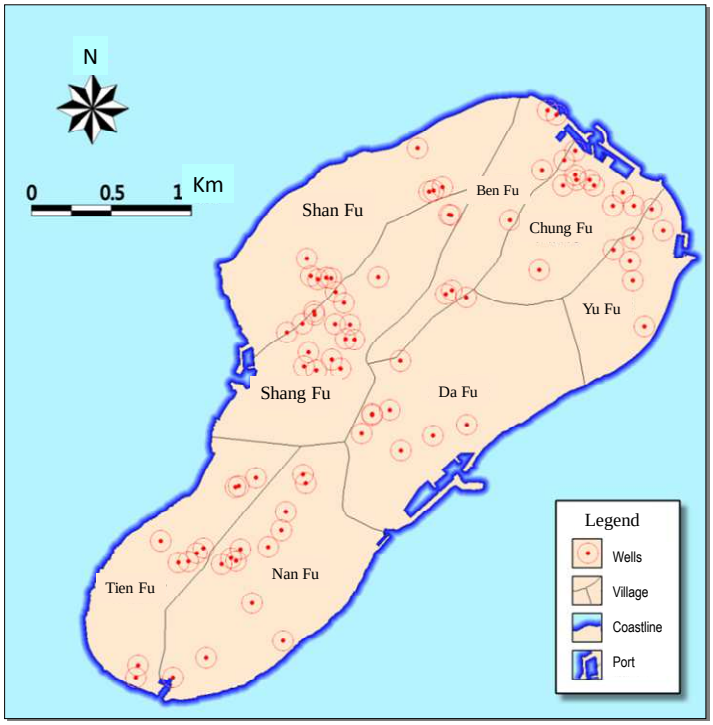

Figure 2. A Chart Showing the Distribution of Wells on Xiaoliuqiu

3. Location and Issues

Xiaoliuqiu Island is located off the southwestern estuary of the Gaoping River at of 120° 21′ 55″ ′′ longitude and 22° 19′ 48″ latitude. It is situated approximately eight nautical miles off the southwestern coast of the Donggang Township and about 18 nautical miles off the south-southwestern coast of Kaohsiung City, appearing in the shape of a floating shoe within the Taiwan Strait. Xiaoliuqiu is the only coral island among the 14 islands surrounding Taiwan. It covers an area of 6.802 km2 and the diameter of its coastline is 11.935 km.2 The highest point on the island is Liuqiu Mountain at an elevation of 87 m above sea level. Climatically, Xiaoliuqiu primarily has a tropical monsoon climate. It is also the only island offshore Taiwan that is not affected by the northeastern monsoon winds because of its lower latitude and position to the west of Taiwan. The land area of the island is relatively small, and there are no rivers to provide irrigation. Thus, the development of an agricultural industry on the island is extremely challenging. Xiaoliuqiu is relatively barren and has limited water resources because of sparse rainfall. Its foundation comprises a base layer of shale, covered by a layer of coral limestone. The island's coastline is composed of protruding coral, connected to a healthy coral reef and extending to the ocean floor. Because Xiaoliuqiu is a riverless island, wells have historically been dug to extract water for irrigation and consumption. The island's rainfall is concentrated during the summer. Although the rainy season brings forth a considerable amount of rain, this rainfall rapidly flows

into the ocean because of the island's slightly elevated plateau-type terrain, making river formation impossible. Moreover, the land's coral surface is highly water permeable and also drains water quickly. Therefore, the underlying shale layer must be penetrated to access groundwater. These characteristics suggest close linkages between the villages, well distribution, and Xiaoliuqiu's geological environment.

The geological foundation of Xiaoliuqiu is primarily mudstone covered by coral reef. Historically, as the island rose to the surface, the coral reef began to grow and expand outward until the older coral rose above sea level, gradually turning to limestone and fossilizing. This is the origin of the island's limestone, which is roughly 4 to 10 m thick and contains a large amount of coral and shell fossils. Being marine sedimentation, this limestone contains a considerable proportion of mineral salt, which is unfavorable for plant growth. Thus, much of land remains barren with eroded slopes and ditches. Moreover, tectonic movement has created two intersecting tectonic lines. One of these lines runs from the eastern to the western side of the island, and the other runs from the northeastern to the southwestern side. These lines divide the island into four regions, depicted in Figure 3.

Historical records show that the first settlers arrived in Xiaoliuqiu during the rule of Emperor Chongzhen of the Ming Dynasty. Literature pertaining to the development of Xiaoliuqiu can be dated back to 1721 (the 60th year of Kangxi), when Beinanmi (a.k.a., Taitung) and Lonkjouw (a.k.a., Hengchun) were "outlands," with access restricted to the Han. This restriction was lifted in 1875 (the 1st year of Guangxu) with the implementation of the "Opening up the Mountains and Pacifying the Aborigines" policy, which resulted in the official inclusion of these areas under the jurisdiction of Fengshan County. During the period of the Qing Dynasty, and specifically under the rule of Emperor Qianlong, Mr. Li, an angler from Quanzhou, Fujian, discovered a small island off the coast of Kaohsiung Port. The waters surrounding the island were teeming with marine life and the land itself was cultivable. Thus, Mr. Li relocated to the island with his family. Natives of the island have resided there since the late 16th and early 17th centuries. Survey statistics released by the Takizawa Police Department during the period of Japanese rule (1914; 3rd year of Emperor Taisho), reveal that the population of Xiaoliuqiu was 3,869 at that time. Extending from the northeast to the southwest, the island measures 17 cho from east to west, with a diameter of about three miles and an elevation of 287 m at the highest point (Liuqiu Mountain). Its terrain is uneven, mainly comprising coral stone, classified into 367.428 jia of swidden fields, 33.582 jia of construction land, 2.933 jia of cemetery land, 0.976 jia of other types of land, and 1.400 jia of open land, amounting to a total of 405.388 jia (Source: Mei Nei, 1916)

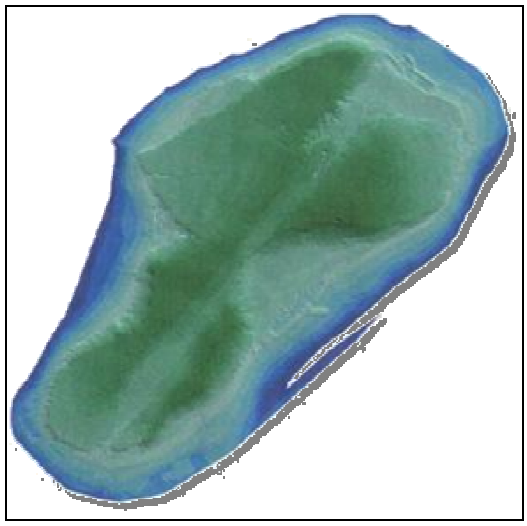

Figure 3. Diagrams Depicting the Terrain of Xiaoliuqiu

The main source of water that sustains life on Xiaoliuqiu is the Mudan Dam. The extracted water is processed at the Mudan Reservoir by the Taiwan Water Corporation and sent to the Chifen Pressurization Station located in Linbian Township. The first underwater water pipeline, which was paved in 1981, extended 14,092 meters from Chifen to Xiaoliuqiu. The completion ceremony was held on July 19, 1981 for this pipeline, which temporarily resolved the water shortage condition and led to improved water quality on the island. The island's wells were subsequently converted for irrigation use, providing a stable source of water for farming on the island (Huang, 2008). However, the pipeline was only 200 mm in diameter, limiting the daily transportation of water to a maximum of 2,700 m3, which was inadequate to meet the demands for water on the island. A proposal for the construction of a second water pipeline was subsequently approved. The pipeline became officially operational on 21 September 2004, providing an ample supply of water for the island.

Older residents on the island reported that in the past, they were required to draw and fetch water from the wells every evening. The wells were available from the time of their youth (during Japanese rule) and were considered "public" property. They were typically located on lower terrain and at a distance from their homes. Therefore, fetching water was challenging, because a number of roads were situated on an incline. Because the island is primarily composed of limestone and coral rock, well water levels are relatively low during the dry season. Seawater frequently seeps into the groundwater deposits, tainting the groundwater with salt and sediment. Therefore, Xiaoliuqiu's wells were not only scarce, but their water quality was problematic (Wu, 2008).

4. Results and Discussion

The well distribution chart (Figure 2) shows that the majority of Xiaoliuqiu's wells are

located to the south of the northwestern plateau, in the central trench and along the flat coastline. The wells are mostly rounded in shape, and the size of each well depends on the number of users. Those located in the lower terrain are relatively shallow, at less than 10 m deep. By contrast, those located on higher terrain extend for 10 m or more in depth. The rainfall on Xailoiuqiu is seasonal. Thus, a number of wells dry up during the dry season, typically extending from October to April, and are replenished with the onset of the rainy season in May. In fact, only a few wells have a sustained water supply throughout the year. In the past, residents on the island were required to physically draw water from the wells and carry it home for household use. During the dry season, many residents were required to travel to wells located farther away to draw water. Women and children living on the island were typically tasked with collecting water from the wells, usually in the afternoon at four or five o'clock. Queues often formed at the wells, providing residents with the opportunity to engage in social interaction (Figure 1). Wells served as information exchange stations where members of a neighborhood interacted with each another, in addition to being evidence of the existence and prosperity of our ancestors. They were integral for settlers on the island, who relied on water for consumption, cleaning, and irrigation. Wells could be built inside or outside of residential properties, farmland, or temples. At present, the wells on the island largely function as emergency or secondary water sources. The attitude of residents toward wells is largely conservative, and they are usually opposed to moving or destroying the wells unless they are in the way of other construction projects. If demolition is unavoidable, residents will generally proceed with caution and organize a ceremony to pay their respects.

The specific findings of this study are presented below.

Figure 4. A village woman washing clothes next to a well

4.1. Periods of Well Construction

Interviews held with older residents of the island indicated that the majority of the wells on Xiaoliuqiu were built during the period of Japanese rule, withstanding several generations of use.

Only a few wells have been constructed in recent years (Table 1). The demand for the construction of new wells diminished after the introduction of running water in the 1980s. Because of the island's water shortage, earlier residents were heavily reliant on the wells as water sources for consumption and farming. However, in an era of poverty and material shortage, building a well was extremely time-consuming and constituted a major event on the island. It not only required extensive fundraising, but religious ceremonies were also organized to seek the blessings of the gods (Figure 6).

A field survey was conducted for this study, entailing the overlaying of locations of the wells with settlement locations during the period of Japanese rule, as shown in Figure 8. Water sources constitute a key environmental factor governing the formation of settlements. Factors relating to the construction of wells include land ownership, geological conditions, locality, and the agricultural/commercial environment. Given the prevalence of tourism in recent years, an increased number of bed and breakfast facilities have emerged, attracting an influx of tourists to Xiaoliuqiu. The residents of the island typically own real estate on the main island of Taiwan, which they have registered at the Household Registration Office. Therefore, population growth on the island is inconspicuous. The present study also examined the distribution of settlements by analyzing terrain images to compare historical changes in Xiaoliuqiu's settlements (Figures 8 and 9). The road development of the settlements exhibited scattered and outward-extending trends.

Table 1. Well Construction Periods

Year	1936	1941	1951	1961	Japanese Rule and Earlier	Total
Number of Wells	1	1	2	1	75	80

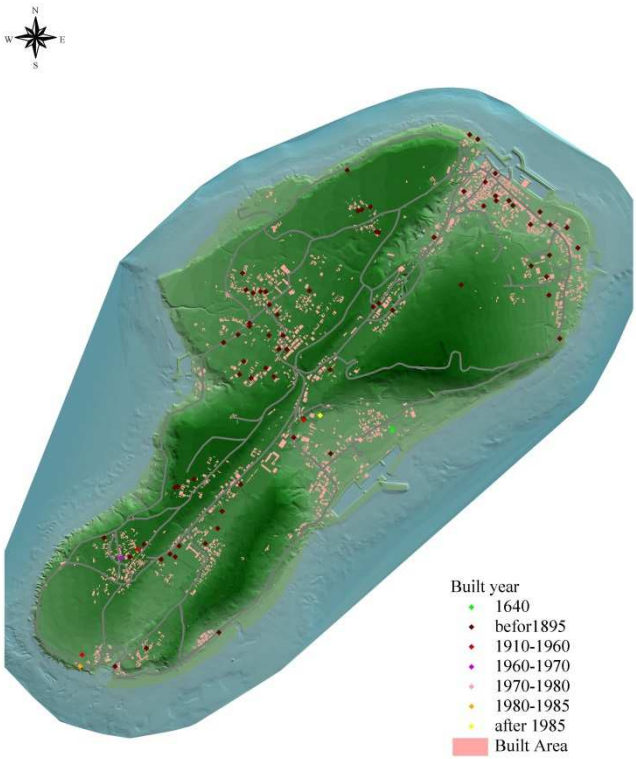

Figure 5. Periods of Well Construction

Figure 6. A Photograph of a Ceremony Conducted to Locate Water Sources (Source: Taiwan Folklore)

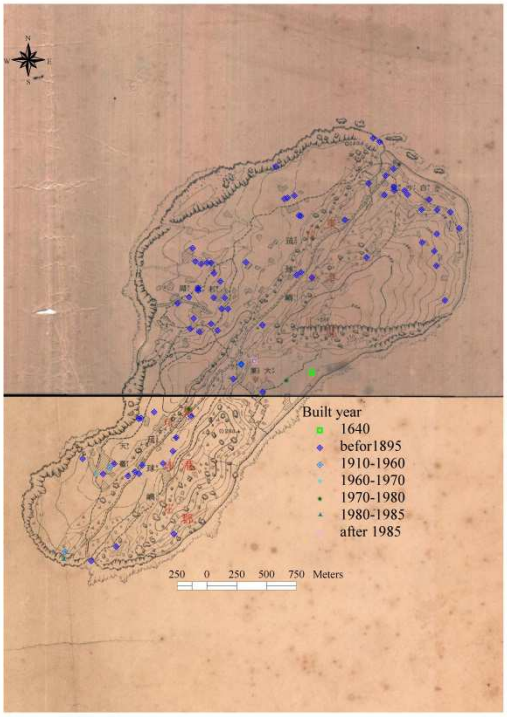

Figure 7. A Map of Xiaoliuqiu with Well Locations (1904)

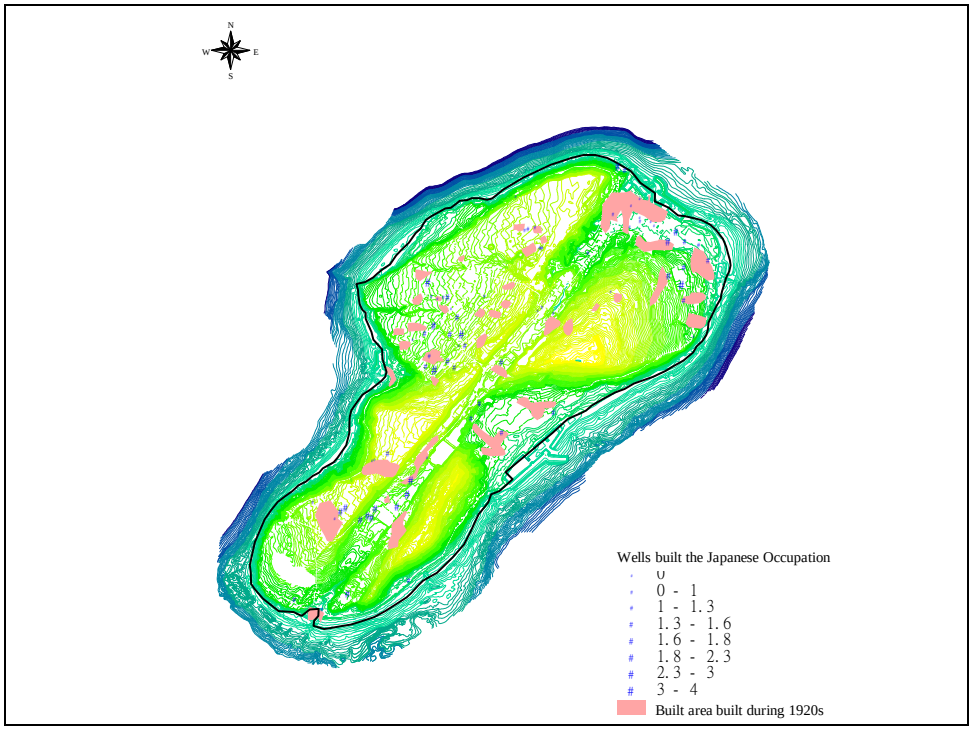

Figure 8. Settlements Existing during the Period of Japanese Rule and Well Distribution (1920)

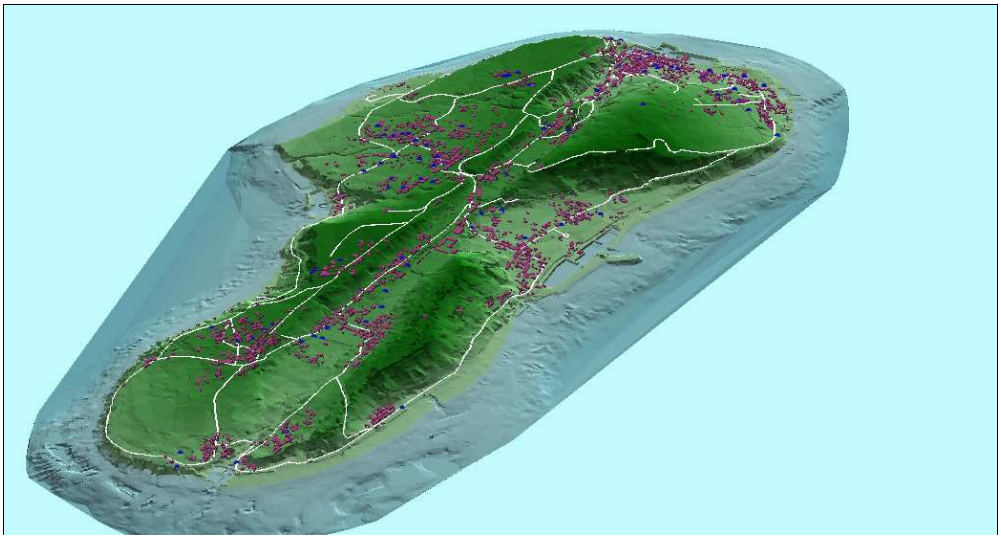

Figure 9. Recent Settlements and Well Distribution (1980)

4.2 Materials Used to Construct Wells

Wells were mainly constructed using bricks or coral stone. Bricks were specially produced for well construction. They were made to specification and delivered from the main island. Therefore, wells were primarily constructed by wealthy families. Coral stone could be acquired on the island. It was a common form of construction material used by general households. More recent wells were completely built from concrete, which made construction faster and more convenient.

Table 2. Well Sizes

Diameter (m)	Small Wells (1 m or smaller)	Medium Wells (1–2 m)	Large Wells (2 m or larger)	Filled Wells (excluded)	Total
Number of Wells	12	40	9	19	80

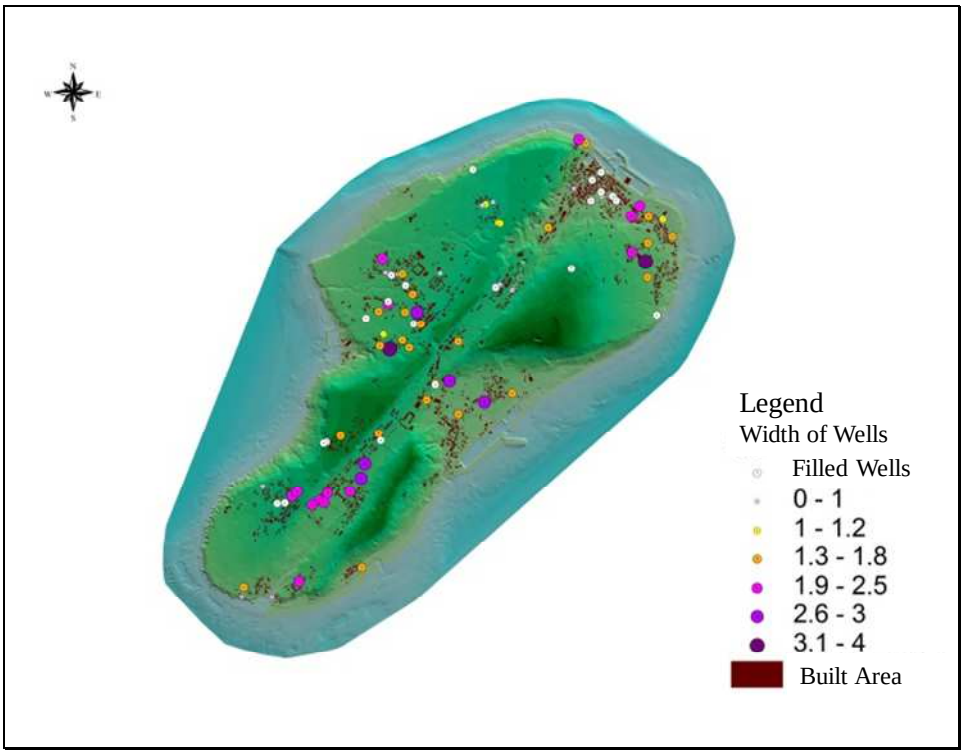

Figure 10. Well Distribution by Size

4.3 Land Ownership

Wells were largely constructed on family land to avoid conflict. Depending on the convenience and popularity of a well, its position within the settlement directly affected the development of neighboring households. Moreover, because water is essential for sustaining life, the distance of the wells and routes to and from the wells indirectly affected the selection of construction sites (Table 3). The majority of the wells were constructed on private land (Figure 11), and a few were constructed on public alleys or streets. Thus, regional relations serve a key function in the construction of wells. The overlay chart of well locations and settlement development indicates that early residents of Xiaoliuqiu first considered water accessibility before considering settlement development. Further investigation revealed that it was necessary to obtain approval from the gods before building or sealing wells. Well sealing cannot be performed voluntarily to prevent angering the gods and inviting punitive action.

Table 3. Well Distribution by Land Type

Land Type	Public Land	Private Land
Number of Wells	20	60

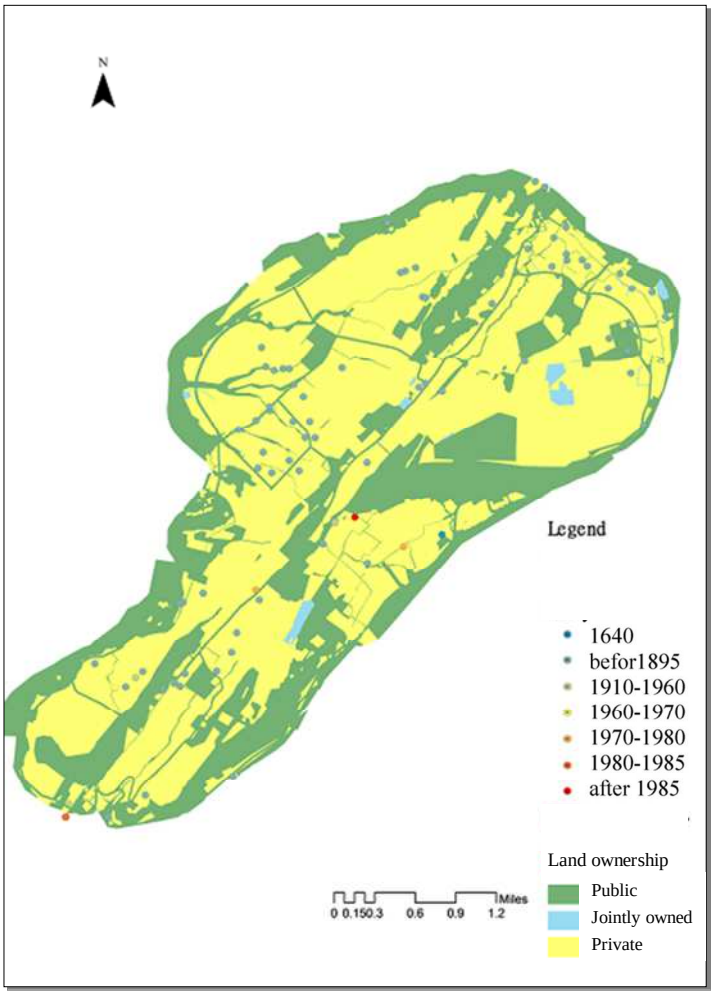

Figure 11. Land and Well Distribution

4.4 Geological Structure Overlay Analysis (Figure 12)

An overlay analysis conducted on the island's geological structure and well locations revealed that the majority of the older wells were located on a layer of coral stone dating back to the mid-to-late Pleistocene period. Moreover, the majority of the wells in Baishawei were located on an alluvium layer dating back to the Holocene period. These findings are indicative of a widely held belief among the island's residents that the increased lime content and sweetness of the water extracted from the Baishawei wells could be partially attributed to the close proximity of the ocean, preventing mineral salts from seeping into the ground water. These wells are largely replenished during the rainy season and emptied during the dry season. The resulting fluctuations in the water quality eventually compelled the residents to search for drinking water elsewhere, using the original wells only for washing and irrigation purposes.

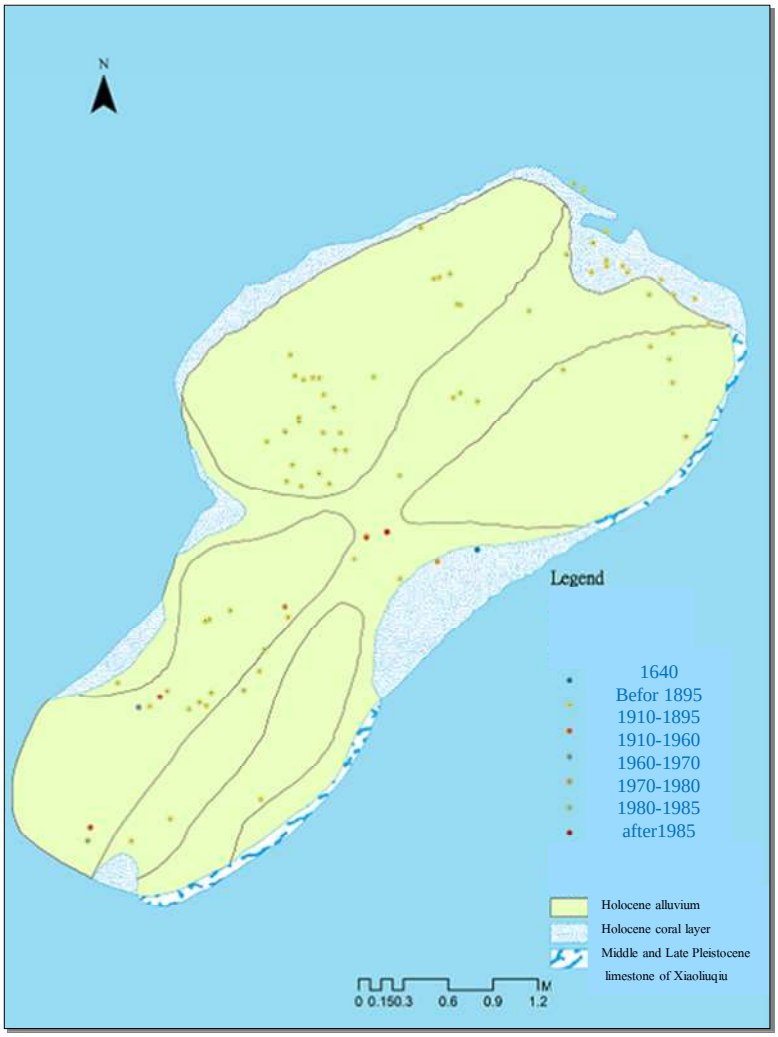

Figure 12. Geology and Well Distribution

4.5 Well Distribution

An overlay analysis conducted on the population distribution and well locations (Figure 13) indicated that there was no direct correlation between population density and well location. Population growth on Xiaoliuqiu has been relatively sluggish following the period of Japanese rule. The land is not only barren and difficult to cultivate, but the island also faces an outflow of population. However, the rise of tourism in recent years has attracted people, causing them to return to Xiaoliuqiu and reflecting a gradual rise in population growth. The majority of the island's wells are clustered around Baishawei and Shanban Road, both of which are located at low to moderate elevations. On average, each well serves roughly 200 people. However, actual numbers of people/households per well differ considerably. Wells in densely populated regions can serve up to 469 people, while those in sparely populated regions can serve as few as 103 (Table 4 and Figure 14). There are no fixed regulations for the use of wells. Their use is based purely on convenience.

Table 4. Settlement Distribution

Settlement	Benfu	Chungfu	Yufu	Shanfu	Shangfu	Dafu	Tienfu	Nanfu	Total
Number of Wells	6	11	6	9	18	8	10	12	80
Average Population	2815	1775	1416	1361	1854	2451	1992	2349	16013
Average Population Per Well	469	161	236	151	103	306	199	196	200

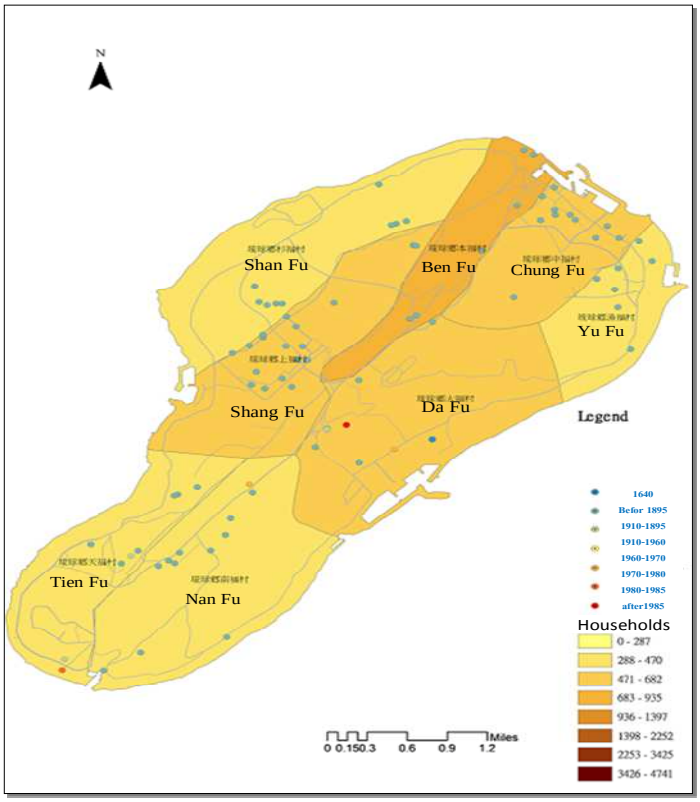

Figure 13. Number of Households and Well Distribution

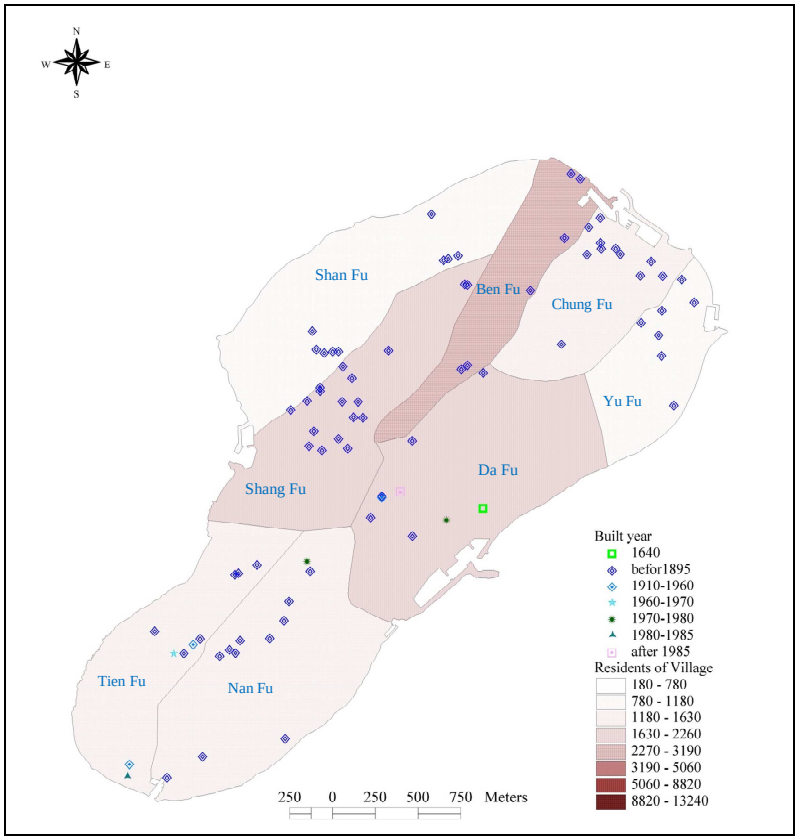

Figure 14. Settlement Populations and Well Distribution

A well built by a household was typically meant to be used by members of the household, and was sometimes also used by neighboring households with whom the household was friendly. Wells could be freely used when water was abundant. However, the use of wells was restricted by location, time, and household during the dry season when overuse ran the risk of depleting the wells. Households that were not permitted to use nearby wells were required to travel great distances to collect water. During interviews, the older residents of the island were asked to recall the hardships they experienced when collecting water. Most responded that they would rather forget about the past. The service areas of the wells are illustrated in Figure 15. When running water became available, the difficulties of water collection were slightly alleviated. Even now, residents continue to praise the benevolence of the government of that time. To assess a number of conditions relating to well construction such as terrain, geology, climate, and human factors, we reviewed historical data on wells relating to their geological distribution and locations, elevations, water levels, and water quality to determine their evolutionary association with the development of settlements. The equidistant influence of the wells is illustrated in Figure 16. Although the wells were primarily built for use by members of a household, they were also used by other households in the vicinity. Xiaoliuqiu evidenced a simple and friendly lifestyle, and others were seldom constrained from using wells. Therefore, there was a subtle correlation between wells and the development of settlements.

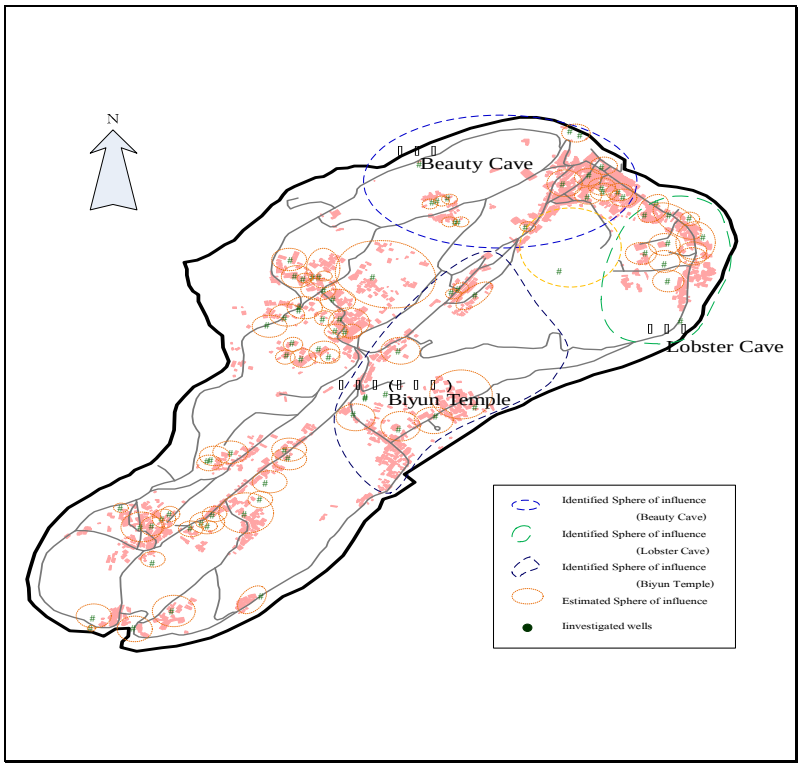

Figure 15. The Service Areas of the Wells

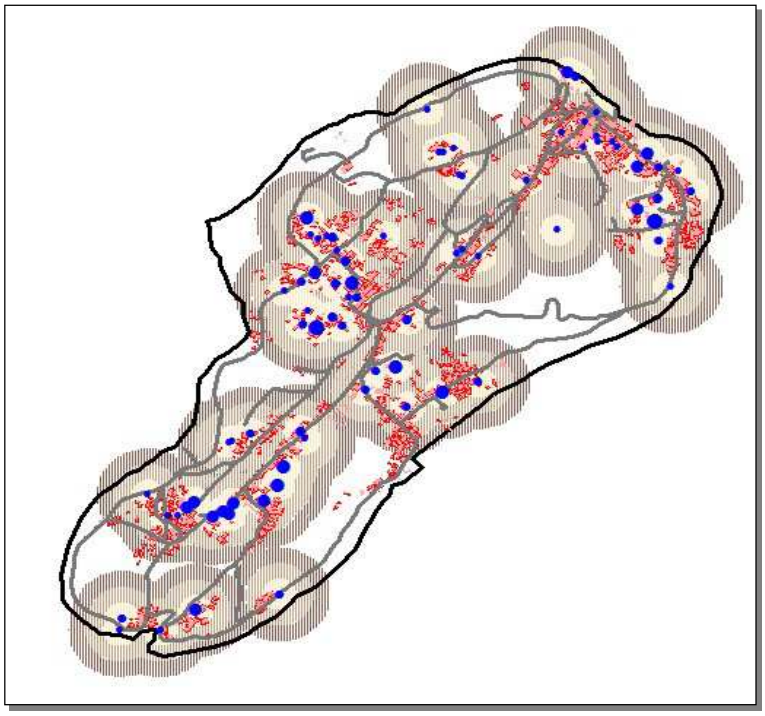

Figure 16. The Equidistant Influence of Wells

5. Conclusion

This study aimed to determine how settlements on Xiaoliuqiu developed in relation to the 80 wells that still exist on the island. The study investigated underlying local customs associated with each well and evidence of demographic changes in human-land relationships. Thus, the study's objective was to examine the influences of the natural environment on human activity, as well as the spatial and temporal changes created by human activity on the cultural environment, to highlight the influences of human activity on the natural environment. In line with economic development, and in cases where interrelations between humans and geological environments have become selective, the impacts of human decisions and efforts have gradually become caught up with and exceeded natural influences. As humans, we are no longer passively influenced; rather, we create influence. However, the formation of social/natural landscapes or regional features continues to be predominantly governed by nature, compelling humans to passively conform to the natural environment. In other words, human activities, both in terms of individuals and groups, are strongly influenced, controlled, and determined by the environment (Huntington). Human-land relationships are dynamic processes that change over time in relation to population growth and social/technical advancement. The cultural landscapes perceived today are products of long-term adaptation between humans and their environment. The findings of this study confirm the complexity and diversity of human-nature interactions.

Analyses of the correlations between well distribution and the formation and development of settlements reveal that early settlement development and land reclamation were based on the convenience of practicing cultivation. Therefore, water resources were a key factor. Without water, cultivation and livelihoods were extremely difficult to sustain. Fishing provides the "bread and butter" livelihood of residents of Xiaoliuqiu. Because of a lack of water resources, the practice of agriculture on the island was difficult, with only secondary upload crops and grains being harvested. Land was reclaimed for reproductive purposes and wells were constructed to sustain life for the formation and development of settlements. Families with adequate wealth and resources typically built a well along with their house. Those who did not have the means to build a well could obtain water from neighboring wells. Therefore, an analysis of the correlation between the development of settlements and wells indicates that water is closely associated with and indispensable for people's livelihoods. Being a critical resource, it consequently governs the development of settlements.

This raises the following question. During times of drought, how many people remember the hardship endured by their ancestors in building wells for survival? Studies on wells are extremely rare. Perhaps people have gradually forgotten the profound role of wells in providing nourishment and irrigation over the last century. Instead, people may consider wells to be of little consequence and without research value. However, the act of showing gratitude, which is a traditional and core custom, can still be observed. People still pay their respects to the gods of surviving wells.

Although wells do not continue to play a dominant role in the development of settlements, they nevertheless remain indispensable. If the water in our dams was to become depleted and no useable water could be found, would we then recall the hardship of building wells for our survival, and would our memories of retrieving water from wells be evoked?

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