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# Understanding of the settlements with coexisting water and earth under the background of climate change—the case of Liang Village in Pingyao County, China

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**Abstract**

Global climate change has caused general and serious damage to cultural heritage sites, and earthen settlements and buildings are particularly vulnerable to water-affected disasters. Thus, this paper uses Liang Village in Pingyao County, China, as a case study, linking the human–land study in the Liang Village Sino-French workshop of 2009/2010 to a disaster assessment completed after the devastating rainstorm in October 2021. We found that the village's rain disaster resulted from the vulnerability of earthen material to rainstorms and from the earthen settlement's evolution from a culture emphasising the coexistence of 'water and earth' to a technic fostering the disintegration of 'water and earth'. The latter is the main cause of the village's decrease in its capacity for disaster prevention and damage reduction. Therefore, in the context of global climate change, we find that the reestablishment of the harmonious relationship of water and earth is critical to both rural heritage conservation and village sustainable development. In addition to repairing their relation from the technical perspective of 'planning and design' by planners and architects, it is more crucial for local people to understand and enhance their contemporary appreciation for the traditional 'coexistence of water and earth' concept.

**Keywords:** climate change, earthen settlement; rural heritage, coexistence of water and earth

## 1 Threats from global climate change to earthen heritage

### 1.1 Influence of and reactions to current global climate change

In the last several decades, climate change has caused many severe disasters. According to the Centre for Research on the Epidemiology of Disasters (CRED), the world encountered 389 cases of natural disasters in 2020, mainly climate-related. This included 9 cases of drought, 5 cases of extreme temperature, 201 cases of flooding, 19 cases of landslides, 127 cases of storms and 8 cases of wildfire. The number of people affected by natural disasters in 2020 was 98.4 million. The CRED also provides data on disasters from the past decade, which show even higher annual averages in almost all areas, except for flood and storm cases (CRED, UNDRR, and USAID 2021).

To mitigate climate change, several measures have been taken worldwide. The United Nations Framework Convention on Climate Change (UNFCCC) was established in 1992 as an international organisation to support the global response to the threat of climate change. The Paris Climate Agreement is the most recent attempt to establish international cooperation over climate change and was instituted in 2016. It was designed to bring nations together voluntarily to take ambitious action on mitigating climate change while developing adaptation options and strategies and guaranteeing the means of

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implementation (e.g., climate finance). The Agreement is aimed at 'holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels' (United Nations 2015).

The built environment is often the major part of the physical infrastructure affected by disasters. Extreme events, such as cyclones and floods, inflict a heavy toll, particularly on structures built with informal building materials and outside safety standards (Scott and Tarazona 2011). Increased climate variability, warmer temperatures, precipitation shifts, and increased humidity will accelerate the deterioration and weathering of stone and metal structures in many cities (Grossi, Brimblecombe, and Harris 2007; Smith, Gomez-Heras, and McCabe 2008; Stewart, Wang, and Nguyen 2011). The increased risks that climate change brings to the built environment also apply to built heritage. In 2017, the 19th Triennial ICOMOS General Assembly meeting in New Delhi adopted Resolution 19GA 2017/30 entitled 'Mobilizing ICOMOS and the cultural heritage community to help meet the challenge of climate change' and established the ICOMOS Climate Change and Heritage Working Group (CCHWG) to support and prioritise the development of ICOMOS's climate-change policies and engagement. In 2019, the CCHWG published 'The Future of Our Pasts: Engaging Cultural Heritage in Climate Action' (ICOMOS 2019) to catalogue the ways that climate-change drivers impact cultural heritage.

### 1.2 Vulnerability of earthen heritage to climate change

Shanxi is located in central China and has a Loess Plateau landscape and an arid climate with approximately 400 mm of annual rainfall (Wang, Zhu, and Tong 2016). As one of the main regions of ancient Chinese civilisation, many ancient buildings still exist, including the world heritage site of Pingyao Ancient City. However, since 2010, due to the Northwards movement of warm and humid airflows caused by climate change, continuous rainstorms have become common in traditional drought areas, further causing great destruction to earthen heritage sites (Fig. 1).

In the beginning of October 2021, Shanxi Province suffered from continuous heavy rainfall, causing floods, landslides and other geological disasters. According to the National Meteorological Centre (NMC), from 2 to 7 October, 13 cities and counties in Shanxi received over 200 mm of precipitation (1 week reaching a half-year), and the rainfall of Pingyao Ancient City was 20–24 times more than the same period in previous years (Fig. 2).

Our team went to Pingyao on 8th October. After investigating and assessing the disaster of the earthen buildings in Pingyao Ancient City and the surrounding villages, including Liang Village, we found that 'earth' was very vulnerable when meeting 'water'. Many earthen built heritage sites in this region were severely affected, seriously damaged, and even partially collapsed. In Liang Village, village walls and door roofs had collapsed; although some materials were not earth, they were also damaged by the loss of earth as filling material (Fig. 3).

In the Loess Plateau region, earth is the main building material of buildings, widely used in roofs, walls and other places, even in buildings with wood structures. Due to the arid climate, the earth can remain dry and firm, and a large number of old buildings have been preserved. However, due to the long-term arid environment, people have forgotten another element, water, and they have also forgotten the traditional 'water and earth' concept, which was so important for ancient Chinese people. Although the 2021 flood in Shanxi was 'unconventional', but it does not mean it is a new problem that Chinese people have no experience with. Thus, we have observed the traditional wisdom in dealing with 'earth' and 'water' within a workshop from 10 years ago, and we believe that people's abandonment of this wisdom partially caused the severe damages. This is the key issue that we discuss in this article.

## 2 Analysis of the 'water and earth' concept in traditional Chinese culture

'Water and earth' can be two elements on the surface of land and can also be the general natural conditions and climate. For example, there is a traditional Chinese saying '*shuitu bu fu*' (水土不服)—people are not accustomed to the local water and earth, which means that if the body is not harmonious with the local climate environment, it is easily affected by illness (Deng 2019). In traditional Chinese culture, 'water' and 'earth' have a contradictory and complementary relationship.

### 2.1 Earth: a stable element and the symbol of spatial order

Earth is the most important carrier of human activities. There was a strong worship of earth in ancient China. For example, in the theory of '*wuxing*' (五行, means five elements[1]), earth represents the orientation of the centre, which is the most important of the five elements. In the ancient *Yueji* (《乐记》), there is a statement that 'earth is the most significant of the five elements' (Pang 1984). There are two main reasons to emphasise the importance of earth: first, China has a long-term agricultural civilisation, and agricultural thoughts are deeply rooted in peoples' minds, so earth (or soil) symbolises agricultural production, which can bring stability to people. Second, earth has a similar meaning as land, which

[1] Wuxing contains five elements: metal, wood, water, fire and earth. The ancient Chinese people believed that the universe was composed of these five elements.

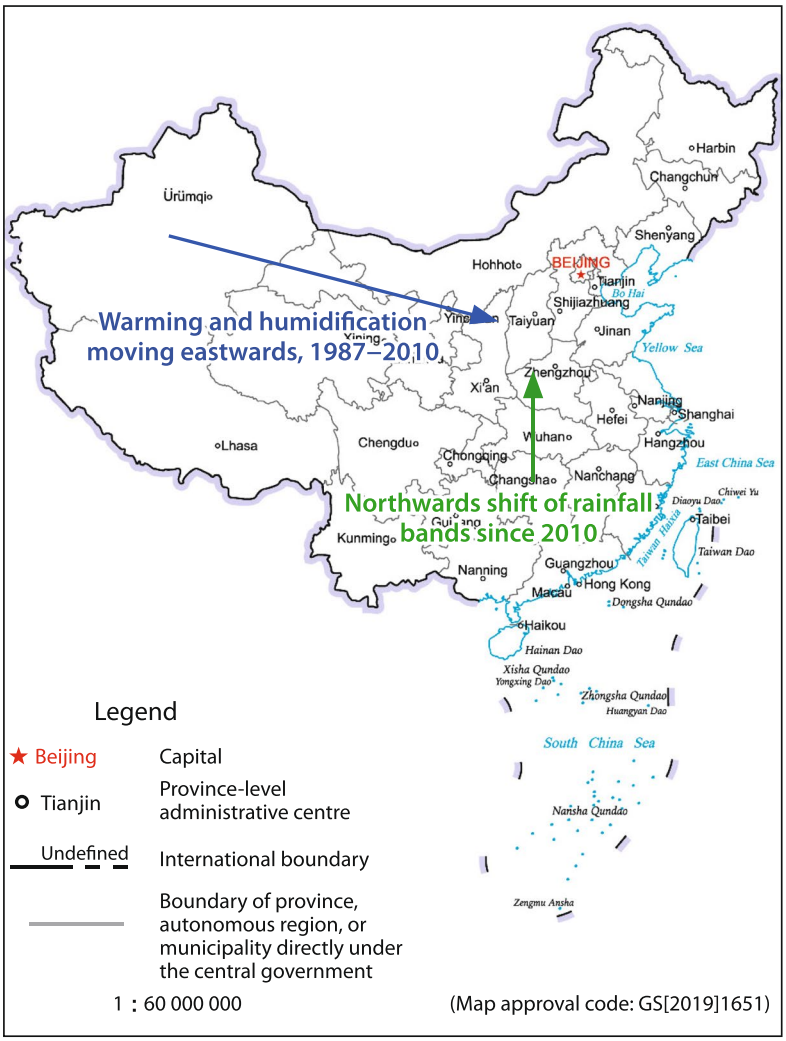


**Fig. 1** Trend of Climate Change in China (Source: the author. Background map approved by Map Vetting Center, Ministry of Natural Resources, PRC. Map approval code: GS[2019]1651)

refers to the boundaries of imperial power. Therefore, there is a saying in China '*putianzhixia mo fei wangtu*' (普天之下莫非王土, means all the earth/land belongs to the emperor). Thus, earth is given special values.

In this article, we define 'earth' as a natural substance element that can be used as a kind of material and discuss its symbolic meaning in China.

### 2.2 Water: a fluid element and the symbol of spatial vitality

Similarly, there are also two meanings of water in Chinese people's minds. The first one is water in nature. 'Living close to water' is not only a Chinese tradition but also an important feature of human civilisation because water is used for drinking, irrigation, and a better living environment by people who regulate their microclimate. In addition, the second definition is water in mind. Due to the significance of water, a strong worship of water has been produced. People worship water with the first purpose of begging for appropriate rainwater and with the second purpose of begging for the reproduction of people themselves (Xiang 1993).

On this basis, 'water' is a symbol of wealth because people find that places with rich water resources are always wealthy. According to the theory of '*fengshui*', water includes rivers, lakes, creeks, etc. and is indispensable for an ideal settlement (Wang and Zhang 2010). To create a comfortable and auspicious environment, it is also necessary to adjust the form or direction of water, which is called '*lishui*' (means adjust

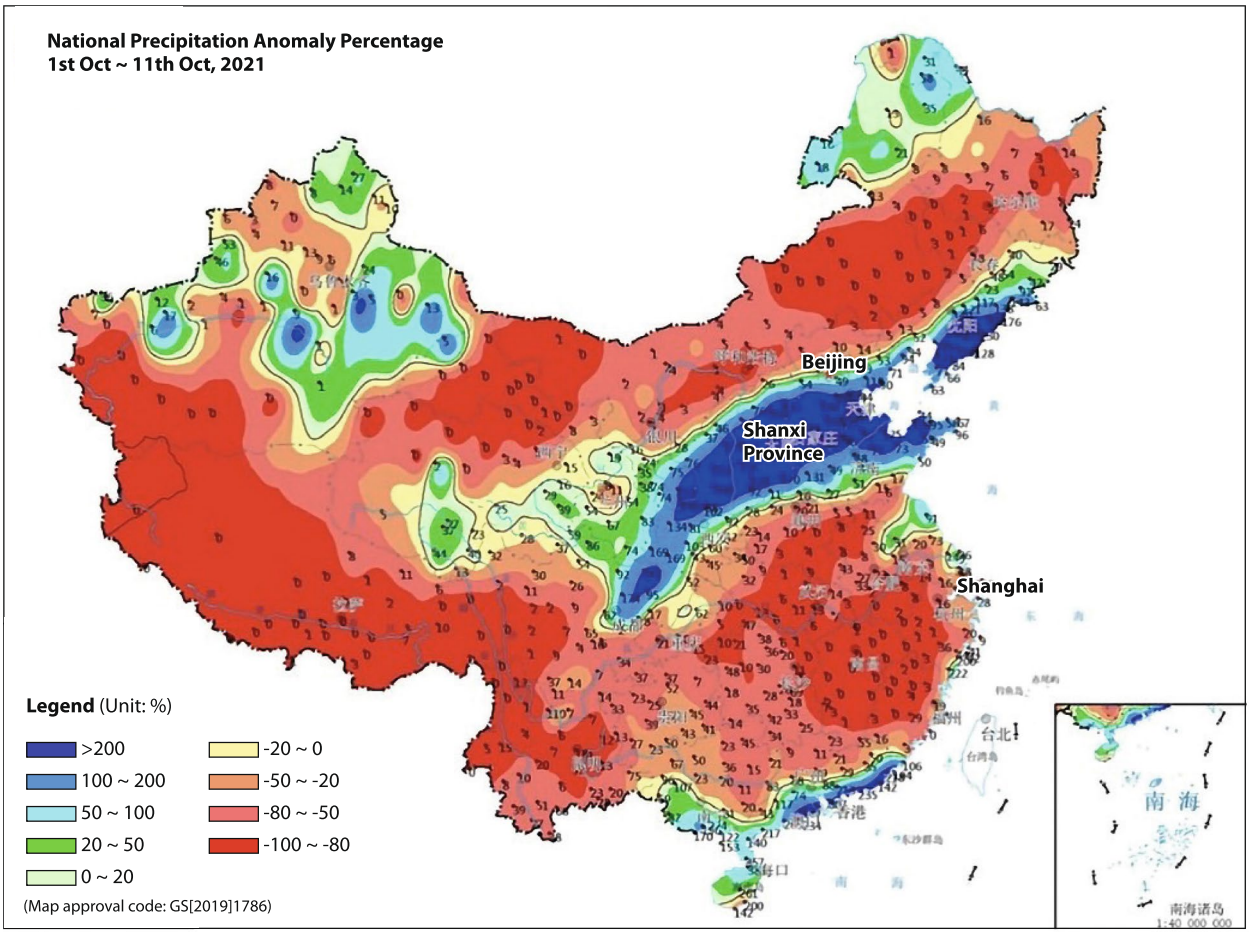


**Fig. 2** National Precipitation Anomaly Percentage from 1 October to 11 October 2021 (Source: NMC: https://cmdp.ncc-cma.net/cn/index.htm. Map approval code: GS[2019]1786)

**Fig. 3** Collapse of village wall and door roof of Liang Village (Source: Pingyao County government)

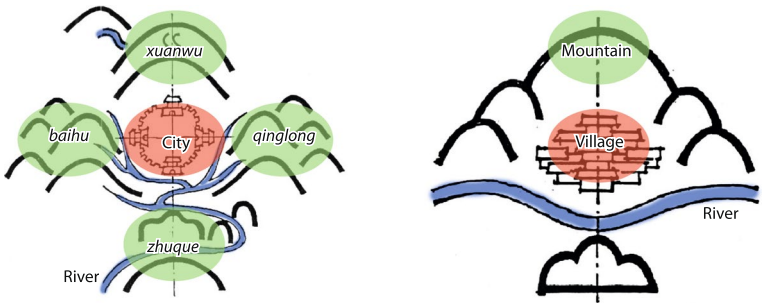


**Fig. 4** Traditional Chinese site selection concept, based on *fengshui* theory (Source: Wang and Zhang 2010)

water) in '*fengshui* theory' (Fig. 4) (Wang 2015; Wang and Zhang 2010).

### 2.3 The balance of 'water and earth' constitutes an ideal settlement environment

Given the above two aspects, 'earth' and 'water' are both important natural elements on the surface of the planet. At the same time, they both represent concepts in the ancient Chinese ideological system; the former represents stability and order, while the latter represents fluidity and vitality, and they are equally important and indispensable.

Scholars have been more concerned with the traditional settlements in southern China because the landscapes there are rather variable, and the balanced nature of 'water and earth' is more apparent (Chen and Cao 2015; Luo 2015; Xiao and Cao 2014; Xu, Peng, and Wu 2012). In contrast, for settlements on the Loess Plateau, scholars have always given more attention to the strong earthen characteristics while ignoring the factor of water (Wang and Zhou 2011; Huo and Liu 2005; Wang and Hou 2006). Indeed, neither of these two elements is capable of individually maintaining a good environment. Especially after the 2021 flood in Shanxi, it is thus necessary to reassess and better deal with the relationship between water and earth to increase the capability of earthen settlements to prevent damage during disasters.

## 3 Liang Village: from 'coexistence of water and earth' to 'disintegration of water and earth'

Liang Village is a typical earthen settlement on the Loess Plateau of China. It is located in the middle of Pingyao County, Shanxi Province, 6 km southeast of Pingyao Ancient City (Fig. 5). There is a common popular saying: 'Liang Village initially, then follows Pingyao Ancient City', which shows that Liang Village has a longer history than Pingyao Ancient City. In June 2007, Liang Village was listed as a National Historical and Cultural Village.[2] In 2012, it was listed as a Chinese Traditional Village.[3]

As mentioned above, the main empirical evidence for this study was obtained from a Sino-French workshop[4] in Liang Village from 2009 to 2010. In this workshop, which 4 teachers and 21 students participated in, the characteristics of the relationship between earth and water were deeply studied, and we obtained two important findings. First, the settlement had a strong characteristic of the combination of rich water and earth, which was very significant. Second, there was an evolution from the 'coexistence of water and earth' to the 'disintegration of water and earth', which corresponds to the village's devolution from prosperity to decline.

[2] '历史文化名村' in Chinese, it has been established by Ministry of Housing and Urban-Rural Development and National Cultural Heritage Administration since 2003, referring to the villages preserving particularly rich cultural relics, and has a major historic value or commemorative significance, which can reflect traditional features and local national characteristics. It has announced seven batches, which are usually announced as a 'National Historical and Cultural Town'.

[3] '中国传统村落' in Chinese, it has been established by the Ministry of Housing and Urban-Rural Development, Ministry of Culture and Tourism, National Cultural Heritage Administration, Ministry of Finance, Ministry of Land and Resources, and Ministry of Agriculture and Rural Affairs since 2012, which refers to the villages with tangible and intangible cultural heritage, with high value in history, culture, science, art, society, and economy. It has announced five batches.

[4] The Sino-French workshop was organised by Tongji University, China and Chaillot School, France in 2007. The aim of the workshop was to highlight the advantages of educational resources and practical experience of the two schools, to establish a way for professionals with different values to understand and communicate with each other, and to set a successful example for international cooperation in the protection of cultural heritage. The methodology of the workshop can be reduced to 3 scales (territory, village and building) and 4 phases (investigation, interpretation, evaluation and project) (Tongji University and Cité de l'architecture and du patrimoine 2013). In 14 days of on-site investigation, students obtained a close awareness of the village. Then, they spent about 1 year organising materials, analysing the value of the settlement, and diagnosing the problems and pathology of the site to form a deep understanding of the village. Based on the above thinking and results, a design project to protect the value of the village and solve the existing problems would be finally executed. In addition, in the second year, teachers and students would bring the results to the site for exhibition and exchange with the villagers, and strive to incorporate them into the government's implementation plan.

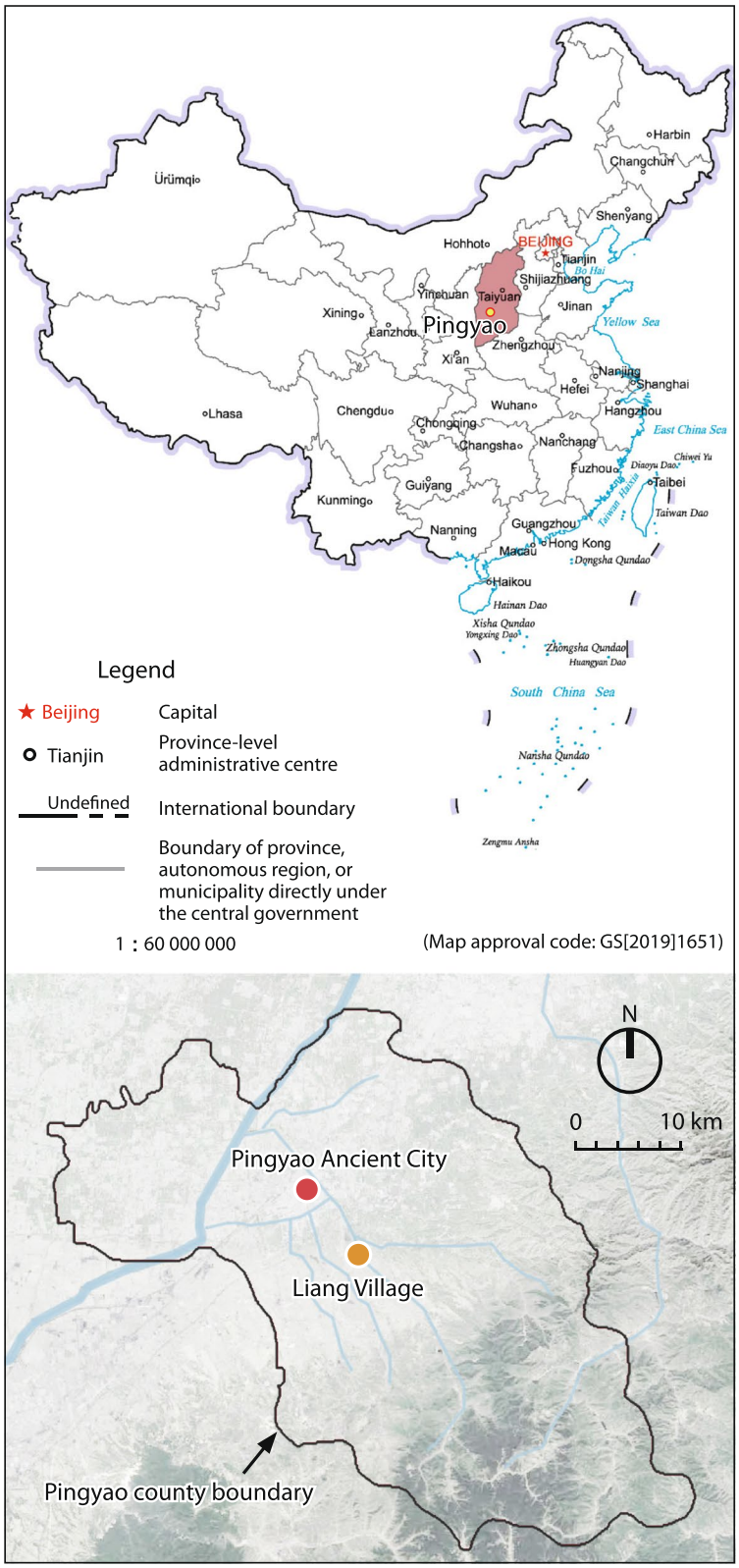


**Fig. 5** Location of Liang Village (Source: the author. Background map approved by Map Vetting Centre, Ministry of Natural Resources, PRC. Map approval code: GS[2019]1651)

**Fig. 6** Spatial pattern of 'living on the terrace and farming in the valley' (Source: Tongji University and Ecole de Chaillot 2010)

### 3.1 'Coexistence of water and earth'

#### *3.1.1 Settlement site selection: close to water on the Loess Plateau*

Liang Village is located in the core area of the largest Loess Plateau in the world. The natural Huiji River and its tributaries pass through the village on the east and west sides, forming a regional landscape with interlaced sandy terraces and valleys. The ancestors of Liang Village made clever use of the relationship between water and earth and formed a spatial pattern of 'living on the terrace and farming in the valley' through generations of transformation. A higher terrace for living could not only provide a good place to defend but also prevent damage from floods. Moreover, it was convenient for villagers in the valley, which had a good irrigation system for agriculture (Figs. 6 and 7). Therefore, even in its period of increasing population, Liang Village did not sprawl continuously but selected another neighbouring terrace to build a new settlement on while leaving the valley as a natural space for water conservation and agriculture.

According to a historical study, the ancestors of Liang Village preferred to build houses by the cliffs on the east side of the tributary of the Huiji River, forming the initial Yaodongs.[5] Then, three settlement units, Donghe Bu (堡),[6] Xining Bu and Nanqian Bu, were built on the terrace. Next, it continued to expand on the flat area with the completion of Changtai Bu and Tianshun Bu. Finally, three settlement clusters were completed, and between them were the valleys with water and farmland (Fig. 8).

Clearly, the site selection of Liang Village took great advantage of water, especially the terrace that was close to the mainstream of the Huiji River. Subsequently, an abundant underground water source was found in the south of the village, which brought great benefits to agriculture, ultimately making Liang Village into a rich lotus root town.[7] Thus, a local folk song, *Praise Local Products* (《夸土产》) sings, 'good rice in Yuanshen Temple and fine lotus roots in Liang Village' (源祠的大米梁村的藕). With the advantage of water, Liang Village became rich because of the cultivation of 'lotus roots', and it formed a beautiful landscape and liveable space on the arid Loess Plateau.

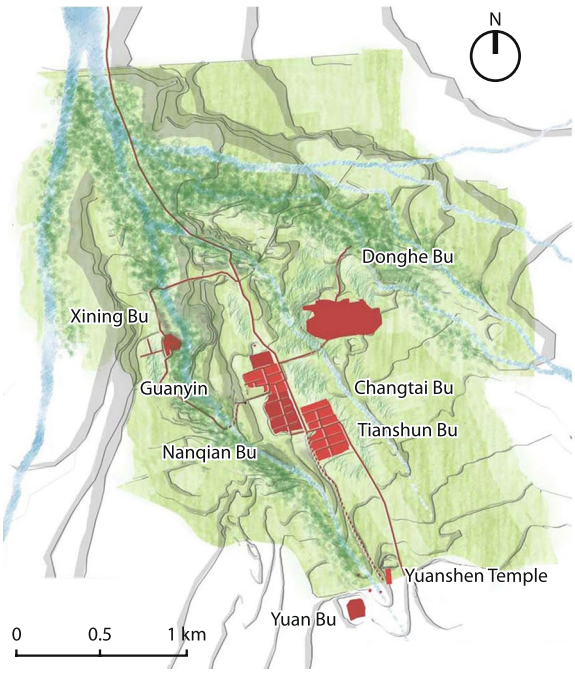


**Fig. 7** Natural environment with the coexistence of water and earth (Source: Tongji University and Ecole de Chaillot 2010)

Because of the lack of water in this arid region, the ancestors of Liang Village cherished the high-quality spring water source and were grateful for the liveable environment provided by nature. Thus, this spring water source was regarded as a god by villagers. To thank

[5] Yaodong is an ancient arch structure architecture style in the Loess Plateau area in China. It is mostly built with earth and has the characteristics of being warm in winter and cool in summer.

[6] Bu is a closed residential unit with insurmountable walls and gates.

[7] In general, rice and lotus root, etc., are crops mainly in southern China, where there is a developed water system, while they are quite rare in the arid Loess Plateau area. It has fully illustrated that the protection for water sources has also brought wealth for Liang Village in return.

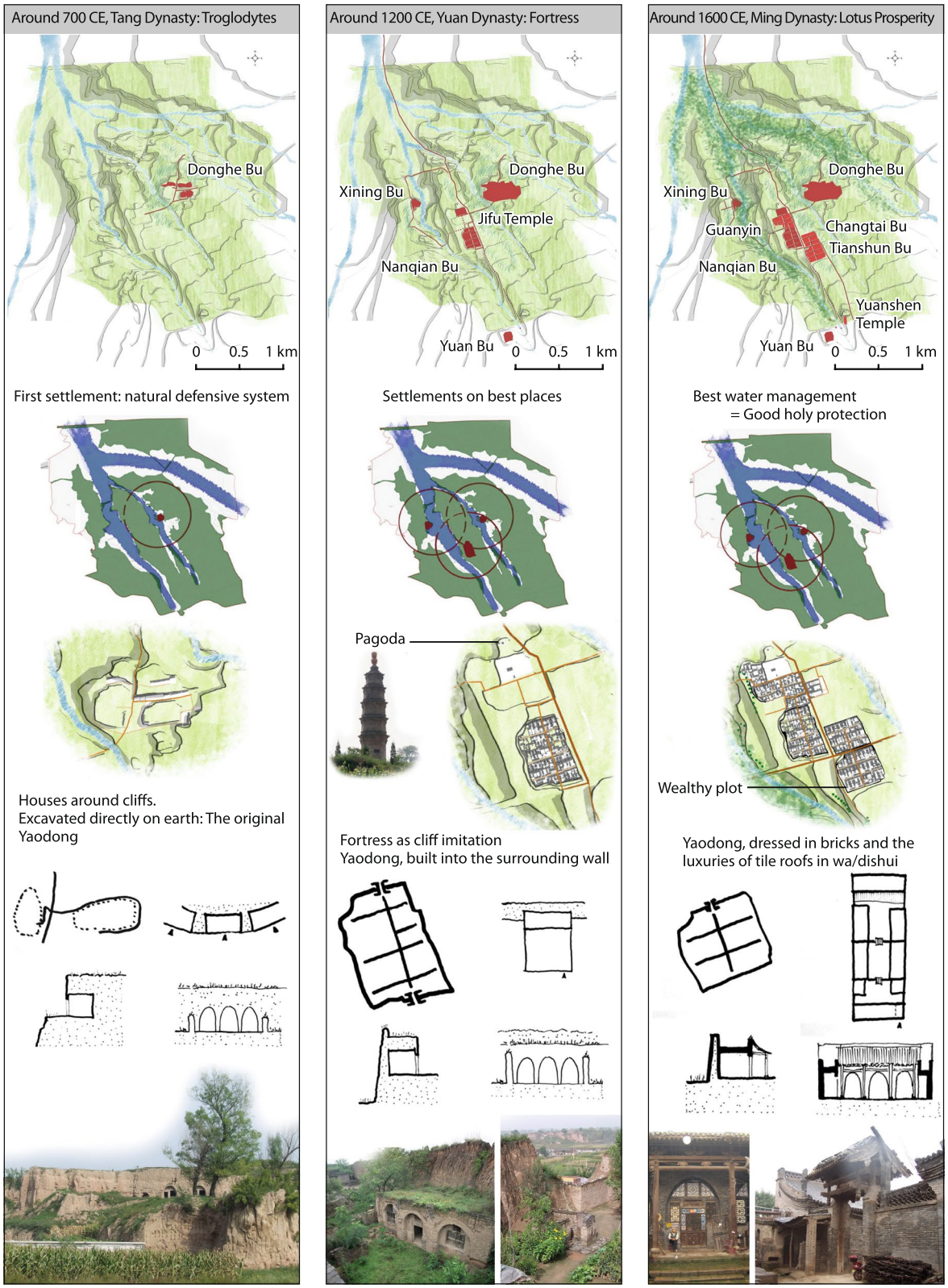


**Fig. 8** From the Tang Dynasty to the Ming Dynasty: From the Loess Plateau to rich lotus roots (Source: Tongji University and Ecole de Chaillot 2010)

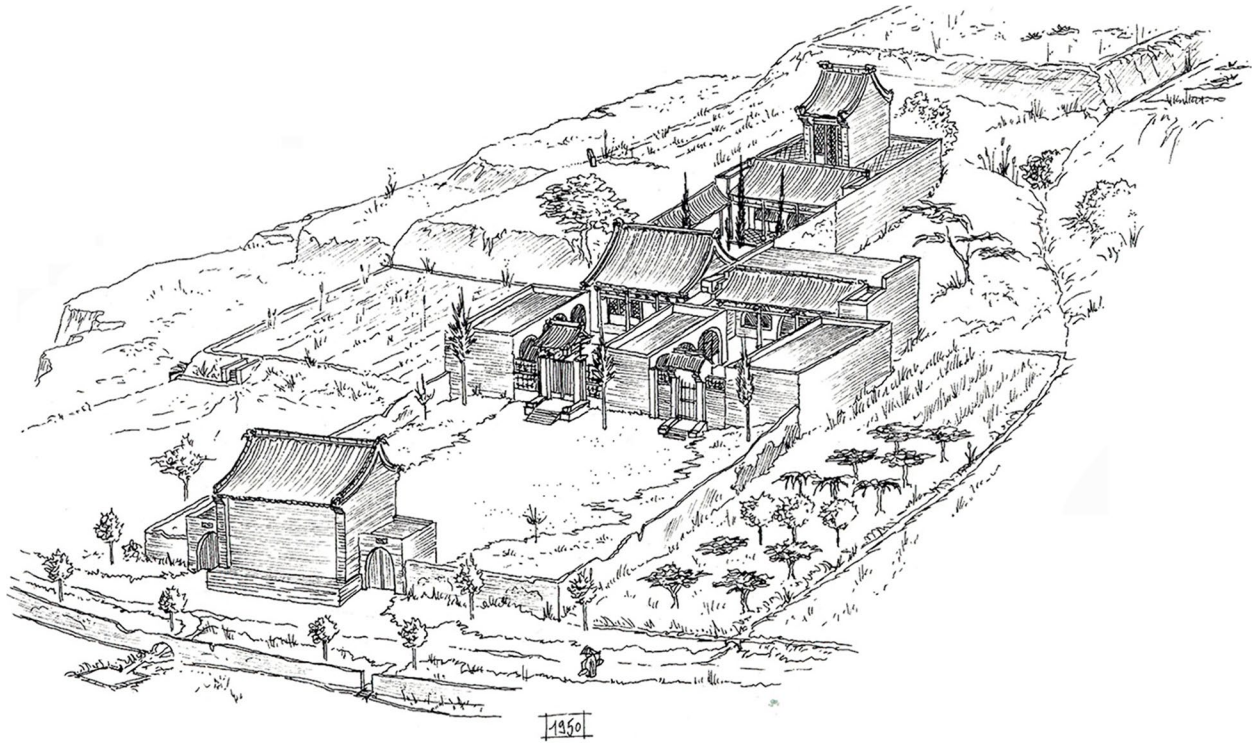

**Fig. 9** Layout of Yuanshen Temple (Source: Tongji University and Ecole de Chaillot 2010)

it, they named it 'Shen Quan' (神泉, means 'sacred spring'), built a fence to protect the outlets of the spring, and even established a temple, 'Yuanshen Temple' (源神祠, means temple for the god of water), on the east side to sacrifice to the god of water. The Yuanshen Temple was located between the fields amid the stage and the wells, taking the natural mountains and water systems as its background, underscoring the history of the endless awe and prayers for water sources among the villagers (Figs. 7 and 9).

#### *3.1.2 Water circulation system inside the earthen settlement: water storage and drainage*

As a single-family group settlement, Liang Village formed a typical Confucian space, with the features of clan hierarchy, large family tradition and defence demand. These social features were all reflected in the spaces. The settlement used the 'Bu' walls (the village walls) as its strict development boundaries, with two gates on the north and south to safeguard the large family. The spatial layout was distinct, which distinguished the public, semipublic and private spaces, while the spaces at all levels were connected by the fishbone street network with primary and secondary relationships.

For a settlement on the terrace, water circulation was an important and challenging part of the liveable space in this region. By manipulating the microterrain, the problems of water provision and flood prevention were impressively resolved for such a closed earthen settlement in the arid Loess Plateau region.

First, the ancestors carefully built a rainwater storage system in the village. The rainwater collection port and passages were well preserved on the top of the 'Bu' walls. Fishbone streets and lanes with a certain slope also had water passages. Rainwater went through the streets, collected in the tanks under the central street, the lowest place in the village, and was stored for daily use. It was very important in dry seasons or in defensive situations. Even today, while the original wells and underground aquifers have dried up, this water collection system can still be used. This was the elastic mechanism that Liang villagers created in response to their arid climate (Fig. 10).

Meanwhile, due to the occasionally large amounts of rainwater, the above system was also very efficient for

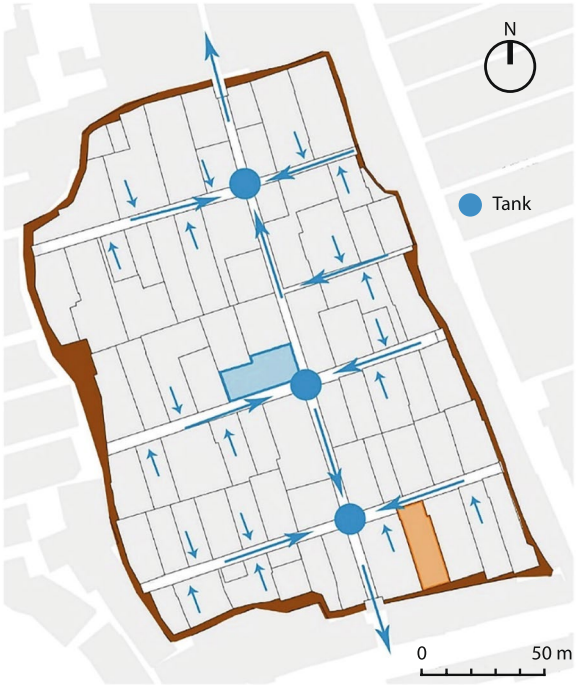


**Fig. 10** Rainwater collection and storage system in Nanqian Bu (Source: Tongji University and Ecole de Chaillot 2010)

drainage. Liang Village Stage Square was not only very secluded in terms of the treatment of the microterrain in accordance with the relationship between the opera stage, stand and the square but also excellent at collecting rainwater and then draining it out of the square quickly via its natural slope (Fig. 11).

#### *3.1.3 Architecture treatment: local earthen material and protection against rain*

Limited by local conditions, traditional buildings were made of local materials, such as earth and bricks, which had the unique effect of warming in winter and cooling in summer and reflected the unique local characteristics and a typical vernacular architecture. There were three main types of local buildings, almost all of which used earth as the main building material. The first was Yaodong, which leaned against mountains and made use of earth directly. The second was the independent Yaodong, which could be built widely on flat ground, the upper layer of which was covered with earth. The third type was a brick house, the walls of which were mostly adobe with a roof with a thick earthen layer. To protect this earthen layer from rainwater, tiles were used to drain water quickly (Fig. 12). Except for the residential buildings, other architectural elements in the settlement, such as the gate and the 'Bu' walls, were mainly built of earth and were also treated in detail to make rainwater flow quickly and prevent erosion.

Accordingly, historic Liang Village obviously reached a 'dynamic balance' by addressing the relationship between 'earth' and 'water'. On the one hand, 'earth' was widely used as the main material in construction; on the other hand, 'water' was smartly treated as a fluid element to bring vitality to this relatively stable and conservative earthen settlement.

### 3.2 'Disintegration of water and earth'

#### *3.2.1 Rural environment: water source exhaustion and farmland degradation*

The increases in population caused greater demands on agricultural production, especially during the Great Leap

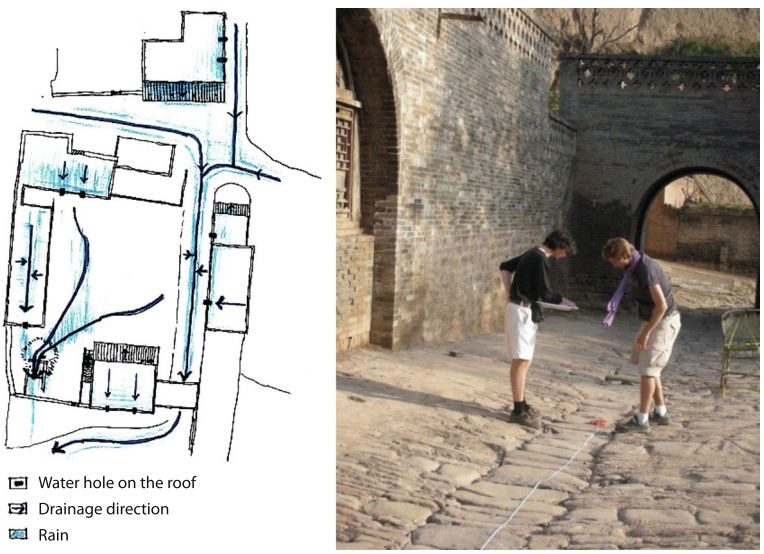


**Fig. 11** Topographic microprocessing in the stage square and underground rainwater collection and drain systems (Source: Tongji University and Ecole de Chaillot 2010)

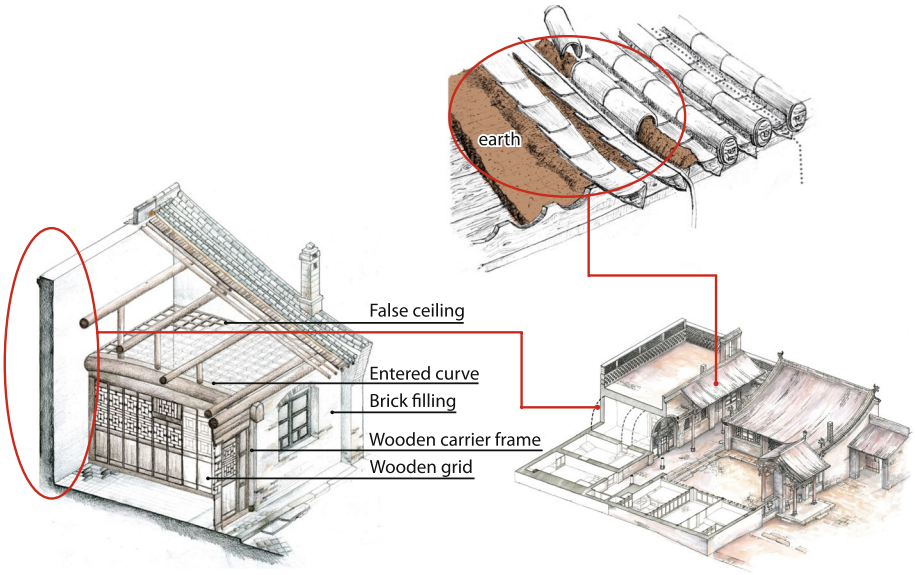


**Fig. 12** Earthen material and the detailed treatment to prevent rainwater in Shanxi residential architectures (Source: Tongji University and Ecole de Chaillot 2012)

Forward (1957–1960).[8] Villages drilled wells in a radical way to obtain water for irrigation, which not only caused the rapid decline in the groundwater level but also caused irreversible destruction to the groundwater layer and eventually caused the drying up of water sources. Meanwhile, the construction of the reservoir to the north of the village accelerated the drying of the river. This further caused the valley north of the village, which attached the rivers, to gradually shrink, and the fertile cultivated land was also gradually degraded. Finally, the landscape of the rivers and valleys surrounding the village was weakened (Fig. 13).

Due to the exhaustion of the water sources, people's worship of nature also disappeared; therefore, the Yuanshen Temple, which was divine in history, became unimportant. In the 1970s, the spring water source was renamed the Hongqi Well (red flag well), and a mechanical pump was built next to it. In the 1980s, a motorway passed through the Yuanshen Temple and separated the temple into two parts: the opera stage on the north of the road and the other part on the opposite side. The spirit and space of this sacred historic site were completely destroyed. The internal space of the temple was used as a primary school for a period and was later abandoned. Unfortunately, the temple was also heavily damaged in the 2021 flood in Shanxi (Fig. 14).

#### *3.2.2 Settlement form: urban sprawl and modern infrastructure intervention*

With the increase in population, the five traditional 'Bu' walls could no longer accommodate all of the people, so it was inevitable to create new living space. However, in the twentieth century, due to improved productivity, the ability to transform nature also increased. Therefore, the villagers abandoned the traditional method of site selection and chose to sprawl adjacent to the old section, which was obviously more convenient.

Similarly, in the new settlement construction, due to the collapse of traditional family concepts and the reduction in defence needs, the traditional urban form, with a strict boundary and a grading structure, was replaced by a more open, efficient and homogenous space. However, with the breaking of the spatial hierarchy, the subtle terrain differences also disappeared. Thus, the village had to rely on a sewer system to drain water, not the natural topography.

Meanwhile, people's worship of water also changed in a subtle way. There were two causes. First, the ideology changed; nature worship was thought to be a feudalistic superstition that should be abandoned amid the New Culture Movement[9] in China in the 1910s and 1920s. Second, the development of technology, especially the popularity of tap water, rendered the relationship between people and nature increasingly indistinct. Thus, the traditional rainwater collecting system was deemed unimportant.

[8] It refers to the socialist movement from the winter of 1957 to early 1960 that set unrealistic goals for industry and agriculture, with an overemphasis on speed. It reflected the people's urgent need for development, but failed to respect basic economic laws.

[9] It criticised classical Chinese ideas and promoted a new Chinese culture based upon Western ideals like democracy and science.

**Fig. 13** New buildings with urban sprawl and dry valleys (Source: the author)

**Fig. 14** Yuanshen Temple after the flood (Source: the author)

#### *3.2.3 Earthen building: loss of function and threat from water vapour*

Whether it was a public building or a residential building, a lack of functions further fostered the destruction of earthen building quality. Most buildings have faced obvious problems such as humidity, weathering, roof leakage, damage to wood components, settlement and deformation. Moreover, with the development of building materials and technology, as well as the improvement of economies and living demands, concrete and ceramic tiles have replaced bricks and earth and have become increasingly popular. In contrast, a large number of traditional architectural spaces have been abandoned, and various pathologies have emerged as a result.

For earthen materials, the greatest threat has come from water vapour, which has caused cracks, spalling, ravines, flooding and other common pathologies due to rainfall and humidity. Regarding the wall on the south side of Xining Bu in Liang Village, for example, after years of erosion, the drainage system was especially destroyed, and the wall was seriously damaged. There were thus many structural pathologies, such as structural cracks, destructive gullies, overturning and settlement, and more surface pathologies, such as microcracks, spalling, scouring gullies, alkalisation and plaster loss, in the wall (Figs. 15, 16 and 17).

Therefore, various spiritual and physical transitions fundamentally caused Liang Village to shift from emphasising the 'coexistence of water and earth' to allowing the 'disintegration of water and earth'. Thus, the loss of 'water' directly caused the deterioration of the ecological environment and the frangibility of the ecosystem. Since 'water' was incredibly significant as a kind of conditioner in the ecosystem, thus the loss

**Fig. 15** Status quo of the south and north facades of the wall before restoration (Source: Tongji University, Ecole de Chaillot and China Academy of Art 2010)

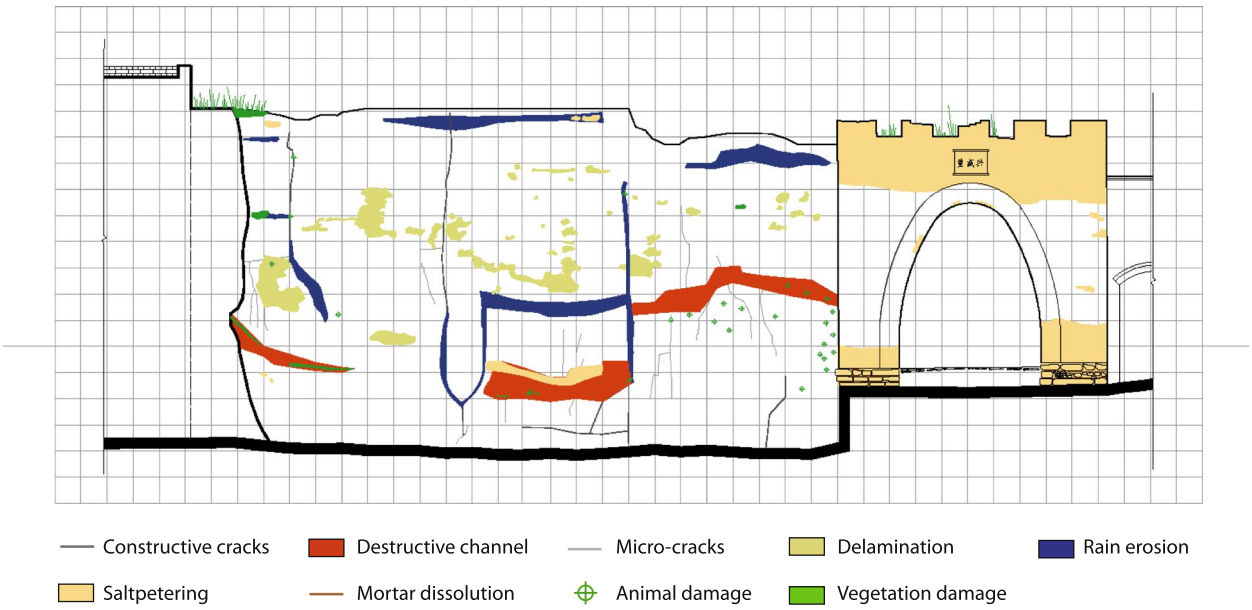


**Fig. 16** Pathological analysis of the south facade of the wall (Source: Tongji University, Ecole de Chaillot and China Academy of Art 2010)

of 'water' not only made the environment no longer flexible but also eroded the vitality of the earthen settlement.

## 4 The contemporary value and the relationship recovery of water and earth

### 4.1 The contemporary value of water and earth

Under the concept of sustainable development, there are new meanings for the traditional elements of 'water' and 'earth'.

#### *4.1.1 The ecological function of 'earth'*

In recent decades, environmentalists, ecologists and architects have realised that earthen material is itself a kind of green material. As a local material, it not only consumes little nonrenewable energy (oil, natural gas, etc.) during processing, production, transportation or construction but also has a minimal carbon footprint (Cancino and Avrami 2015). Furthermore, raw earth has good heat preservation and insulation performance, which can control for the loss of heat. It is particularly prominent in Yaodong buildings. For example, in winter, earth absorbs heat and stores heat during the day and then releases heat indoors at night. Warm in winter and cool in summer are therefore the most praised advantages of Yaodong buildings (Shen 2020).

#### *4.1.2 The resilience of 'water'*

Resilience as an academic term was first put forward by Canadian ecologist C. S. Holling in 1973. It means the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes in state variables, driving variables, and parameters and persist (Holling 1973). Due to the vulnerability of traditional cities when facing external disturbances, such as natural disasters, the concept of resilience was introduced to cities. City managers hope that 'resilient cities' are more integrated and forward-looking

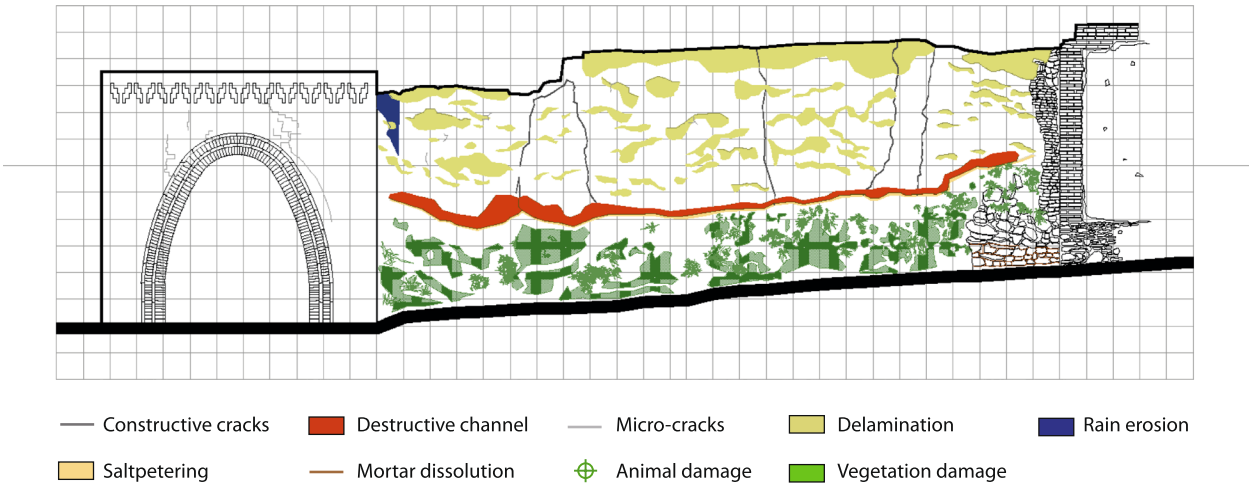


**Fig. 17** Pathological analysis of the north facade of the wall (Source: Tongji University, Ecole de Chaillot and China Academy of Art 2010)

concerning disaster prevention, climate-change adaptation and risk management (Yang and Lin 2015). Hence, the establishment of an adaptable and resilient urban water system is an important part of a resilient city (Rijke et al. 2013).

In response to the serious problem of the urban water ecological crises, the government of China published a series of policies about 'Sponge City' in 2013. The aim of these policies is to make cities like sponges, with good performance in adapting to environmental changes and responding to natural disasters. When it rains, such cities can absorb, store, seep, and purify water, and after rainfall, these cities can 'release' the stored water and make use of it as needed (MOHURD 2014). Therefore, it has been gradually observed that the resilience effect of water is both obvious and significant.

### 4.2 Exploration of the relationship recovery of water and earth in Liang Village

Based on this understanding, a decade ago, the workshop team made efforts to restore the relationship of water and earth through urban planning. The working team put forward a design strategy regarding the environment, urban form and building levels after an in-depth analysis of the characteristics and evolution of the 'water and earth' of Liang Village and a comprehensive consideration of the needs of contemporary production and life. Its aim was to effectively restore the village's relationship between 'water and earth', to better demonstrate the characteristics of the village, and finally to form a new harmonious relationship between humans and nature.

#### *4.2.1 Environment: restoration of the 'water and earth' relationship*

According to the traditional characteristics of Liang Village, such as following *fengshui* theory and considering security and defence, as well as its current heritage distribution features, the conservation and development plan of Liang Village was proposed. There were several strategies in the plan, such as the delimitation of the ecological protection areas, the built heritage protection areas and the areas where construction would be conditionally permitted. The target of these strategies was to protect the spatial order and spatial pattern with the characteristics of 'living on the terrace and farming in the valley' in Liang Village (Fig. 18).

To improve the drought environment and thus to enhance the resilience of the village to cope with natural disasters that may occur again in the future, the remaining water conservancy facilities and irrigation system were rearranged. Initially, rainwater would be collected and filtered for daily use by the villagers. The domestic wastewater, once used, would flow to the fields. Through ingenious terrain treatment and pipe arrangement, the wastewater should be fully utilised for plant irrigation. Meanwhile, the excess water will be refiltered by the ecological purification function of plants, such as reeds, and finally returned to the village for daily use by the residents; thus, a water circulation system could be established. To protect the surface runoff, we also suggested building a plank road system in the valley that would be fully integrated with terrain (Fig. 19).

Because of the important symbolic meaning of the Yuanshen Temple and the water source, it is necessary to restore the harmonious historical relationship

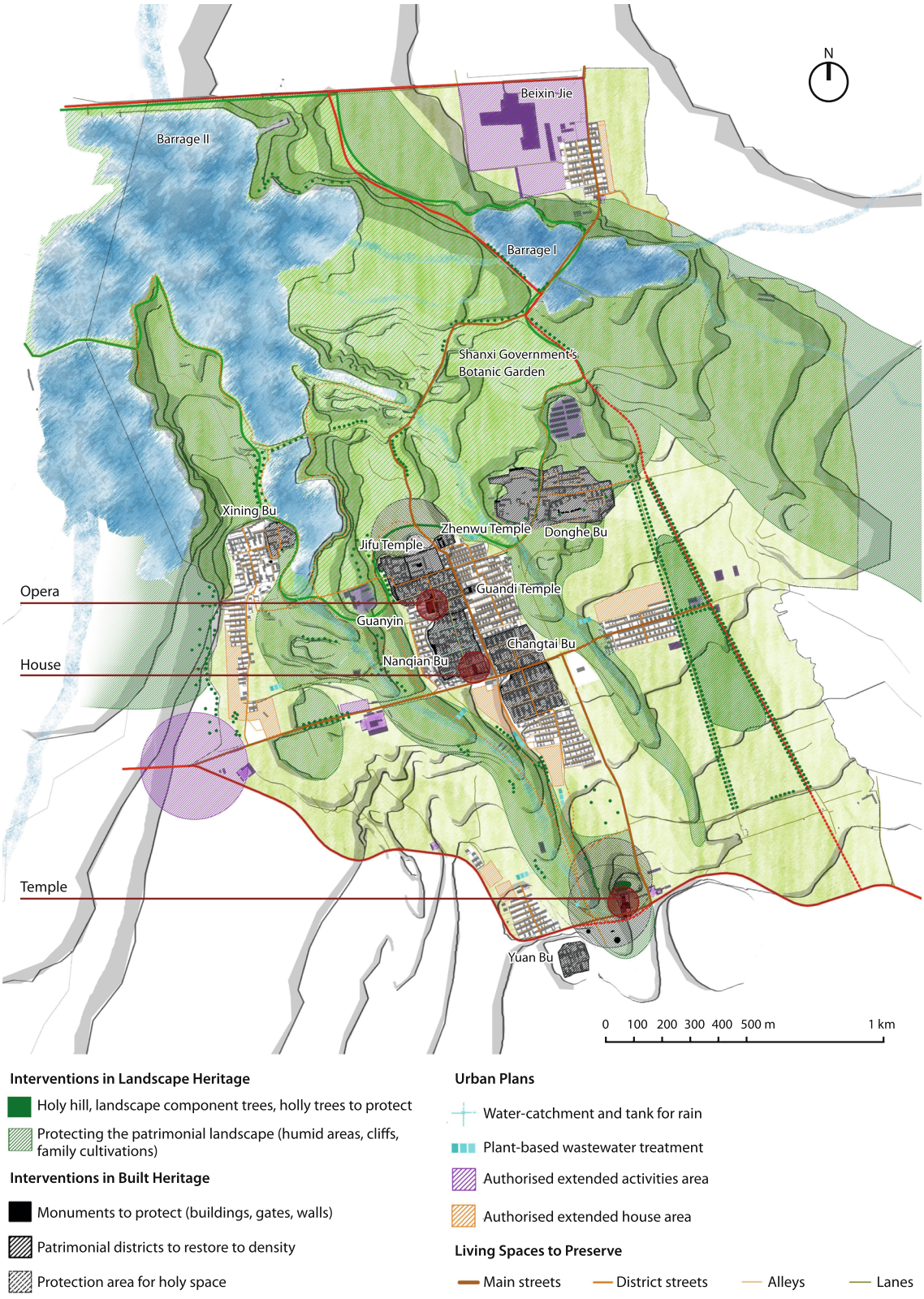


**Fig. 18** Conservation and development plan of Liang Village (Source: Tongji University and Ecole de Chaillot 2010)

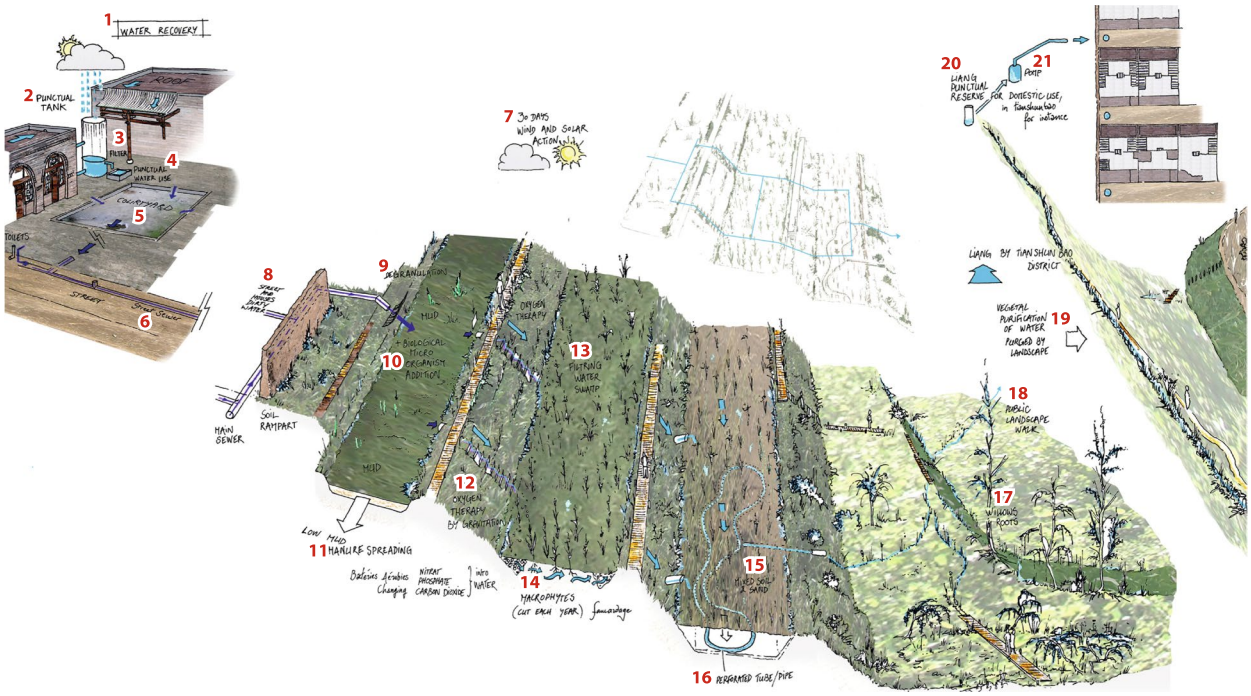


**Fig. 19** Rainwater collection system in the region, from settlement to building (Source: Tongji University and Ecole de Chaillot 2010)

between people, god and nature through landscape restoration. First, the traffic road that separates the temple and stage should be diverted from the south of the stage to recover the original integrated layout of the temple. Second, more green plants should be added around the water source to gradually form a good ecological environment. Last, Yuanshen Temple should fulfil new functions as a public facility for ecological restoration with planned exhibitions, cultural tourism and management. Although it does not retain its original sacrificial function, the temple can allow people to gain respect for nature, restoring the power and wisdom of the balance between man and nature (Fig. 20).

#### *4.2.2 Settlement: site protection and terrain restoration*

In addition to protecting the traditional sites, including the 'Bu' walls and gates, street system and the traditional courtyards, it was also necessary to repair and enhance the damaged elements. The most important one to repair was the stage square at the centre of the village. Specifically, the northwest gate, the affiliated buildings and the detailed paintings needed to be repaired to strengthen the central position of the stage and to foster the cultural functions of watching and performing to revive the centre of the village. Meanwhile, to recover the original drain system, it was also necessary to repair the microterrain of the square because some terrain has been artificially altered and would easily block water (Fig. 21).

The rainwater collection system inside the village needed to be repaired and strengthened to improve the village's ability to cope with extreme climates. Moreover, the village's microclimate needed to be adjusted through water circulation to create a more liveable environment for the residents (Fig. 22).

#### *4.2.3 Architecture: restoration with traditional savoir-faire*

For earthen material, the core target was to decrease the threat from water vapour. Taking the wall on the south side of Xining Bu in Liang Village as an example, the workshop team made several efforts to realise this

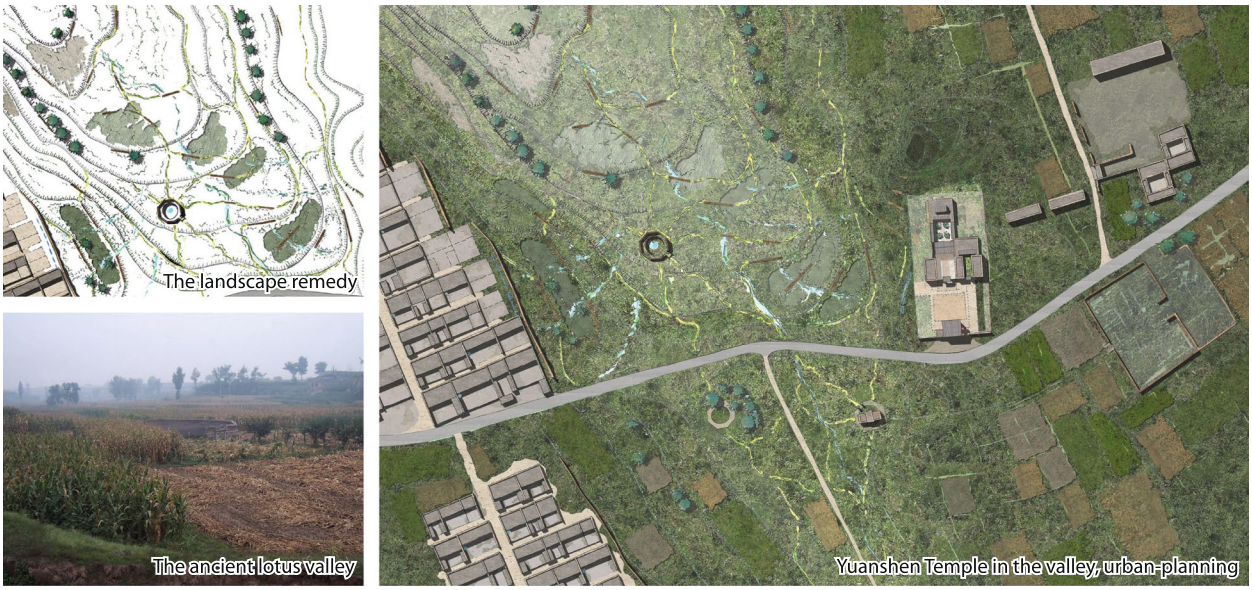


**Fig. 20** Landscape restoration (Source: Tongji University and Ecole de Chaillot 2010)

target. First, they planned to restore the underground drainage system before repairing the body of the wall. Then, to increase the strength of the material, they chose to add lime or rice slurry but not cement, which is impermeable and may adversely introduce more vapour into the earth.

### 4.3 The implementation of the plan and the limitations of the workshop

After the workshop, the local authority carefully considered the suggestions from the workshop team and immediately implemented two restoration projects: the wall on the south side of Xining Bu and the damaged stage square drainage system. The core of these two restorations was to deal with the relationship between water and earth. The key to the former project was to dredge the underground drainage system so that the water vapour could be discharged without damaging the wall, while the key to the latter was to adjust the terrain so that the rainwater could drain quickly without clogging. The effects of these two projects have been excellent; not only have the structures remained in good condition for 10 years but they also avoided any damage from the flood disaster in 2021 (Figs. 23 and 24).

However, except for these two projects, most of the proposals in the workshop were not adopted. There are two reasons for this. First, the workshop's implication is systematic, comprehensive, and even idealistic; however, for Liang Village, there are great difficulties in concept changing, obtaining financial support and village management, which make it difficult to implement. Second, the actual problems of the village are more complex, such as the serious problems of industries and population decline. Due to their limited time and ability, the workshop team did not consider these aspects, thus making their suggestions incapable of solving the most fundamental problems of the village.

## 5 Discussion and conclusion

Liang Village's case is a very good example of the importance of the coexistence of water and earth. When the ancestors fully respected the natural environment, they cleverly used two major elements, water and earth, to create an ecological, liveable and beautiful settlement, an ancient society with low productivity. When modern people ignore the laws of nature, they destroy the harmonious relationship between water and earth, thereby causing serious environmental damage. Although the implementation of the workshop was very limited, the impacts of the flood disaster on these two projects further validated our judgement.

Global climate change seems to be a new vast challenge to earthen heritage conservation work, and it seems to be inevitable for earthen heritage to suffer from rain and floods. However, if we change our minds, if we harness the traditional wisdom contained in the heritage itself, we may avoid or at least decrease such losses. The important concept of 'water and earth' in traditional Chinese culture is full of wisdom; something that seems to be an 'earth' problem (such as the cracking of an earthen wall) can be due to 'water' (such as rainwater erosion). In contrast, something that seems

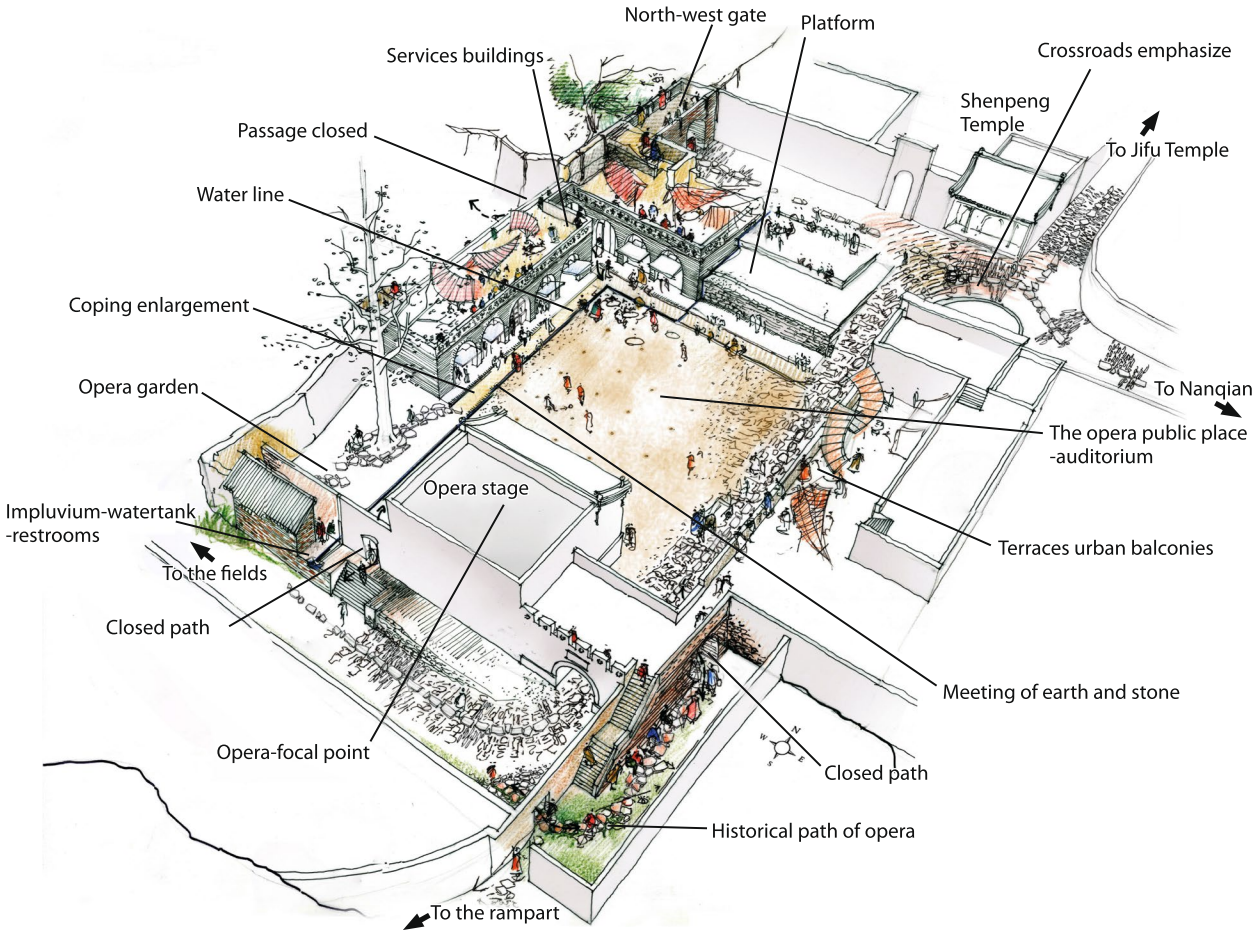


**Fig. 21** Regeneration of the stage square and recovery of the microterrain (Source: Tongji University and Ecole de Chaillot 2010)

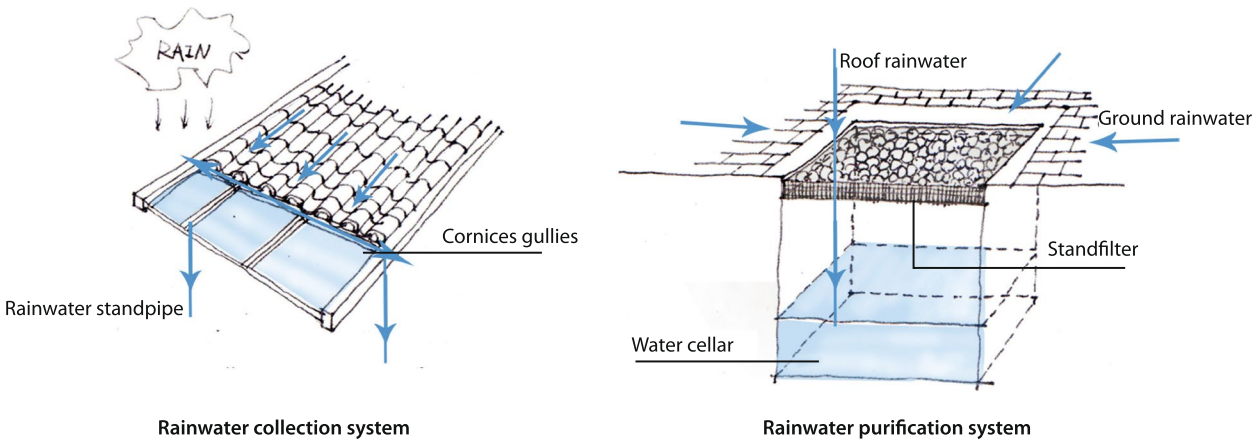


**Fig. 22** Rainwater collection system for traditional residential buildings (Source: Tongji University and Ecole de Chaillot 2010)

to be a 'water' problem (such as flood disasters) can be resolved by 'earth' (such as terrain treatment). Therefore, improving the disaster prevention capabilities of earthen heritage is not simply handling 'earth' issues but should involve strengthening the coordination of 'water' and 'earth'. In short, the core of the 'water and earth' concept is the harmonious relationship between people and nature.

**Fig. 23** The effect of the wall after restoration (Source: the author)

**Fig. 24** The status of the stage square after the 2021 flood (Source: the author)

It is also necessary to state that in actual conservation work, we should more comprehensively consider local economic, social, cultural and management realities and adhere to the concept of 'people-centred'[10] to formulate and implement conservation plans. This inevitably entails long-term and comprehensive work that requires the joint efforts of all salient professionals and parties. Liang Village's case therefore demonstrates a method of treating earthen settlements and provides ideas for earthen settlement conservation in other regions.

**Abbreviations**

CRED: Centre for Research on the Epidemiology of Disasters; UNFCCC: United Nations Framework Convention on Climate Change; CCHWG: Climate Change and Heritage Working Group; NMC: National Meteorological Centre.

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[10] In 2015, ICCROM put forward a 'people-centred approach' in the cultural heritage management of its living heritage program, emphasising that people related to the heritage, including users, managers and enthusiasts, should be regarded as the core of heritage management, and that heritage should also be regarded as a kind of factor that can effectively stimulate the vitality of a community and provide benefits to all kinds of people.

Mr. John Hurd in on-site guidance (Source: the author).

**Authors' contributions**
Yong Shao organized the Liang village Sino-French workshop and the disaster assessment for Pingyao, established the writing framework of this article, and identified the cultural heritage value of the site. Yue Chen participated in the Sino-French workshop and was a major contributor in writing the manuscript. Jianming Su participated in the Sino-French workshop and contributed ideas in writing the manuscript. All authors read and approved the final manuscript.

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## Declarations

**Competing interests**
The author declare that they have no competing interests.

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**References**

Cancino, C., and E. Avrami. 2015. Earthen architecture: Sustaining heritage, diversity, and the environment. *Conservation Perspectives: The GCI Newsletter* 30 (2): 22–25.
Chen, Fangbing, and Lun Cao. 2015. Yi hongcun weili tan fengshui dui gucunluo xuanzhi jianzao de yingxiang [Taking Hongcun as an example to talk about the impact of feng shui on the site selection of ancient villages]. *Sichuan Architecture* 35 (5): 66–68.
CRED, UNDRR, and USAID. 2021. Disaster Year in Review 2020: Global Trends and Perspectives. *CRED Crunch Newsletter* no. 62. https://reliefweb.int/report/world/cred-crunch-newsletter-issue-no-62-may-2021-disaster-year-review-2020-global-trends-and. Accessed 7 Jan 2022.
Deng, Yuxia. 2019. Cong shuitubufu shuo yidi yangsheng [From the perspective of water and earth uncomfortable to discuss health]. *Home Medicine* 4: 63.
Grossi, C.M., P. Brimblecombe, and I. Harris. 2007. Predicting long term freeze–thaw risks on Europe Built heritage and archaeological sites in a changing climate. *Science of the Total Environment* 377 (2–3): 273–281.
Holling, C.S. 1973. Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics* 4 (1): 1–23.
Huo, Yaozhong, and Peilin Liu. 2005. Town form and earth-scape on Loess Plateau. *Architectural Journal* 12: 42–44.
ICOMOS. 2019. *The future of our pasts: Engaging cultural heritage in climate action outline of climate change and cultural heritage*. http://openarchive.icomos.org/id/eprint/2459. Accessed 10 Sep 2021.
Luo, Yong. 2015. Kejia minjian fengshui xinyang yu shuiziyuan de liyong he baohu [The utilization and protection of Hakka folk fengshui beliefs and water resources]. *Folklore Studies* no. 122: 37–43.
MOHURD (Ministry of Housing and Urban-Rural Development of the People's Republic of China). 2014. *Technical guideline for sponge city construction: Low impact rainwater system construction*. Beijing.
Pang, Pu. 1984. The origin of Yin, Yang and five elements. *Social Sciences in China* 3: 75–98.
Rijke, J., M. Farrelly, R. Brown, and C. Zevenbergen. 2013. Configuring transformative governance to enhance resilient urban water systems. *Environmental Science & Policy* 25: 62–72.
Scott, Z., and M. Tarazona. 2011. *Study on disaster risk reduction, decentralization and political economy. Global assessment report on disaster risk reduction*. Oxford: ISDR, UNDP and Oxford Policy Management. https://www.preventionweb.net/english/hyogo/gar/2011/en/bgdocs/Scott_&_Tarazona_2011.pdf. Accessed 8 Mar 2021.
Shen, Ziyi. 2020. Shanxi jinzhong diqu shengtu minju de kechixu yanjiu [Sustainable study of earthen residence in Jinzhong district, Shanxi province]. *MING(Attitude)* 11: 153–154.
Smith, B.J., M. Gomez-Heras, and S. McCabe. 2008. Understanding the decay of stone-built cultural heritage. *Progress in Physical Geography* 32 (4): 439–461.
Stewart, M.G., X. Wang, and M.N. Nguyen. 2011. Climate change impact and risks of concrete infrastructure deterioration. *Engineering Structures* 33 (4): 1326–1337.
Tongji University, and Cité de l'architecture & du patrimoine. 2013. *Apprendre a lire le patrimoine*. Shanghai: Tongji University Press.
Tongji University, and Ecole de Chaillot. 2010. *Sino-French joint conservation workshop of Liang Village*. Shanghai: Tongji University Press.
Tongji University, and Ecole de Chaillot. 2012. *Sino-French joint conservation workshop of Shui Motou village*. Shanghai: Tongji University Press.
Tongji University, Ecole de Chaillot, and China Academy of Art. 2010. *Sino-French restoration workshop of earthen architecture*. Shanghai: Tongji University Press.
United Nations. 2015. Paris agreement. https://unfccc.int/sites/default/files/english_paris_agreement.pdf. Accessed 28 Mar 2021.
Wang, Lina, Qingke Zhu, and Xiaolin Tong. 2016. Characteristic analysis of temporal and spatial variation of precipitation during recent 50 years in loess plateau. *Agricultural Research in the Arid Areas* 34 (03): 206–212.
Wang, Qiheng. 2015. Fengshui: zhongguo gudai jianzhu de huanjingguan [Fengshui: Environmental view of ancient Chinese buildings]. *Art Panorama* 11: 97–100.
Wang, Qiheng, and Hui Zhang. 2010. Document classic and Chou Li: Classics of city planning and fengshui theory in ancient China. *Journal of Tianjin University (social science)* 12 (03): 225–231.
Wang, Xiaowei, and Jian Zhou. 2011. The evolution of traditional village pattern: Case study of Liang village in Shanxi. *Modern Urban Research* 26 (04): 30–36.
Wang, Xuan, and Xin Hou. 2006. Study on the category of traditional stockaded village in Shanxi. *Human Geography* 6: 35–39.
Xiang, Bo Song. 1993. Study on Chinese water worship culture. *Journal of South-Central University for Nationalities (Humanities and Social Sciences)* 6: 49–53.
Xiao, Jing, and Ke Cao. 2014. Analysis of feng shui pattern in traditional Chinese settlements based on the concept of cultural landscape: A case study of ancient town of Shangli, Ya'an in Sichuan province. *Journal of Human Settlements in West China* 29 (03): 108–113.
Xu, Yan, Qiong Peng, and Yinjie Wu. 2012. An empirical study on the influence of geomatic environmental school's theory on ancient village's space pattern: Taking Donglong village as the example. *Journal of East China Institute of Technology (Social Science)* 31 (04): 315–320.
Yang, Yang, and Guang Si Lin. 2015. A review on sponge city. *South Architecture* 3: 59–64.

## Publisher's Note