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Sustainable Water Management Model as Landscape Heritage in Shang Gan Tang Village, China

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Abstract: With the rapid expansion of economic production and urban areas, the climate becomes abnormal and the original water circulation disturbed or totally destroyed, which makes the settlements and communities suffer from water related threats such as drought, flood and water logging. The water management strategies in the heritage landscape concerned are in line with landscape ecological requirements, and the need for sustainable development through practice and the test of time. Vernacular architecture, as part of the landscape heritage, has a deep root in tradition, being a cultural asset which influences the traditional and sustainable land use through the location, form, material, structure and size of the buildings. The classical courtyard house of China, the „YuanLuo", represents an outstanding type of vernacular architecture, representative for many different regions of the country. The paper highlights the ecological importance of the „YuanLuo" as a cultural heritage asset, focusing on the traditional rainwater management system invented and used from ancient times in the Shang Gan Tang region. The water retention facilities and water resource management strategies of Shang Gan Tang village are analysed through field investigation, and its "X-Y water resource management model" is obtained. The functions of water circulation, energy exchange, rain and flood control are explored.Accordingly, sustainable development strategies for modern urban development and rainwater management can be provided, and contemporary Chinese (and international) housing design should evolve along this architectural and ecological legacy.
Keywords: landscape heritage; water management; sustainable landscape; Shang Gan Tang village, cultural landscape

I. INTRODUCTION

In today's society, climate change often leads to natural disasters (Casey & Becker, 2019), which has brought great challenges to economic production and human life. (Xiao, Li, & Wang, 2011; Naustdalslid, 2011) Among them, the instability of the water environment leads to a large number of human settlements facing floods, droughts and other natural disasters (Qiao, Liao, & Randrup, 2020). Regarding the water cycle, the production process of human life has more influence on all aspects of water circulation, resulting in water circulation imbalance, or even break, and eventually cause drought disaster (Carter, Tyrrel, & Howsam, 1999; Pahl-Wostl, 2007; Stead, 2014). Therefore, we urgently need to change the existing way of production, find a balance between the water environment and human life, and ultimately achieve sustainable development. (L. Liu, Fryd, & Zhang, 2019) In order to achieve this goal, scholars from all over the world have put forward a variety of research perspectives and methods. From the discovery and understanding of problems, through the problem-solving ideas to review, there are various approaches to the goal of sustainable development. The article presents special aspects in the case of the areas and objects belonging to cultural heritage or historic landscapes. (Zhang, 2015)

Some researchers believe that the development of a general targeted cooperation policy and the application of existing knowledge to practice as a key to solve the problem (Biesbroek et al., 2010; Naustdalslid, 2011), from a macro perspective is worthy of promotion, but lacks micro-practice support. Moreover, there are scholars carrying out research on adaptive strategies to manage climate anomalies by the means of urban planning and water resources management, (Stead, 2014) or through strategies based on blue-green infrastructure facilities. (L. Liu et al., 2019) There are also sustainable, historic blue-green infrastructural facilities to explore, offering traditional water management models. (Moutsopoulos & Petalas, 2018; Crouch, 1990; Völker & Kistemann, 2011)

In traditional Chinese society, due to the building materials and construction technologies used, the impact of the settlement and human activities on the water environment is lesser. (Qiao et al., 2020; Hoang & Fenner, 2016; Li, Uyttenhove, & Vaneetvelde, 2020) In addition, the concept of nature-human harmony of self-regulation has given birth to a large number of historic water landscapes, as well as sustainable water

management strategies. (Guangzhen, Qi, & Yuye, 2019; W. Liu et al., 2019) This study begins with a general presentation of rainwater facilities in the Cultural Heritage of Shang Gan Tang village, exploring and combining traditional architecture and the concept of sustainable water management to provide sustainable, long term ecological resource strategies for future's settlement planning and development.

Fig. 1.a.

Fig. 1.b.

Fig. 1.c.

Fig. 1.a. Location of the study area in Hunan province, China. Source: Map prepared by the Authors
Fig. 1.b.-1.c. Typical landscape of Xiang Jiang River basin (Chu Dong and Gou Lan villages) Source: Photos by the Authors

II. OBJECTIVES AND METHODOLOGY

The aim of the paper is to systematically explore the ecological relevance of traditional vernacular architecture in rainwater resource management of some settlements located in the Xiang Jiang River basin, especially in the case of Shang Gan Tang village. The paper analyzes the rainwater collection and storage methods used in the village since the 12th century and highlight its past, present and future importance for sustainable settlement development.

Regarding the methodological approach, the research may be practically divided into two main parts: the historical research and the site survey.

The historical research starts with an overview of cultural and technical parameters of the traditional residential buildings and courtyards in Shang Gan Tang, based on a review of fundamental publications on comprehensive rainwater management research and architectural history. Fundamental works were determined according to the most-cited publications in rainwater management research and heritage protection at local, national and international level.

For a systematic survey of the site (fieldwork), we established a theoretical framework, analysing the general landscape conditions, the climate characteristics (with special focus on rainfall), the architectural and heritage based identification of relevant courtyards. The fieldwork survey methodology of Shang Gan Tang courtyards was based on the principle that the house and the courtyard may and therefore must be interpreted as a whole, in the context of the settlement and landscape, as the only way to understand their historic importance, current value and future potential.

The study has multiple outcomes. The results inform researchers, professionals, teachers and students more on the importance and the need to preserve and use traditional techniques in sustainable water management. Secondly, the research conclusions are suitable to support the elaboration of a rainwater management strategy for historic site renovation projects and the design of contemporary urban courtyards or public open spaces.

III. TRADITIONAL WATER MANEGEMENT STRATEGIES IN SHANG GAN TANG VILLAGE

Shang Gan Tang is a village located in the Xiang Jiang river basin, Hunan province, China (Figures 1a-1c). Thanks to its traditional landscape, settlement structure and vernacular architecture, the village has been recognized by the State Administration of Cultural Relics as a national key protection unit of cultural relicts (sixth batch) in 2007.

The oldest building existing in Shang Gan Tang was founded in 1126, during the reign of the emperor WanLi of the Ming dynasty. The village was enlarged during the Qing dynasty. It counted approximately 200 densely built traditional houses made of stone and wood, the 500-meter-long Xie Mu River flood control wall, two bridges and four pylons (Figure 2). Much like Zhang Gu Ying, Shang Gan Tang is praised as one of the largest and best example of Ming-Qing era village still standing in south Hunan province. Comparable to Zhang Gu Ying in style, Shang Gan Tang is much smaller. The overall layout of the settlement is still relatively regular nowadays, with a south facing north arrangement. Shang Gan Tang village faces mountains on both sides, The Xie Mu River crosses the front of the village from west to east. There are two artificial ponds in the northeast side of the village. It has a traditional Feng Shui Bureau surrounded by mountains and waters. (Figure 2) There are 450 households with more than 1,700 people within the scope of the traditional village under special protection and planning in Shang Gan Tang village. 68 residential houses of the Qing Dynasty are designated as monuments.

3.1. The traditional water storage system in Shang Gan Tang

The traditional water storage system and especially the rainwater management in Shang Gan Tang has three basic units, which are strongly linked to each other and which are in a constant and organic connection with the landscape:

A - the „YuanLuo” (private)

B - the settlement level water management and drainage

C - the pond (common)

Fig. 2. Aerial view of the traditional village structure in Shang Gan Tang, China (coordinates: 25°09'09''N 111°10'55''E) Source: Photo by the Authors

A - The „YuanLuo"

The „YuanLuo" is a historical residence type that was commonly found throughout China, most famously in Beijing. But we can find similar traditional landscape heritage in Xiang Jiang River Basin or in the middle and lower reaches of the Yangtze River Basin as well. (for example Chu Dong village, Zhang Gu Ying village and Zhong Tian village) (Figures 3a-3c)

The name „YuanLuo" literally means a courtyard surrounded and defended by four buildings. Through its architectural characteristics and spatial dispositions the „YuanLuo" defines a specific settlement fabric and a very typical landscape pattern. Its connection with the landscape has significant regional characteristics and profound cultural connotation, and is the product of the environmental experience and wisdom of ancient Chinese working people. At the same time, its sustainability and ecological approach are of great significance to water resource management, water landscape construction and water related cultural heritage.

Although the first „ YuanLuo" was built more than 700 years ago, some of the ideas are still being used today, and are highly valued in sustainable architectural design. (Soflaeia, Shokouhianb&Zhuc, 2017)

The „YuanLuo" is mainly composed of four parts:

- earth/stone platform/raised basement (base),
- wooden column/pillar structure (body),
- overhanging roof framework (head) and
- the courtyard, surrounded by the buildings.

The platform prevented moisture from penetrating into the column feet and walls; it was solid enough to support walls made of rammed earth, adobe, or fired brick above, which either supported the roof structure directly or served as a curtain wall around a timber framework. (Knapp, 2005; Liang, 1998)

The elevated structure also provided an observation function that made defense more readily achievable (Pheng, 2001). Basement foundations were rare across China, maybe because of Daoist environmental ethics as indicated in „Tai Ping Jing" (The Book of Great Peace) that advises people not to dig or gouge Mother Earth to avoid calamity. (Lai, 2001).

The research started on site through identification of all potential units („YuanLuo") in Shang Gan Tang, followed by an assessment of the spatial layout and defining the main courtyard types.

Fig. 3.a.

Fig. 3.b.

Fig. 3.c.

Fig. 3.a. Chu Dong village (coordinates: 28°27'39''N; 114°01'38''E)
Fige 3.b. Zhang Gu Ying village (coordinates: 29°00'33''N; 113°28'32''E)
Fig. 3.c. Zhong Tian village (coordinates: 26°10'28''N 112°31'01''E)
Source: Photos by the Authors

A very typical element of the courtyards in Shang Gan Tang, important from water management point of view, is the **water basin** located in the middle of the courtyard, used for the storage of the rainwater collected mainly from the roof and from the courtyard's platform.

Regarding rainwater management, besides the courtyard's basin, the roofs of the surrounding buildings have a great importance, being directly involved in the water collection, storage and drainage processes.

The roof

The most striking feature of a classical Chinese courtyard house was the elaborate roof. Since the Chinese worshipped Heaven, they employed a large, sweeping overhang as a link between Heaven and Earth, while at the same time expressing their aspirations to enter an eternal life (Liu, 1989). Large eaves also helped to protect the walls and wooden columns from rainwater while allowing unobstructed daylight. There were many regional variations of roof types and degrees of slope, depending on the temperature, rainfall, winds, and availability of material. (mud compositions, thatch, clay tiles, wood, and stone shingles, etc.) (Knapp, 2005; Liang, 1998).

Traditionally, a tiled pitched roof was the norm for buildings in eastern China, and the degree of slope was at least 4:12, often between 6:12 and 8:12 (or the inclination angle at least 30°, normally between 45°–60°). The depth of eaves was typically 60 cm to prevent rainwater from slanting in (Characteristics of Timber-Structured Chinese Ancient Buildings, 2008).

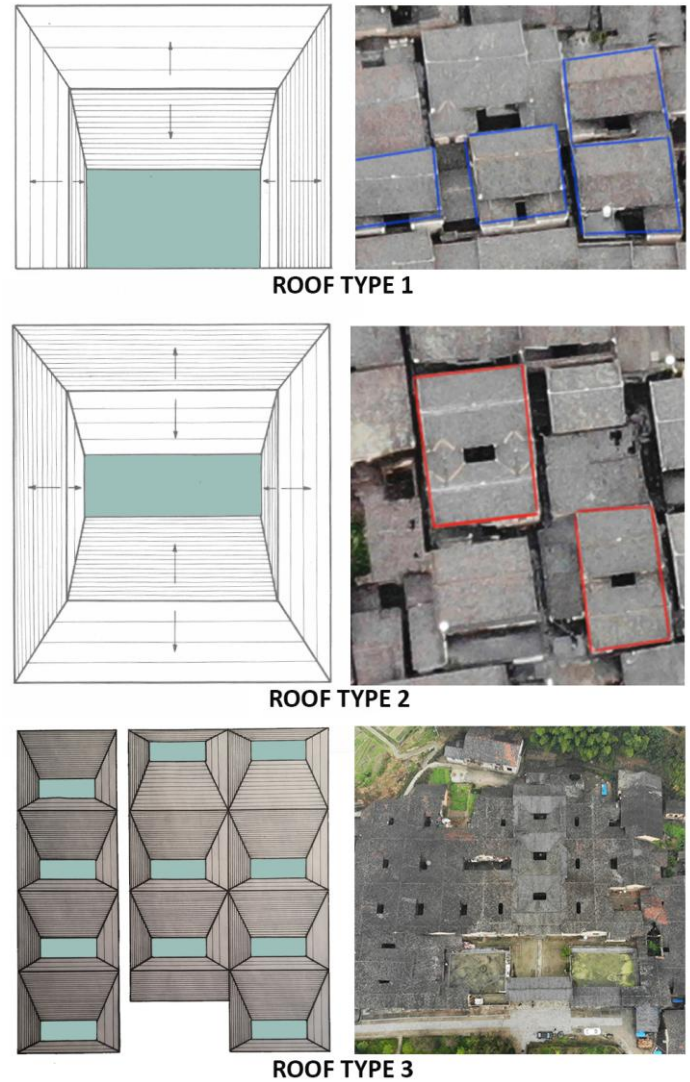


Figure 4. The three basic types of roofs in Shang Gan Tang presented by sketches and photos
Source: Photos and sketches by Authors

Although the double-pitched roof was the most common, single-pitched, flat, and sometimes even convex-curved roof profiles were built in northern and north-eastern China.

The roof in Shang Gan Tang village has a special structure, which is surrounded by four inclined eaves, on which there are curved tiles, which can make a part of rainwater collect from the four sides to the middle, and finally drip into the courtyard (patio). There are three basic types of roofs, presented by photos and sketches in Figure 4. This traditional building method incorporates 500 years of local experience in architecture, based on the typical climate and precipitation of the region.

The inclination angle of eaves and the density of tiles have been designed adaptively, so that the collected rainwater is not too much and will not damage the structure of the house.

The patio (courtyard)

The courtyard in Shang Gan Tang has a square shaped, semi-closed layout, with an usual dimension of about 12 m2 (sides ranging from 3 to 4 m, occupying about 15% percent of the total ground area of the „YuanLuo." (Figure 5) The proportion of the roof surface and the courtyard surface is 5:1. The water storage pool in the courtyard has a capacity of 2.4 m3.

Fig. 5. The patio and the central pool in two different houses from Shang Gan Tang village. Source: Photo by the Authors

The courtyard as an "outdoor room" was often paved with bricks for domestic activities. Although the courtyard was a pleasant outdoor space, the inhabitants had to walk across it to reach each room even in severe weather conditions, an inconvenience especially for the elderly. The vast majority of Shang Gan Tang "YuanLuo"-s are single-storey, to be close to earth qi for health. Some large houses had twostorey buildings in the northern end of the settlement (Ma, 1999). Although multi-storey buildings emerged in China as early as the Warring States (475-221 BCE) (Pheng, 2001), they were widely adopted only in southern China where the ground floors are often wet and damp. (Knapp, 2005)

The patio is an important element in the water management of Shang Gan Tang village, and it is also the most important feature that represents the water culture, which is most in line with the harmonious and co-prosperity of human beings and the water environment.

Shang Gan Tang village people think that water is the symbol of vitality and wealth. Therefore, when building houses, rainwater is kept in the patio so that to return water to the hall. The bottom of the patio has a permeable pavement with a flexible substructure (paved with stone bricks placed in clay and sand), so that it is permeable for rainwater and can store it. However, there is a certain gap between the bricks, and the water will slowly infiltrate into the subsoil to supply subsoil water. Moreover, to prevent excessive water levels caused by heavy summer rains, drains are also installed on the side of the patio to drain excess rainwater (Figure 6).

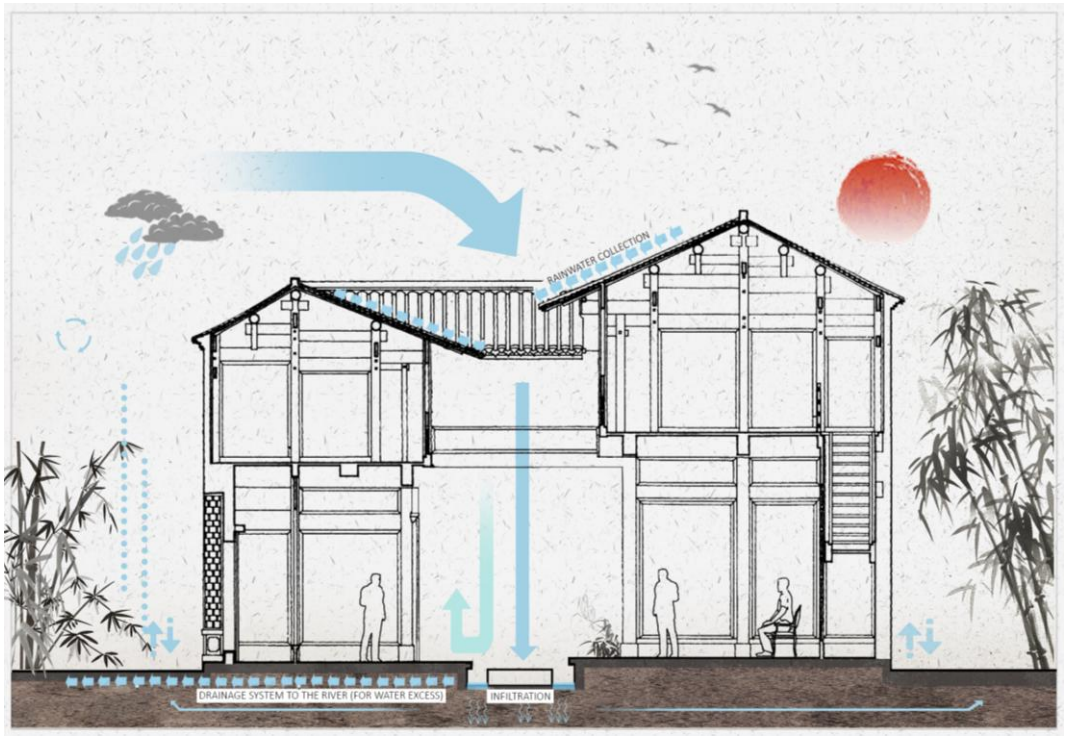
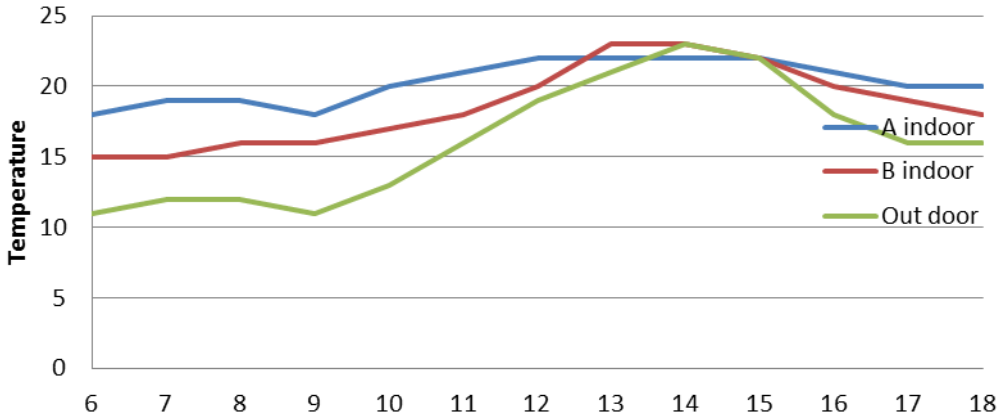


Fig. 6. Theorethical scheme of water collection and sewage system of a courtyard in Shang Gan Tang village. Source: Sketch by the Authors

The water in the patio is not only symbolic, but also practical. Shang Gan Tang village is located in the subtropical monsoon area. The survey of climatic conditions proved a high rainfall in the rainy season (229.2 mm in May, based on 1971-2000 data statistics). Average summer temperature is 28.8° Celsius.
The patio – thanks to its structural characteristics – can absorb a portion of the surface water, and reduce the flood caused by rainwater. On the other hand, a part of the water in the patio evaporates in the daytime, moderating the indoor temperature, reducing it even with 4–6 degrees. (Histogram 1)



Histogram 1.
Average temperature change in a YuanLuo at Shang Gan Tang during a day (from 06.00 to 18.00)
A-line (blue) - indoor temperature in the buildings with a patio
B-line (red) - indoor temperature in the buildings without patio
C-line (green) - outdoor temperature

B. The settlement level water management and drainage

The landscape character of the region strongly influenced the water resource management of Shang Gan Tang village, which is also reflected in the location and the planning of the village.

A general landscape assessment of the present conditions on the site show that, established on the river shore and located at the bottom of four hills, the village uses the river as a water resource, on the one hand, and

for drainage (of the excessive rainwater), on the other hand. The water infiltrated and drained from the patio (excess rainfall) is collected by an underground drainage system through the descending terrain and finally flows into the river.

Besides the river, water bodies are also represented by some rainwater retention ponds created at the edge of the settlement, at the bottom of the hills. The role of these ponds is to collect the excessive rainwater running down from the hills and storing it for later use.

The water from the ponds is conducted to the houses of the village, and the excess of the rainwater is also conducted directly into the river. (Figures 7a-7b)

Due to the topography, the rainfall in the settlement will gradually accumulate in the pond, and the pond will supply humid air to the settlement owing to the southeast monsoon. In combination with the function of the patio, the ventilation of the settlement area is good. In this way, in addition to the economic use of water, the water also contributes to the improvement of the climatic conditions of the settlement.

This process reduces the negative impact of settlements on the surface runoff. Combined with the water collection and infiltration of the patio, it extends the time while rainwater remains on the surface and has certain effect on the control of rainwater and flood. As the precipitation passes through the vegetation, the settlement and finally arrives into the pond, it can effectively slow down the surface runoff and increase the infiltration after repeated detention of the rainwater.

The structure of the settlement is similar to that of the residence. In the settlement, the pond is equivalent to the patio of the residence. They both have the functions of transpiration and water storage, and can also supply each other through the groundwater. This is the function of water culture, and it also reflects the worldview of local people living in harmony with nature.

C. The pond

The pond has the following parameters:

- surface area: 1100 m2,
- maximum depth: 2 m,
- average depth: 1.5 m,
- water quantity: 73.4 m3,
- type of lakeshore: artificial

The water in the pond can be used for many purposes, such as fire fighting, daily washing, irrigation etc. Besides, the pond also has ecological benefits. Thanks to the participation of the public, the water quality of the pond is protected and a permanent aquatic biotop has been established here during decades, with various aquatic species (animals and plants) living in it. The protected species are: *Rana limnocharis, Chinemys reevesii, Ceratopteris pteridoides, Anser anser, Caldesia grandis, Nuphar sinensis, Nymphaea tetragona, Isoetes sinensis, Euryale ferox Salisb, Typha orientalis Presl.*

3.2. X-Y water management model in Shang Gan Tang village

According to the above presented research, the water facilities in Shang Gan Tang village are connected into a whole system, resulting The Water Resources Management Model X-Y of Shang Gan Tang Village. The scheme of the model is presented in Figure 8.

The overall model is divided into two parts: a horizontal (X) and a vertical (Y).

In the X part, the patio is the core as the basic (family) unit for the water collection, while the pond is the community (village) water collection center. Vegetation has a resupplying role in the system.

In the Y part, again, the patio is the core, which is linked to and mutual supply each other with the groundwater and is also part of the evaporation and precipitation processes. Moreover, there are interrelations between the six water resources links, forming a water circulation system with the patio as the core.

The system is a good example on how to deal with the relationship between people, landscape and water environment. It not only meets the needs of human existence, but also minimizes the impact on natural water bodies, meeting the needs for sustainable development.

The X-Y water resources management model provides a systematic solution for the water environment and human life, which we can learn from, and apply into the settlement planning of nowadays.

Regarding the overall planning of the settlement, we can scientifically site selection, the original water system for the settlement of the construction. Follow the natural runoff in the Y1 process and increase the combination of vegetation and water bodies. From the point of view of residential housing, the appropriate increase in sponge facilities, so as to reduce the environmental impact on the original water environment. Increase the water body interaction in the process of X2Y2, using the X1 process, the natural adjustment of indoor temperature.This study, based on field work, from the settlement scale to straighten out water resources

management strategy, there are many details worth further study, such as compared with contemporary architecture, the quantitative analysis of the impact of traditional architecture on the environment.

Fig. 7. The village-river connection and the conceptual landscape scale diagram showing the water cycle in Shang Gan Tang village.
Source: Photo and sketch by the Authors

For an efficient modeling of rainwater management systems, supporting future urban planning and design processes, we need to collect some important data on site:

- amount of precipitation (mm/year);
- rainfall pattern (the type of rainfall pattern; a climate where rain falls regularly throughout the year means that the storage requirement is low and hence the system cost will be correspondingly low – and vice versa); more detailed rainfall data is required to determine the rainfall pattern; the more detailed the data available, the more accurately the system parameters can be defined;
- drainage surface area (m2);
- available storage capacity (m3);

- daily consumption rate (liters/capita/day); this varies enormously and this will have obvious impacts on system specification;
- number of users;
- costs;
- alternative water sources (where alternative water sources are available, this can make a significant difference to the usage pattern);
- water management strategy – whatever the conditions, a careful water management strategy is always a prudent measure; in situations where there is a strong reliance on stored rainwater, there is a need to control or manage the amount of water being used so that it does not run out before expected.

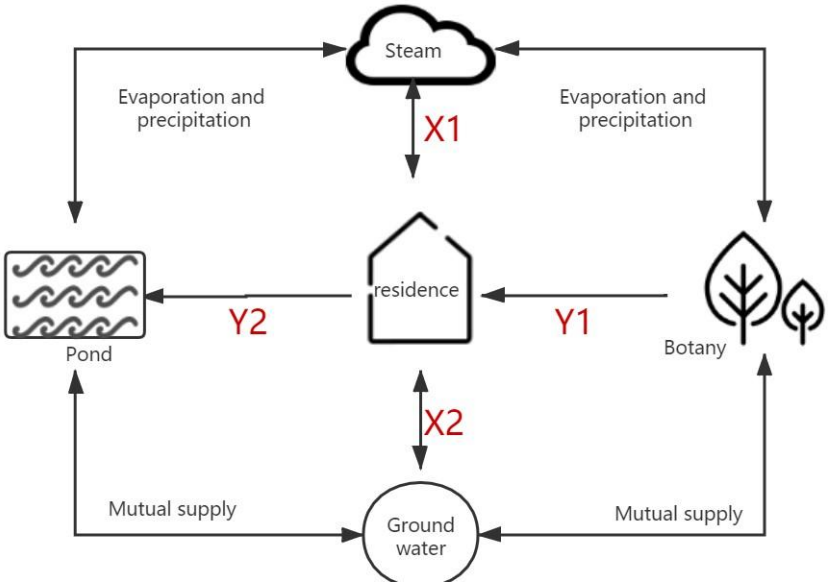


Figure 8. Water management model in ZhongTian Village (Source: sketch by Authors)

IV. CONCLUSIONS AND RECCOMENDATIONS

This paper examined the traditional water management as a basis of sustainable strategies in urban environment. The study explores the contemporary challenge of recognising, protecting, managing and using a unique asset of the Chinese cultural heritage as a development model for the future, with a special reference to cultural landscapes.

The paper provides some background information on the urban fabric in Shang Gan Tang, on how the system of traditional courtyard houses determines the settlement layout, and how the houses and courtyards themselves – with regard to their exterior form, interior space, building materials, and construction technologies – influence the water management of these units and of the whole village. The paper is based on a review of relevant Chinese and international literature and on analysis of case studies on Shang Gan Tang village.

The basic element in the system is the courtyard that, besides the water storage, provides also natural light, air, visual features (trees, plants, flowers, rocks, etc.) and social connections, acting as a family activity space whenever the weather allows. The key idea of the water management strategy is the drainage and water storage system developed on settlement and landscape level, using the existing natural resources and processes.

The paper presents the organic structure of the „YuanLuo" and of the whole settlement, which guaranteed an outstanding and self-sustaining water management in the past of Shang Gan Tang; it took Chinese designers and builders much care and effort to complete a project to such an excellence that contemporary housing designers and builders should learn from.

The presented X-Y water management model in Shang Gan Tang village offers a suitable example for the harmonious integration of buildings, settlement and landscape without negative ecological impact. The socio-environmental sustainability in traditional courtyard houses of Shang Gan Tang „YuanLuo" represents significant work of art, technology and ecology, which deserve attention. The authors have proposed a model to follow in by the residential courtyard gardens in the future, in order to realize energy saving, being eco-friendly and comfortable.

Beyond the ecological aspects, from the heritage point of view, the traditional water management system in Shang Gan Tang village has the functions of bearing regional characteristics, building local identity of the community, and transmitting cultural traditions. It is an important heritage reflecting regional human-landscape relationship and highlighting regional cultural identity.

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