Regional characteristics of the point-like historical water supply facilities of traditional villages in semi-arid China

Weinan Zhou a, Kunihiko Matsumoto a, Zurui Lin b and Masanori Sawaki a

Graduate School of Engineering, Osaka University, Osaka, Japan; b China University of Mining and Technology, Xuzhou, China

ABSTRACT
In this study, we use the integrated concept of the "historical water supply facility" to advance the regional characterization of point-like facilities. Eighteen villages in eastern Shanxi Province, which has a typical semi-arid climate, were taken as the study area, and data were collected by field observations and in-depth interviews. The results reveal that the natural environment, especially the terrain and river systems, influenced the formation of water cellars and water-logging pools, but had less direct effects on well construction. The formation of these facilities was eventually influenced by the residents pursuing stability and exhibiting a preference for water resources. Furthermore, under the pressure of survival, the types of facilities gradually diversified, while the numbers changed dynamically. Additionally, water cellars exhibited a minor correlation with the flood prevention, environmental sanitation, and yard drainage facilities of the village. These findings demonstrate that the core issue in the formation of diversified regional water supply characteristics is the attempt to find a balance between nature and water use/flood prevention, an embodiment of the explicit recognition of limited self-capability.

1. Introduction

Water is a fundamental requirement for human beings; meanwhile, sustainable water intake facilities vary worldwide. Differences in the geographic environment between southern and northern China are obvious, leading to the formation of various types of water supply facilities in traditional villages. In this study, we categorized a collection of water supply facilities, that were designed and built using indigenous materials and techniques to meet the demands of agricultural societies before the foundation of the modern Republic of China (1949 C.E.) and functioned for collecting, storing, and using water. These "historical water supply facilities" (HWSFs) were categorized under the perspective of integration – in other words, considering HWSFs as organic and integral parts of their villages.

In this study, HWSFs were classified as the point-like, linear, and planar, according to their morphology (Table 1). Two of these three categories, linear, and planar, are generally located in southern China, in which point-like historical water supply facilities (PL-HWSFs) are represented by wells and springs. The focus of studies on these facilities has been uneven. Studies on linear and planar facilities have mainly been performed in southern China, which displays a higher density of interweaving river channels and abundant rainwater. Both the regional and individual levels, such as the construction of water systems (Li 2012; Min, Huang, and Duan 2018), the layout of Feng shui (Xiao and Cao 2014; Xing 2014), and the relationship between water and traditional villages (Fu, Xu, and Xiao 2013; Shao 2014; Tao, Chen, and Xiao 2017) have been explored. Among these studies, wells and springs have been treated as minor and trivial parts of overall river systems.

In areas that experience water shortage, water is always more valued. Essentially, large numbers of all types of PL-HWSFs only exist in semi-arid areas in China. However, in most cases, PL-HWSFs have been discussed separately in these areas. Recent years have witnessed increased research on cultural convention of wells (Hu 2006), the constructional techniques and functions of water cellars (Hou, Hu, and Chen 2011; Lu, Wen, and Lu 2004; Xu and Lei 2017), the traditional constructional techniques of water-logging pools (Yang et al. 2015), and the cultural landscaping of spring facilities (Jiao 2014; Zhang, Yan, and Huo 2017). Additionally, some individual studies have focused on the wisdom of storage and drainage in semi-arid village areas (Guo and Bai 2016). However, the regional characteristics of all types of PL-HWSFs, especially the crucial reasons behind their construction, have never been fully investigated. As one key part of multiple-value cognition, as well as further regional conservation, we aimed to articulate the regional characteristics of PL-HWSFs in semi-arid areas of China. The objectives of this study are: (1) to illustrate the geographical distribution and the
selected construction reasons of PL-HWSFs under the natural environment of complex terrain and river systems; (2) to define the relationship between water cellars and flood prevention, as well as the living environment; (3) to reveal the interactions between water cellar and other components of the sampled villages.

2. Study area and methodology

This study was conducted in eastern Shanxi Province (Figure 1), which has a typical semi-arid climate; the mean rainfall in Yangquan City is 400–500 mm, and the peak period of rainfall, which appears during the flood season (June–September), accounts for more than half of the total rainfall annually. Moreover, the space and time of rainfall are very unevenly distributed. This study area was selected for three reasons. First, the irrigation and digging skills of wells in Shanxi Province during the Qing Dynasty (1636–1912 C.E.) were ranked the highest (Li 1995), and there were underlying technologies that were favourable for the construction of water cellars and water-logging pools. Second, the eastern part of Yangquan City is richer than other areas in underground water, and the terrain is mostly mountainous, which ensures the diversity of types of PL-HWSFs. Third, two main rivers (Wen River and Tao River) are both seasonal and only small parts of villages located nearby enjoyed an adequate supply of river water, which also resulted in the diversification of PL-HWSFs.

The research methods employed in this study are based upon field observations and in-depth interviews with the residents (Table 2). First, we determined the preliminary features of PL-HWSFs in eastern Shanxi by means of telephone interviews and by scrutinizing related planning materials and references. Eighteen sample locations (Figure 1) were then selected, among which 17 villages were located in Yangquan City. The remaining one, Nanzhuang in Jinhong City, was chosen because of its historical relocation due to water use problems; this location is discussed separately with respect to its old and new sites due to its unique history. The criteria of the study area included the integrity of the facilities, the historic culture of the facilities, and their regional representativeness for the national-level traditional villages selected.

3. Geographical distribution of PL-HWSFs in traditional villages

According to the influences on PL-HWSFs originating from various combinations of terrain and river systems, the samples were categorized into three clusters: Cluster A, which included areas with rich rivers; and clusters B and C, which were located in areas with minor rivers (Figure 2 and Table 3). Meanwhile, the

| Type          | Composition                                      |
|---------------|--------------------------------------------------|
| Point-like    | Wells, spring pools or wells, water cellars, water-logging pools |
| Linear        | Artificial rivers, ditches and waterways, etc.    |
| Planar        | Artificial ponds and lakes, etc.                  |

Table 1. Types of historical water supply facilities of traditional villages in China based on the morphology.

| Methods           | Survey contents                                                                 | Survey period             |
|-------------------|----------------------------------------------------------------------------------|----------------------------|
| Field observation | Data collection of number, location, and spatial characteristics of the point-like historical water supply facilities (PL-HWSFs) | 2017.09.01–2017.09.07      |
| In-depth interview| Interview with residents about the construction time and reasons, functions, and customs of the PL-HWSFs | 2019.08.10–2019.08.25      |

Table 2. Research methods, survey contents, and survey period.
criterion for classifying cluster B and cluster C is the marked difference in terrain and the former has a certain terrain slope while the latter is flatter and even valley. In this sense, it can facilitate understanding of how terrain further affects the formation of PL-HWSFs with similar river system conditions. The differences in the types and numbers of PL-HWSFs in river-rich areas and river-shortage areas were substantial, with various types of PL-HWSFs serving as the testimony to this fact. According to Figure 2, except for the spring facilities located from groundwater without excavation, the geographical distributions of other PL-HWSFs were (1) wells lacked any apparent distributional features, as they are present in three clusters simultaneously, although most were unusable; (2) water-logging pools were only located on plains with a high probability to form internal floods, and in valleys; (3) water cellars were only sited in river-shortage areas. In short, the formation of water cellars and water-logging pools is profoundly associated with natural terrain and river systems; water cellars more related to the absence of rivers and water-logging pools pertaining to the terrain. Hence, each of the three clusters is characterized as below.

Cluster A (N = 6) was found where a cornucopia of water resources (river water and underground water) brought about the construction of limited types of PL-HWSFs, and no water cellars or water-logging pools were used for collecting rainfall. There were fewer restrictions brought on by the terrain. Water demand was completely solved by rivers in 50% of villages, where no PL-HWSFs were sighted. Similarly, 33.3% of villages only developed single-style PL-HWSFs, while only 16.7% of villages constructed two types (wells and spring facilities).

Cluster B (N = 10) was found where hillsides occupied 80% of villages, and piedmont occupied the remaining 20%. Forty percent of these traditional villages were situated far from rivers, while villages without a river nearby or with a small river accounted for only 60% of all cases. Water cellars were found in 80% of the villages, and the water demands for daily use were completely reliant on water cellars in 40% of the villages. Additionally, 50% of the villages had constructed wells, in which only 40% of wells were located in the residential area. Finally, Cluster C (N = 3) was found where in every village located on a plain or in a valley-owned water-logging pools, as no rivers passed through.

4. Construction of PL-HWSFs

4.1. River-rich areas: PL-HWSFs in cluster A

Ample water resources only exist in a small number of villages in semi-arid areas, which has facilitated population growth and economic prosperity to some extent in these regions. The convenient water-obtaining environment in water-rich areas attenuates residents’ reliance on PL-HWSFs, or eliminates the emergence of any PL-HWSFs.

Three situations commonly occur under the combination of convenient water-obtaining environments with different terrains: (1) When living on slopes, residents choose to carry water directly from the river. In these regions, a Gutuo, a rarely sighted facility, comes into being. A Gutuo is a small pit randomly dug along the riverbank, piled with river stones in its interior (Figure 3). Actually, it is a natural water-purifying device, since the water-proof red earth functions as the membrane. As a result, Gutos are both imitations of wells by local residents and the embodiment of wisdom with respect to reshaping of the environment. (2) When living on a plain with rivers passing through villages, residents usually broaden the river channels for the convenience of retrieving water, and also because doing so can prevent water-logging when storms occur. (3) When living in valleys, residents face the extreme condition of inevitable floods, even while reconstructing the environment and confronting the convenience of fetching water, which forces residents to migrate, and proves to be the vital principle in the safe construction of traditional villages.

Springs are a priority when choosing the location of a village, and even determine the sites of villages in cooperating plains and available lands (Figure 4). Under such circumstances, the steep terrain limits the availability of fetching water from rivers. Springs may be classified as upward or downward, which determines the types of spring facilities. With higher pressures, upward springs gush plenty of water. Thus, residents can build spring pools and channels, or convey the water into their yards through the power of watermills. Conversely, the outlook of spring facilities
Table 3. Details of the natural environments and water use of sampled villages before the founding of the Republic of China (1949 C.E.) (After the founding of the Republic of China, the traditional settlement patterns gradually suffered huge damages. The scope of villages before 1949 was considered to be the same as the “core conserved area” in traditional village conservation and development planning/conservation plans of historical and cultural villages, and in the historical architecture areas of those villages where planning has not yet been completed).

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Cluster A

Terrain: Hillside River: Vertically away Residents relied on the springs in Nianziguan and were unable to use the river water due to the vertical distance from the residential area.

Terrain: Piedmont River: Close to residential area Water use in Dayangquan was mainly supplied by the river, wells, and spring wells simultaneously.

Terrain: Hillside River: Close to residential area Residents in Xiapanshi directly drew water from the river, and invented a simple device, the Gutuo, for collecting river water. No PL-HWSFs.

Terrain: Hillside River: Waterfall There were three waterfalls at the entrance to Dapin. The residential area occupied the largest waterfall (The streamlines and scope of the waterfall before AD 1949 were unknown). No PL-HWSFs.

Terrain: Plain River: Across the residential area In the early days, water use in Zhangzhuang relied on the rivers. In order to divert the floods, the river was deepened and widened. (18 wells were built after the Late Qing Dynasty).

Cluster B

Terrain: Valley River: Across the residential area The buildings in Nanzhuang old site were built along the river, and residents directly use river water. No PL-HWSFs.

Terrain: Hillside River: Horizontally away There were four wells in Luanliu, three of which were located in the southern farmland for agricultural irrigation. The one close to the residential area was for drinking.

Terrain: Hillside River: Vertically away Each household in Xinzhuang owned a yard water cellar. There were seven wells, but most of them cannot be used. The water use relies mainly on water cells.

Terrain: Hillside River: Vertically away Each household in Xiaodongzhai owned a yard water cellar.

Terrain: Piedmont River: Vertically away Each household in Shangdongzhai owned a yard water cellar.

Cluster C

Terrain: Hillside River: Small; Across The residents of Xiaoxie directly drew water from the small river that was not stable. They never gave up digging the wells, but eventually, all failed.

Terrain: Piedmont River: None Songjiazhuan is rich in groundwater resources, with a total of five wells, and the water use was completely satisfied.

Terrain: Hillside River: None Each household in Taoyebo owned a yard water cellar. One well was drilled in the southeast of the village, costing about 18 minutes to reach from the nearest yard.

Terrain: Hillside River: None Each household in Nanhuang owned a yard water cellar.

Terrain: Hillside River: None Each household in Daqian owned a yard water cellar.
derived from downward spring shapes is like that of a well. The downward spring water is abundant during rainfall periods, but shortages occur during arid periods. Owing to the extremely unstable amount of water in downward springs, the drinking function of downward springs can be terminated.

In general, the abundant river resources bring convenience to residents. However, great threats to lives and properties also exist because of the low ability of flood prevention in villages located close to rivers. Additionally, the appearance of unstable rivers after the Qing Dynasty galvanized residents to construct stabilizing wells.

4.2. River-shortage areas: PL-HWSFs in clusters B and C

By means of engineering, residents in river-shortage areas have adapted to the environment by coexisting between flooding and drought. This is demonstrated by the construction of water cellars to adjust the timely, uneven rainfall and the building of waterlogging pools to accommodate natural flooding patterns. Moreover, these two facilities may then be transformed to function as containers of usable water resources. Additionally, the coexistence between residents and the environment has fostered construction wisdom and techniques. Compared with the river-rich areas, the water consumption of residents in river-shortage areas heavily relies on PL-HWSFs. The earlier formation of each sort of water supply facility facilitated maximum usage of limited water resources, as well as greater compatibility with natural disasters (ie, better prevention and recovery).

Numerous studies have indicated that water has both positive and negative effects on traditional villages (Tao, Chen, and Xiao 2017). Some villages are vertically far from rivers owing to their high altitude, although they are horizontally nearby. When selecting village locations, the ancestors who founded the villages lacked long-term knowledge of the maximum range of the flooding; they could only calculate safe distances according to their lived experiences, which often led to excessive horizontal distances. When faced with the same dilemma, residents living in traditional villages in southern China could solve that problem by diverting water and building inner lakes. However, those in semi-arid areas cannot achieve similar patterns because of the relatively harder soil quality and the smaller river water volume. To ensure water consumption, Cluster B residents were forced to utilize rainwater by building rainwater collection facilities, such as water cellars and water-logging pools. Moreover, because of the shallow and fast-drought wells, the dominant water supply facilities in these villages are still water cellars.

We noticed two behaviours relating to water in Cluster B villages: (1) search for multiple water resources or water facilities, and (2) search for underground water. The underlying process of these phenomena is the same, and its formation is attributed to two reasons: (1) multiple water resources and (2) water facilities indicate a more positive position in dealing with drought. Additionally, the taste and quality of underground water are better than those of river water, and it is available in more stable quantities.

As interior flooding would frequently occur because of the terrain of valleys and plains, water-logging pools are mainly found in Cluster C. Thus, the primary functions of water-logging pools could be divided into two types: flood control and agricultural irrigation. For the villages located on plains, severe interior flooding would occur if there was no river crossing the village. Under such a circumstance, the primary function of water-logging pools was to prevent flooding with the regulation of draining followed by barricading flooding. In contrast, if located in valleys without rivers, the principal function transferred into water supply. Invariably, water-logging pools...
also bear supplementary functions such as livestock drinking and laundry. Additionally, the proximity to farmlands and sitting the lowest altitude in villages are two main points when choosing location. Nevertheless, it should be noted that the plains have no causal relationship with the formation of water-logging pools. Some Shanxi villages located on plains have successfully avoided interior floods by improving the foundation of the buildings (Figure 5). Undoubtedly, wider road and higher building foundations involve huge economic investment, as well as adequate land, and thus may not become prevalent owing to these constraints.

Wu categorized flood prevention strategies into two classes: flood control and flooding adaptation (Wu 2017). Water-logging pools and water streets both achieve the effect of preventing disasters when flooding, and sometimes manage to bring benefits to residents with flooding. Thus, we conclude that PL-HWSFs, such as water-logging pools with multiple functions, belong to the flood adaptation class of Wu (2017). Additionally, most villages lack sufficient resources to build large-scale flood control facilities to change the regulation of nature. Essentially, these lower-cost facilities may be the most suitable for such local villages.

4.3. From river-rich areas to river-shortage areas: PL-HWSFs of cluster B after immigration from cluster A

Traditional villages cannot be relocated unless facing major factors, such as political upheavals and/or serious natural disasters. Among the sampled villages, only 1/18 was once relocated, which we consider here as a unique individual case for discussion. The location and layout of ancient Chinese cities were fastidious and well-planned. In contrast, almost all traditional villages arose spontaneously. There is no trace of unified planning, showing the pattern of villages adapting to various natural spaces. However, the site selection and planning of villages were as systematic as the ancient cities when considering relocation due to unavoidable negative elements.

The former village site (No. OLD 18) before the Ming Dynasty (1368–1644 C.E.) was located in a valley, with a river going through the southwest of the new site, so it was accessible to fetch water and occupied naturally concealed effects. However, it suffered from severe floods year-round because it was located in a low-lying area, and all of the build yards were flooded by the river because of the limited land, which brought about the “nine floods in ten years” aphorism. This seriously endangered the daily lives of residents, which elicited a wish to immigrate. Judging from the perspective of the living environment, the original site led to disordered living conditions. After the Ming Dynasty, the population and economy could accommodate relocation.

To traditional villages in mountain areas, the emphasis on being realistic is identical to the idea of obtaining material from the local environment from the three construction concepts3 of an ancient city (Wu 1996). The construction of traditional villages involved a construction pattern organized by scholars, craftspeople, geomancers, the “noble families” in the village and the villagers (Wang and Li 2008). Nanzhuang also followed this pattern and was led by these four forces. Nevertheless, the new high platform site selection also caused disadvantages in terms of defensive function and inconvenient water use. To revise the negative side of the original village, the new site adopted the following measures: (1) to ensure security owing to frequent wars in the Jincheng area, craftspeople built a defensive wall funded by the local “noble families”; (2) a water well on the west side of the high platform was constructed, and could just meet the drinking needs of residents (Figure 6). Meanwhile, the construction of the village walls brought about barricading and the dispersing of water, leading to the problem of interior flooding.

Figure 5. Water street in Shangzhuang, Jincheng City, Shanxi, China with trapezoidal entrance steps.

3Three construction concepts in Chinese ancient cities are (1) the system embodying the Rite system; (2) the system paying attention to the environment and seeking functional effects; (3) the philosophical ideological system seeking harmony with Heaven.
To have enough water to use and to prevent flood, the operation of rainwater collection facilities was incorporated into the overall layout of the village. First, the main roads were planned according to the mountain conditions and water flow direction, which played the role of canals. Second, considering the large number of people taking water from the water cellar, a large square space was reserved in the village center. Third, a water-logging pool was set up in the lowest part of the village, and the spilled water was discharged into adjacent farmlands as agricultural irrigation water. The construction of the traditional village was thus transformed from being irregular to regular and all segments of living conditions began to develop more evenly.

Overall, the new site of Nanzhuang has been given priority in terms of defensive function and water intake, which also demonstrates that the primary issues of the rural living environment in the agricultural era remain water use and safety. Accordingly, we concluded that when traditional villages relocate from river-rich to the river-shortage areas, PL-HWSFs will be incorporated into the overall planning and even dominate the layout of historical buildings. Hence, the formation of PL-HWSFs is intentional and their quantity and scale are relatively steady.

5. Interaction between water cellars and traditional villages

5.1. Construction and utilization of water cellars

Water cellars were found to be the most common and convenient water supply facility in traditional villages of Cluster B in semi-arid areas, and were shaped like bottles in all sampled villages. Water cellars could be divided into four types according to the special location: yard water cellars (A and B), square water cellars, and agricultural water cellars (Table 4). In addition to water storage, the rainwater-collecting structure of a water cellar could be divided into a water-collection surface, water conveyance channel, desilting basin, and water inlet-pipe, which the agricultural water cellars lacked.

The location selection for water cellars in the public spaces is less regulated than in private spaces. They are generally built on squares in the centre of villages and make full use of the square space. However, as they are privately owned, despite their public location, they are still covered in locks. The rainwater supply and water-demanding period of crops in semi-arid areas are not coeval. The agricultural water cellars, located in the centre of farmlands, could only store water with a capacity of two-fold or four-fold that of the general water cellars. Agricultural water cellars are spatially irrelevant to villages.
Conversely, the interactive relationship between yard water cellars with villages is the closest. The priority of selecting a location for yard water cellar Type-A and B is to obtain clean rainwater. The number of Type-A water cellars is comparatively less, with the decisive elements when choosing the location being as follows: (1) it should be sited on the upstream; (2) the slope should be relatively more precipitous if close to the street and it should be at the end of a street; (3) as water would be fetched in the centre, the profile of the road should be shaped to be higher at both ends and lower in the middle. More, residents who use yard water cellar Type-A would spontaneously maintain a clean yard.

To ensure clean rainwater, the rainwater collection process of the yard water cellar Type-B is summarized in Figure 7. First, cleaning of the yard ash layer lasts for ~5 minutes. The rainfall entrance of the water cellar is stemmed and the yard drainage outlet is opened. In step two, the rainfall is filtered for ~2 minutes. In this stage, the entrance and the exit are both blocked, and sandbags are applied to filter the ash from the wall corners. The third stage is to collect rainwater by removing the small sandbags. Unfortunately, the sediment pool still leaves particles flowing into the water cellars, leading to severe sedimentation. Those using Type-B would continue cleaning the yard.

In terms of the construction of water cellars, we found a tradition related to the site selection of yards. When choosing the site of a yard, residents would first determine whether or not the geology was suitable for digging a water cellar. If the geology was not suitable, a second site would be considered. Furthermore, the construction of buildings would not begin until the water cellar had been put up. This was to ensure that water was available immediately after moving in.

5.2. Interaction between water cellars and the entire village

In most previous studies, the rainwater operation mode has been explored from the two separate perspectives of water supply and drainage. To illustrate the interactive relationship between water cellar operation mechanisms and the entire village, we concluded the ecumenical water process patterns by analyzing three dimensions of buildings, yards, and streets under the standard of water collection, utilization, and drainage (Figure 8). The first dimension was related to water collection, which means that buildings, yards, and streets all function as rainwater collectors; rainwater is gathered into the water cellar and finally flows into the water-logging pools. The second dimension involved water consumption, suggesting that daily water is provided by water cellars, while water-logging pools function for irrigation, laundry, and livestock feeding. The
third stage pertained to water drainage; the rainwater discharged into the road could be quickly discharged from the village or into a water-logging pool and farmland.

The intersection and combination of water-collecting and drainage can be seen from the process shown in Figure 8. Through the coordination and interweaving of various facilities, the goals of water collection and flood prevention have been achieved. Essentially, the PL-HWSFs tend to realize flood storage and drainage and groundwater replenishment by dispersing the source in semi-arid areas. Additionally, some studies have shown the benefits of this operation mode to the natural environment, including the ecological environment and microclimate (Xu and Lei 2017).

However, it must be clear that although this operational mechanism facilitates increase in the quality of the entire environment of villages, it is a random process rather than purposeful planning. The ultimate function of water cellars is water storage, despite their great impact on ameliorating negative impacts on village environments. Furthermore, their ability to store water and prevent flooding is circumscribed to some extent by their capacity, so they are unable to cope with extreme disasters.

5.3. Influence of yard water cellars on the artistic characteristics and conservation of yard drainage facilities

The forms of local architectural decorations in China are diverse, transformative, and resident-involving during their creation (Lou 1999). Drainage facilities in each village exhibit local styles, which also evolved into the embodiment of local cultural elements during hundreds of years of development. The artistic forms differ in style and without categorical appearances and rules. Additionally, we found that the pattern of water cellar influences the artistic formation of drainage facilities adjacent in space and time.

The delicacy and diversity of yard water drainage facilities may generally be ordered as follows: yards in river-rich areas, yards without water cellars in river-shortage areas, and yards within water cellars in river-shortage areas. This phenomenon reveals the fact that the residents consciously focus on the design of drainage facilities more when using yard water cellars. The residents combined the eager of abundant rainfall and traditional belief into the design of these facilities (Figure 9).

Historically, the construction of water cellars reflects different impacts on the drainage facilities. There are

Figure 8. Rainwater operation modes involving water cellars and water-logging pools.

Figure 9. Diversification of drainage facilities of a yard with a water cellar: (a) flat-roof drain outlet with a turn meant to retain wealth (according to traditional beliefs) and also avoid pedestrians becoming drenched; (b) flower-shaped drain outlet under a door indicating happiness.
three stages, simplification, complexification, and unification, in the development of the artistic features of yard drainage facilities. During the first phase in the earlier periods of villages, which were small-scale and involved less communication, the outfall was treated without aesthetic. Then, in the second phase, Shanxi merchants became very active during the Ming and Qing Dynasties. In some villages, owning a water cellar became a symbol of status and identity, which drove owners to design yard drainage facilities according to their own preferences. The yards within water cellars reveal further diversification compared with common yards. During the third stage, with the decadence of Shanxi merchants in the Later Qing Dynasty due to wars, the construction of houses gradually followed a modularization, while the craftspeople paid more attention to efficiency. Meanwhile, with the attenuation of traditional beliefs, the outlets of drainage facilities were no longer specifically designed based on personal preferences, but followed the fixed patterns designed by craftspeople.

Today, the construction of water cellars cannot influence the creation of drainage facilities because of the degradation of traditional beliefs. However, we observed that some yards maintained or adopted the original drainage outlets purposely during renovations, even when the water cellars had been removed, which reflects the persistent cultural impact of the water cellar. In our interviews with the residents about their willingness to keep the original drainage outlets if the house was updated. We found that only those who owned water cellars maintained a positive attitude toward the original construction. We were also able to conclude that the water cellars aided in the future conservation of these outlets, although their influence is growing weaker.

6. Conclusion

Here, we describe the regional characteristics of PL-HWSFs in the semi-arid eastern Shanxi Province of China. The analyzed contents are the geographical distributions, construction, and interactions between water cellars and villages. First, in terms of the geographical distributions and construction, we have grouped PL-HWSFs into three clusters under a criterion of integrated terrain and river conditions and main conclusions are as follows: 1) With respect to all clusters, the geographical distributions of water cellars and water-logging pools are conspicuous, because their construction is directly influenced by the natural terrain and river systems. Conversely, no apparent features in the distribution of wells were observed. 2) The category of PL-HWSFs in river-shortage areas (cluster B and cluster C) tended to be more diversified, as compared with river-abundant areas (cluster A). Moreover, water-logging pools are more often built in traditional villages with flat terrain (cluster C) rather than terrain with gradient (cluster B); hence to accelerate the adaptability of the traditional villages to droughts and flooding. 3) For all clusters, the category and quantity of PL-HWSFs in semi-arid areas are flexible, but generally display a dynamic increase under the impact of the quality of rivers and scale of the population. In other words, they are congruent with the increasing scale of human populations, while showing an inverse proportionality with the decreasing abundance and deterioration of rivers. Second, water cellars, through synergy with both other PL-HWSFs and drainage facilities, contribute to the dual roles of water collection and flood prevention. Nevertheless, this flood control function is an unintentional role beyond prime water supply purposes and works limitingly due to capacity constraints. Furthermore, the combination of water cellars and drainage systems contributes to the maintenance of the overall environmental hygiene of residents. Third, concerning other interactions, based on preliminary spatial observations and interviews, the construction of water cellars historically facilitated the artistry and diversity of overall drainage facilities. Nevertheless, due to the commercialization of drainage systems, the impact is diminishing.

It is noteworthy that the formation of PL-HWSFs was eventually influenced by the residents’ pursuit of stability and preferences for water resources, despite the huge influence of the natural environment in river-shortage areas. The pressures of survival drove residents to continuously conquer the restrictions of the natural environment. During the process of searching for optimized water usage and flooding prevention solutions, the residents implicitly recognized their limited human and material resources. Consequently, they chose to obey the natural patterns and to achieve a win-win situation of water usage and flood prevention by means of adapting rather than controlling flooding. This adaptability avoids the excessive depletion of labor and property due to the implementation of large-scale projects, and minimizes the temperate interference of the environment. The crucial issue of formation of diversified regional characteristics was in seeking a balance with nature. However, we must also admit that the functionality of these facilities is minor when confronting extreme disasters. Hence, in this study, the explanation in response to the multiple functions of water cellars and the interaction between other components has been constrained by the methodology. Future research should further explore other potential impacts such as how water cellars affect the interior design of yards through quantitative analyses.
Acknowledgements

We would like to acknowledge the Kajima Foundation’s Research Grant for the support in the field survey. We thank sample villagers’ leaders for their contributions to the annual data collection.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Weinan Zhou http://orcid.org/0000-0001-7726-642X

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