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Water management -
New ways for sustainable cultural landscape

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CHAPTER 1. INTRODUCTION

1.1 Research background

Globally, the recent years have witnessed an increase in environmental and ecological issues caused by climate change, making sustainable development one of the most pressing concerns of our time (Vitousek, 1994). Sustainable development is a multidisciplinary subject. From the perspective of Maslow's hierarchy of needs, its essence lies in humanity's pursuit of a favorable environment, which is fundamental to human survival and development (Elias et al., 2019). Water resources, essential for human sustenance and progress, are pivotal (Gleick, 1996). The United Nations Sustainable Development Goals underscore the significance of environmental protection and resource management, where water resource management plays a key role in maintaining ecological balance and social welfare (Bexell and Jönsson, 2017).

Water, as a fundamental material resource constituting life, is indispensable in the Earth's ecosystem. However, with urbanization, surfaces that once facilitated water cycling are increasingly covered by artificial materials, altering the depth and breadth of the natural water cycle and significantly reducing its efficiency (Ramanathan et al., 2001a). Population growth has led to a dramatic increase in water demand for agricultural and industrial production, contributing to water pollution (Jury and Vaux Jr, 2007). Climate anomalies, manifesting as frequent extreme weather events, have altered precipitation patterns, causing uneven distribution of rainfall over time and space (Trenberth et al., 2003). This exacerbates water shortages and urban flooding issues. These challenges pose significant obstacles to the goal of sustainable development (Koop and van Leeuwen, 2017). Therefore, effective water resource management is crucial in adapting to climate change and achieving sustainable development goals and understand the underlying principles of their responses to climate change (Smit and Pilifosova, 2003).

Effective water management strategies are key to adapting to climate change. This includes improving the collection, storage, distribution, and efficient use of water resources, as well as the protection and restoration of aquatic ecosystems (Misra, 2014) . Through these measures, it is possible to mitigate the impacts of climate anomalies on agriculture, ecosystems, and human communities. Based on past research on the topic of climate change, we find that climate change is a global phenomenon with varying impacts across different regions (Parmesan and Yohe, 2003). Taking the Eurasian continent as an example, stretching from the equator to the Arctic, it is divided into climatic zones such as the monsoon climates of Southeast Asia and South Asia, and the Mediterranean and temperate maritime climates on the western side of the continent. Each climatic zone has unique natural geographical features like temperature, precipitation, and vegetation, which play a significant role in responding to climate change (Mark, 2023) .

Corresponding to these natural characteristics, humans have continually adapted and adjusted their survival strategies to their environments over the course of their long-term living practices (Bates and Plog, 1991)

Therefore, to effectively address climate change adaptation, it is imperative to learn from the survival strategies of local residents in different climatic zones and understand their basic principles in responding to climate change (Laukkonen et al., 2009). These insights can guide the development of context-sensitive and culturally aware adaptation strategies, ensuring that efforts to combat the challenges posed by climate change are grounded in local realities and experiences (Moser, 2014).

Different climatic patterns shape diverse natural and ecological environments, which in turn sculpt varied cultural landscapes (Simmons, 2013). Environmental determinism, a perspective from geography, was a widely prevalent viewpoint at the end of the 19th and the beginning of the 20th century (Peet, 1985, Livingstone, 2011). Its fundamental proposition is that the natural environment significantly determines the development of human society and culture. This theory posits that human behavioral patterns, social structures, and cultural characteristics are dictated by their geographical environment. However, with the evolution of modern geography, environmental determinism faced criticism for overly emphasizing environmental factors while neglecting human agency (Livingstone, 2011).

Yet, in the study of climate-adaptive cultural landscapes, particularly in hydro-cultural landscapes, environmental determinism provides a framework to understand and explain the formation and development of these landscapes. Hydro-cultural landscapes, such as rivers, lakes, and canals, can be natural geographical features or the result of human adaptation and management of these water resources (Huntington, 1924).

From the perspective of environmental determinism, hydro-cultural landscapes significantly influence human settlement patterns. For instance, in regions abundant with rivers, people tend to settle along the rivers, forming river-centric settlement patterns. This pattern influences human social structures, economic activities, and cultural development. Furthermore, the impact of hydro-cultural landscapes on agriculture is particularly evident. In areas with scarce rainfall, the development of irrigation agriculture is often limited by the availability of water sources. This leads to the evolution of irrigation techniques, which in turn affects crop planting patterns, agricultural production structures, and even forms of social organization. In many cultures, hydro-cultural landscapes are not only the foundation for living and production but also vital elements of culture and religious beliefs. Rivers, lakes, and other water bodies are often imbued with sacred meanings, becoming spaces for various cultural rituals and festive activities (Mori, 2020).

It is noteworthy that environmental determinism also emphasizes how humans adapt to and modify their environment in response to climate change. Human interventions in water resource management and development, such as the construction of dams, restoration of wetlands, and the development of sponge cities, are vital strategies for coping with climate change and ensuring the sustainable use of water resources.

In summary, environmental determinism provides an important perspective in explaining the relationship between cultural landscapes, particularly hydro-cultural landscapes, and climate adaptability. However, this theory has been criticized for neglecting the reactive power of humans over the environment, particularly in addressing issues such as greenhouse gas emissions and ecological degradation caused by human activities (Lewthwaite, 1966) .

In contrast, possibilism, a human-centered theory proposed by the French geographer Lucien Febvre in the early 20th century, argues that civilization is shaped not by geographical environment or climate, but by human habits, customs, and other cultural elements. Febvre, in his book "A Geographical Introduction to History," suggested that the habits formed in a particular environment quickly gain coherence and stability, shaping the forms of civilization. While the natural environment provides certain possibilities and constraints, humans can choose and change these conditions through technology, knowledge, and creativity. (Febvre and Bataillon, 1925) In this framework, humans are viewed as active participants who shape their way of life and cultural forms through adaptation to, modification of, and management of their environment. This viewpoint emphasizes human agency, opposing the environmental determinism stance of "environment determines everything" and advocating "environment provides conditions, human determines development." For example, residents in various locations have gradually accumulated, over time and space, natural-based water management strategies that withstand the test of time and are continuously improved and adjusted (Tatham, 2015).

With a deeper understanding of nature and culture, concepts gradually converge, and cultural landscapes are interpreted as the joint work of nature and humans, expressing the long-term and intimate relationship between people and their natural environment (Elfert, 2015). Therefore, under this definition, cultural landscapes are global in nature but regionally based in composition (Antrop, 2005) .

This study, with a focus on sustainable cultural landscapes, centers on the topic of water management. It uses time as a parallel line to investigate different hydro-cultural landscapes shaped by various geographical spaces, discussing the characteristics and future trends of water management strategies within this coordinate system. Thus, my research will employ a comparative approach, initially investigating the impact of climate change on water resources in different climatic zones (Adopted, 2014). This includes studying changes in rainfall patterns and the corresponding adaptability adjustments in water resource management strategies, assessing their effectiveness in various situations (Adger et al., 2005). With different climatic zones as references, water management strategies serve the corresponding environmental and demographic needs of those zones.

On the other hand, the study will also discuss how to extract and apply region-specific traditional water management wisdom in a cross-cultural context. For example, linking cultural heritage with sustainability to achieve innovative water resource management strategies, drawing from rich water management cases based on heritage (Larsen and Logan, 2018). Traditional water systems often embody sustainable practices, optimizing water use, protecting ecosystems, and fostering community connections (Vörösmarty et al., 2018). Recognizing the intrinsic value of water in these heritage systems helps cultivate a symbiotic relationship with the environment. It encourages the use of local knowledge and community participation in water resource management, thereby creating avenues for sustainable and resilient water management systems based on a deep understanding and respect for cultural heritage. Integrating cultural heritage into water resource management strategies not only preserves the rich history contained in these traditions but also proposes a forward-looking approach to sustainable development that harmonizes modern practices with historical wisdom. (Figure 1.)

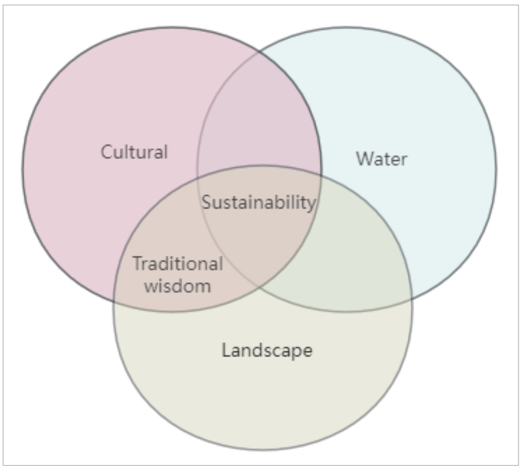

Figure 1. Relationship between the main components of the sustainability (Author)

1.2 Research value

The primary aim of this comprehensive study is to critically analyze and synthesize traditional water management strategies historically employed in various environments (urban and rural) and different scales (object, settlement, regional) in Europe and China, elucidating their relevance and applicability in the contemporary context. Through detailed literature and case studies, this research seeks to reveal the intricate ecological, socio-cultural, and technological aspects of traditional water management. These interacting aspects shape water resource management practices, and considering the differing methods used in urban and rural settings, the study endeavors to integrate multidisciplinary and multi-scalar perspectives in exploring the application of traditional water management wisdom in current sustainable cultural landscape design.

The value of this research is categorized into five aspects: academic value; methodological value; practical value; socio-cultural value and interdisciplinary value.

In terms of academic value, the study contributes to existing theories through literature and case studies on sustainable water management. This includes enriching current sustainable development theories, reinterpreting Nature Based Solutions (NBS), and proposing a new concept: Nature Replacement Solutions (NRS). By integrating a comprehensive theoretical framework that combines water resource management, landscape ecology, and cultural heritage conservation, this framework can provide theoretical support for water management practices.

Regarding methodological application and innovation, the study combines quantitative and qualitative research, incorporating methods from human geography's field surveys and landscape architecture's site analysis. It involves site observations and field research in different regions, understanding, and summarizing the historical and spatial processes and cultural significance of water management. By integrating relevant literature, policy documents, and planning materials, traditional water resource management strategies are reapplied in design and planning. Data collection methods include drone modeling, virtual surveying, offering more flexibility than traditional surveying methods.

In practical value, the study conducts field research and data collection on multiple cases, including image documentation, landscape architectural surveying, climate change trend analysis and prediction, rainwater collection surface measurement, and data processing and analysis of rainwater collection. It also calculates the rainwater collection capacity of buildings and categorizes and evaluates the roof types regarding rainwater management. This research provides valuable references for strategies addressing uneven spatial and temporal distribution of water resources due to climate anomalies and offers insights for landscape architecture, architecture, urban planning strategies, and sustainable water management system design.

In terms of socio-cultural value, the core water resource management in this study is closely related to sustainable development and climate change adaptation. Combining traditional wisdom with modern needs in water management design can promote community participation, foster public awareness of environmental conservation and water-saving, and enhance public involvement in community building. The policies and theories provided by this study can be applied across different social groups, and the research on water cultural heritage has significant implications for cross-regional and cross-scale studies of water culture.

In the interdisciplinary value aspect, the study creates an innovative research path for sustainable water management based on cultural heritage, through the interdisciplinary perspective of landscape architecture and human geography, facilitating knowledge and technology exchange between these fields.

In summary, this research, by summarizing and generalizing traditional water management models, strategies, and technical methods, concludes universally applicable water management strategies. Applying these strategies to the design of new water management facilities achieves harmony and sustainability in cultural, ecological, and social dimensions.

1.3 Research content and scales

The primary focus of this study is the reuse of traditional water management, specifically the conservation of water cultural landscapes and the reapplication of their water management strategies from a sustainable perspective. Water cultural landscapes represent a comprehensive subject of geographical space and its environment, where the regional differentiation of geographical elements within this space holds significant implications for the research framework of this study. Water, as a crucial element in geographical space, follows a distribution pattern both horizontally and vertically. Additionally, water, being a vital resource for life, directly impacts human society's survival, making water management a key aspect of human-environment interaction and a central focus of this research. Particularly, the study of water cultural landscapes across various regions, histories, and cultures facilitates a comparative analysis, highlighting commonalities in water management strategies and leading to the development of universally applicable water management practices. The scale of comparative research plays a crucial role in the establishment of the research content and framework.

This research defines the scale of water cultural landscapes from three dimensions. The first is the temporal scale, focusing on the historical existence of water cultural landscapes and their impact on socio-economic and cultural aspects. This includes the results of environmental interactions, specifically time-tested water management strategies over lengthy historical periods. Part of this study also involves water management-related cultural heritage, defined here as the tangible and intangible wealth related to water management created and passed down through a society's historical progression. The study focuses on the role of these water management practices in historical and cultural evolution, especially in terms of environmental adaptability and interaction, proposing innovative conservation approaches for such cultural heritage. The temporal scale of this research is determined by water-related cultural heritage, defined as the sum of tangible and intangible wealth created, maintained, and passed down through the historical process of a society, group, or human collective. These heritages reflect a group's identity, culture, and values, marking significant indicators of historical and social evolution.

Secondly, the spatial scale of water management in this study is defined across three levels: regional; settlement; and dwelling. The research initially reviews traditional water management systems in representative global water cultural landscapes, including their origins, development, and technical characteristics, as well as spatial structural features. Furthermore, the study is dedicated to comparative analysis of water-related cultural landscapes in Europe and China, examining the unique and common aspects of water management strategies and water-related landscape spatial structures at regional, settlement, and dwelling scales in these geographically distinct regions. This comparative approach provides new insights into the convergence of environmental adaptability and cultural narratives, enriching the understanding of the symbiotic relationships between different communities and their water environments.

Another crucial aspect of this research is exploring how to integrate cultural water landscapes of different scales into a single, comprehensive and interconnected water management system, summarizing traditional water management strategies at the regional, settlement and object (residential) scales into a multiscale-compatible water management system.

By studying traditional water management cases and aligning them with current sustainability and climate adaptability needs, traditional water management wisdom is reapplied in landscape practice. This research takes a designated spot of the Budapest cultural heritage area as a design case study, applying traditional water management strategies to landscape conservation design.

Throughout this process, traditional water management strategies are applied to landscape nodes, proposing comprehensive water management design solutions for Budapest at different scales.

1.4 Research framework

The dissertation is composed by seven chapters.

Chapter 1 introduces the research background, discussing the relationship between water resource crisis, climate change, cultural heritage, and sustainability. It defines the content and key scales of the study from ecological, cultural, and social (local community) perspectives.

Chapter 2 mainly presents the research objectives and questions.

Chapter 3 provides a literature review on global water cultural heritage, discussing the value of traditional water management strategies from technical, ecological, and philosophical perspectives.

Chapter 4 outlines the research methodology, including the definition of research cases and areas, a summary of research methods, and data collection and analysis.

Chapter 5 is a case study of traditional water management in three scales. Discusses and concludes, summarizing traditional water management strategies from the perspectives of water cultural heritage, ecology, and philosophy, along with their characteristics.

Chapter 6 reuse the traditional water management strategies in design

Chapter7 presents new findings, discussing the potential application value of sustainable water management heritage, cross-cultural and cross-regional characteristics of water management, and summarizing traditional ecological wisdom. This leads to a reinterpretation of Nature Based Solutions (NBS) and introduces a new concept: Nature Replacement Solutions (NRS). The chapter also proposes a rainwater collection equation based on roof surface area and summarizes water management models at three scales. Concludes the study, summarizing its contributions to theory and literature, offering prospects for future research, and reviewing the research project, findings, and contributions. It combines policy recommendations and practices, culminating in a final summary. (Figure 2.)

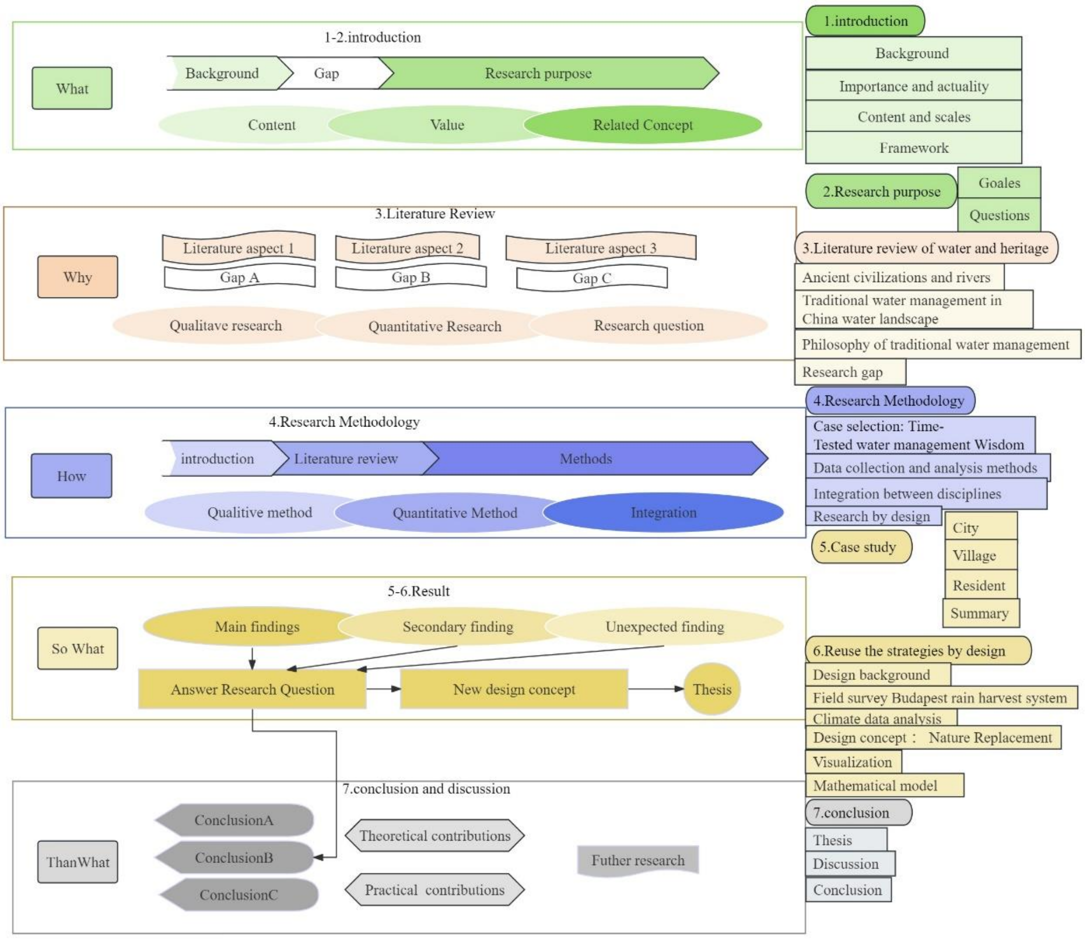

Figure 2. Thesis Structure Diagram (Author)

CHAPTER 2. RESEARCH PURPOSE AND QUESTIONS

2.1 Research purposes

This research, centering on traditional water management, aims to summarize the knowledge, techniques, and experiences of predecessors from the perspective of cultural landscapes. The primary research objective is to identify water management strategies that align with current sustainable development needs, and based on this, to establish new, innovative ways to develop and manage cultural landscapes.

Initially, the study conducts a historical review of several cases related to traditional water management strategies, identifying similarities and differences across various regions and scales. Conducting comparative analysis, the study synthesizes the common logic underpinning traditional water management strategies and explains why this logic can be applied across cultures and regions.

Representative cases of traditional Chinese water landscapes are selected for field investigations to delve deeply into the technical knowledge of traditional water management. This research incorporates interdisciplinary methods from disciplines such as geography and landscape architecture, aiming to provide a multifaceted perspective for the study of traditional water management strategies. It also explores how various factors, including culture, society, religious beliefs, and traditional philosophy, influence or dictate the formation of water cultural landscapes.

Theoretically, this study conducts an in-depth exploration of traditional water management strategies. By engaging with discussions on Nature Based Solutions, it establishes new concepts. Additionally, the study innovatively employs drone 3D modeling for water landscapes, utilizing these models for data measurement and analysis.

Furthermore, the research is committed to offering landscape architectural solutions to address climate anomalies. It involves analyzing precipitation data to predict future rainfall trends and providing landscape design strategies based on these trends. The effectiveness of these strategies is validated through data analysis.

2.2 Research questions

The dialectical relationship between matter and consciousness determines that different natural and human-made environments provide different paradigms, the understanding of which could help humanity transform the world The dialectical relationship between matter and consciousness determines that different natural and human-made environments provide different paradigms, the understanding of which could help humanity transform the world. (Gladwin et al., 1995).

As a cultural landscape, traditional landscape architecture not only has cultural attributes, but also has regional characteristics (Rapoport, 1992). The continuation and evolution on the time scale makes the traditional landscape architecture have a certain environmental adaptability. (Antrop, 2005) This is the premise for the continuation of traditional landscape architecture.

As the subject of changing the objective world, man creates landscape architecture and maps the culture and environment at the same time. On the time scale, summarizes and maps the experience through the object, forming the landscape object under the influence of empiricism (Lothian, 1999). After the external conditions change, it is impossible to judge whether the experience is applicable, but the subject logic can be tested repeatedly in practice. This study, grounded in an interdisciplinary and multiperspective approach, aims to provide a rich array of tools and methodologies while clearly defining the fundamental questions of water management. Due to the extensive technical details associated with this subject, the study focuses exclusively on the exploration of ecological wisdom in traditional water management, particularly its environmental adaptability and sustainable reuse. The research primarily seeks to address the following questions:

1. How were traditional water landscapes formed? How do traditional Chinese philosophies influence the design strategies of water-related cultural landscapes, and what role do internal and external elements play in forming a harmonious design philosophy system?
2. In what ways do interdisciplinary perspectives contribute to our understanding of historic water management as a landscape that transcends time, space, and culture?
3. What is the universal logic underlying traditional water management? Do these water management strategies meet current needs? How might current climate anomalies impact precipitation, and how can traditional water management mitigate problems caused by these anomalies?
4. How can traditional water management strategies be applied in landscape design?

By answering these questions, the study aims to deepen the understanding of traditional water management's role and potential in contemporary ecological and landscape practices, especially in the context of increasing environmental challenges and the need for sustainable solutions. Therefore, a common problem is raised:

5. What is traditional wisdom in the domain of landscape architecture and landscape ecology, and what is the role of the water heritage in this context?

To answer this general question, first we need to have an overview of the cultural heritages related to the landscape architecture and landscape ecology.
Afterwards the understanding of the historical-philosophical background of the traditional water management it is necessary, in order to explore the enlightenment and value of modern landscape construction in cultural heritage according to the current demand. Therefore, the 6th research question is put forward:

6. How does traditional water management contribute to the sustainability of landscape heritage, and what principles underlie its successful integration into modern sustainable landscape development practices?

To answer this question, the cotemporary need is the key. The cultural heritage was treated as the cultural marks, but the sustainable potential is missed. For developing countries, it is the most urgent need to face the problems caused by climate anomalies in a low-cost and simple way, focusing on the new, innovative ways of reutilization of traditional knowledges related to the water. For developed country, also need to face the future of the climate change. After analyzing the cultural heritage related to traditional water management, this study will conduct in-depth investigation on the cases that meet the above requirements.
The value of cultural heritage has local characteristics, but the problems brought by climate change are global, and the types of problems are different in different regions.

Therefore, the seventh question is raised:

7. How can traditional water management methodologies and strategies be adapted for sustainable landscape design in different regions, considering the variance in rainwater collection potentials?

For answer this question, this research focuses on the water related issues triggered by climate change. Especially for the investigation and analysis of traditional water management, model thinking is a better strategy to solve commonness and individuality, whole and part. And here I made a deep overview about the popular concept NBS, than provided a new concept: NRS

This part of research will try to establish the relationship between water management model and local practice, and try to match the model with climate and hydrological data. Try to establish a model that can adapt to different environmental data (precipitation) and actively learn and adjust. The result will prove the traditional water management model can realized the local/ individually practice.

For climate change, scale is also a key to the application range and effect of the model. Water management and thermal environments at different scales have the gap, how the model can be applied in the different scales?

Accordingly, the 8-10 research questions are:

8. How can traditional water management be modeled at urban/regional, village/settlement, and dwelling/object scales, and what are the implications for sustainable landscape heritage?
(City - village - dwelling)

9. Is the NBS concept well interpreted in water management perspective? How we can use this concept in Design?

10. What are the time, spatial, and social dimensions of traditional water management strategies, and how do these dimensions contribute to sustainability?

CHAPTER 3. LITERATURE REVIEW

3.1 An overview of ancient civilizations and rivers relationship

Traditional water management refers to the technologies and applications that emerged from the human civilization process based on the demand for water resources. (Pahl-Wostl, 2007)

During agricultural evolution, practical utilization of water resources was carried out, and methods with sustainable characteristics were summarized. (García-Tejero et al., 2011) The use of these methods and technologies gradually shaped the cultural landscape based on water, as well as the planning and design theories and methods of water landscapes. (Fouad et al., 2022) These methods are deeply rooted in the local natural environment (such as precipitation, terrain, etc.) and are closely integrated with community culture, such as water-related religious cultures (Groenfeldt, 2006). Reasonable water resource management further promotes local economic and cultural development, thereby fostering the growth and strengthening of communities. (Macklin and Lewin, 2015) Globally, human civilizations often originated in major river basins, such as the Nile River Basin, the Tigris-Euphrates River Basin, the Ganges River Basin, or the Yellow River Basin. (Mori, 2020) Comparing these cradles of civilization, it is not hard to see that a good natural environment providing stable water resources for agriculture is a necessary condition for the origin of civilization. (Figure 3.)

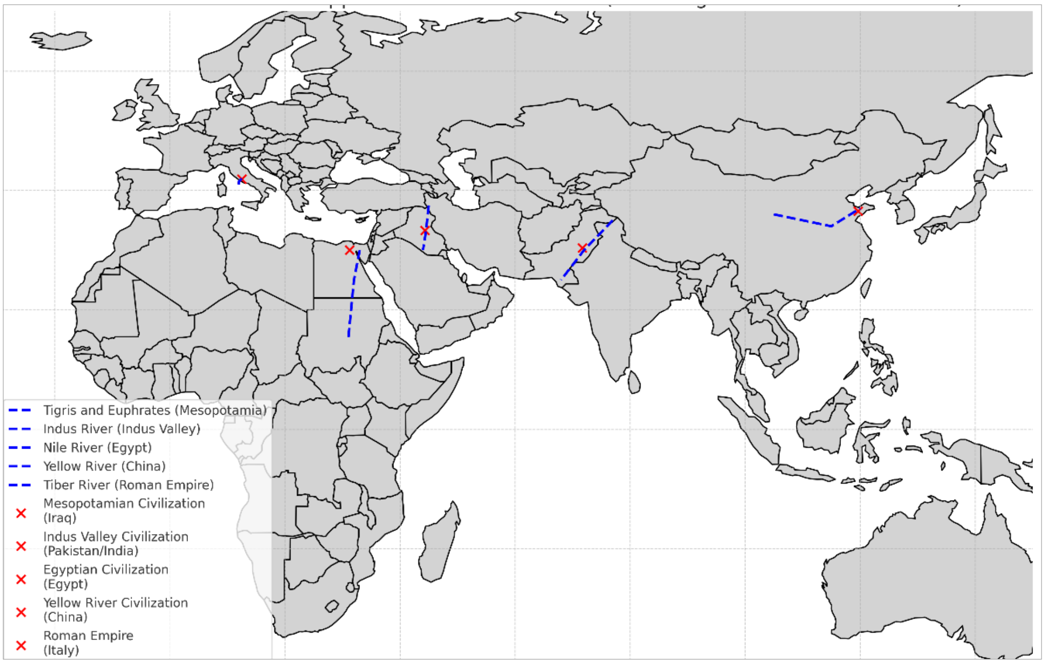

Figure 3. Rivers and ancient civilizations (Author)

Especially, rivers provided multi-faceted favorable conditions for the rise and development of civilizations. From an agricultural perspective, periodically flooding rivers brought fertile sediments from the riverbed to the middle and lower reaches of the rivers or the flat open areas through which the rivers flowed, gradually forming river alluvial plains (Bridge, 2003). Under suitable climatic conditions, with abundant nutrients and water sources, and flat terrain, this was conducive to the cultivation and growth of crops. This agricultural landscape typically had spatial characteristics: centered around rivers (water resources). This proves that the initial environmental adaptation strategy of human civilization was: selection over transformation. That is, choosing a good environment is preferable to transforming and developing it. After a long period of practical experience and technological accumulation, with good water resources and natural endowments, the population gradually increased. (Jacobsen and Adams, 1958) Humans began to further develop water resources, expanding the scale of agricultural production through means such as digging canals and building dams, thereby enhancing productivity. (Wittfogel, 1959) On this basis, surplus value was created. However, since single-crop production could not meet diverse needs, trade based on bartering emerged, creating a demand for transportation (Marx, 2004). This led to the shaping of the original water landscape from a transportation perspective. In addition to material exchanges through trade, cultural and technological exchanges between different regions and countries occurred, further promoting the development of water management. Therefore, a large number of water-related cultural landscapes and cultural heritages appeared in the process of civilization (Hosner et al., 2016). This chapter will provide a literature review and discussion on the spatiotemporal distribution of ancient civilizations and water cultural landscapes.

3.1.1 Egypt-Nile

Ancient Egypt was located in the middle and lower reaches of the Nile River Basin in northeastern Africa. Around 6000 BC, due to climatic factors, the dense grasslands of North Africa began to recede. People abandoned nomadism and began seeking stable water sources for fixed cultivation. In the lower Nile region (Noaman and El Quosy, 2017), with rich alluvial soil washed by summer floods, it was suitable for planting activities during the dry autumn and winter seasons. Residents gradually gathered and established villages in this area, which is now the lower Nile Valley. In the second half of the 4000 BC, this area gradually formed a state. The territory of ancient Egypt was tightly distributed in a narrow strip around the Nile River (Erman, 1971). In the book "Oriental Despotism" by Karl Wittfogel, ancient Egypt is considered a typical hydraulic empire, where state rulers established control over politics, economy, and culture through water resource management. This privilege-based politics through monopolizing resources still exists today. However, researchers represented by Joseph edham believe this theory exaggerates the role of water management in the formation of civilization. They argue that mature states appeared before large-scale irrigation (Needham, 1976).

Nonetheless, it is undeniable that the emergence and development of ancient Egyptian civilization were inseparable from the Nile River. As the ancient Greek historian Herodotus said, "Egypt is the gift of the Nile." (Griffiths, 1966) In ancient Egypt, the Nile flooded almost every year, inundating farmlands but also making the submerged land fertile for cultivation The Nile also provided convenient transportation for the Egyptians, allowing easy travel between cities along the riverbank (Noaman and El Quosy, 2017). Another important reason for the continuous and uninterrupted survival of the ancient Egyptian civilization for thousands of years was the relatively closed geographical space formed by the Nile and its surrounding natural environment. Ancient Egypt was bordered by the Mediterranean Sea to the north and the Red Sea to the east, with the desert to the west and a series of waterfalls to the south, and only a passage to the northeast through the Sinai Peninsula to West Asia. This geographical space, easy to defend and hard to attack, made it difficult for foreign tribes to enter Egypt, thus ensuring the stable continuation of the ancient Egyptian civilization. In contrast, the contemporaneous Mesopotamian civilization was often invaded by different ethnic groups, and its terrain was more open than the Nile Basin, making it easier to enter and leave (Poo and Pu, 2005).

Another detail overlooked by the hydraulic empire theory is that most ancient Egyptians were peasants, the primary users of water resources for large-scale agricultural production (Oleson, 2000). Egypt, located in a desert region, experienced annual flooding of the Nile in July. However, ancient Egyptian peasants knew how to build reservoirs to store floodwaters and cultivate the land once flooded by the river, turning water disasters into water benefits. (See picture 1 from Appendix A) They also knew how to dig canals to irrigate crops and invented the plow pulled by oxen to till the soil for planting. In addition, they used the shaduf, a device for drawing river water to irrigate fields. It's clear that these water resource management and usage techniques or methods were all based on a wealth of production practices accumulated over time (Postel, 1999). Although the ruling class of ancient Egypt could control large-scale water infrastructure, the specific production practices related to water resources still required the experience and technology of the peasants (Tatham, 2015). Therefore, from this perspective, the theory of the hydraulic empire does not hold.

In addition to agriculture, ancient Egypt also developed trade by relying on its convenient geographical location and water transportation conditions (Bernstein, 2009). The transportation tools they used were also special products of the Nile. The Nile banks were abundant in reeds. The ancient Egyptians discovered that these reeds had great buoyancy and were waterproof, making them good materials for boat building. The ancient Egyptians built boats using reeds and traveled on the Nile, the Mediterranean, and the Red Sea, bartering goods with local residents (Hornell, 2015). Through these trades, the ancient Egyptians spread their civilization and lifestyle to other places. In the later period, Egyptian shipbuilding technology developed significantly, and the Egyptians even dug a canal between the Nile and the Red Sea. The Lighthouse of Alexandria, one of the wonders of the ancient world, was born during this period (el Fakharani, 1974).

These large-scale water infrastructure projects undoubtedly required strong central governance to mobilize the necessary manpower and resources. However, at their root, they were the wisdom developed, discovered, summarized, and passed down by the working people in their daily practices. In this study, we interpret these wisdoms from the perspective of sustainable water resource management, with a focus on the collective cooperation of local communities.

3.1.2 Mesopotamia - Euphrates, Tigris

Apart from ancient Egypt, the ancient Mesopotamian civilizations of the Tigris and Euphrates region also reflected a wealth of traditional water management wisdom originating from the people. The Mesopotamian region is essentially surrounded by deserts, mountains, and seas; to its west lies the Syrian Desert, to the north the Taurus Mountains of Turkey, to the east the Zagros Mountains of Iran, and to the south the Persian Gulf. The Tigris and Euphrates rivers originate from the mountains and highlands in eastern Turkey and then flow almost parallel to the south into the Persian Gulf, forming the alluvial plains along their banks, which is Mesopotamia (Hosseiny et al., 2021).

Similar to the civilization of the Nile River Valley in ancient Egypt, Mesopotamia is located in a relatively arid area with rivers flowing through it. (Picture 2 from Appendix A). A feature very similar to the Nile is that the melting snow in the upper reaches regularly causes flooding in the middle and lower reaches. This region formed numerous fertile alluvial plains. As early as 4000 BC, the Sumerians and Akkadians in this region began to use the river water for irrigation agriculture, gradually forming a natural economy. In the early 19th century BC, ancient Babylon unified the upper and

lower reaches of the two rivers and developed large-scale water projects, establishing a systematic reservoir and irrigation canal system. (Angelakıs et al., 2020) During this period, the development of cities was rapid, with urban landscapes mainly composed of the Tigris and artificial canals, including moats, and the construction of one of the ancient wonders, the Hanging Gardens of Semiramis. Built at a height of about 20 meters and irrigated with river water, researchers today are still uncertain about how the ancient Babylonians achieved this engineering feat. Undeniably, they must have had superb water management experience and technology based on the local community to realize this series of blue-green infrastructure. (Stevenson, 1992)
The Hammurabi Code, in clauses 53 to 56, specifically addresses water issues: “If someone neglects to repair a dike and causes a breach, they must compensate for the loss caused to other landowners… If they cannot afford the compensation, they and their property will be auctioned, and the victims will share the money.” (Kornfeld, 2009) This legislation shows that irrigation facilities were communal, and every user had the obligation to maintain them. The operation of this irrigation system was not managed by an independent department or institution, but directly involved the local residents who participated in farming. It was collectively built and orderly used, with the state supervising at the legal level. Under this logic, the interconnected and flowing nature of water led early civilizations to develop a sense of collaboration. The regular flooding of the Tigris and Euphrates also led local residents to form an early astronomical calendar, and customary laws and regulations emerged for issues arising from the use of water resources and their solutions (Rost, 2019). Therefore, the logical chain of river - water resource - agriculture - settlement - civilization was established.
Another convincing evidence is the city of Eridu, considered the world's earliest city, according to Sumerian mythology. Eridu was the abode of Enki/Ea, the god of fresh water, wisdom, and magic (Enki in Sumerian, Ea in Akkadian). Enki's dwelling was the Abzu temple (Abzu in Sumerian means "deep water"), symbolizing the underground fresh water. This highlights the influence of water on the origins of Sumerian civilization (Glasgow, 2009).

3.1.3 Ancient Rome - Tiber

When discussing the relationship between cities and water, it is essential to mention the influence and inspiration of the ancient civilizations of the Tigris-Euphrates and Nile River valleys on ancient Greek and Roman civilizations. As one of the world's famous ancient cities, Rome perfectly learned, inherited, and constructed an aqueduct system. (Picture 3 from appendix A). Similar to the Tigris-Euphrates and Nile River valleys, ancient Rome was situated on the Tiber River plain of the Apennine Peninsula. (De Feo et al., 2013) Like the Nile and Tigris-Euphrates valleys, Rome relied on river water to develop agriculture, applying the irrigation systems originating in agriculture to the city. During the entire Roman Empire period, each Roman could use 1100 liters of water per day, whereas today the average citizen uses only about 200-300 liters per day (Taylor, 2000). Vitruvius, in his "Ten Books on Architecture," elaborately discussed the importance of aqueducts to cities and even nations. He stated, "Physicians, philosophers, and priests all believe that everything depends on the power of water," and "I should write down the methods of finding water sources, the special advantages due to regional characteristics, ways of drawing water, and how to test water sources in advance. Because it is the main necessity of life, happiness, and daily use." In the eighth book, he detailed the technology and methods of water resource management, from evaluating water veins to constructing and maintaining water facilities. He described in detail the construction and design of aqueducts, with a focus on using terrain to generate water pressure for long-distance transportation of water, and employing the siphon principle for water flow across different terrains. Interestingly, he used the method of finding levels (commonly used in building engineering measurements) as the fifth chapter in this book. In explaining this technical detail, he drew on a wealth of principles and methods accumulated from the use of aqueducts. The tendency of water to seek a level and its interaction with air in pipes were inspirations for leveling technology (Rowland and Howe, 2001).

Specific aqueduct construction began with finding water sources. Groundwater from all directions seeped into arched reservoirs, where it was collected. The aqueducts connected to these reservoirs, and air entered above the water surface, allowing the stored water to naturally flow out through open-air concrete channels. In the process of water transportation, the Romans built many sturdy elevated aqueducts, siphon tubes, and tunnels to bypass deep valleys and cliffs. Finally, the water in the aqueducts flowed into concrete cisterns for purification. After purification, the water flowed naturally into distribution tanks through the aqueducts. In the distribution tanks, several partitions separated the water. From there, the water was connected through pipes to sophisticated public drainage systems, large fountains, public baths, and toilets. To this day, Rome's urban water system is still based on the ancient Roman water management foundation (Wikander, 2000).

A common feature of these ancient civilizations and their relationship with water sources is that they were all located in arid or semi-arid regions. They experienced little natural rainfall, abundant heat, and valuable water resources. Therefore, relying on rivers to develop irrigation agriculture nurtured the development of civilizations and cities in these regions. We can conclude that ample water resources and arable land are necessary conditions for the development of agriculture, and subsequently civilizations, in arid areas.

But in the monsoon climate zones on the east and south sides of the Eurasian continent, where the rainy and hot seasons coincide, with abundant rainfall and wide distribution of subtropical evergreen broadleaf forests and tropical monsoon forests, two great ancient civilizations also flourished: ancient India and ancient China (Lu, 1988).

3.1.4 Ancient India - Indus

The Indus River Valley, located in the subtropics, was shielded from cold air moving south by the Himalayas. The monsoons from the Indian Ocean brought seasonal abundant rainfall, along with temperature variations, making the region particularly suitable for wheat farming (Jarrige and Meadow, 1980). However, this climate also made the river basin prone to flooding during the rainy season and droughts during the dry season. (Picture 4 Appendix A). Therefore, the construction of water conservancy projects for flood prevention and irrigation was a necessary prerequisite for agricultural production. By 2500 BC in the Thar Desert and the Indian Desert regions traversed by the Indus River, a class society had already formed, centered around cotton and wheat cultivation and the large-scale irrigation systems necessary for agriculture. The civilization's heyday spanned from 2600 to 1900 BC. At that time, people used both diversion irrigation and water storage irrigation methods to develop water conservancy, ensuring the smooth progress of agricultural production. To this day, the Indus River remains a vital irrigation source for agriculture in Pakistan, boasting the world's largest irrigation canal network (Weerahewa et al., 2023). In addition, similar to ancient Rome, abundant water supply supported the development and prosperity of cities. At the citadel of the archaeological site of Mohenjo-Daro, a large public bath was discovered: a series of long corridors and numerous rooms surrounding a huge pool, 12 meters long,

7 meters wide, and 2.5 meters deep, coated with thick asphalt and built with intricately carved fired bricks, surrounded by wells and drainage ditches (Jansen, 2011). Scholars speculate that the great bath was mainly for religious purposes, indicating a kind of belief in water or a sacred worship of bathing. This might be the origin of the sacred river bathing culture in Indian religions that continues to this day (Eck, 2012).
The most representative aspects of the Indus civilization are urban planning, large-scale public facilities, and supporting systems. The cities of Mohenjo-Daro and Harappa were supplied with water from two sources: one was channeling river water into the city and building storage tanks; the other was digging wells. In the Mohenjo-Daro site, more than 600 circulars well remain were found, with well platforms and walls built of bricks, providing the citizens with ample clean drinking water. (Picture 5 Appendix A).
The city's drainage system was distributed along every street and alley, connecting the sewage pipes or sloping troughs of each household's bathrooms and flush toilets to various drainage branches and main channels, forming a network-like layout. The main drainage channels were arranged from high to low according to the terrain, eventually discharging sewage into the rivers downstream of the city. Most of these drainage ditches were underground (covered) and constructed of bricks, with many filtration facilities to prevent clogging; the corners of the drainage channels were rounded and polished to prevent blockage. Some of the larger main sewage channels were even large enough for people to walk inside. Such a sophisticated, intricate, and detailed urban drainage system is unique in the early history of human civilization; preserved for four to five thousand years, they fully demonstrate the advanced level of Indus Valley civilization's water management technology (Jansen, 2011).
From these water facilities used in every household, we can understand that their use was based on the public and the community. Especially the stepwells in India, they not only provided water sources for nearby residents but also served as a space for locals to escape the heat, socialize, and interact, reflecting an early sense of fairness in water rights. Unfortunately, only ruins remain of the ancient Indian civilization today, making it difficult to discern the details of local community involvement in water resource management from the existing remains.

3.1.5 Ancient China - Yellow and Yangzi River

In the Yellow River basin of East Asia, ancient Chinese civilization was nurtured and developed. Unlike other ancient civilizations, the indigenous civilization of this land has experienced climate change, natural disasters (Li et al., 2020), and invasions by foreign tribes. Today, the people living in this land still carry the same blood as their ancestors from thousands of years ago, and the culture has been continuously passed down through generations (Chen et al., 2017). As an agrarian civilization developed along a major river basin, the Yellow River region, like other ancient civilizations, developed advanced irrigation techniques and water resource management methods. This legacy includes historical relics, operational water conservancy facilities, and documented materials, such as the "Commentary on the Water Classic". The "Commentary on the Water Classic" is China's first specialized book describing river systems. Its original version is untraceable, but the edition compiled by Li Dao yuan(郦道元, 1958) in the sixth century CE covers the comprehensive geographical environment and water-related data of 1,252 rivers nationwide, making it a major reference for water resource development and management at that time. (Picture 6 Appendix A)
It also describes more than five hundred lakes and marshes with fourteen types of lake names, including lakes, marshes, seas, inlets, ponds, moors, abysses, pools, tanks, swamps, islets, reservoirs, lagoons, and bogs. It details over two hundred springs and

wells, more than thirty subterranean streams, over sixty waterfalls, forty-six karst caves, thirty-one hot springs, and more than ninety various bridges, along with over ninety ferry crossings. In terms of architecture, it records more than thirty ancient towers from China and abroad, over one hundred and twenty palaces, over two hundred and sixty tombs, and twenty-six temples. Moreover, it provides detailed observations, such as categorizing the temperature of hot springs into five levels: "warm", "hot", "very hot", "extremely hot", and "dangerously hot". In some places, it meticulously records the width of river valleys, the depth of riverbeds, seasonal variations in water volume and level, sediment content, ice periods, etc., like Dong ting Lake being described as "the lake is wide and round, covering five hundred li, with the sun and moon appearing to rise and set within it", and Hua Pool as "the pool is square, three hundred and sixty steps on each side", and the thickness of the ice layer in the Yellow River's Mengjin section as "in cold times, the ice is several meters thick, and when it first forms, carts and horses dare not cross".

The chapter on "River Water" specifically discusses the Yellow River and its upstream water systems and is the longest chapter in the "Commentary on the Water Classic", comprising five volumes, accounting for one-seventh of the entire text. It refers to the two major changes in the Yellow River's course as "the old course of the great river" and "Wang Mang’s River". Volume five even describes the hydrogeography of the Ganges and Indus rivers in ancient India and the Bay of Bengal (Wenren, 2014).

In addition to water resource records, ancient water conservancy is also detailed in books. "The Rites of Zhou" is the earliest Chinese record of the relationship and principles between water conservancy and the natural environment, and it also details a considerable amount of water management administrative systems, water rights and laws, the use of water conservancy facilities, and laws and regulations issued for the sustainable use of water resources. For example, "The Rites of Zhou" records in the section "Di Guan Situ-Cao Ren": "The river official is in charge of patrolling the rivers and lakes and issuing relevant orders and enforcing them", "The lake official manages the government orders related to the national lakes and establishes strict prohibitions". The river and lake officials were responsible for overseeing rivers and lakes, respectively. The river official's duties included inspecting rivers and water conservancy facilities for compliance, supervising local residents in maintaining these facilities, organizing local responses to water and drought disasters, and guarding local water resources to ensure agricultural production. This shows that a systematic and procedural water management system was already established before the Qin dynasty and was institutionalized in law and administration. (Wang et al., 2017) The lake official's responsibilities, apart from implementing laws and regulations related to lake water resources, included demarcating lake areas, timely submitting various resources produced in the lake area to the central government (mainly pearls, furs, shells, etc.), and properly distributing the remaining resources to the local people. It is evident that in the pre-Qin period, not only was irrigation water rationally allocated, but a distribution system for regional division and remaining agricultural by-products was also formed. The importance of this rational allocation lies in its ability to use resources rationally while achieving sustainable utilization, in line with today's concept of sustainable development.

In addition to local officials managing water conservancy affairs, there were also professionals in the central government responsible for managing rivers and lakes. "The Rites of Zhou" records." (Miller, 2004)

The official of territories is in charge of the maps of the entire land, to manage the land of the world". The official of territories was responsible for managing the country's

natural resources, specifically for dividing the national land into zones and creating maps for national management and jurisdiction. (Picture 7 Appendix A). The country was divided into nine provinces, and the natural resources of each province were classified and marked. For example, the water resources within the nine provinces were categorized as follows: marshes and swamps were areas where people engaged in aquaculture and fishing; rivers were waterways suitable for water transportation; and irrigation ponds or rivers were specifically identified for irrigation benefits.
This early administrative planning based on natural resources, as well as the classification and naming of various resources, represents the earliest systematic description of resources in China and the earliest planning of water and soil resources. These have provided important references for later generations in the development, utilization, and management of water resources.
Additionally, the book records China's 'Ganzhi-style' canal system construction and maintenance: "The field official is in charge of the nation's fields. In managing fields, there are paths for every ten families, paths above ditches, ditches above ridges for every hundred families, ridges above roads for every thousand families, roads above rivers for every ten thousand families, ensuring connectivity to the capital." This description clearly shows that the ancient Chinese irrigation canal system was distinctly divided into different levels, increasing step by step, and interestingly, this grading system was shared with the road transportation system, indicating that ancient China's irrigation system was as important as transportation system. (Lowdermilk and Wickes, 1942)
From extensive historical records, it is evident that a crucial aspect of the origin of human civilization was the mastery and application of water management knowledge, specifically manifested in:

A. Locating water sources and utilizing water resources through spatial adaptation (both horizontally and vertically),

B. Understanding the patterns of water resource changes and systematically distributing resources through dams and canals for more uniform distribution over time,

C. Deep community involvement in water resource management, ensuring rational and orderly use of water.

Ancient Egypt, due to climate change, saw human settlements cluster around the Nile River basin. However, the civilization vanished due to warfare and abrupt Holocene climate shifts. The disappearance of the Mesopotamian and Indus River Valley civilizations can be attributed to abrupt climate changes, over-exploitation of resources, and foreign invasions. While the grand water conservancy facilities of these civilizations have now turned into ruins, China still uses water management facilities that date back thousands of years. Admittedly, the Mesopotamian, Egyptian, and Indus Valley civilizations developed earlier than the Chinese civilization, but the fact that the ancient Chinese civilization has endured through climate changes, natural disasters, and wars until today is a testament to its adaptability to the environment and sustainability. Therefore, the following will detail the sustainable characteristics of traditional Chinese water management.

3.2 Historical overview of water management in China water landscape

Water is a basic element of Chinese traditional landscape and the management of water resources had played an important role in the development of China's ancient civilization. (Pengfei, Di, 2011) China's complex topography and diverse climate has created a large number of unique water landscapes under the joint action of nature and humans. Water not only shapes the landscape, but also shapes the behavior and logic of

harmony between man and nature. (Qiao et al., 2020)
The ancient Chinese understanding of the world is that mountains and water constitute the main body of nature. Moreover, old representations and descriptions show that water has complex functions: drinking, irrigation, food production, cleaning, transportation, defense, energy production, leisure, artistic role. The ancient Chinese people transformed the natural environment and accumulated the experience how to live in harmony with nature (Jie, 2003). Exploration of the historical Chinese relationship with water is of great value for tackling today's climate anomalies. These experiences offer a good opportunity to understand the important ecological role that water plays in long-term social development. (Li, 2018)
In retrospect, scholars' research on climate anomalies are carried out mostly from the perspective of reducing carbon emissions and fossil energy. But also, from the perspective of ecology, focusing on minimizing negative environmental impacts through integration with living processes (Walther, Blair & Pachauri, 2006). Compared to ancient or traditional water resources management, it has the same logic. The western water management already started to move from technical approach to a true integration of the human dimension (Pahl-Wostl, 2007). This means that we have to look at water resource management solutions from the comprehensive dimension of time and space. Ancient Greece and Rome considered the geographical characteristics, introducing advanced urban water supply and drainage systems (Crouch, 1993). The rainwater management, the irrigation system and the rainwater storage system in antique Egypt and in the Middle East are all worthy of reference for today’s water landscape (Mays, 2010). Water management technologies and facilities in China are also changing with the changes of the natural and social environment. Up to now, there are still well functioning traditionally rooted water management facilities. This is big difference from other ancient civilizations which only some archaeological remains left, and has a great significance for contemporary urban and landscape planning and the development of water conservancy facilities. From a relatively continuous historical perspective, it is possible to study the origin and the evolution of traditional water landscapes, to predict the future applications for the current situation and to facilitate ecological solutions to combat global warming. (Li & Xu, 2006).
The main aim of this overview is to find out the traditional ecologic wisdom from water-related heritage. In order to achieve this, illustrates and highlights the essence of traditional Chinese waterscapes, analyzes the water landscape heritage and old hydrological maps in order to obtain the essence of the ancient Chinese water management from the Qin Dynasty to the Qing Dynasty during 2400 years. The overview intends to show how vernacular water management solutions can be applied in specific design situations and locations in contemporary landscape architecture in order to increase the ecological impact and benefit, and how tradition can be used as a source of inspiration for shaping and developing today’s waterscapes.
Regarding the designated aims and research questions, a harmonious water management model was hypothesized. Based on this, the ecological model of water management in traditional Chinese water landscapes can be derived:

- Circulation
- Adaption to the environment
- Harmony of man and nature

This ecological logic can provide empirical support for water resources management and water landscape planning in the context of today’s climate change.

Through literature review and case analysis, provides heritage utilization framework from the perspective of ecology, according to different climate zones and historical periods, which provides a comprehensive approach to the climate crisis. The survey methodology was based on the principle that the sites concerned must be interpreted in context with the relevant periods and landscapes, as the only way to understand their historical importance and current value. For a systematic survey of the most important waterscapes, I have established the following theoretical framework:

- Identification of all potential regions with unique and traditional waterscape and water management
- Selection of the highlighted locations in specific region for detailed studies
- Historic overview of the selected area
- General landscape and ecological assessment of the present conditions of the selected areas
- Conclusions related to possible applications of the analyzed waterscapes and water management solutions

This overview presents four case studies in four given geographical and climatic regions of China intending to provide a closer and more detailed view of their water resources management and discover their ecological benefits share characteristics in water resources projects. The four case studies are Jing-Hang Grand Canal (Southeast China), Ganzhou City (Lower Yangtze plain), Turpan City (Northwestern China), and Chengdu City (Southwest China).
I discuss and analyses the most important and representative water resources projects of these cases, which including:

(1) the canal and moat system and its flood control project in Chengdu,
(2) the water supply system in Turpan, and
(3) the water system combined with artificial canals and ponds in the city of Ganzhou,
(4) the artificial river and Multifunction water system of the Jing-Hang Grand Canal. I also sum up some drawbacks and lessons of the ancient Chinese cities' water resources management.

China's complex topography and diverse climate have created many unique water landscapes under the joint action of nature and humans. Water shapes the landscape and shapes the behavior and logic of harmony between man and nature (Qiao et al., 2020). The water resource representation from the ancient map in (Picture 8 Appendix A) explains the importance of water resources in China's life in the 14 century (Ming Dynasty, Southeast of China).
The Chinese ancients' understanding of the world is that mountains and water constitute the main body of nature; on the other hand, the representations show that water has complex functions: drinking, irrigation (food production), fishing, fish farming, cleaning, transportation, defense, energy production, artistic aspects.
The ancient Chinese people transformed the natural environment and accumulated the experience of how to live in harmony with nature (Jie, C. H. E. N. 2003). One of the most representative examples in this regard is the water culture and water management experience from different areas and climates of China. Exploring the historical Chinese relationship with water is of great value to face today's climate anomaly in the ecological aspect. These experiences offer an excellent opportunity to understand the vital role that water plays in long-term social development. (Li, 2018)
In retrospect, scholars' research on climate anomalies is mostly from reducing carbon

emissions and fossil energy from the perspectives of Ecology that minimizes environmentally destructive impacts by integrating itself with living processes (Walther, 2002; Blair, T., & Pachauri, R. 2006). Compared with the way of ancient water resources management, it is the same logic.
Western water management already starts to move from technical management to proper integration of the human dimension. (Pahl-Wostl, 2007). This means that we have to look for water resource management solutions from the comprehensive dimension of time and space. Ancient Greece and Rome combined with geographical characteristics, with a forward-looking urban water supply and drainage system. (Crouch, D. P., 1993). The rainwater management and irrigation system in ancient Egypt and the Middle East's rainwater storage system are all worthy of reference for today's water landscape (Mays, L., Ed. 2010).
Unlike the west, as one of the ancient civilizations, China has continued from cultural history to the present. Water management technology and facilities are also changing with the changes in the natural and social environment. Up to now, there are still well-functioning water management facilities. Those technology and facilities are of great significance for today's urban construction, landscape construction, and water conservancy facilities construction. From a relatively continuous historical perspective, it can study the origin and development of the traditional water landscape, to predict the future combine with the current situation (Li, K., & Xu, Z. 2006) and facilitate ecological solutions against global warming and urban heat island effects.
To obtain the ancient Chinese water management wisdom from the Qin Dynasty to the Qing Dynasty during 2400 years. Shows how traditional water management solutions can be applied in specific design situations and increase the ecological benefit in landscape architecture. We present a different type of China traditional waterscape by maps and sketches, generalized ecological friendly water management methods, which can be inspired for today's waterscape shape and development.

3.2.1 Waterscape in different history periods

I have done bibliography research to identify and compile the potential regions with typical and traditional water management systems in different climatic zones of China. Significant architectural, landscape architectural, ecological, and historical works, essays, descriptions, and depictions have been studied. (Picture 9 appendix A). Shows coastlines, Yellow River, Yangtze River and its branches, Tai Lake, Dong ting Lake, and Fan yang Lake. The original stone was engraved in Wuchang 7 year, i.e., 1136 AD. The ancient Chinese experienced primitive worship, religious deification, Imagination, miniaturization of landscapes, and reproduction of waterscapes for the natural element of water. (Li Zong Xin.2011)
In ancient Chinese times, 2500 BC, has suffered the flood. Up to now, many myths and stories related to floods have been handed down, such as water god, river god, and other primitive worship images. Until Dayu according to the topography of high west and low east, Dredge river course, connect water system, dig canals and build dikes, The systematic water management in the Yellow River Basin he builds has reduced the threat of flood to human settlements and laying an important material and environmental foundation for the development of agriculture in China in next period(Wu et al., 2016) (Qing, W.1999). In the Qin Dynasty (221-206 BC), Li Bing and his sons built Dujiangyan in Shudi. (Picture 10 Appendix A)
which enabled floods and droughts to follow people's control, the kingdom of abundance was realized, and agriculture flourished (Li, K., & Xu, Z. 2006).

In addition to water conservancy facilities, emergency strategies for sudden floods are also applied. (Picture 11. Appendix A) The red stickers with different lengths are used to mark the hydrological information of different river sections for flood control reference. Simultaneously, there was special personnel responsible for different river hydrological monitoring, who was also responsible for monitoring and organizing people to flood control during flood season.
In the early Han Dynasty, the theory of Geomantic omen emerged, that is, the doctrine of choosing residence according to the environment, and it has continued to this day. It has a profound impact on the city's location, the Architecture, and the traditional Chinese environmental aesthetics (GE & HU, X. 2014). (Picture 12 Appendix A). The importance of the waterscape and its preservation as natural scenery and artistic view.
The best principle for city site selection: Living by the water, backing the mountains and facing the water, sitting north facing south. (Picture 13 Appendix A.) During the Tang and Song Dynasties, foreign trade gradually matured, and the Silk Road emerged. The foundation of this Silk Road is the water source of the oasis in the northwest's arid area (Li, P., Qian, H., & Zhou, W. 2017), which is like a string of pearls, connecting all the oasis in series. The water not only connected with trade but also connected with the economic culture and civilization of Eurasia. During the Ming and Qing Dynasties, the construction of flood control and diversion of the Beijing-Hangzhou Grand Canal was further improved, which not only solved floods but also embodied the thinking of today's South-to-North Water Diversion, and at the same time realized the shipping value of connecting the north and south. (Qiao-yi, C. H. E. N. 2005).
Looking back on the Chinese water landscape history, which is mainly divided into four historical periods, namely, the pre-Qin period, the Qin and Han periods, the Tang and Song Dynasties, the Ming and Qing dynasties. The processing ideas corresponding to the water landscape have experienced primitive worship-simulation of fairyland-combination of landscape and nature-simulation of nature, and its functions can be divided into viewing, drinking, irrigation, shipping. In different climatic regions, the functionality of water landscapes also has a different emphasis. The cases selected in this study are based on different climatic regions and water landscape heritage with different functions still in operation. (Figure 4).

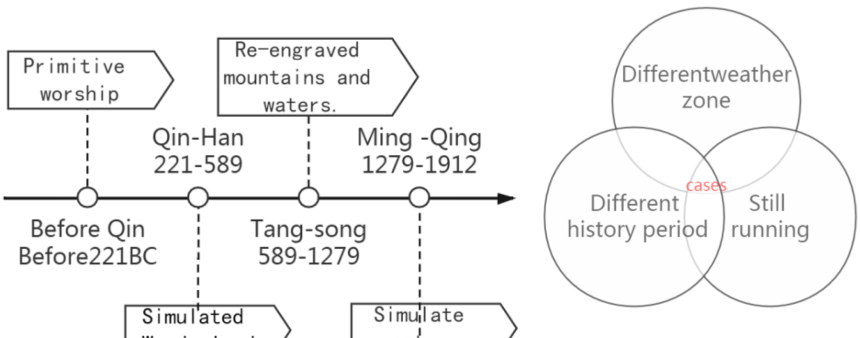

Figure 4. Timeline and case selection (Author)

3.2.2 Case studies from different climate regions of China

The cases cover water storages in arid regions in the northwest, adjacent water settlements in the southeast monsoon region, and irrigation facilities in the mountainous regions in the southwest to cover climate differences and water resource functionality.
My framework shows that a division in four climatic zones – according to Figure 5, and a presentation of a case study from each area (regarding different historical periods) can offer a comprehensive overview of the most traditional waterscapes and water

management methodologies used in China during centuries.

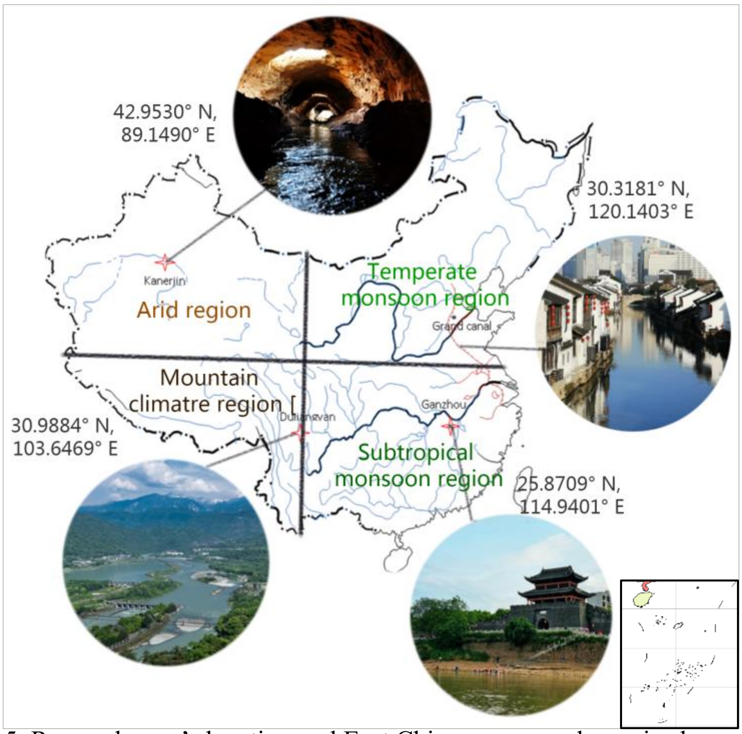

Figure 5. Research case’s location and East China monsoon dynamic change (Author)

Case study No.1:

The southeast of China is a monsoon region, with average precipitation from 800 mm to1600 mm. The northwest region is dry because of its deep inland precipitation. The precipitation has decreased from southeast to northwest since ancient times. (Figure 5) Therefore, the precipitation distribution space is uneven, and the monsoon has caused the climatic characteristics of high temperature and rain in summer, and cold and dry winter result in uneven distribution of water resources.

Therefore, the water landscape in China's humid regions is dominated by rivers and lakes' surface water and the groundwater in the northwestern region.

The water and soil feed the different people, and the uneven distribution of water resources in time and space has also resulted in large differences in water resources management strategies in the northwest and southeast.

According to local conditions, it is not difficult to see from the water landscape heritage that has survived time-tested ancient people's wisdom in water management.

As China's terrain is high in the west and low in the east, most of China's rivers flow from west to east. The Beijing-Hangzhou Canal spans 1776 km, and other precipitation lines run through multiple rivers longitudinally and connect the north and south of China through waterways. （Picture 14 Appendix A） It has an essential impact on the natural environment and the eastern coastal areas' economic and cultural development. Since eastern China is located in the monsoon region, the precipitation of the temperate monsoon north of the Huaihe River in the Qinling Mountains and the subtropical monsoon south of the Qinling Mountains have significant differences in precipitation. Due to the subtropical high-pressure zone's influence every year, the rain belt is narrow and long from east to west. The entire basin often covers）similar precipitations (Figure 5. It is easy to cause floods, and the Beijing-Hangzhou Grand Canal runs through multiple watersheds from north to south, so it can disperse the flow of different watersheds and weaken the flood peaks. In the dry season, the rivers in the south are abundant in water and can supply water for agricultural production in the north through the canals. Today, the Beijing-Hangzhou Grand Canal has become a part of the South-to-North Water Diversion Project.

Case study No.2:
Case 2 is located in the southwest of China, on the Chengdu Plain, in Sichuan Province. It was established in the Qin Dynasty and was completed by Li Bing and his sons for several generations. Its central part comprises fish mouth, aquarium mouth, and Feisha weir, which can control the channel's flow rate and flow through intervention in the river bed. Therefore, whether it is in the dry season or the rainy season, the Chengdu Plain can obtain sufficient irrigation water. Besides, it has a robust ecological significance. Unlike modern dams, Dujiangyan uses Kuanglou and other facilities to build temporary dams. Semi-open, the gap can allow some aquatic organisms to pass smoothly, which is of great significance for migratory aquatic animals in the basin. It is a model of harmony between man and nature.
The construction of Dujiangyan also has its peculiarities. The river is curved, slowed down, and interspersed with mountains and rivers, which played a fundamental role in forming the weir. However, Li Bing and his sons were able to choose this place for construction in many areas shows that the ancients already knew well about the importance of topography.
The main structure of Dujiangyan is a river segmentation system composed of three artificial dams and a buffer zone. This system divides the Minjiang River three times. As shown in (Picture 15 Appendix A), the first segmentation is located at Yuzui, dividing the river into external and internal. The dam's location and construction conform to the principle of concave bank erosion and convex bank accumulation in hydrology, and the difference in flow velocity between the inner river and the outer river is taken into account. It will lead to sedimentation of the Neijiang River, so the river bed of the Neijiang River will be deepened to prevent the sedimentation of the river bed and ensure the stability of the water. The second division is located in Feishayan, from Neijiang to the second division. As the river is narrow and the flow rate slows down, sediment will be deposited here to form a buffer zone. As a result, the river bed rises in the buffer zone, which prevents the river from flowing into the outer river during the dry season, and during the flood period, the rise in the water level will take away the sediment in the buffer zone and deepen the river bed to accelerate drainage. The lower third division is located at the Aquarius's mouth, where it took eight years to excavate the rock to form a relatively stable waterway manually. Due to the first two divisions, the amount of water entering the mouth of the Aquarius will remain relatively stable, thereby achieving sufficient throughout the year. Irrigation and domestic water.

Case study No.3:
In northwest of China, Xinjiang has a temperate continental climate, with aridity and less rainfall throughout the year, with precipitation of 170 mm. The main water supply is glacier meltwater. Kanerjing has been popular in Xinjiang since the Han Dynasty (Historical records), and it has been used today, which is very similar to Iran's water facilities. They named it Qanat (Haidari, R., &Fekete, A. 2015). The principle of Kanerjing is to establish underground channels to protect precious water resources from being quickly evaporated through soil layers. Generally, the search for diving sites is started in the foothills, and the vertical wells are drilled first, and then the horizontal wells below the diving level are drilled, and the vertical wells are penetrated to form

underground water channels from the foot of the mountain to the oasis. (Figure 6.) These Kanerjing nourishes the oasis around the Tarim Basin in Xinjiang. The karez located around Turpan's city in China's western region of Xinjiang is an incredible example of an ancient irrigation system and the Uyghur ingenuity that developed it. The karez well system is considered the greatest Uyghur engineering accomplishment (local named "The Underground Great Wall").
The essential function of the Kanerjing is to provide a reliable and clean water source for agricultural life in Xinjiang through underground canals. The construction of underground canals utilizes the difference in terrain and expands Xinjiang people's living space and time by reducing evaporation. (Picture 16 Appendix A)

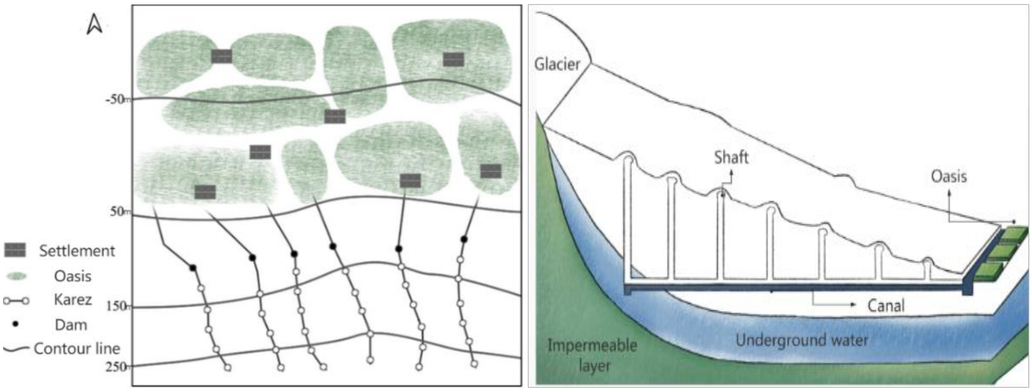

Figure 6. Kanerjing model – an ancient water management strategy at northwest China (Author).

In ancient Chinese society, it was built and used by the workforce, and its development concept of conforming to the natural environment is worth learning and learning from today's water landscape construction.

Case study No. 4:
The southeast of China Song Dynasty ancient city，Ganzhou, Jiangxi Province, is located in the middle and lower reaches of the Yangtze River. It has been a flood-prone place since ancient times. Its drainage system is still in operation. It has protected the ancient city from floods from 975 years ago to the present day. (GE, Y. & HU, X. 2014) The waterproof system of Ganzhou is divided into three parts, from the inside to the outside: the reservoir, the water window, and the city wall. There are six pools connected in the city, collecting precipitation and providing domestic water and other functions. When the rainwater collected by the pool in the city is too much, it will be discharged outside the city through the water channel's water window. The water window design uses water pressure to achieve the only drainage. Do not backflow. Establishing a buffer zone for floods can ensure that even the river water level is higher than the ancient city when the flood peak arrives, there will be no backflow.
Besides, the city wall adopts a bionic design. The entire wall is elliptical and streamlined like a tortoise, which can withstand the impact of floods. (Figure 7）

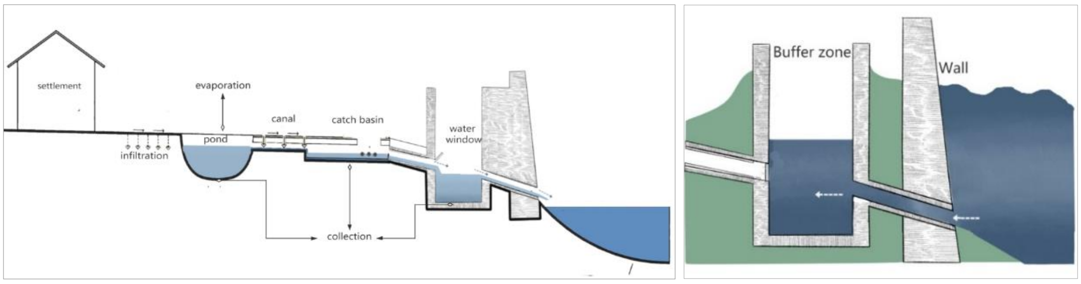

Figure 7. Water management example at southeast of China (Author)

The most important flood control measure of Ganzhou ancient city is the water window in the city wall. It has two essential functions: to drain the water in the city and to prevent the flood from flowing back. The functionality of water windows is achieved by the interaction of walls, buffers, and drainage pipes. As shown in the figure, in average years, the water level of the river is low. As the terrain of the inner city is higher than the riverbed, the accumulated water in the city will be discharged into the buffer zone along the pipeline through the water window, and a certain amount of water will continue to be discharged into the river along the drainage pipeline in the city wall.
When the river water level rises, and the water level exceeds the city's terrain, the river water will flow back into the buffer zone along the drainage pipeline. Because the water window has a unique structure similar to the vein valve in the blood vessel, when the water level in the buffer zone exceeds the height of the water window, it will be automatically closed under pressure to prevent the flood from flowing back to the inner city, to ensure the urban drainage and prevent the flood from flowing back. (Picture 17 Appendix A)

3.2.3. Conclusions - Ancient China water management model: Logic of harmony

Summarizing the above cases of water landscape in China, although the climate has affected water functionality, the logic of creating various water landscapes by Chinese ancestors is indeed the same.

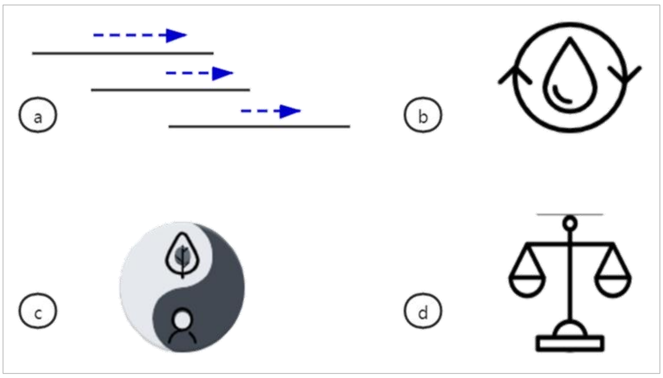

Figure 8. Scheme of the traditional Chinese waterscape wisdom (Author)

a. Harmonious water-space relationship: Cleverly borrowed the original topography to make fair use of the situation.
Make full use of the principle of the hydrodynamics of water flowing to low places, especially in diversion, the establishment of canals, flood discharge, and prevention of disasters, which can accurately reflect.

b. Harmonious dynamic and static relationship: Circulation and adaption.
The ancients of China realized that water in nature as a whole, in the process of constant

movement, change and circulation, conforming to the situation of nature, making fair use of the beneficial parts of each link of the water cycle, participating in the water cycle process, but not destroying or blocking. The process of the water cycle is a symbiotic relationship.

c. The Harmony of man and nature: Cohesion

The attitude of the ancient Chinese towards the natural environment is awe. The ancient Chinese's dualism classified everything in the world into two parts, yin and yang, and yin and yang are in a symbiotic cycle. For example, in nature, mountains can be classified as yang, and water is classified yin. Men are classified as yang, and women are classified as yin, so everything in the world is mutually opposed and interdependent to some extent. Humans must find a way to live in harmony with nature.

d. Harmony of time and space：Consider balance from both space and time.

Two thousand years ago, Confucius said that he is not worried about small amounts but only about imbalances. Concerning the temporal and spatial distribution of China's water resources, what nature gives us happens to be unbalanced. Therefore, the Chinese have long considered time and space into the construction of water landscapes. (Figure 5).

By comparing history with the present, we can discover the experiences and wisdom in history that can serve as references.

At 2021.7.18-20. China is experienced a flood breaking the historical record, (Chen et al., 2022)and a large number of cities are waterlogging and flooding. What is worth exploring is that the ancient city with a regular drainage system was free from flood disasters. The Three Gorges Dam (Wu et al., 2004) in China opened its floodgate to discharge flood beyond the warning water level, which aggravated the water level rise in the middle and lower reaches of the Yangtze River Basin. Under abnormal climate background, modern engineering has not achieved the expected ability to prevent the flood once in 100 years, while Dujiangyan (Li and Xu, 2006) has continued its function of flood control and irrigation for thousands of years. These realities tell us that we need to learn from traditional wisdom.

Compared with the traditional methods of water conservancy facilities construction and today's methods, the most significant difference is that the traditional water landscape construction uses the original natural environment as much as possible, but with more intervention, flood control and irrigation can be realized in the process of normal River movement, and the coexistence of human and nature can be realized. The thinking of modern water conservancy facilities is mostly interception, blocking, and utilization (Hewlett, 1982). In the process of blocking by the dam, the original environmental balance is destroyed. However, the advantage is that power generation provides clean energy. Therefore, under the guidance of the traditional harmonious thinking between man and land, the water landscape construction from the perspective of landscape ecology is inspired. Taking natural water as the main body, water diversion and saving can realize the water conservancy function of irrigation flood regulation and power generation and the ecological effect of water landscape. (Figure 9)

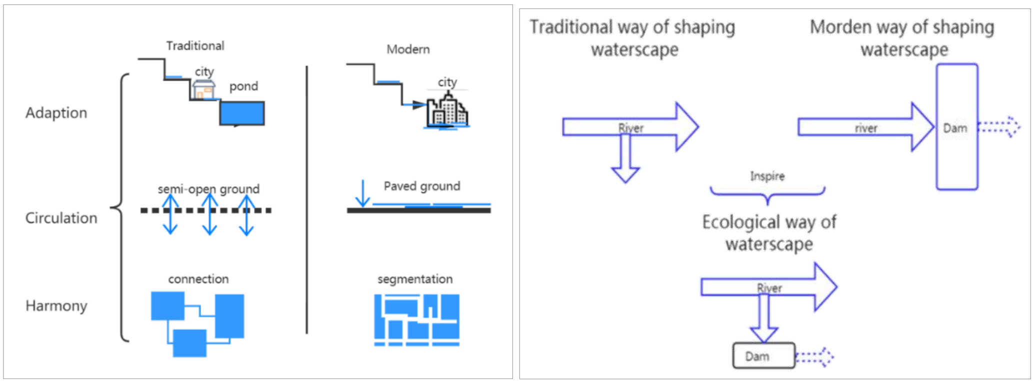

Figure 9. Scheme of an inspiration from Chinese traditional waterscape (Author)

Traditional cities' location layout is more inclined to use the original topography, back to high-lying areas, facing rivers or lakes. (Picture 13 Appendix A) The advantage of this is that the terrain can be used to avoid flooding, and the nearby water resources can also be used. The construction of modern cities pays more attention to the economic benefits brought by urban agglomeration (Glaeser and Gottlieb, 2009). Therefore, in urban expansion, modern construction technology is used to overcome the obstacles of terrain to the urban layout. However, it cannot overcome the physical principle of water flowing to low places, resulting in urban waterlogging (Zhang et al., 2012). Therefore, we should learn from traditional wisdom, try to conform to the terrain in the process of urban construction, and build water catchment areas in cities in low-lying areas to achieve ecological functions.

In addition, the ground paving of traditional cities is much lower (Scholz and Grabowiecki, 2007) than that of modern cities, and the infiltration of rainwater is more efficient than modern cities. Therefore, modern cities should increase the design of open space, increase sponge facilities (Xu et al., 2018), and minimize the process of natural infiltration Impact.

In terms of systematic treatment of water bodies, traditional cities have adopted more connection, sorting, and guiding treatment methods to expand water capacity while achieving the effect of dispersing pressure. The construction of modern cities has blocked and divided the original natural water system (Russo et al., 2014). Although it can meet the short-term development needs, it violates the principle of sustainable development.

The Harmony logic of the ancient Chinese water landscape is of great significance to urban construction, stormwater management, and construction of water conservancy facilities under the background of today's abnormal climate.

Before land planning and construction, the underlying surface analysis must be carried out (Scherer et al., 1999). The urban drainage system must have storage and decentralized units. The riverside settlements must be designed to prevent floods and to waterlog. At the same time, the existing surface runoff should not be directly intercepted and built. Use the riverbed to leave a biological channel. (Steward et al., 2012)

3.3 Water and nature: philosophy of traditional water management

Philosophy plays a critical role in traditional water management by weaving together ethical principles, holistic understanding, cultural values, adaptability, and inclusivity into a coherent approach. It emphasizes sustainability and equitable use, ensuring the preservation of water resources for future generations through ethical stewardship. This perspective promotes viewing water as an integral part of broader ecosystems, advocating for practices that maintain natural balances. Moreover, it highlights the cultural and spiritual significance of water, urging the incorporation of community values into management practices.

As early as the pre-Qin period（before 221 BC, Mencius said: 竭泽而渔，而明年无鱼 (if one catches all the fish in the lake at one time, then there will be no fish in the lake next year); Lao Tzu said: 道法自然 (truth comes from nature); and other similar environmental views were expressed. Guided by these simple philosophical views, the ancient Chinese practices of scientific and technological development were significantly different from those in the West. Western industrial civilization, beginning with Newton's physics and mathematical principles, began to question and research natural phenomena and summarize scientific laws.(Harari, 2014),The development of civilization in ancient China was based on the agricultural economy and continuously summing up life experience around agricultural production - the Chinese tradition emphasizes the inheritance of experience and value (Xu and et al., 2018).

One of Needham’s questions is why ancient Chinese science and technology had been leading the way, but its modern industrial civilization lagged behind that of the Western countries. One of the important answers is that Chinese people have different environmental values. From the perspective of sustainable development, traditional Chinese technology is an important resource today. Regarding ecological and environmental protection, agriculture-based countries must protect the environment to sustainably develop their agricultural economy. Therefore, in ancient China, development was achieved more through discovery than invention. It was the slow accumulation and superposition of experience rather than western-style advancement. (Needham, 1976).

Taoists say: 天道有常，不为尧存不为桀亡. It means that absolute truth exists as an object and will not be changed by human society. In the course of China’s history, the protection of the environment and the requirements for sustainable production are one of the important components of a social collective consciousness. (Li et al., 2016)

China's high-speed modernization is not a native process. It was forced to embark on a fast, catch-up industrialization process by the advance of Western industrial civilization after the Opium War. (Reinsch, 2005) Today, China is faced with similar environmental problems to those faced by developed western countries. But can we learn something about sustainable development from the form of Chinese civilization that lasted for 6000 years? (Birkin et al., 2021). Thus, this research starts with three case studies in the Xiangjiang River Basin, exploring the sustainable paradigm of traditional Chinese landscapes, and how traditional philosophy shapes Chinese waterfront landscapes, and finally discusses the value and significance of traditional philosophy for future sustainable development. (Picture 18 Appendix A)

3.3.1 Water culture and traditional philosophy

The ancient Chinese understanding of water landscapes can be traced back to the time when the oracle bones appeared (1250BC - 1200BC). (Keightley, 1985) As a pictograph, oracle bone inscriptions can record and transmit civilization in an intuitive way, (Keightley, 1985) and through the continuous evolution of ancient characters, we can also deduce the changes in the perception of water and the evolution of social group values. The origins of the water and river characters used in China today are presented in (Picture 19. Appendix A)

An archaeological interpretation of the word “water”: according to the research report on the oracle bone inscriptions in the Yin Ruins of China, the origin of the shape of the letter” water” was created by the ancients based on the water flowing down a cliff. The letter” river” combined the letter “Water” with the letter “confirmation”. (Picture 19. Appendix A)

An alternative view of the letter “water” is that the river is in the middle with the settlement circles surrounding it, indicating that ancient residents mainly settled near the water, and the word "river" has a positive meaning. From the perspective of the evolution of the calligraphy, the shape of the letter “river” has not changed considerably. Today we it still bears a positive meaning. Therefore, the memory and association of living by the water have continued to this day.

In addition to its meaning in text, water is also an extremely important element in Chinese painting. (Picture 20. Appendix A) Mountains and water are the basic components of traditional Chinese painting. The mountains represent stability firm and upright, masculine qualities, while water is flexible and winding, gentle and calm, representing feminine qualities. The combination of these two forms illustrates the harmony of the male and female elements (yin and yang). (Edwards, 1976)

The philosophical idea of yin-yang harmony comes from the Taoists.

In addition to the discussion of the feminine yin attributes of water, Laozi also put forward the idea that:上善若水 (in chapter eight of the Tao Te Ching): he believes that the highest good is like water - invisible and colorless, but can nurture and nourish all things. (Laozi et al., 2007) These philosophical ideas exhorted those in power to help the people in accordance with this belief about water (Waley, 2013) - selflessly and humbly. (Giblett, 2009)

In Chinese poems, water in the landscape features prominently. For example, Li Bai's 将进酒. (Picture 20. Appendix A). This poem, through describing the water of the Yellow River that is never to return, laments the passing of time and expresses the idea of cherishing the good times. The philosophical support behind it is that Confucius once said, while by the river, 逝者如斯夫: Sighing that time passes like flowing water. In addition, the philosophical enlightenment of water to Confucianism is 智者乐水.(Tu, 1998). It means that wise people have water-like characteristics – they are intelligent, flexible, and clear. In addition to the philosophical interpretation of water by Confucianism and Taoism, many philosophical arguments related to water have emerged since Buddhism was introduced into China, such as 善心若水. It means that Buddhist believers should keep their inner peace, just like a calm lake in the forest. No matter how noisy the outside world is, they should always keep their inner peace, and practice good intentions. (Liu, 2006).Regardless of the form of characters, paintings, poems, and belief systems, water is a fundamental element within traditional culture; the philosophical drive behind it all comes from the three main sources of Taoism, Confucianism, and Buddhism. These ideas have been continuously exchanged and passed on through history, and gradually formed the values that influenced how the Chinese perceived and transformed their world. (Lee et al., 2009)

3.3.2 Three cases of water landscapes shaped by traditional philosophy

a. The Waterfront Settlement Landscape of Goulan Village, under the Framework of Taoist Philosophy

Goulan village (DongGe et al., 2022) is a typical traditional waterfront settlement. The location of mountain and water and the vertical layout along the river realize the ideal settlement model of the mountain surrounded by water. Taoism plays a key role in the location and layout of the settlement. In the belief system of Taoism, mountain belongs to Yang, water belongs to Yin, and the environment of the mountain surrounded by water creates a harmonious landscape layout of Yin and Yang. (Figure.10)

Figure 10. The ideal location for the settlement is between mountains and water. (Author; photo: 2018.09)

b. The metaphor of the water from the Zhang Gu Ying village under the influence of Confucianism.

One of the important thoughts of Confucius was self-restraint and courtesy, thus advocating the realization of harmonious social order both for adults and children. Under the influence of this idea, most of the traditional Chinese settlements are led by the elders, which are composed of male relatives with the same surname. The result is the distribution of settlement space based on social status and kinship.(Zhao and Huang, 2022) The core position of the settlement is inhabited by the highly respected patriarch, surrounded by the younger generation. (Figure 11)

Figure 11. Photo and scheme of the clan settlement and water metaphor. (Author, 2018. 09)

This also implies that the family's continuous inheritance and continuity of culture are consistent with the continuous characteristics of water. Therefore, it has a long history to advocate the same family name in ethnic culture.

In addition, Confucianism also emphasizes the unity of clans: water can support a boat, but also overturn it, just as the clan's rule depends on the clan leader, but also needs the approval and support of the clan members. Therefore, the clan leader must be an elder

with a high moral standing. Such a social structure can ensure the continued prosperity of the family. (Wright, 1975)
Clan cohesion is reflected not only in the living space but also in the patio structure of the building. The pitched roof around the patio is suitable to collect rainwater, symbolizing unity and cohesion. The patio owned by the patriarch is also the largest in the village.

c. Water and Chinese Buddhism in KaiFu temple: not just lotus pond.

Traditional Chinese philosophy is not only Confucianism and Taoism - Buddhism, which originated in ancient India, also plays an important role.
After Buddhism was introduced into China by master Xuanzang, based on the original Mahayana Buddhism and combining Taoism and Confucianism, it gradually evolved into different Zen, and then had a profound impact on Chinese philosophy. (Liu, 2006)
The characteristics of water have been extended by Buddhism with its cool, clean, and unsullied qualities: 心静如水. means the mind should be peaceful like calm water. Also, the description of heaven in Buddhism is of a world that is as clear as water, and illusory. (Karetzky, 1997)
The understanding of water in Chinese Zen is diverse. By observing and contemplating water, we can understand Zen, remove the influence of the material world, and create inner peace. This is one of the ways that monks practice. (Picture 21 Appendix A)
In addition, Buddhism contains the idea of cherishing life and admonishing people to set animals free and accumulate good karma (Karetzky, 1997). The KaiFu temple, as an example: the construction of the drainage pool in the temple has realized the function of ecological diversification. (Picture 21 Appendix A)

3.3.3 Sustainable water landscape paradigm

China's sustainable water landscape is composed of two parts: internal drive and external landscape expression: the internal drive includes traditional values, customs, and belief systems.

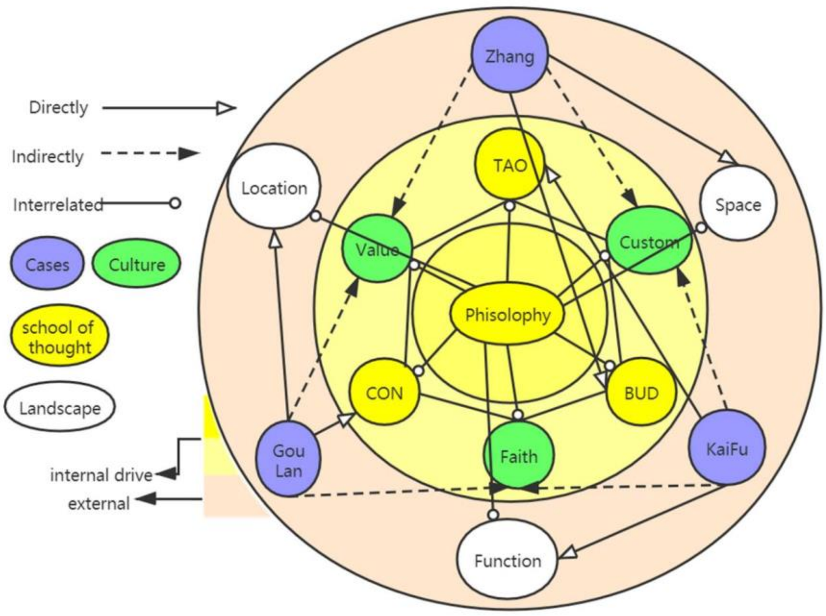

Figure 12. Scheme of the sustainable water landscape paradigm (Author)

External expressions include: the settlement site selected to be situated on the back of the mountain with the water lower in the front and higher in the back; settlement space allocation; building structure; and waterscape function. All the internal and external elements combined and linked as a whole stable system. (Figure12)
From the analysis of the above three waterside developments, it can be concluded, that the traditional Chinese philosophies of Confucianism, Buddhism and Taoism have had an important influence on the values, customs, and beliefs of the Chinese people, which in turn has helped form a solid and sustainable concept of environmental planning. This is of great value for the promotion of sustainable development.
For the construction of an ecological civilization, we must also fully explore the practical application value of traditional philosophy, and make full use of the internal drive of traditional philosophy in the process of design and application, in order to achieve an ecologically harmonious and sustainable landscape.
The landscape heritage based on traditional philosophical concepts is also necessary to fully explore and protect, utilize its educational function, and apply it innovatively for the success of sustainable development.

3.4 Research gap

Based on the above history and literature overview，I found water management practices have evolved significantly throughout history, illustrating a deep understanding of sustainability principles well before these concepts became central to environmental discourse. Traditional water management systems, which have developed across various cultures and geographical regions, reflect humanity's long-standing interaction with natural environments, showcasing centuries of indigenous and local practices finely tuned to specific climatic, hydrological, and ecosystem dynamics. (Angelakıs et al., 2020) Such systems not only demonstrate a profound comprehension of hydrology and climate but also embody cultural and social dimensions that offer insights into community engagement and stewardship.
Conversely, modern sustainable water management approaches often rely on technological solutions, framing their strategies within the concept of ecological or Nature Based Solutions (O'Hogain and McCarton, 2018a) (NBS). NBS emphasizes solutions that are inspired and supported by nature, offering cost-effective ways to deliver environmental, social, and economic benefits while enhancing resilience. Despite their potential, many modern frameworks tend to overlook the sustainability principles inherent in traditional water management practices, particularly the reuse and preservation logic already prevalent in pre-industrial agrarian societies. These societies, reliant on agriculture and thus deeply interconnected with their environment, inherently practiced coexistence with nature, a philosophy that NBS seeks to recapture and formalize in contemporary water management strategies.
Research gaps emerge at the intersection of traditional knowledge and modern sustainable water management approaches. These include:
Gap in Systematic, Cross-scale Water Management Strategies: A lack of interdisciplinary and cross-specialty perspectives on traditional water landscapes and their integration with modern water management designs and philosophies.
Status of Sustainability Research in Traditional Water Management: Studies related to traditional water resources often focus on heritage conservation, examining the relationship between water management and landscape heritage, with less attention to the sustainability of traditional strategies in contemporary settings.
Traditional Water Management as Nature Based Solutions: While traditional practices are inherently aligned with NBS principles, there's insufficient exploration of their

application and value in today's water resource management, especially in how these age-old strategies can contribute to modern challenges.

From an academic perspective, research on traditional water management should not only delve into uncovering and protecting its cultural heritage aspects but also investigate its potential applications and value in contemporary water resource management. The integration challenges between traditional and modern practices arise from differing scales, methodologies, and objectives. There's a crucial need for research aimed at exploring synergies and developing integrated approaches that leverage the strengths of both systems. By bridging this gap, we can foster a transition from exploiting to coexisting with nature, drawing upon the wisdom and experiences accumulated over millennia (Angelakıs et al., 2020) to inform and enhance modern water management practices.

CHAPTER 4. RESEARCH METHODOLOGY

Using the urgency of sustainable development and the need to protect cultural landscapes as a research background, this study explores an innovative approach to water management that aims to achieve sustainable development while protecting cultural landscapes. To achieve this goal, this study focuses on the harmony between modern needs and traditional wisdom, combining environmentally adaptive traditional water management strategies with present and future cultural landscape needs, contributing new insights and strategies to the practice and theory of sustainable development.

To achieve this goal, the primary research methods employed are literature review and field research, analyzing and integrating traditional water management knowledge and techniques to further identify general water management strategies applicable across different environments. The relationship between local communities and their cultural heritage related to water management will also be examined.

Adopting an interdisciplinary perspective, the study analyzes case studies in China and Europe to understand the common logic behind local communities' water management strategies under varying natural and cultural contexts, ensuring the cross-regional applicability of water management strategies.

The study also presents case studies of traditional water management at three scales in the same cultural landscape area: Southeast China (including urban, rural and residential scales). Traditional water management strategies at these different scales are summarized and a general integrated water management framework is derived. Finally, through research by design, the framework is applied to the redesign of water management facilities in Budapest to enhance local community participation, landscape sustainability, and cultural heritage conservation and reuse.

In summary, the aim of this study is to attempt to establish a harmonious coexistence between human and natural environments by analyzing and justifying data on traditional water management (derived from cultural heritage). This study also explores sustainable water management strategies that combine modern needs with traditional wisdom in order to preserve cultural landscapes. It explores case studies from different backgrounds and at different scales, developing widely used strategies and their application in Budapest, demonstrating a future where heritage and sustainability combine.

4.1 Case selection: Time-Tested water management Wisdom

As the ancient Greek philosophers said, one cannot step into the same river twice. The fluidity of water makes it constantly move and change. In geomorphology, it is an important shaper; in human society, it is the origin of civilizations and history. It shapes both nature and human societies, traversing geological layers and time, sculpting the ever-changing landscape as well as the splendid tapestry of human civilization. Therefore, taking the water landscape as the research subject, tracing its historical sedimentary rocks, learning from history, and summarizing the successes or failures of our ancestors' experiences, we can better face future challenges such as climate anomalies.

I have already discussed the characteristics and formation logic of traditional water management in Chapter 3, and we have a preliminary understanding of the civilizations and water management strategies of major river basins based on literature and historical data. However, further in-depth research into the application details and principles is still needed. Therefore, this study combines quantitative research, namely empirical research on the application of traditional water management in different environments,

through actual cases, data analysis, and field investigations.
Considering the enduring nature of traditional water management in China in terms of time and practice, this study chooses Chinese water management cases for research.
Given the community and cultural characteristics of traditional water management strategies, we further focus our case studies on traditional settlements as a cultural landscape. Since the environmental context within the river basin is relatively independent, and the hydrological characteristics of the rivers are similar, we choose the Xiangjiang River Basin for our research.
In the Xiangjiang River Basin, we examine traditional water management and water culture on the basis of its natural and cultural background, in both temporal and spatial dimensions, and ultimately select traditional settlements within the Xiangjiang River Basin as the case study for this research.
Considering that the reuse of traditional water management strategies design into the urban scale, but most of the ancient cityscapes within the Xiangjiang River Basin have been covered by modern urban planning, to achieve completeness in the scale of cities, villages, and residential areas, we have also added Ganzhou in the Yangtze River Basin as an additional case study in our selection.

4.2 Data collection and analysis methods

This study adopts a research principle that combines qualitative and quantitative analysis. Focusing on the topic of sustainable water management, it utilizes methods such as literature review, interdisciplinary concept integration, field investigations, case analysis, data collection, linear regression analysis, and equation modeling. These methods provide theoretical and data analysis support for the reuse of water management cultural heritage.

4.2.1 Landscape historical survey

Archival research and Literature review
Sort out the historical documents of water cultural heritage and excavate the relevant data. As well as the cultural heritage, settlement landscape, traditional ecological strategy, adaptive system and other related literature are reviewed, and to complete the qualitative analysis of the traditional water management model.
The historical survey focuses on landscape history research consisted of the mapping of previous research on the topic and the collection of data. Source research is a qualitative research method, during which a comprehensive study of primary and secondary sources was carried out. I divided the examined historical sources into three major groups:

- For written (textual) sources, of which unpublished documents, usually kept in archives and records, as well as scientific processing are of outstanding importance.
- Image sources, i.e. various visual displays, representations and their interpretation.
- Material sources, i.e. historical memories preserved on site.

The most important research institutions used for the research:

- Hengyang Normal University provide the references of traditional village in Hunan province.
- National-Local Joint Engineering Laboratory on Digital Preservation and Innovative Technologies for the Culture of Traditional Villages and Towns,

provided the 3D module of ZhangGuYing village and ShangGanTang village

- Institute of Rural Revitalization Research Changsha University, Provided the river basin map of Hunan province
- Hunan Archives, provided the picture collection of vernacular buildings
- Ganzhou City Museum, offered the city history references
- Hunan province library, provided the books of traditional settlement landscape analysis
- Hungarian Academy of Sciences: provided the Status overview for the National Water Programme.
- Hungarian Academy of Sciences (all the aerial Photo collections from on-site survey.)

Important scientifical sources accessed by internet:

- Archival sources:
- The First Historical Archives of China
- https://www.acas.ac.cn/
- https://www.digital.archives.go.jp/
- https://www.un.org/geospatial/
- https://hanziyuan.net/
- https://www.shuge.org/

The climate date access by:

- Hunan Meteorological Bureau,
- Orszagos Meteorológiai Szolgalat,

Sources offered by local authorities：

- Shanggantang Village People's Committee offered the family history the village developing history and original planning map,
- Zhang GuYing village provided Family book, the family tree and history background. (Picture 22 Appendix A)

4.2.2 Site survey and data processing

Based on the climate and hydrology of the Yangtze River Basin, conduct field investigations on water management in three scales: traditional dwellings, villages, and cities, collect relevant data to complete quantitative analysis of water management

Detailed schedule and description of the field survey:

- 2018.10 - 2019 .03 In Hunan province Xiangjiang River (branch of Yangze river basin)
  Investigation of 6 traditional villages.
- 2019.03-2019.05 In Hunan Province Xiangxi, minority resident areas.
  Investigation of Wengcao Village.
- 2019.05-2019.08
  Investigation of Hunan Xiangxi, Hibiscus town.

The most important two villages are ShangGanTang and ZhangGuYing; I rendered 3D models for these two villages through the datas collected by drone; through this way I measured the whole village, analysing the layout related to the water management. Through the interview I collected the history of the village and the experiences of the

local communities related to the local water management models, knowledges and problems.
The local governor gives a presentation about the village situation and an introduction about the water management system.

Photos: Photographic documentation was done to capture the current state of the site, including vegetation, river, pond (and other types of water bodies) and features of the built environment.

Discussion with Local People: Interviews and informal discussions were conducted with local residents to understand historical land use, cultural significance, and other traditional knowledge and intangible legacy that might not be documented.

Drawings: Sketches and drawings were made on-site to capture key elements, layouts, cross sectios, and spatial relationships, which were later digitized.

Background Material Used

- Maps: Topographical and geological maps were used to understand the lay of the land
- Historical Data: Old descriptions, photographs, land-use records, and other archival materials were consulted to understand the site's past.
- Climatic Data: Historical and current climate data were analyzed to understand seasonal variations and trends.

Techniques for Data Processing

- Photo Documentation: Photos were cataloged and processed using software Adobe Lightroom. GIS software for spatial analysis.
- Topographical Survey: Data from the topographical survey were input into Surfer software to generate a 3D model of the site.
- Drone Survey: For larger sites, drone footage was captured and processed using photogrammetry software to generate a detailed topographical map.
- Aerial and Satellite Photos: These were used for macro-level analysis and were processed using GIS software to extract useful information like land cover types, vegetation index, etc.
- Data Analytics: All collected data were analyzed using statistical software, often employing python and predictive modeling.

The techniques and tools used are grounded in established methodologies within the fields of geography, landscape architecture, and environmental science.
By combining these diverse methods and tools, a comprehensive understanding of the site was achieved, which is crucial for any subsequent planning or development work. (Picture 22 Appendix A)

4.3 Integration between disciplines

According to Jack Ahern (1995), the landscape planning can be understand, according to the resources and goal orientation, we use. The abiotic-biotic-cultural model to describe the specific resources and disciplines addressed in design and the level of integration between these disciplines. In this model, abiotic goals include water resources, soil and air quality. biotic goals focus on biodiversity in general, cultural goals are human-based and include: re-creation, historic preservation public health and economic goals. As you can see from this picture, I use this model to integrate the goals and the disciplines for my research, The circle which near the center and with the dote line are represents the resources and discipline which are strong related to my research. (Figure 13).

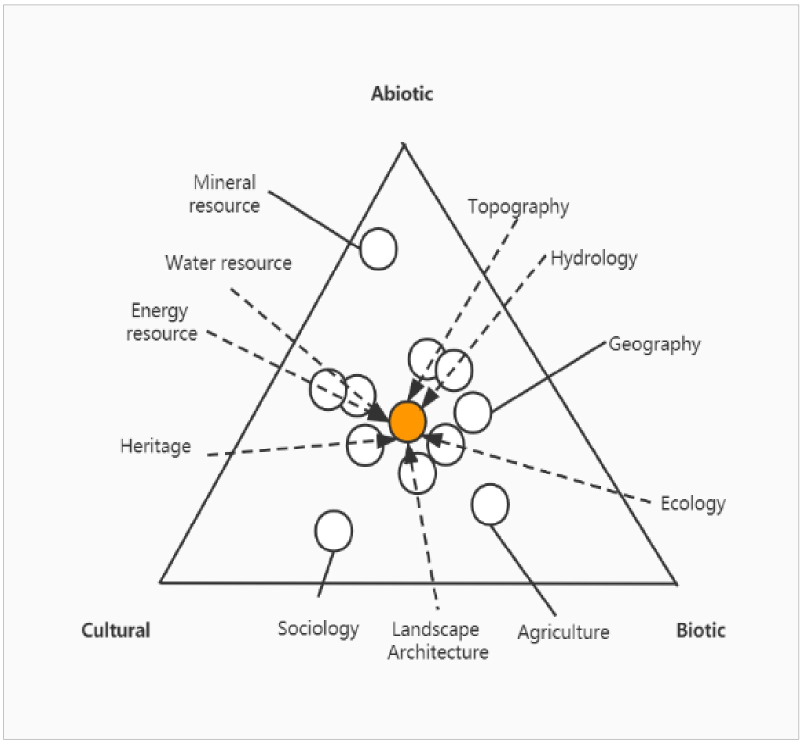

Figure 13. Integration between disciplines (Author)

4.4 Research by design

It includes: design principles, case study analyzes, planning strategies, and some other disciplines. The research based design process is a research process proposed by Teemu Leinonen inspired by design theories (Leinonen, 2010). It emphasizes creative solutions, exploration of various ideas and design concepts, continuous testing and redesign of the design solutions (Leinonen et al., 2016). This method is also influenced by the Scandinavian participatory design approach (Gregory, 2003). Therefore, most of the activities take place in a close dialogue with the community that is expected to use the tools designed. (Ehn, 2017)

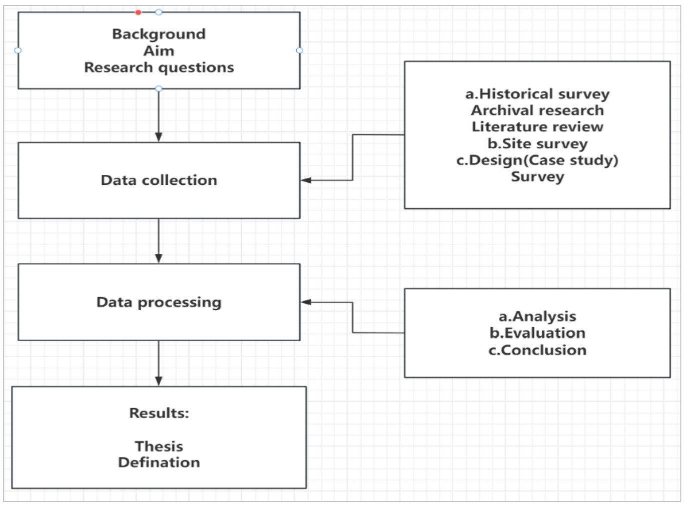

Figure14. Scheme of research by design (Author)

CHAPTER 5. REGIONAL ASPECTS OF TRADITIONAL WATER MANAGEMENT - CASE STUDY OF 3 SCALES

For sustainable development and the conservation of cultural landscapes, the significance of water management spans across multiple scales - regional, settlement, and object (residential). Each scale plays a crucial role in sustaining ecological balance, supporting cultural heritage, and meeting the needs of contemporary and future societies. Here I make the introduction of how traditional water management practices can be integrated at different scales to achieve a harmonious blend of tradition and modernity, ensuring the sustainability of cultural landscapes.

At the regional scale (city and its environment), water management is pivotal in shaping the broader ecological and cultural landscape. By analyzing regional traditional water management strategies, this part of research aims to identify patterns and principles that can inform contemporary practices, emphasizing the balance between development and conservation.

Moving to the settlement (village level) scale, the focus shifts to communities and their direct interaction with water management practices. Settlements-villages, are where the application of water management strategies becomes tangible, impacting daily life and the local environment. The case study examines how traditional settlements have adapted to their hydrological context, utilizing water for domestic, agricultural, and ceremonial purposes in sustainable ways. It explores the integration of traditional water management systems, like rainwater harvesting and communal wells, have the potential to enhance resilience against water scarcity and climate change. The objective is to understand how these practices can be scaled and adapted to contemporary settlements, fostering a sense of community, enhancing the sustainability of local ecosystems, and preserving cultural heritage.

At the object or residential scale, traditional water management becomes a personal endeavor, with individuals and households playing a direct role. This scale explores how traditional practices of water use and management can be incorporated into modern living spaces, promoting sustainability at the most basic level. It involves examining traditional residential designs that efficiently use and reuse water, such as greywater recycling and the use of water-efficient fixtures inspired by age-old wisdom. The study looks into how these practices not only contribute to reducing the environmental footprint of individual households but also enhance the quality of life by fostering a deeper connection with nature and heritage.

Bridging these scales, the research proposes an integrated framework for water management that combines traditional knowledge and modern techniques. It recognizes that solutions at one scale can influence and be influenced by practices at another scale, necessitating a coordinated approach to water management that respects cultural values while addressing environmental challenges. The framework aims to guide the redesign of water management systems, from regional water policies to settlement planning and residential designs, ensuring that each level contributes to the overarching goal of sustainable development and cultural landscape conservation.

5.1 Case study on regional scale: Ganzhou City

The ancient city of Ganzhou has a drainage system with traditional principles and has been in operation until now. However, compared with the Forbidden City (Bijing), it has a longer history meanwhile insufficient funds and technology. Through the historical review and analysis of this case, it can be more clearly demonstrated that the traditional Chinese water management strategy has been continuously improved over time and the environment and its enlightenment for today's sustainable development. Ganzhou is located in the middle and lower reaches of the Yangtze River and the south of Jiangxi Province. It belongs to the subtropical monsoon climate zone. (Figure 5). The average annual precipitation: 1461.2mm. The average annual temperature: 16.18℃. (He et al., 2020)The Zhangjiang and Gongjiang rivers converge here to form the Ganjiang. (Figure 15). Ganzhou is surrounded by water on three sides, high in the middle and low around, like a tortoise floating on the water. Accordingly, ancient ancestors also called it the turtle city or floating city. (Li et al., 2020)

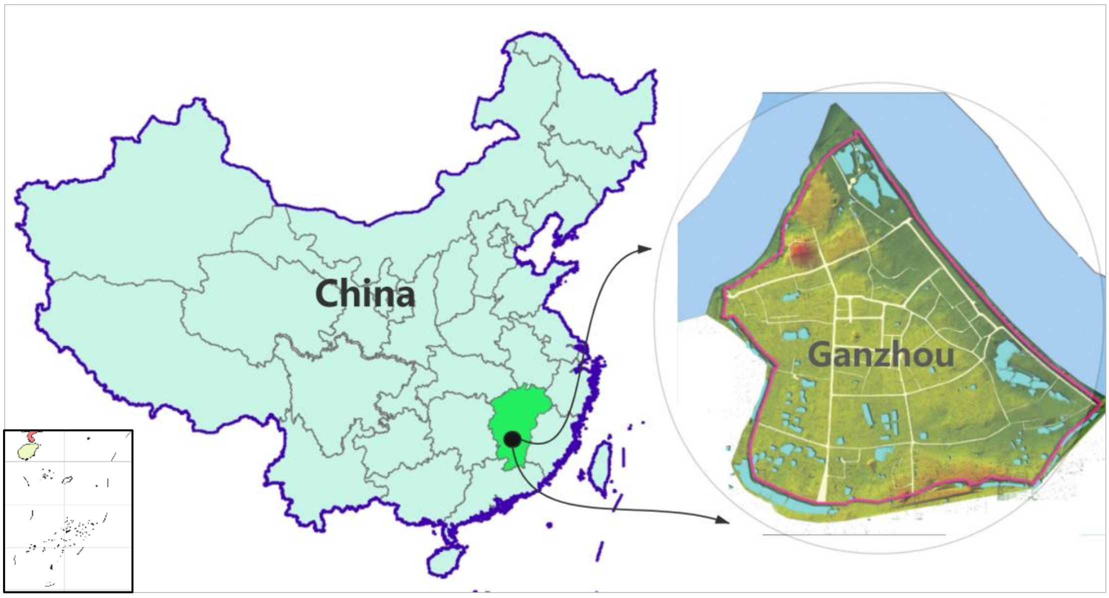

Figure 15. Location of Ganzhou city (Author)

Ganzhou City is one of the oldest cities in China. The city is located in an important position of China's waterway transportation, so it has a long history of urban development and a profound urban cultural heritage. (Xu et al., 2018) After the first emperor of the Qin Dynasty (206 BC) established the State of Qin, he sent troops to guard Jiujiang County. The administrative system of Gannan began here. In 349 AD, Gao Yan arrived in Ganzhou and layout the city. The city area is 1.23km2, and the average height of the city is greater than 100m above sea level. In 885 AD after the peasant uprising, in order to strengthen the rule, the expansion was completed in 910, the city area is 3.05 km2 (Figure15). The hight of the city was 90 m above sea level. In 1013, Kong Zong Han replaced rammed earth building with a brick city. During the Qiandao period of the Southern Song Dynasty (1165-1173), Hongmai built bridges to further expand the scope of the city. (1068-1077) Yi arrived at Ganzhou and designed two underground ditches based on the local hydrology and geomorphology to alleviate urban waterlogging. In 1867, Wen Yi took office in Ganzhou and asked the central government to repair the Fushou Gully, which was silted up by the war and neglected management. At that time, it was difficult to allocate funds due to the central financial difficulties. Therefore, he created a model of spontaneous management by local residents. Time has continued this pattern, and the city is also in the process of continuous expansion. (Ganzhou Gov,2020)

Evolution of water management in Ganzhou

Ganzhou, as a waterfront city, has experienced a large number of flood disasters in its history, and with the expansion and improvement of the city, the water resources management in Ganzhou has been continuously improved. There are five steps in terms of time. (Figure 16)

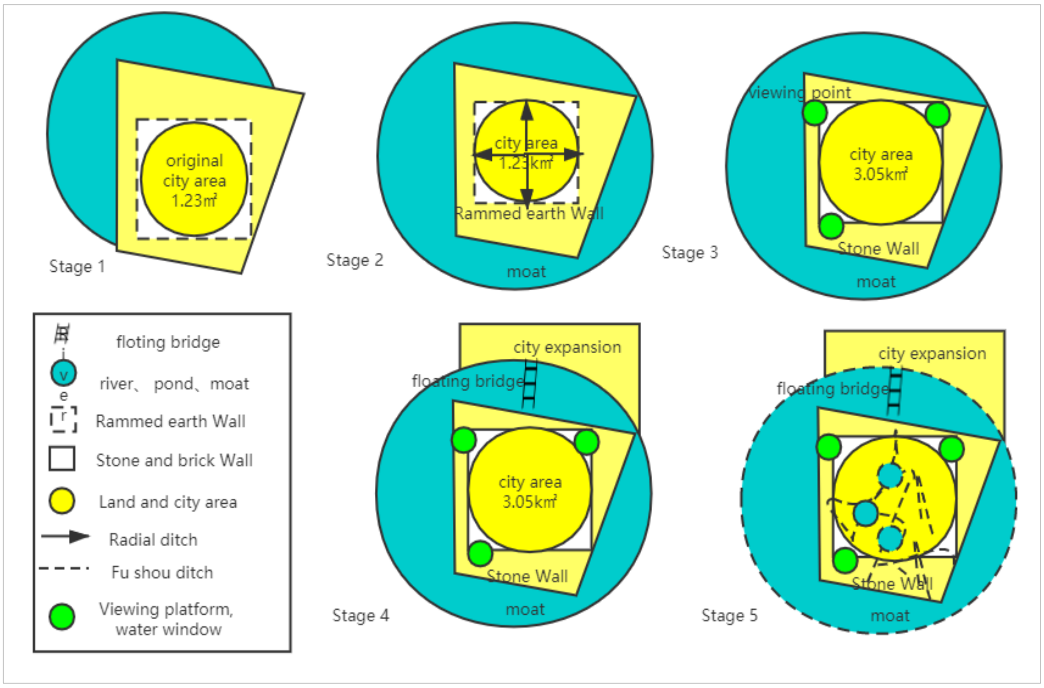

Figure 16. Five stage of water management improve process in Ganzhou (Author)

Step 1: With the establishment and gradual expansion of the city, as the city gradually close to the water body, resulting in a large number of waterfront landscape, making the flooding increased.

Step2: Yang Junsong, a geographer who is proficient in site selection and construction, conducted a re-planning of Ganzhou City based on the original shape of the city (turtle) by investigating the topography of Ganzhou. This new plan focuses on the prevention and control of floods and carrying out radial drainage channels based on the slope of the tortoise's back. It was build to prevent floods from flowing back and discharge sewage. Simultaneously, a moat was excavated on the south side of the city so that Ganzhou City was surrounded by water, and the central high point of the city was 1km away from the water body. The water on the south side of the terrain slope can be drained more easily. After the re-planning of the water canals inside and outside the city, the urban functional zoning was also proposed. The southwest side of the city is the training ground and the garrison camp. The southeast side of the city is the gathering area of religious temples. The economic center of the city gradually changes from the riverside area to the west. Moved to the east side, the east side became the main residential area and commercial area. Moreover, these urban zoning plans have been in use today.

Step3. Due to the years' erosion, the waterproof wall embankment and other facilities built from the ammed earth have lost their usefulness and need to be refurbished and rebuilt. The new manager Kong Zonghan after surveying the flood control facilities in Zhangzhou, decided to rebuild the key waterproofing project. That is, push to the earth wall, build a new brick wall. Kong Zonghan ordered melted iron water to be poured into the cracks in the city walls, and when the iron water cooled down, the entire wall was impervious to the wind, according to the Luzhou Provincial Journal. At the same time, the wall was raised to 10 meters to effectively prevent flooding. The design of the city gate also fully considers the needs of flood control, and the general defense function-based city gate, Ganzhou's five-city gates are designed as gates before the flood to close the gate, combined with a strong wall, can effectively prevent flooding. After constructing the wall gate with flood control as its primary function, a new landscape plan is also proposed on this basis. The city flood control and landscape construction cleverly combined, in the planning of the hole, artisans in the wall to build a stone building, climb the stone building can see the eight scenery of Zhangzhou, as if in a mirror, so the building is named: eight mirrors.

Eight Mirrors became China's first scenic landscape integration, and since then, various places have started to build an urban landscape. (Cun et al., 2019)

Step 4. Because the city shape surrounded by water hindered the further development of Ganzhou, Zhijun Hongmai began to build a floating bridge on the Gongjiang River, which opened the further expansion of Ganzhou City to the other side of the river. Due to the broad surface of the Gongjiang River and the rapid flow of water, it was difficult to build wooden or stone bridges due to the limitation of capital and technology. Zhijun designed a floating bridge connected by 100 wooden boats, a unique landscape heritage of Ganzhou ancient city. Ganzhou has developed from a city near the river to a city across the river. However, due to the increasing density of the city, the problem of waterlogging began to appear again.

Step 5. After Yi arrived in Ganzhou, according to the local hydrology and landform, he redesigned two underground ditches under the original ditch system to connect the water system inside and outside the city, which resembled the two characters "Fu Shou" in calligraphy, so it was called Fu Shou Ditch. The construction was completed in 1077, and since then, the waterlogging of Ganzhou City has been solved (Ganzhou gov).

Two thousand years ago, Chinese ancestors summarized the theory of site selection and construction of cities. In ancient times, cities were called ‘Chengchi’. In a literal sense, they were cities and ponds. The ‘Cheng’ refers to the living area inside the city wall, while the ‘Chi’ refers to the moat outside the city. According to (Guanzi), site selection and city building should be near the water, adapting to the terrain, the city is high, and the pond is low, convenient for residents to use water, and at the same time, prevent floods.

Furthermore, these ideas of site selection and city building are all from real-life experience, which is a historical theory from practice. It can be concluded that traditional water management in China results from systematic engineering and in-depth participation of local residents.

A. Systematic engineering: the combination of landscape and sustainable water management

Ganzhou's water management system comprises five main parts: lake Fushou ditch-water window-city wall-moat, each part has a different water management function or urban landscape function. The city wall has the function of imperial and flood control, and at the same time, the city wall also has the function of viewing: The Eight Mirror Terrace and Yugutai built on the wall has been an urban viewing spot that has continued to this day.

The lakes in the city have multiple functions such as water storage, maintenance of ecological diversity, and adjustment of urban microclimate. The lakes in the city are connected with each other by the Fushou ditch. When the water level inside and outside the city rises due to heavy rains, the water windows are closed, no drainage is possible, and the water level inside the city rises, the pond can store the accumulated water in the city. According to the records of (Ganzhou Chengxiang Ancient Street), Ganzhou’s 84

reservoirs are scattered near and connected to Fushougou.
The structure of the Fushou ditch in Ganzhou is divided into two parts: open ditch and culvert. The open ditch collects and discharges rainwater, and the culvert collects and discharges gray water. The culvert is an arched structure that is firm and stable. Increase the flow velocity to discharge the silt at the location.

B. Community spontaneous management and responsibility contracting system
In addition to fully considering the water management function in the design, the quality is ensured in the construction process, and the continuity is ensured in the later maintenance, which makes the sustainable water management of Ganzhou ancient city realized. The bricks and stones used in the walls of Ganzhou ancient city and Fushougou are collected from the local residents. The detailed information of the donors and builders is recorded on the corresponding bricks and stones, which can ensure the construction quality and unite with the local community. Today, seal cutting remains from the Northern Song Dynasty to the people's Republic can still be found, like the cultural layer in archaeology, record the ancient ancestors' water management engineering construction and renewal process. Local residents also participate spontaneously during the maintenance. Especially when part of the Fushou ditch passes through residents' buildings, these nearby residents will carry out daily maintenance and regularly clean up the siltation to ensure smooth drainage.
Summary:
Ganzhou has gone through a thousand years of history. In the process of water management, it has been continuously adjusted and adapted to the local environment. Through five-stage design and construction, as well as continuous maintenance and repair, sustainable water management is finally realized.
The sustainable water management strategy for the ancient city of Ganzhou can be summarized in the following three aspects:

a. Realize systematic design and adaptive design in design;

b. Pursue high standards and high quality in the construction process.

c. Maintain and implement an innovative management model and make full use of the strength of the local community.

5.2 Case study of settlement scale

Under the conditions of abnormal climate and more frequent water crises in modern cities, we can learn from the experience and wisdom left by the ancients to achieve sustainability in the process of urban design, construction, and maintenance.
Shang Gan Tang is a village located in the upper part of Xiang Jiang river basin, Hunan province, China (Figure 17). The Xiangjiang River Basin is located in the middle reaches of the Yangtze River and is an important tributary of the Yangtze River Basin. It originates in the northeast of Guangxi and runs from south to north through the eastern part of Hunan Province before finally flowing into the waters of Dongting Lake. The Xiangjiang River passes through eight prefecture-level cities and is the largest river within Hunan Province. (Figure 17) In the past, it was a vital waterway in the regions of both Hunan and Guangdong. The Xiangjiang River Basin is situated in a typical subtropical monsoon climate zone of China, with favorable hydrothermal conditions and passing through the Dongting Lake Plain, which is suitable for the development of agriculture, accumulating a rich and splendid farming culture over thousands of years. During the pre-Qin and Han dynasties, the basin nurtured Chu culture. After multiple historical changes through the Song, Yuan, Ming, and Qing dynasties, especially under

the influence of the gradual southward shift of the economic center, the Xiangjiang River Basin, as an important transportation hub, attracted a large population.

Figure. 17. Location of the investigated settlements in Hunan province, China. (Author)

Shang Gan Tang village is located 25 km southwest of Jiangyong County Town, with the provincial road S325 running through it. The village office is about 2 km away from the provincial road, further south 80 kilometers from Yangshuo, Guangxi, and 125 kilometers from Guilin. It is called a millennium-old village because it has been established for over 1240 years, making it the oldest ancient village discovered in Hunan Province and the first settlement of Han Chinese in Jiangyong County. According to county records, at the beginning of the Song Dynasty, the Zhou ancestors migrated here from Qingzhou, Shandong, and gradually established a village primarily inhabited by the Zhou clan. 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 (Picture 29 Appendix A). 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. (Picture 29 Appendix A). 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.
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. (picture31 Appendix A)
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.
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 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 patio (private) level
B - the settlement level water management and drainage
C - the common pond of the village.
(Picture 31 Appendix A)

5.3 Case study of object scale

The patio is a historical residence objects 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) (Picture 23-29, Appendix A)

The name patio literally means a courtyard surrounded and defended by four buildings. Through its architectural characteristics and spatial dispositions, the patio 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 patio 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, Shokohianb&Zhuc, 2017)

The Patio 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 (patio) in Shang Gan Tang, followed by an assessment of the spatial layout and defining the main courtyard types.

A very typical element of the courtyards in Shang Gan Tang, important from water management point of view, is the water collection area 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 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).

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. (Picture 32 Appendix A)

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 (Picture 32 Appendix A). 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 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 courtyard (Figure 18) 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.

Figure. 18. The patio and the central pool in two different houses from Shang Gan Tang village. (Photo by the Author 2018.09)

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 BC) (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 19).

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.

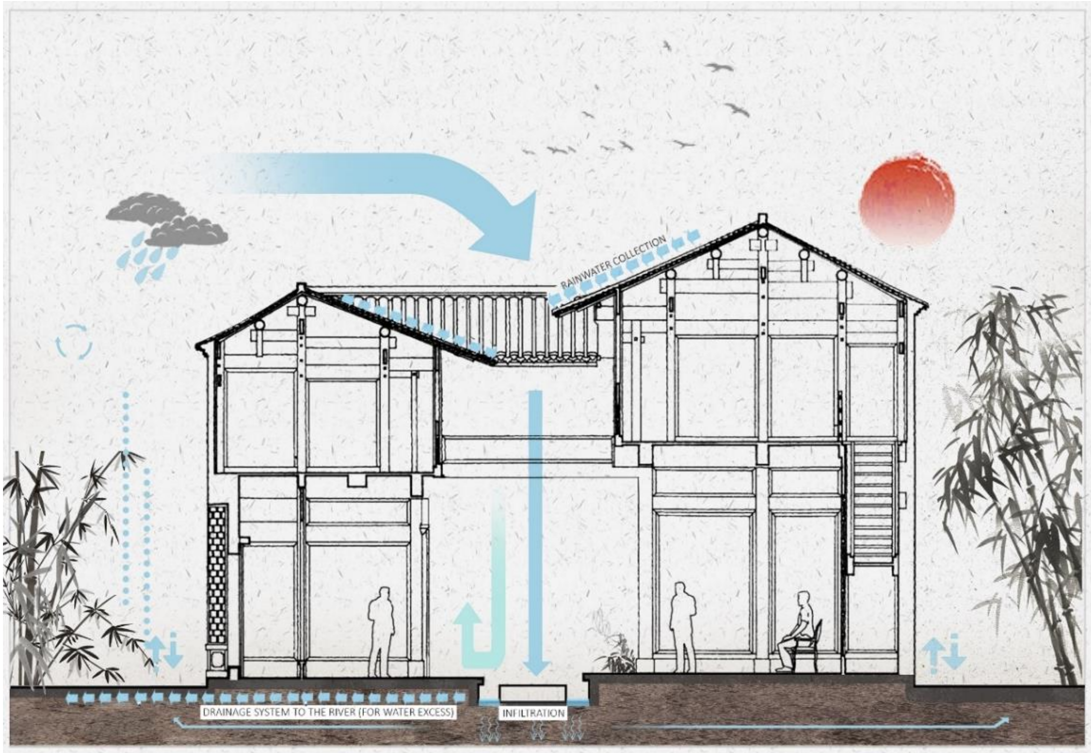

Figure 19. Theorethical scheme of water collection and sewage system of a courtyard in Shang Gan Tang village. (Sketch by the Author)

5.4 Summary

According to the above presented research, the water facilities in the three scales can connected into a whole system, resulting The Traditional Water Management Model X-Y . The scheme of the model is presented in Figure 20.

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 (objects) unit for the water collection, while the pond is the settlement (village) water collection center. Vegetation has a resupplying role in the whole 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.

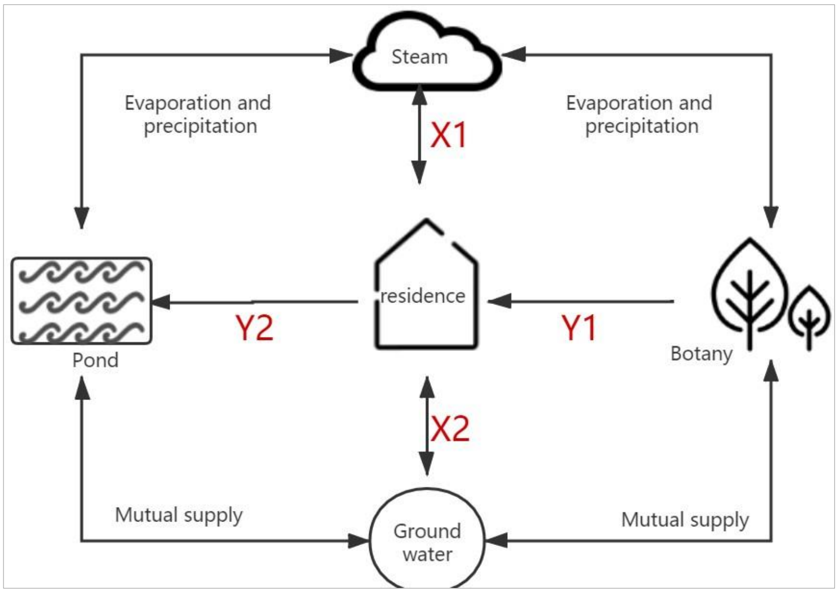

Figure 20. Water management model in ZhongTian Village (Source: sketch by Author)

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. 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.

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.

The case studies examined the traditional water management as a basis of sustainable strategies in urban environment. The research 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 research provides some background information on the urban fabric in Ganzhou, on how the system of traditional courtyard houses determines the settlement layout in Xiangjiang river basin, 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 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 reginal level, using the existing natural resources and processes.

The case study presents the organic structure of the patio 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 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 represents significant work of art, technology and ecology, which deserve attention.

From the heritage point of view, the traditional water management system in 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.

CHAPTER 6: REINTERPRETATION OF THE TRADITIONAL WATER MANAGEMENT STRATEGIES BY DESIGN

Based on the landscape architecture of traditional settlements in southern China, this part of research takes water as a vital element through further field investigation and model analysis to explore the water management strategies of two traditional villages in Xiangjiang River Basin, Hunan Province.

I have found that: Traditional settlements are located between rivers and mountains. The community of the settlement has a strong interaction with the water environment. The water management system consists of two parts: the rainwater collection and storage system of a single building and the settlement's water collection and drainage system. Through calculation, I found that the amounts of water collected (per year) between the two villages are different: ZhangGuYing (Z village) = 5.739 million l, ShangGanTang (S village) =1.784 million l, in spite that water management strategies of the two settlements are similar. Further analysis shows that the difference is related to the adaption of the precipitation and topography of the surrounding areas. The above-mentioned systematic management strategy of water resources has been used until nowadays, with adaptability, low cost, and sustainability. It has outstanding significance for the current demand for sustainable development from both resource management and cultural aspects.

Focusing on water as a crucial resource for community building, this chapter utilizes a comparative case study approach to investigate traditional Chinese settlements and the world heritage landscapes of Budapest. The goal is to elucidate the commonalities and differences in the management of shared water resources by local inhabitants, with a particular focus on the functions of rainwater harvesting systems. The findings indicates that, despite the distinct cultural landscapes represented by the two case studies, there exists architectural features that potentially encourage resident involvement in water management. This suggests that a water management solution that leverages such architectural features could foster a harmonization of social and environmental objectives. This approach underscores the benefits of minimalistic logic and low-investment strategies in promoting sustainable water management by local communities. Furthermore, building on this conceptual framework, the study delineates three different dimensions of rain garden designs, advancing a sustainable landscape framework with potential applicability in other European cities.

6.1 Design background

Traditional settlements, As part of the landscape where people have lived in compact communities throughout history (Anagnostopoulos, 1977), is similar to modern settlements. Our lifestyles are based on the development and distribution of resources (Wirth, 1938) (Beatley and Manning, 1997). However, because of the lack of advanced production tools and productivity, traditional settlements are more dependent on a stable and suitable ecological environment (Meggers, 1954), including climate, topography, soil, water resources and other basic natural conditions (Priscoli, 2000). Therefore, the traditional ecological knowledge of how to achieve and maintain sustainable development of a settlement has gradually accumulated in different places all over the world (Grof, 1984). Because of the importance of water for human beings, ancient civilizations around the world have accumulated their own technologies and strategies (Jiang, Han and Wu, 2006), such as the canals in ancient Rome, which realized the spatial distribution of water resources. Ancient Greece also realized the reuse of water resources in the Mediterranean region through the design of urban water pipes and public facilities, and solved the problem of uneven time distribution of water resources (Fernandez-Gimenez, 2000). Ancient Egypt took advantage of the seasonal changes of the Nile to achieve agricultural prosperity. (Wang et al., 2020) Although the traditional ecological knowledge is effective, some of it no longer matches the current situation (Fernandez-Gimenez, 2000). Therefore, it is particularly important to study the traditional strategies and internal mechanisms of the ecologically sustainable settlements which have survived to this day. Unlike other ancient civilizations, some of the Ancient Chinese settlement/facilities still functional well until today (Liu, Duan and Yu, 2013) The traditional Chinese agricultural landscape is highly dependent on the stable natural environment (Li et al., 2014) , so the location of settlements (Rapoport, 1983) and the management and distribution of local resources – especially the water – are prerequisite conditions for the local sustainable development (Gao, Wang and Huang, 2015).

Based on experience (or observation), traditional knowledge is tentative and probabilistic and will be constantly revised and falsified." (Needham, 1974) , So as the ecology of small-scale (settlements) can be continuously adapted iteratively to finally realize a sustainable system of self-sufficiency (Huang, 1990) , and at the same time, a highly stable local economy with families as its basic units can be realized (Chang, 1992) , which is characterized by high-level social coordination, organized division of labor and effective autonomy (Perkins, 2013). On the basis of a farming economy that relied on natural resources, ancient Chinese ancestors summed up and developed a set of systematic management theories based on nature for the selection and planning of ecological settlements and management of natural resources (Wang et al., 2016).

The goal of this study is to reinterpret the accumulated experiences and theories in history from a sustainable perspective for the urban landscape, with a special emphasis on today's increasingly obvious water resources problems (Tundisi, 2008). From the experiences and strategies, we can learn how human-environmental interactions changed through time and space and further discuss how to extend its value (Lepofsky, 2009).

The current research on traditional water resources is mainly qualitative research, which explains the experience, methods and technologies of traditional water management in some developing regions (Yang and Liu, 2017) (Prajnawrdhi, Karuppannan and Sivam, 2015) (Ye et al., 2020), and tries to apply the simple logic and low cost strategies to other regions (AlSayyad, 1995). In addition, there are also studies on the application of rainharvest to agricultural production (Tsartas, P., 1992). The roof rainharvest function has potential value (Daugstad, Rønningen and Skar, 2006), but is limited by the data validity (Setijanti et al., 2015), the quantitative analysis based on specific studies cannot be carried out to provide more convincing conclusions for the implementation plans. (Setyaningsih et al., 2015). Some quantitative analysis of rainwater collection has implications for this study (Wang et al., 2011), especially the analysis and comparison of the changes in precipitation amount and distribution on water resources (Vythoulka et al., 2021)

In addition to the research on low-cost rainwater harvesting in traditional settlements, the research on traditional settlements' response to floods also has implications for urban stormwater management under today's climate change situation. (Graham, Ashworth, and Tunbridge, 2016) (Li et al., 2021)

Some other studies take the perspective of the functionality of the architecture itself , the water resources management as the main research topic (Fekete et al., 2022) , and combine the quantitative analysis and qualitative analysis to research the sustainability and cross-regional application potential of traditional water management (Zhou, Matsumoto, and Sawaki, 2022) (Song et al., 2011 , which can explain the mechanism of traditional ecological knowledge (Zheng, 2015) , but it does not directly prove the effectiveness of its mechanism and the details of its dynamic changes (Wu, Qiao, and Wang, 2013) (Dong, Zhang, and Li, 2019).

This research will explore water-related data from the perspective of water management to prove how traditional settlements can achieve adaptability across time and space scales. The research focuses on analyzing the background, logic, and action mechanism of the traditional water management strategies, and finally providing solutions for urban landscape planning and water resources management in the new period.

Through field investigation, on-site interview, and photogrammetry, this study collected, analyzed and compared the basic data related to water management in two traditional settlements so as to obtain the operation mechanism of traditional settlement water management system and further discuss the possibility of its wider application.

The two villages involved in the research are located in Southeast China, Xiangjiang River Basin (Picture 33 Appendix A).

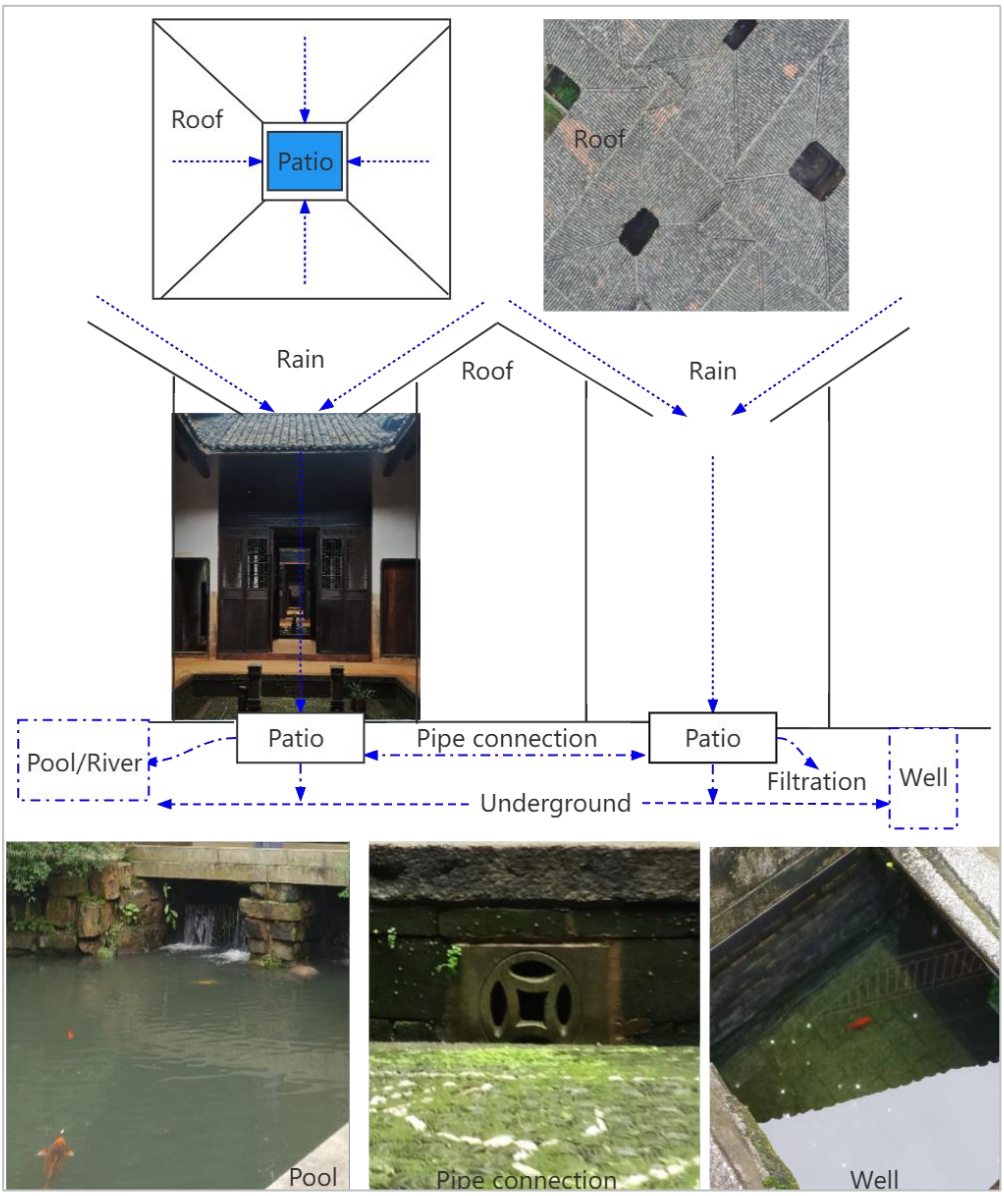

Figure 21. The water collection system used in the villages. (Author)

The ZhangGuYing village of YueYang City (29°00'36"N; 113°128'30"E) population: 2169(data from year 2000) and ShangGanTang village of YongZhou City (25°09'09"N; 111°10'57"E) population:1865 (data from year 2000) are located in Hunan Province in terms of administrative division. In terms of geographical location, the two settlements are located in the upper and lower half of the Xiangjiang River Basin. They belong to the subtropical monsoon climate area, but according to the data of the local weather station, the precipitation, humidity, and annual average temperature of the two settlements are different, as shown in (Table 1. Appendix B)

The rainwater collection and storage system mainly have three parts：

- The rain harvesting roof.
- The patio and underground pipe connection
  (Patio has water capacity of 2.4 m3)
- The water storage pool for ShangGanTang water storage to the pond,
  (The capacity around 73.43 m3)

As we can see from Figure 21., the rainwater was collected by the roof from 4 directions, falling down to the patio, each patio being connected by the underground pipe system, and big amount of water drained into the river，few amount water was store to pool. Some part of the water after infiltration goes down (underground), and the water which was left at the patio can be used for daily purposes (for washing, for microclimate amelioration of the courtyards, etc.). Less for drinking, as far as the drinking water got from the well. Due to the traditionally used wooden construction materials of the villages, the water from the pond is also used in case of accidental fire.

The villages are located in rural landscapes, representing the organic part of the landscape, which has as its main use paddy rice production. The rice field has a totally independent water supply system called the rice canal, which is connected to the river. For the whole research area, this study will explain the function of the different parts of the water management system used in the village. The data analysis will only focus on the rain harvest part to calculate the amount of water collection and compare the two villages for the similarities and differences in water management strategies.

The settlement image data was collected by DJI phantom3, and the 3D model was rendered by the Contextcapter software. Surface measurements and linear regression analysis were performed by Acute3D viewer. Topographic data were collected through Google Earth, and topographic maps and cross-sections of settlements were processed by Surfer software (Figure 22.)

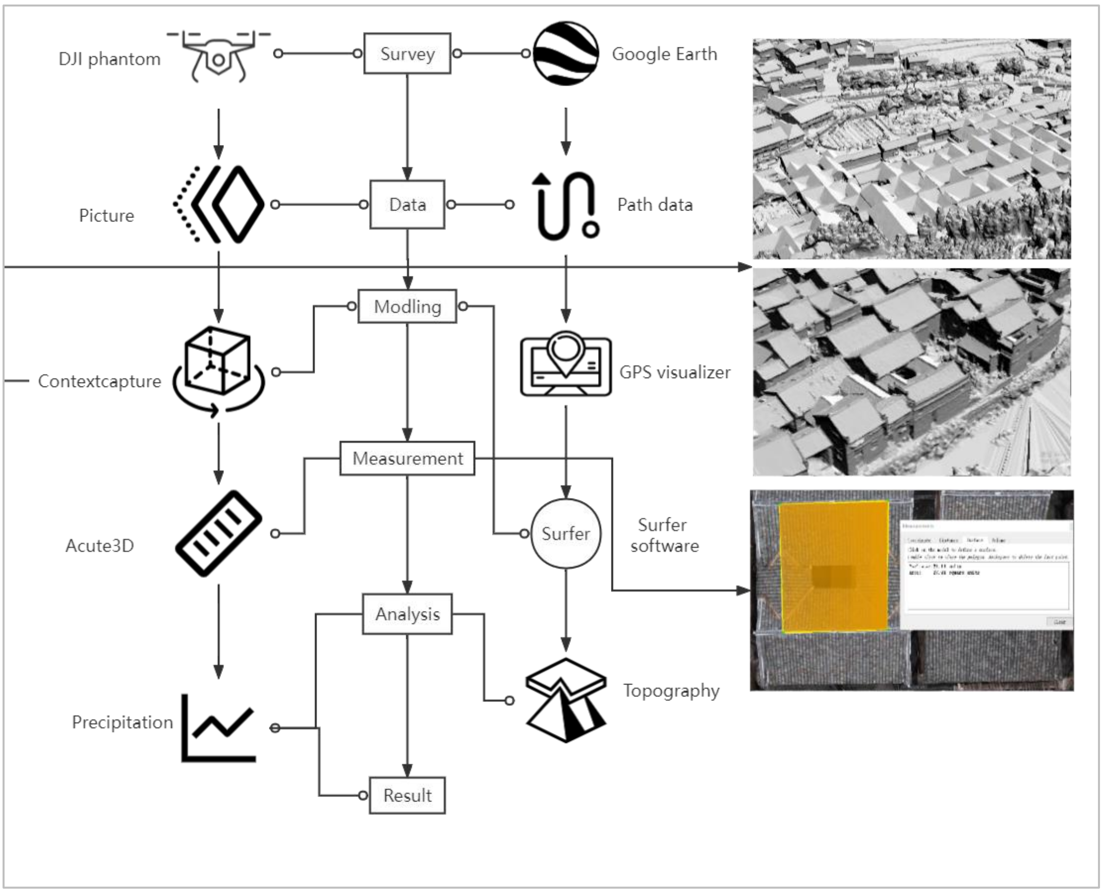

Figure 22. Conceptual framework of the research process. (Author)

Drone photogrammetry was performed on the two urban landscapes in the Xiangjiang River Basin, and the drone routine collection data was entered into the Contextcapture software for processing in order to obtain 3D models of the two settlements. The 3D model was then measured to get the catchment area of the patio and roof (Table 2 Appendix B). The regression analysis of the patio and roof area of the buildings showed that there was a linear correlation between the patio and roof area of the two settlements. Combining precipitation data, the catchment area of the roof, patio, and the measured area were calculated. With data and interviews, the similarities and differences in water management mechanisms of the two settlements were further compared.
Through Surfer software and Google Earth data, the topography of the two settlements was modeled and profiled to obtain the direction of surface runoff, the topographic relief, and a spatial overview of the site.
Finally, the analysis of precipitation and water retention was combined with the logic of village planning and its related adaptive mechanisms. (Figure 22)

As we can see from Figure 23, the regression formula is:

Y1=6.3367X1+86.638 (ZhangGuYingP/R2)
Y2=3.4467X2+21.23 (ShangGanTangP/R1)

Y 1: ZhangGuYing village rainwater harvesting roof area
Y 2: ShangGanTang villages rainwater harvesting roof area
X1: ZhangGuYing village patio area
X2：ShangGanTang village patio area

The median of the patio area from 68 dwellings is 3.9m^2
Bring the median of the patio area into equation 1: Y1=111.35 m^2 and Y2=34.67 m^2

As the equations show, the two ratios of the roof catchment area to the patio area are close: in the case of ZhangGuYing (Z) 6.3367 and in the case of ShangGanTang (S) 3.4667. Both the R^2 value is greater than 0, and the area of the roof and patio are positively correlated; that is, the area of the roof (rainwater harvesting) and the area of the two settlements is related to the patio (water storage) area. There is a linear correlation between the roof and the patio. (Figure 23).

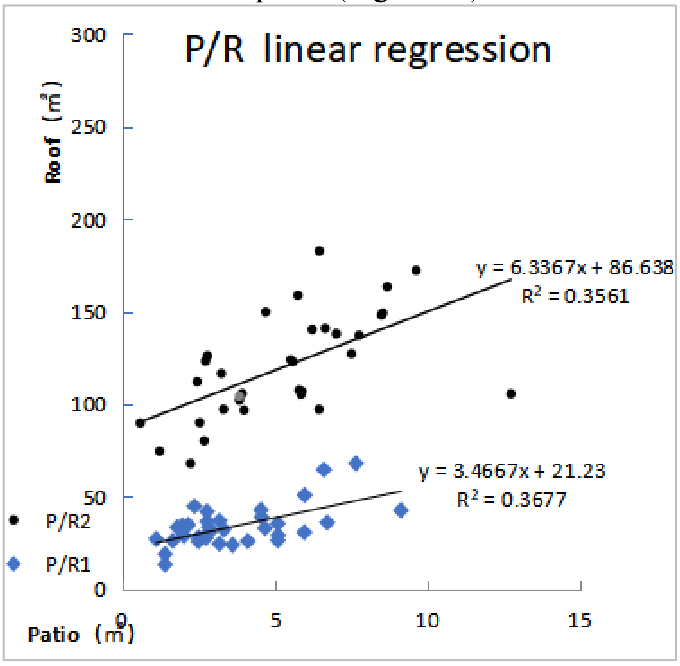

Figure 23. The linear regression of roof and patio surface areas of the two villages. (Author)

This is in line with the design language patterns of traditional Chinese architecture; that is, each component of the building is designed according to strict, designated proportions (Cody, Steinhardt, and Atkin, 2011). This design logic has two reasons: one is the standardization of traditional architectural theory, and the other is that it can be combined or adapted to local conditions. It involved adaptive adjustment of the scale and function of the landscape to different situations (Li, 2001). From the regression analysis results, we can indirectly conclude that the water management logics of the two traditional settlements are very similar. Meanwhile, the difference is obvious from Table 2: the total roof area of 34 buildings in Z village is 4242.25m^2, and in S village is 1251.05m^{2}As we can see from Figure2, the architectural design and structure of the two villages is different: Z village design called “DaWu” which means the whole village members as a clan family living in one big house, the S village is in same clan clustering situation, but DaWu is a special form to emphasize the bounds between the family members, it reflected in the design by connected the roof of each dwelling together. Both villages belong to the logic of clan settlement, but the architectural expression is different. This is the explanation from a cultural perspective.
More important, for water management purposes, here we assume that the differences are caused by the adaptation to the environment and topographical conditions of the two settlements. The hypothesis was interpreted in combination with the local interview, topography analysis, and meteorological data.

Rainwater amount collection

S village yearly average precipitation（roof） 1426 mm/m^2 *1251m^2 =1.784 millionL

August（max）： 255 mm/m^2 = 0.319million L

Z village yearly average precipitation（roof）1 353 mm/m^2 *4242m^2 = 5.739millionL

August（max）： 172.9 mm/m^2 = 0.733 millionL

Based on the average annual precipitation and the surface area of the settlements, the annual water quantity collected by the roofs of S Village is 1.784 million l, while in the Z village is 5.739 million l. In (Table 3 AppendixB), using the Acute3D measurement tool selected the area including the 34 dwellings and part of the river that flows through the settlement as the total area, and comparing the river area with the selection area of the study area. (ShangGanTang have 367 traditional dwellings in total, selected 34 buildings, which rainharvest function is still working, and maintaining by villagers. ZhanGuYing have 1062 traditional dwellings in total, due to the long term expansion, the village mainly have three parts: DangDaMen 422,1593DC; WangJiaDuan 468,1802DC; ShangXinWu172, 1803DC. I only choose 34 buildings which were built in same period in WangJIaDuan part and all the buildings have the same rainharvest function. The total area was selected through surface measurement tools, I used the 367 buildings and the river surface area which go through the village as the selected area for ShangGanTang 34174 m2, 468 building area of WangJiaDuan part and river surface area which go through the village as the selected area for ZhanGuYing16334.39m2) I found that the river area ratio in Z village is 6％, much smaller than that in S Village 10％, and the precipitation in Village Z 1353mm is lower than that in S Village 1426 mm. So, the theoretical water collection in Z village can increase significantly larger than in S Village. Combined with local interviews, the number of floods in the village was also higher in S than in Z village. For S villages, the flood control function is more important, so the patio and roof are smaller than in Z villages; thus, the meteorological analysis supported the hypothesis.

According to (Picture 34 Appendix A), we can see that both Z and S villages are located on flat ground between hills and rivers.

In the process of the landscape development of the traditional Chinese settlement, the most important step is the positioning of the settlement (Bruun, 2003), which can also be understood as the choice of an adequate living environment (Marafa, 2003). Just like in the case of painting (Zhang, 2013), the choice of location is equivalent to the painter's first stroke on the canvas, followed by the construction and management of the surrounding environment of the selected location, that is, landscape transformation (Han, 2001).

In terms of location selection, Chinese landscape architects need to consider many factors, and they also gradually develop a systematic Fengshui theory in the process of practice (Xu, 1990). According to the positioning in Fengshui, the most beneficial settlement location is the "Livable" position (Han, 2001). In the Chinese classical philosophy system, "qi" is divided into two kinds: Yin and Yang, which are reflected in the landscape as a mountain (Yang) and water (Yin) (Zhang and Rose, 2001) (Wang, 2005). Therefore, in ancient times, Fengshui chose the positions between mountains and rivers to build settlements (Li, 1993). From the artistic perspective, this site selection layout is conducive to borrowing scenery, that is, using mountains and rivers to create visual order and a sense of harmony (Xu, 2003) (Bruun, 2008). This type of selection and location is also enlightening from the perspective of contemporary science:

a. The thermal circulation generated between the mountains and rivers meets the needs of heat dissipation and ventilation.

b. The wind direction of the monsoon climate is conducive to cooling in summer and avoiding cold air intrusion in winter.

c. Meet the needs for water use and avoid floods.

d. Use the change of topography to create the layering of the landscape.

e. Layout of the settlement along the river to alleviate spatial and social conflicts.

f. Use the change of topography combined with the water collection facilities for the sponge effect (Liu, Duan and Yu, 2013).

The location of the settlement is part of the: adaptive to Topography strategies. The surface runoff was considered during the settlement planning. ZhangGuYing Village is relatively flat, while ShangGanTang Village is a typical traditional Feng Shui layout, surrounded by hills on three sides and a river on one side. In this landscape setting, the planners of the traditional settlement fully considered the water management strategies. For ShangGanTang Village, due to the proximity to the river, the river flow is high, and the surface runoff path of the mountain needs to pass through the settlement. Analyzing Figure 4, it is clearly understandable that the adjustment of the collection capacity of rainwater is low, which is conducive to preventing waterlogging. For Zhanguying Village, the altitude is lower (Table 3 Appendix B). The average annual precipitation is low, the surface runoff is slow, and the settlements are distributed along the two sides of the stream so that the water collection function can be maximized.

It can be seen that, according to different environments, the water collection and storage of each building in different settlements has the same logic but with different capacities. The water collection volume is adjusted according to the precipitation, the size of the river, and the topographic characteristics of the landscape. In other words, the strategies are the same but adapted to the specific environment. (Table 4. Appendix B)

For Z village, the Precipitation is 1353mm, lower than S village, and the river size is 1125.23m^2 Also smaller than S village, the highest point is around 150 m, lower than S village; thus the Z village adjusted the roof size, maximum the rainwater collection function.

In addition to the roof-patio rainwater harvesting system based on residential buildings, the location of the settlement also plays an important role in water management. Taking ShangGanTang as an example, the site selection of the settlement conforms to the principle of the traditional Feng Shui theory: the settlement faces the water/river and has the mountain at its back (Lee, Yang, and Wang, 2009). Such a site selection can combine the water collection and storage systems of single buildings to participate in the water cycle during the formation of precipitation and runoff, and has a similar function of regulating water bodies as sponge cities (Qi et al., 2020).

The integrity of ZhangGuYing Village is more obvious. The roof and patio are linked to each other, which can maximize the collection and storage of rainwater. In addition, the patio and the stream are also connected, and there is a water outlet to control the flow and thus actively adjust the storage capacity. (Figure 21)

From the above analysis, we can find that the water management strategies of the two villages are logically similar.

From the point of view of landscape pattern, the two traditional settlements are represented by three parts: dwellings-settlement-landscape (surrounding environment) in terms of water management. The three parts are independent but interconnected. It can be said that the traditional settlement uses landscaping and architecture to achieve less interference with the natural surface runoff and underground runoff.

These functions can be interpreted from an ecological perspective today, but in traditional Chinese society, they are better interpreted in terms of culture, practice, and

meaning (Lomas and Xue, 2022).
According to traditional Chinese culture, man, as a part of nature (Li, 2006), also has natural attributes (Fang, Wang, and Liu, 2020), while Fengshui in the traditional landscape literally means Feng: wind (air flows) and Shui: water flows (Cooper, 2014). Air and water are also common fluids in nature, with the attributes of circulation and movement. On the human side, it is more important to enable people and culture to flow continuously, like wind and water. This makes the Chinese traditional water management strategy more disseminated and sustainable at the cultural level (Capra, 1983).
In other words, in traditional society, the sustainability of material resources is also culturally combined with the trend of material sustainability. This sustainable strategy has an important impact on today's material resources and spiritual culture. What human beings need is not only the sustainable demand for resources and materials but also the support of sustainable ideas and culture rooted in human consciousness beyond resources and materials.
This research proved the importance of the Chinese traditional cultural heritage in rainwater management through the design of the settlement and dwelling architecture (structure, form, and size). From a heritage point of view, sustainable water management strategies also have their cultural roots in the local community. Some future studies are still needed, in order to focus on some practical issues, like the contemporary adaptabilities of traditional rain harvesting methodologies from a global perspective. The new challenges of climate change and urban sustainability raise the importance of such traditional methods in the collection and use of rainwater, especially in the urban environment. In a European context, there are similar urban and landscape structural systems, which can be improved using the oriental traditions. This is expected to mitigate, among other positive effects, the urban flooding from climate change as well.

6.2. Field survey - Budapest rain harvest system case study

In recent years, with the changes in the natural environment and the frequent occurrence of water-related natural disasters, water resource management has become increasingly important. As a part of the interaction between human activities and the environment, traditional water management strategies profoundly reflect the relationship between communities and landscapes, demonstrating people's understanding of the spaces to which they belong. Therefore, a water management solution characterized by cultural landscape features and centered on local residents holds significant implications in addressing climate crises. More importantly, grounded in the cultural heritage of the local residents and continuously refined through practice and improvement, traditional water management approaches not only realize the framework of water management solutions from a theoretical perspective but also embody adaptability and adjustability to various spatiotemporal environments from a practical standpoint.
In the current context of dynamic changes in the environment, the revolutionary design concept based on environmental adaptability is particularly important. Through using nature- and environment-friendly techniques, materials and in a way that they are also related to the physical environment and the custom of the region. (Fekete et al., 2022). As a popular method to deal with environmental changes and social challenges in recent 10 years, Nature Based Solutions (NBS) may contribute to clean and reliable water supply, flood control and drought resistance. “Nature Based Solutions are defined as actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human

well-being and biodiversity benefits.” (Calheiros & Stefanakis, 2021)
NBS integrates related concepts such as ecosystem services, ecosystem –based adaption/mitigation, green and blue infrastructure, and tries to inspire by, using, coping from or assisted by nature through the development of industrial and technological solutions. (de Jesús Arce-Mojica et al., 2019) It is not difficult to see that NBS is trying to accommodate a variety of sustainable development related concepts under a new framework, but at the same time NBS needs to offer new theoretical insights while synthesizing other concepts, (Roggema, Tillie & Keeffe, 2021) and give a clear Definition of Nature. The philosophical interpretation of the concept of nature is very important. At present, most of the problems that are not clear enough in NBS are related to the definition landscape, as a result of a human intervention in the nature and transformation of the nature accordingly to human expectations.
For example: Is the relationship between man and nature antagonistic or united in the current climate anomaly? Based on nature, does it mean based on the natural environment or based on human perception of the natural environment? How to learn and coping natural dynamic processes? Based on nature, does it mean bionic design from the perspective of landscape design? Adaptive design refers to adaptation to the natural environment or adaptation to human needs? In the process of dealing with social challenges based on nature, is it based on natural facilities (elements) or consensus on natural ideas (Seddon et al., 2019)? In industrial civilization, people often focus on the causes and consequences of problems and put forward targeted technical solutions. The innovation potential of NBS lies in the multi-disciplinary perspective, from the perspective of natural system and the inspiration and expansion of dynamic processes, and try to solve environmental, economic and social problems from the perspective of system theory and holism. That is, “design natural in”. The traditional grey infrastructure is “design in nature” (O’Hogain & McCarton, 2018). This requires us to transform the original design concept of pursuing linear, simple, certain, predictable and controllable parts into a dynamic, complex, uncertain, unpredictable and uncontrollable holism design concept based on natural system
Unlike NBS, the solutions/strategies used in local communities is holistically and encompasses both natural and human dimensions that mean not only water is the resources for the physical needs but also for psychology needs. The natural provided background for the communities the communities shaping the structure, the structure have function and the function influence the natural. During this process the cultural heritage formatting, these cultural heritage with context design and adaptive expressions that can provide sustainable landscape benefits. (Picture 35 Appendix A)
For example, China's water management has experienced a long historical evolution process. With the development of time and changes in the environment, the ancients constantly tried to fit themselves in the local environmental context (DongGe et al., 2022) , they unite as a family/society and finally formed a water management system with environment adaptability. (Mak & Ng, 2008) For more than 4,000 years, ancient China had its own set of landscape theory systems. It has its own set of theoretical frameworks for how man and nature can coexist (Ge, Fekete & Yang, 2020). Since the pre-Qin period, the site selection, planning and landscape design of Chinese cities and settlements have been supported by rigorous Shanshui theory (which means water and Mountain). (Cody, Steinhardt & Atkin, 2011) Until today, we have experienced many rain and flood disasters and found that, compared with contemporary landscape architecture, ancient landscapes and buildings are of high quality, highly adaptable to the environment, and scalability and sustainability at many levels such as environment and society. (Han, 2001)

While Eastern and Western approaches to water heritage can differ markedly, Budapest stands as an example of Western perspectives (Puczkó & Rátz, 2006), leveraging its rich sweet and thermal water resources to foster a vibrant cultural space (Bottoni et al., 2013). This Hungarian city, affectionately known as the "City of Spas", carries a history that's echoed through its iconic thermal baths, drawing from Roman, Ottoman, and Austria-Hungarian influences that have shaped its landscape over centuries Dryglas & Smith, 2023). Moreover, the presence of the Danube, as the biggest European river, influenced from the beginning the establishment and development of the city and the relationship between inhabitants and water (Budapest, 2008).

Each water facility, whether a thermal bath or a historic fountain like the Matthias Fountain in Buda Castle (Alfoldi, 1981), these spaces have grown to become more than just a showcase of architectural prowess and hydrological innovation; they are communal hubs that encourage the coming together of locals, promoting interaction and the continuation of longstanding traditions (Dúll & Pálfy, 2014). They serve as a bridge between the past and the present, offering a continuity of cultural practices where the community can actively participate and immerse themselves in a rich historical tapestry (Taylor, 2012). In essence, Budapest has successfully transformed its water cultural heritage, using it in the creation of a well functioning urban structure, with multifunctional open spaces, marrying history with present-day urban life (Csizmadia et al., 2016). This not only fosters a deep appreciation and understanding of the city's historical and cultural resources but also encourages active participation, making history a tangible and living experience for all (Mérai & Kulikov, 2023). But meanwhile we have observed that a portion of Budapest's cultural heritage shares a similar structure with traditional settlements in China in terms of landscape, suggesting that they might possess comparable functionalities for rainwater harvesting.

From the perspective of Budapest communities, we can explore the potential application of rainwater collection in Budapest, where rainwater gathered in housing estates and apartments can serve as a source for irrigation, climate adaptation and aesthetical improvement laying the groundwork for community-centric rain garden designs.

In this regard, we can delve deeper into the design and structure of courtyards within two distinct cultural contexts. In China, courtyards, also known as "patios," typically constitute the inner spaces of houses, offering ventilation and natural light, while also serving as venues for family members to socialize and carry out daily activities (Zhou, Matsumoto & Sawaki, 2022). Furthermore, these courtyards can facilitate rainwater collection (Song et al., 2011), beneficial for irrigating plants within the courtyard or ther purposes. (Picture 36 Appendix A.)

Similarly, courtyard designs in Budapest (and more broadly in areas) influenced by Roman culture (Sekenwa, Hamza & Vivanco, date unknown), carry similar functionalities and focus. (Picture 37 Appendix A)

These courtyards not only provide a space to enjoy natural light and fresh air but also function as communal gathering spots, fostering connections and interactions within the members of the community (Abass, Ismail & Solla, 2016).

As we examine the potential applications of rainwater collection, this study emphasizes contemplating ways to optimize courtyard designs to better harness rainwater. For instance, this can be achieved through the design of appropriate drainage systems and water storage facilities. By comparing the courtyard designs and histories of both locales, we can identify unique and innovative solutions suitable for implementation in Budapest to enhance its rainwater collection and utilization capabilities, thereby realizing a more sustainable and environmentally friendly community design.

The results further provide cross-cultural and cross regional design solutions for water resource management in other European cities

6.3 Climate data analysis

The historical antecedents were explored on the basis of archival and literature research. The information related to the traditional communities' water management was collected through field interview. Through field investigation, the information about water management of traditional communities is collected, and the mapping data are obtained, the detailed data of water management and rainwater collection of traditional settlements in Xiangjiang River Basin of China are obtained. Finally, the solutions are used to simulate the rainwater collection in Budapest, to test whether it effective in cross-regional application.
The study is based on case studies located in the two countries involved in the research: China and Hungary. The Chinese case study is represented by ShangGanTang, ZhangGuYing,village, located in central China, Xiangjiang River basin (Figure 24/a). The Hungarian location is in the capital of the Country, Budapest (Figure 24/b)

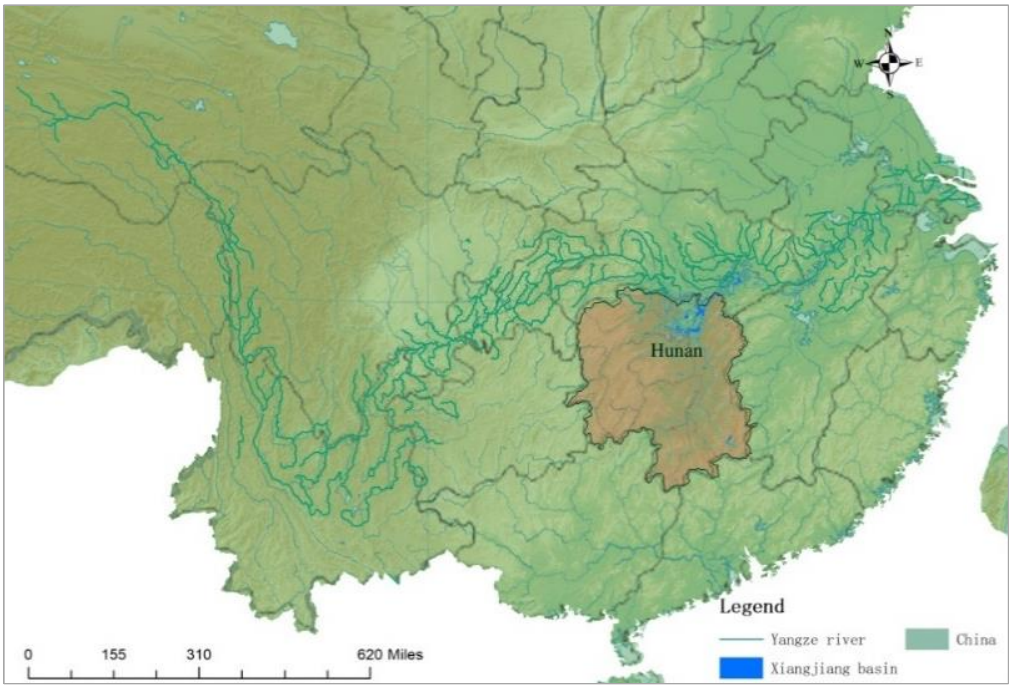

Figure 24a. (Source: Author)

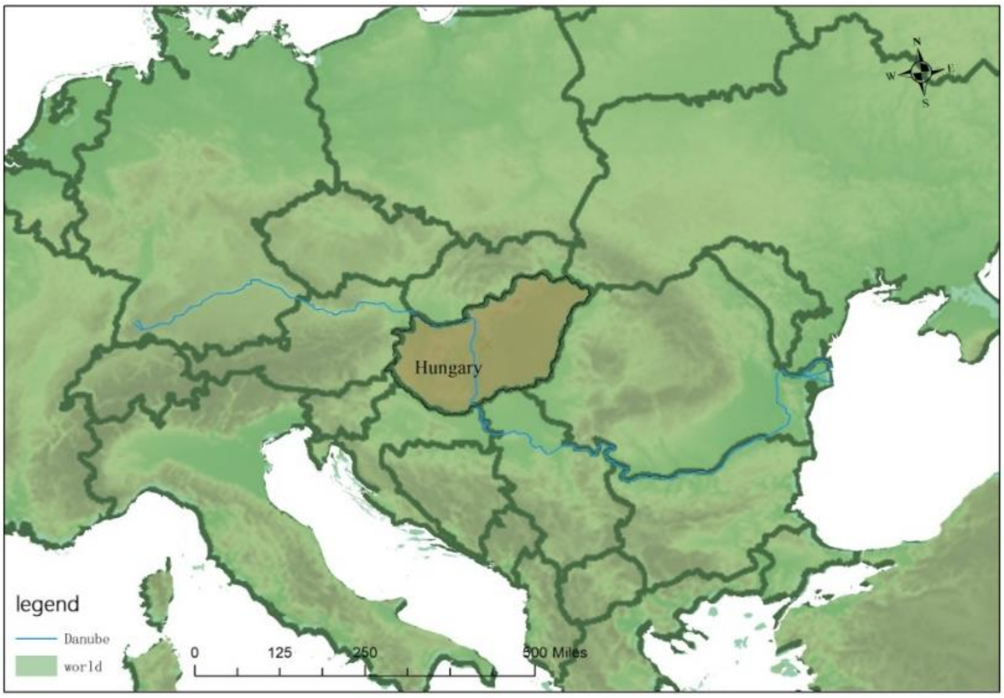

Figure 24b. (Source: Author)

Figure 24. Study area from central China (a) ShangGanTang village of HuNan province: 25°09'09"N 111°10'57"E, ZhangGuYing: 29°00'36"N 113°28'30"E in Xiangjiang River Basin. and central Europe(b) Budapest, Hungary :47°29'33"N 19°03'05"E, in Danube river basin

The meteorological datas of the investigated places are presented in the Table 1. As we can see, in the precipitation quantity between Budapest and ShangGanTang village is a considerable difference: while ShangganTang belong to the subtropical monsoon climate area, where the average yearly (from1981-2010) precipitation is 1426 mm Budapest belongs to the Humid continental climate area, where the average yearly (1985-2015) precipitation is about 500mm.

The settlement image data was collected by DJI phantom3, and the 3D model was rendered by the Contextcapter software. Collection of topographic datas has been executed through Google earth and processing topographic maps and cross-sections of settlements by Surfer software. (Figure25/a)

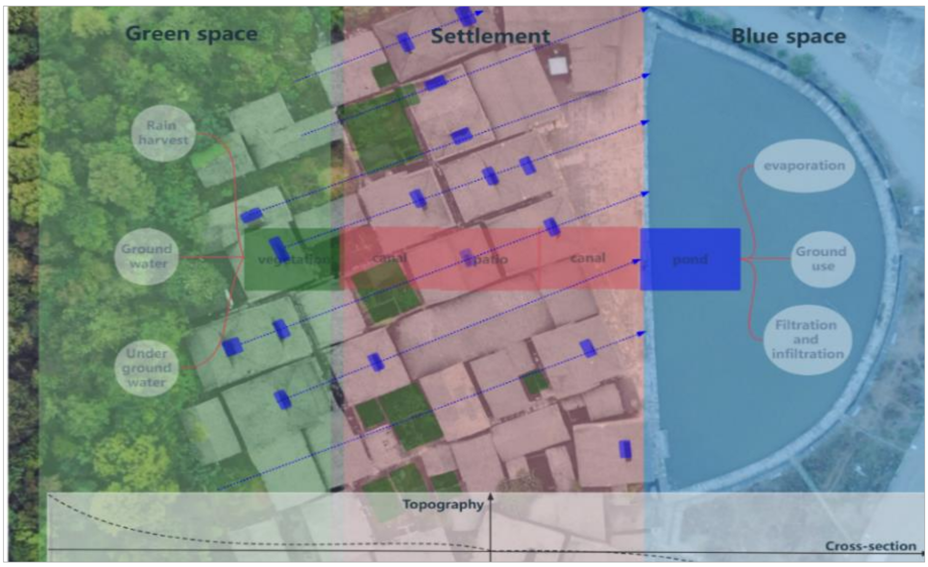

Figure a

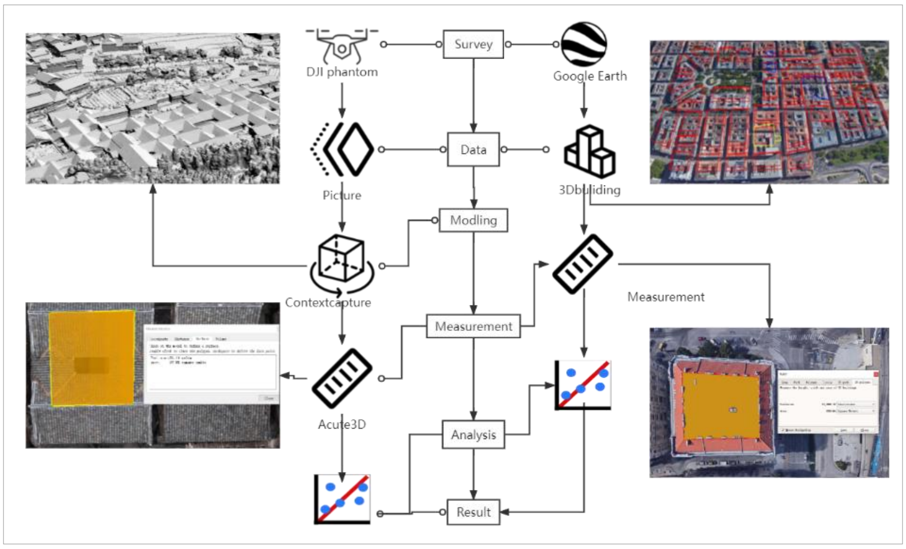

Figure b.
Figure 25. The measurement of the roof and patio rain harvest area in case of the two locations. As we can see, the structure of the buildings and of the urban fabric are very similar between ShangGanTangvillage (a) and Budapest (b)

Drone photogrammetry was performed on traditional settlement landscapes in the Xiangjiang River Basin, and the drone routine collection data was input into the Contextcapture software for processing to obtain 3D model the two settlements. The 3D model was further measured to get the catchment area of the patio (1) and roof (1). (Table 5). The regression analysis of the patio and roof area of buildings showed that there was a linear correlation between the patio and roof area of the two settlements. For Budapest, through the Google Earth pro finished the measurement. As P3 R3 model water catchment area measurement.
By consulting the local meteorological datas, the catchment area of the roof, patio and the measured area was calculated. Combined with data and interviews, the similarities and differences of water management mechanisms of the two settlements were further compared.
Finally combine the analysis of precipitation and water catchment with the logic of settlement planning and its related adaptive mechanisms. (Picture 38 Appendix A)
The linear regression equations for the three different locations - Zhang Gu Ying village, ShangGanTang village, and Budapest - indicate a positive correlation between the roof catchment area for rainwater harvesting (R) and the patio area (P) for each respective location.
As we can see from Figure26 the regression formula:

$$R1=6.336P1+86.63$$
$$R2=3.466P2+21.23$$
$$R3=1.224P3+1156.2$$

Roof 1: Zhang Gu Ying village roof rain water harvest area
Roof2: ShangGanTang villages roof rain water harvest area
Roof3: Budapest roof rain water harvest area
Patio1: ZhangGuYing village patio area
Patio2：ShangGanTang village patio area
Patio3: Budapest patio area

As the equations shows, the two ratios of the roof catchment area to the patio area are close: Zhangguying 6.3367 and ShangGanTang 3.4667. Both the R^2 value is greater than 0, the area of the roof and patio is positive correlated, which means that here is a positive correlation between the roof and patio areas in all three locations, indicating that as one increases, the other tends to as well.

Slope Interpretation:
The slopes of the lines (6.336, 3.466, and 1.224) are measures of how much the roof area changes for a unit change in the patio area.
For Zhang Gu Ying village, a unit increase in patio area results in a 6.336 unit increase in the roof area.
For ShangGanTang village, the corresponding increase is 3.466 units.
For Budapest, the increase is much smaller, at 1.224 units.
The slope values suggest that this correlation is stronger in Zhang Gu Ying and ShangGanTang villages compared to Budapest. This could be attributed to local communities' practices, climate, or cultural heritage factors that prioritize larger roof areas relative to patios for rainwater harvesting.

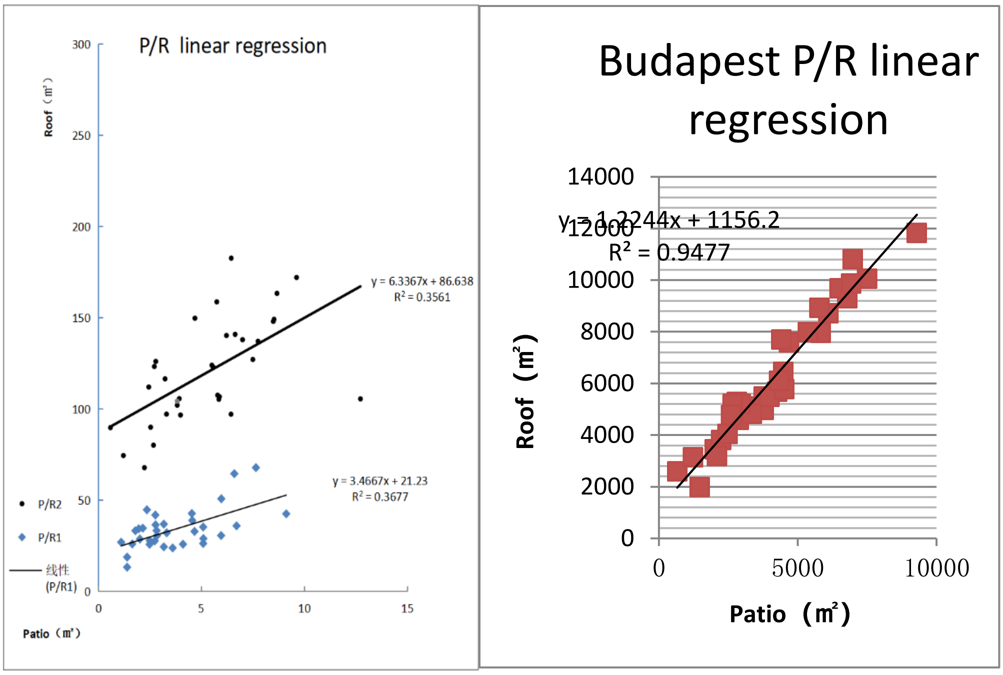

Figure 26. The linear regression of roof and patio surface area from two places. (Author)

This is in line with the patterned design language of traditional Chinese architecture, that is, each component of the building is designed according to strict proportions (Li, 2001). The basis of this design logic is two points, one is the standardization of traditional architectural theory, and the second one is that it can be combined with local settlements. It had adaptive adjustment of the scale and function of the landscape in different situations (Han, 2001). From the regression analysis results, we can indirectly conclude that the water management logic of the two traditional settlements is the same. Compared to two traditional settlements in China, the R^2 value of the P/R regression in the Budapest study area is close to 1. This indicates that Budapest model fit the data very well, the data points are closely aligned with the regression line, thereby indicating a more predictable and consistent relationship between these two variables.

Predictive Power: A high R^2 value implies that the model can more accurately predict one variable based on the other, which is immensely beneficial in planning and implementing water management systems.
Efficient Resource Allocation: The strong correlation allows for more reliable estimates when allocating resources for the construction or expansion of either patios or rooftops for rainwater harvesting.
Resilience and Adaptability: A more predictable system can adapt more effectively to external pressures, such as increased demand for water or changing rainfall patterns due to climate change. (Székács, Mörtl & Darvas, 2015)

Rain water amount collection
S village year average perception（roof）：1426mm/㎡ *1251 ㎡=1783.93L
August（max） ：255 mm/㎡ =319L
Z village year average perception（roof）：1353mm/㎡ *4242 ㎡=5739.4L
August（max） ：172.9 mm/㎡ =733.44L
Budapest year average perception（roof）:500mm/㎡* 144824 ㎡=72412L
August（max） ：70 mm/㎡ =10137.6L
The evaporation in Budapest：86%
The water amount be storage(processed):10138L
The Budapest Rain Harvest equation:
$M(R)=(1.224R+115.6)\times a\times b$

M(R) is the amount of water that roof should be processed, in units of mm or L.
1.224R+115.6 represents the roof area for rainwater harvesting and storage, presumably in square meters.
a is a dimensionless constant, replacing the specific precipitation value of 500 mm per square meter.
b is another dimensionless constant, representing the Effective Precipitation rate, replacing the specific value of 0.14.

Based on landscape architecture and structures that focus on water management, we conducted interviews in several villages in the Xiangjiang River Basin. We found a significant correlation between these types of landscape architectural structures and the organizational forms of local communities (Han, 2001). Taking ZhangGuYing Village as an example, the settlement is primarily inhabited by the Zhang clan, displaying strong familial characteristics. (Picture 38, AppendixA) This is manifested through a spatial arrangement resembling a river's main course and tributaries. The core spaces are occupied and managed by the elders, centered around courtyards. Subsequent living spaces are hierarchically allocated to younger generations. Courtyards situated along the main axis are also the largest in area. Apart from collecting rainwater, these larger courtyards symbolize greater authority, status, and community influence within the societal context (Wang, 2005). Mirroring natural water systems, these courtyards are interconnected through an underground piping network. This connectivity metaphorically represents the intimate and clearly stratified relationships among community members. Similar landscape architectures that portray community power distribution through spatial and water linkages are also evident in the cultural heritage of other traditional Chinese settlements (Li, 1993) (Xu, 2003)
In addition to spatial scales, local communities also have unique perspectives on water management at the temporal scale. Local communities consider water as a bond for

harmonious coexistence between humans and nature (Bruun, 2008). Traditional Chinese medicine posits that precipitation during different seasons has distinct functions; for example, rainfall in spring can cure certain ailments, whereas rainfall in summer and winter cannot (Beinfield & Korngold, 2013). Based on this awareness of seasonal rhythms, local communities utilize courtyards to collect rainwater during summer in a rectangular pool for irrigating ornamental plants within the courtyard, and for having aesthetical experiences through the water surface (Juzefovič, 2013). Current research also substantiates that evaporating water collected in courtyards can reduce indoor temperatures during summer (Xu et al., 2018). In this manner, local residents' lives resonate with natural rhythms. Interestingly, water features within the cultural context of European landscape heritage also often serve as decorative elements in urban or private gardens (Langston, 2003). Such designs centered on water features often gather community members and provide public spaces for relaxation and cooling (Carr, 1992). Additionally, European civilizations have their own understanding of water-related natural rhythms (Klaver, 2012), such as Hungarian fishermen capitalizing on the Danube River's cyclical flooding (Guti, 1993). This intangible cultural heritage, generated through the participation and practices of local residents, should also be preserved (Olson & Krug, 2020).
Therefore, this study focuses on serving local residents. Against the backdrop of climate anomalies, it draws on water management strategies from both China and Europe to propose new water facility design plans for community spaces in Budapest. The aim is to enhance community participation, achieve sustainable development, and preserve and inherit cultural heritage at the local level."
By drawing on strategies from different cultural contexts, the study serves as a comprehensive approach to community building functions. Through field investigations and modeling, the cultural heritage related to water management are explained by 3 dimensions. The analysis shows: the cultural heritage regards water as the core element of landscape, it shaped the settlement structure and deeply involved into the local ecology and community(family) system.

Time dimension: Inspired by the circulation of the season.

As an ancient civilization based on agriculture, China not only accumulated agricultural technology in the pre-industrial period, but also developed a very complete calendar related to agriculture (Capra, 1983).
The representative is China's twenty-four solar terms, which can be regarded as farmers Schedule for farming and living. The ancient Chinese ancestors' perception of time and they follow the laws of seasonal changes enabled China to gradually develop a culture and philosophy based on accumulated experience (Wangsheng, Lingwei & Qingtong, 2017).
For example, the ancients of China realized the logic of Yin and Yang's rhythm and flow, and finally balanced and dynamic cycle from the changing law of day and night in a year. In addition, the description of the seasonal differences of water in the four seasons and the transformation and circulation between different forms of water in Fengshui's theory is also in line with this logic (Lee, Yang & Wang, 2009).

Spatial dimension: A balance of landscape elements and structure

To achieve the harmony, Fengshui designs use water as the link of the green space, the settlement and the blue space. At the same time visually achieved the balance of the structure. (Figure 25)
The geometric symmetry can be found from Fengshui design. Taking water line as the

axis and the depth of space can be felt from any point on the axis. This shows the coordination and harmony of waterscape. (Erdogan & Erdogan, 2014)

Human dimension: Holism

Humans are also a part of nature, so ethically they also follow the metaphor of nature. Not the law of the jungle and the survival of the fittest, but seeking and maintaining the harmony between different elements and groups to achieve sustainability (Li, 2006).

The family tree of clan settlements and spatial grading of vines, it emphasized order and inheritance, aesthetically inclined towards natural metaphors. (Picture 38 Appendix A)

In addition, Fengshui's design classifies different water and gives water a humanized label, different characters have different design, this view of life and aesthetic value is also reflected the holism way of thinking (Erdogan & Erdogan, 2014).

The water management strategies discussed across these three dimensions are community-centric, aiming to serve the needs and preferences of local residents. Taking into account Budapest's existing landscape architecture heritage and intangible cultural heritage, this study redesigns the drainage system. For design concepts, please refer to (Figure 27).

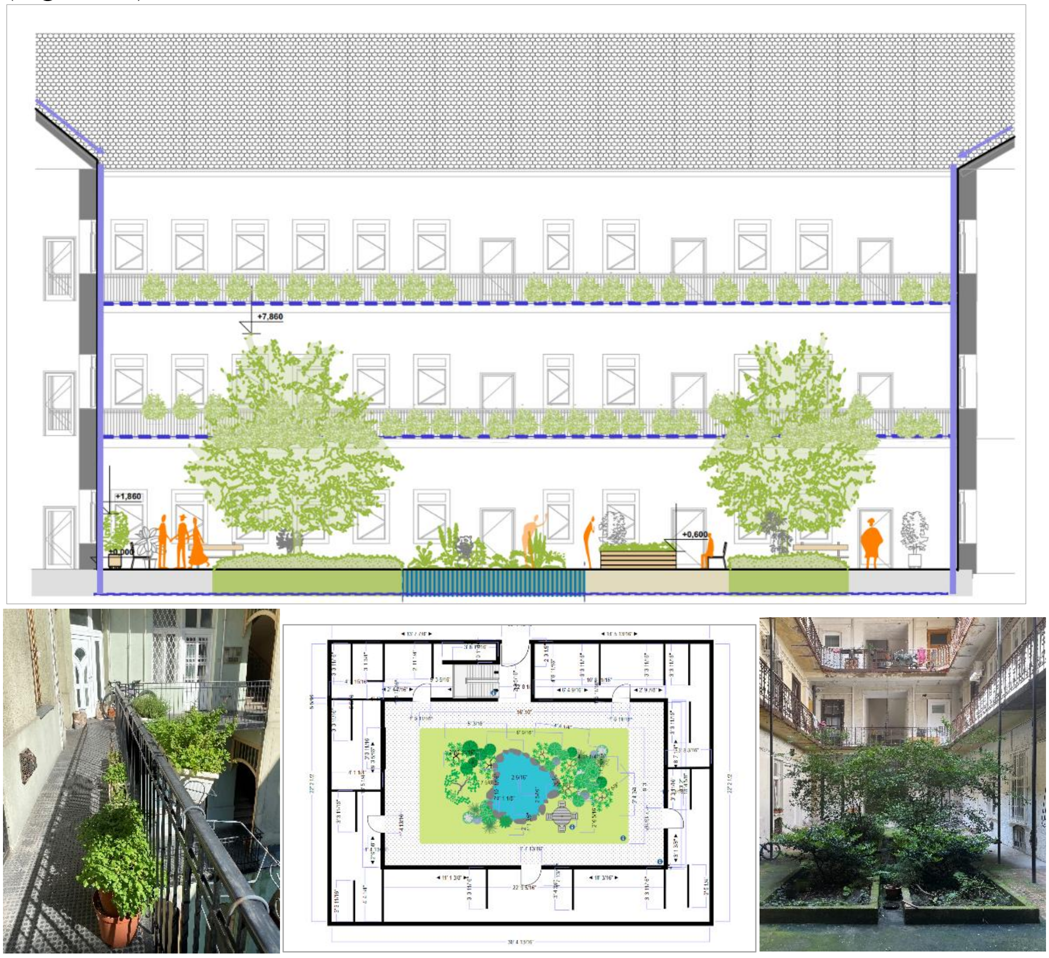

Figure 27. The design concept of roof and patio water harvest system. (Author)

<u>Theoretical solution from three dimensions:</u>

Time Dimension:

Taking into account the temporal patterns of precipitation in Budapest, this design integrates a piece of Hungarian intangible cultural heritage: floodplain agriculture, ("Ártéri fokgazdálkodás", Kohán, 2003) which involves utilizing vertical water level differences created by seasonal variations of the rivers for fishing and agricultural activities (Bryan, 1929). This design exploits the height differences within the courtyards and seasonal variations in rainfall. During the summer, rainwater is collected from rooftops and channels into an extended drainage system - consisting of horizontal pipes at each floor level - for irrigating courtyard vegetation or replenishing pond water. This storage structure extends the retention time of rainwater, thereby alleviating the pressure on street drainage systems during flood-prone periods. It also utilizes natural water pressure to facilitate flow.

Spatial Dimension:
Through the redesign of water facilities, water elements are used to extend blue-green infrastructure horizontally across originally vertical courtyard spaces. The design aligns with the concepts of vertical gardens and "pocket parks," thus achieving protective development within limited heritage spaces.

Human Dimension:
While offering public spaces for local residents - like pocket parks situated in the courtyards—this design also aims to enhance community engagement. The selection and cultivation of plants in different floor corridors are left to the community, offering choices ranging from ornamental to medicinal and edible plants. This selection process can also serve as an opportunity for ecological education among local residents (Chen et al., 2016).
This design remark solidifies the research focus on community-driven strategies, emphasizing the integration of both tangible and intangible aspects of heritage. By proposing a redesigned drainage system specifically tailored to Budapest, the study not only addresses technical issues related to water management but also aims for a holistic approach that encompasses cultural preservation and community engagement. Such an approach has the potential to significantly contribute to sustainable development goals and the conservation of cultural heritage, which is particularly crucial in climate change situation.

<u>Modulization solution:</u>
Taking the climate change influenced precipitation in Budapest as an example:
The Figure28 is a visualization chart of Budapest's precipitation data from 1901-2020
From the above figure, we can clearly see the similar pattern of precipitation on a yearly time scale, in other words, Budapest's annual precipitation is cycling a unique pattern, conducting time series statistical analysis (ARMA) based on 119 years of data, we can derive Budapest's monthly average precipitation pattern (Picture 39 Appendix A)
This chart shows the repetitiveness of Budapest's precipitation on a time scale, combining the concept of rhythm analysis (Rhythm analysis) proposed by Henri Lefebvre, we define it as the rhythm of precipitation. (Figure 28)

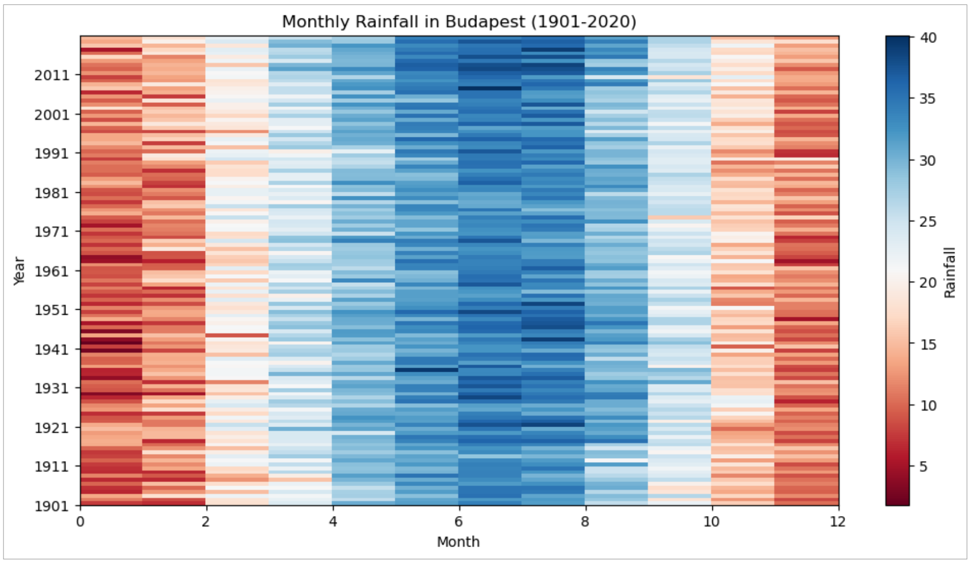

Figure 28. The rhythm of precipitation in Budapest (Author)

Water management design based on cycle and rhythm:
It is worth noting that due to the complexity of natural systems, this theoretical rhythm and cycle often experience anomalies in reality, combining Budapest's abnormal precipitation data analysis we conclude (Figure 29)

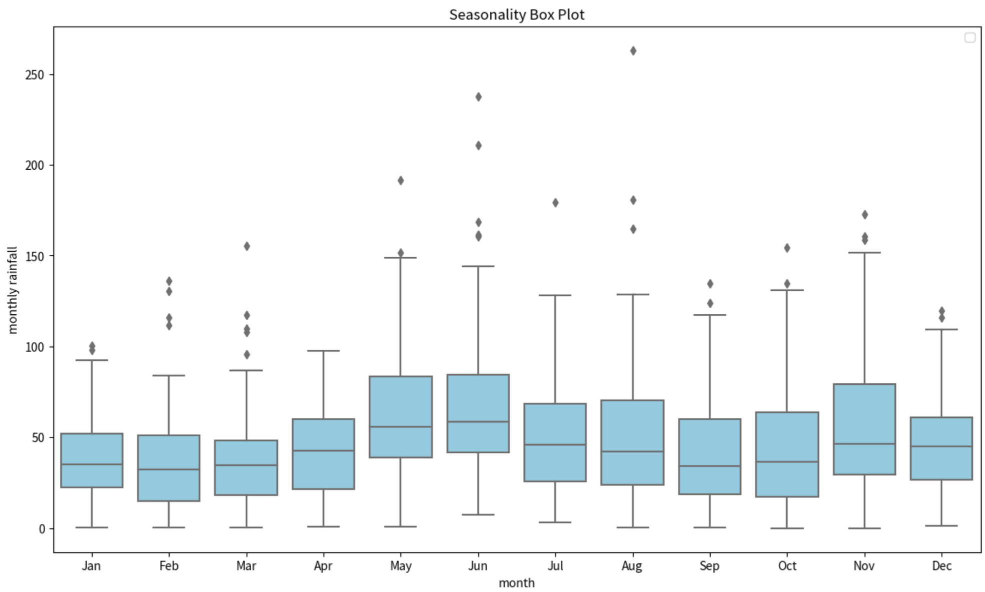

Figure 29. The Budapest's abnormal precipitation (Author)

It can be seen that the abnormal values of precipitation are distributed within 12 months, with more distribution and larger values in the spring and summer seasons, and Budapest's urban waterlogging also mostly occurs in these two seasons, and how to mitigate the impact of abnormal precipitation through reasonable water management has important research value.
Here we still borrow the physical concept of frequency, defining the abnormal values as noise in the precipitation cycle rhythm, and the technical means in physics to deal with signal noise is through filters for noise reduction, in water management we also need to design facilities to handle abnormal precipitation values.
Define states: Define the state of each observation according to the average monthly

precipitation and the new standards.
Label states: Mark the state for each observation in the dataset.
Calculate transition frequency: Analyze the state transition between two consecutive months and calculate the frequency.
Construct a transition frequency matrix: Construct a matrix based on the calculated transition frequencies.
The transition frequency matrix calculated according to the new standards is as follows (Table 6)
This transition frequency matrix shows the probability of transition from one precipitation state to the next month. For example, the probability of transitioning from an average precipitation state to a high precipitation state is 31.54%, and the probability of returning to an average precipitation state from a low precipitation state is 23.61%.
The dynamic characteristics of precipitation changes, providing valuable information for climate analysis, water resource management, and prediction models. It indicates that regardless of the current state, there is a certain level of uncertainty in the precipitation change for the next month, but it tends to remain in the current state or transition to a lower precipitation state, especially starting from high and average precipitation states.
Based on up above analysis, we propose the design concept of natural replacement, functional design for rainwater harvest on the roofs and patios of Budapes (Figure 30)

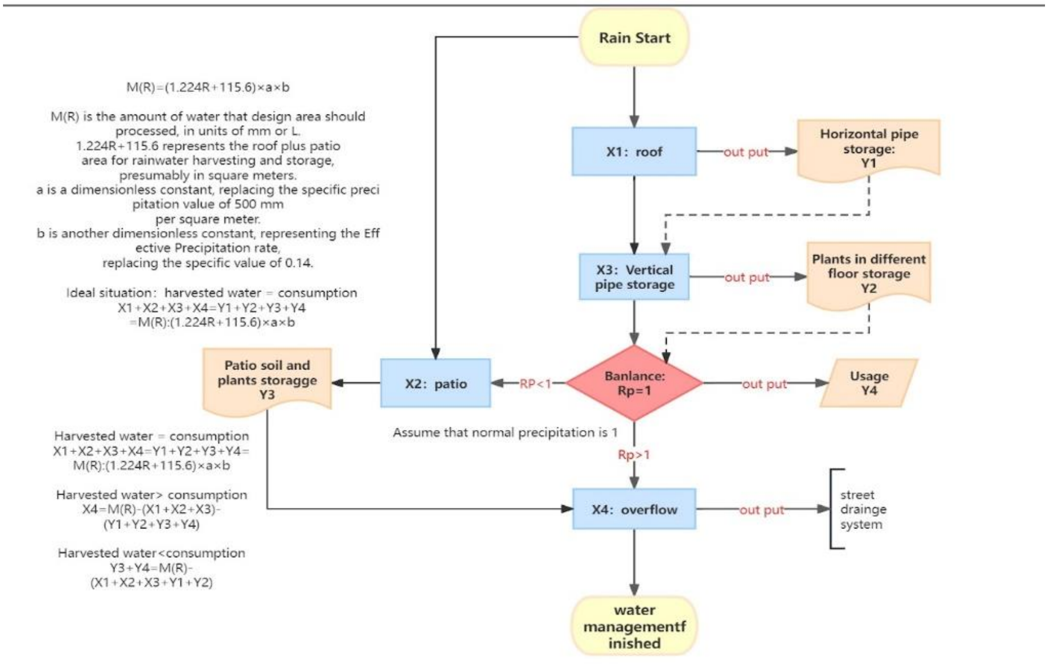

Figure 30. Budapest roof-patio water management system model (Author)

6.4 Design concept：Nature Replacement Solution (NRS)

From Chapter 3, we can see that a crucial aspect of the origins of human civilization is the mastery and application of water management knowledge. This is manifested in

a. finding water sources and utilizing water resources through spatial adaptation (horizontal and vertical),

b. discovering the patterns of water resource changes and using dams and canals for systematic allocation to make water resources more evenly distributed over time, and,

c. deep community involvement in water resource management, ensuring the rational and orderly use of water resources.

These all demonstrate that traditional water management is based on natural solutions, specifically: based on the natural water cycle, managing water on time scales, spatial scales, and social scales according to the rhythms of natural precipitation. As a popular method in the last decade to address environmental changes and social challenges, "Nature Based Solutions (NBS)" are defined as actions that protect, sustainably manage, and restore natural or modified ecosystems, effectively and adaptively addressing social challenges while providing benefits for human well-being and biodiversity. (Calheiros and Stefanakis, 2021), However, it is worth noting that NBS integrates concepts related to ecosystem services, ecosystem-based adaptation/mitigation, and green and blue infrastructure, aiming to draw inspiration, use, imitate, or get help from nature through industrial and technological solutions. This review, through the Scope retrieval system, entered NBS and set restrictions as articles, with the keyword: “natural based solutions”, retrieving a total of 392 pieces of literature, and conducted a keyword analysis based on titles with vosviewer software, resulting in the following keyword network (Picture42 Appendix A)It is evident that current NBS-related research is attempting to accommodate various concepts related to sustainable development within a new framework, but at the same time, NBS needs to provide new theoretical insights when integrating other concepts (Roggema et al., 2021), and offer a clear definition of "nature." The philosophical interpretation of the concept of nature is very important. Currently, most of the unclear issues in NBS are related to the definition of nature.

For example, in the current climate anomalies, is the relationship between humans and nature antagonistic or unified? Based on nature, does it refer to the natural environment or human perception of the natural environment? How to learn and imitate the dynamic processes of nature? Based on nature, does it refer to biomimetic design from the perspective of landscape design? Does adaptive design refer to adapting to the natural environment or to human needs? In the process of addressing social challenges based on nature, is it based on natural facilities (elements) or a consensus on natural concepts? (Seddon et al., 2019).

People often focus on the causes and consequences of problems and propose targeted technical solutions. The innovative potential of NBS lies in the multidisciplinary perspective, inspired and expanded from the perspective of natural systems and dynamic processes, attempting to solve environmental, economic, and social problems from a systems theory and holism perspective, i.e., "natural design." Traditional gray infrastructure is "designed in nature." (O’Hogain and McCarton, 2018b), This requires us to transform the original pursuit of linear, simple, certain, predictable, and controllable design concepts into holistic design concepts based on dynamic, complex, uncertain, unpredictable, and uncontrollable natural systems.

With dynamic natural elements: water as the core of the relational network, we can see: Research on Nature Based Solutions related to water focuses on mitigating natural disasters, government management, community participation, green roofs, related technologies, etc. The red/blue-green tags in the figure represent social/nature, showing that in most NBS research, humans and nature are independent but interactive.

Unlike NBS, the concept of nature in traditional water management is based on holism, including social and human dimensions, meaning that water is not only a resource in the physical sense but also a resource for psychological needs. Similar to NBS, traditional water management is suitable for context-based design and adaptive expression, providing sustainable landscape benefits for local communities. For example, the traditional Chinese Feng Shui theory aligns with this nature-based holism.

(Mak and Ng, 2008),
Here re-interpret the Concept of "Nature" in Traditional Water Management perspective: Circulation, Balance, Holism

The origin and development process of the concept of "nature" in traditional water management theory need to start from important concepts in ancient Chinese philosophy: the interaction of the two qi (energies) of Yin (- -) and Yang (-) generates all things. (Bruun, 2003)

The concept of Yin and Yang originated from the "I Ching" (Book of Changes). Ancients believed that natural things with masculine or positive characteristics belong to Yang, while the opposite, feminine, and gentle traits belong to Yin. In nature, the sun is characterized by Yang, and the moon by Yin. Literally and visually abstractly, Yang represents light or heat (white), and Yin represents darkness or cold (black). Yin and Yang are symbols of the unity of opposites in nature, that is, Yin and Yang are a whole, inseparable, and equally important. Ancients summarized various phenomena in nature and human society through their arrangement and combination. (Wang, 2005)

Interestingly, the combination of Yin and Yang is also a metaphor for the interaction of warm and cold air masses forming precipitation.

The "I Ching" considers Yin and Yang as the origin of the universe, with nature, humans, and even ecosystems all transforming from the two qi (forces). However, the most favorable situation is the cycle and balance of Yin and Yang, which was also a key factor for ancient Chinese people in choosing settlement locations.

Ancient Chinese people believed that biologically humans and sociologically human societies are essentially composed of Yin and Yang, with everything else in the universe also composed of Yin and Yang, thus essentially no different: in the process of balancing Yin and Yang, there is no distinction between nature and humans.

Influenced by this view of nature, coupled with ancient Chinese people experiencing several extreme climate disasters over a long history, Feng Shui theory gradually formed, that is, the theory of choosing, creating, and managing time, space, and the human world. (Wang et al., 2011)

○ Time Dimension:
Landscape design focuses on the cycle of the four seasons, summarizing the rhythms and patterns of nature. Seasonal water retention measures extend the water cycle time. The agrarian civilization has accumulated a profound perception of the rhythms of nature through experience.

○ Spatial Dimension:
Balance between water and landscape structure
Managing water resources from both horizontal and vertical spatial angles with water as the axis

○ Human Dimension: (Holism) Humans are also part of nature, hence ethically follow nature's metaphor.
(Not the law of the jungle and survival of the fittest, but seeking and maintaining balance between different elements and groups for sustainability) Family settlements' genealogy and the spatial hierarchy of vines, emphasizing order with Heaven, Earth, Sovereign, Parents, Teacher, and aesthetics leaning towards nature's metaphor.

Traditional Chinese Feng Shui attributes different characters and traits to different forms of water, this view of life and aesthetic value is also reflected in the process of water landscape design.

What is worth absorbing for NBS theory from traditional water management is the three-dimensional theoretical framework about nature, taking the time dimension of cycle and rhythm as an example:

Cycles and rhythms are essentially interconnected, forming the basis for many phenomena and processes in the natural world and human society. For example, the natural water cycle circulates between the ocean and land, in solid, liquid, and gas states, and rhythm refers to the temporal laws of the development and change of things, emphasizing the speed, frequency, and interval of changes in the process of things changing. It refers to the characteristic of a thing or process that, after completing a certain stage, can return to a certain starting point and begin again, a repetitive, cyclical phenomenon.

Combined with NBS, based on these natural cycles and rhythms character, we propose the concept of NRS, (Natural Replacement Solution):

The commonality of time structure (the rhythms of precipitation and water cycle): The cycle provides the material basis and space for rhythm. In the cycle, events occur in a certain order and periodically repeat, while rhythm is the temporal characteristic and regular expression of this repetition. In other words, the water cycle establishes the framework for the existence of precipitation rhythm, and rhythm gives cycle a sense of time dimension.(Ramanathan et al., 2001b)

The manifestation of regularity (the existence of water cycles allows precipitation rhythm to be observed and perceived): In the natural world, such as the change of seasons, the alternation of day and night; in human society, such as the beat of music, the arrangement of work and life, etc., are the result of the combined action of cycle and rhythm. The cycle ensures that events can recur under certain orders and conditions, while rhythm decides the speed and intensity of this repetition.

Adjustment and adaptation: In natural and social systems, the existence of cycles requires the system to adjust itself to adapt to the changes, and rhythm is a key factor in this adjustment process. By understanding and mastering the relationship between cycle and rhythm, humans can better predict, adapt to, and even influence the changes in nature and society(Press, 2006).

In the fields of water management, urban planning, architectural design, etc., understanding and applying the concepts of NRS are crucial. For example, by designing water management systems that are in harmony with the natural water cycle rhythm, the efficiency and sustainability of water resource use can be effectively improved.

In summary, the insights of NRS lie in: on the temporal scale, grounding in the cycles and rhythms of nature; on the spatial scale, basing on the horizontal and vertical differentiation structures of nature; and on the societal scale, grounding in sustainable community management.

CHAPTER 7. RESEARCH RESULTS

7.1 THESIS

I formulated my novel research results in 9 theses, as follows

THESIS 1 - Sustainable Heritage: Traditional water management

I found, that traditional water management is one of the basic conditions to achieve the harmony and balance between economy, society and environment. I found, that the theory and practice of the traditional water management worldwide can be considered as tangible and intangible Landscape Heritage, and this is an organic and indispensable component of the concept of sustainable landscape development.

I summarized the knowledge, techniques, and experiences related to traditional water management, highlighting the strategies and application of water management across different cultures and regions.

Through a literature review that organizes the relationship between ancient civilizations and rivers, I concluded that water management plays a crucial role in the origin and development of human civilization. By examining ancient China's historical documents and case studies in conjunction with the definition of cultural heritage, I discovered that traditional water management constitutes a sustainable form of cultural heritage and has three principles: circulation (flow), adaptation to the environment, and harmony of man and nature.

Through historical review and field investigations I identified key similarities and differences in traditional water management strategies in vernacular settlements located in Xiangjiangg River basin, providing a rich comparative analysis and proving the versatile applicability of traditional water management practices under different environmental conditions.

Further investigation through field research, interviews and archival studies revealed that six traditional villages in the Xiangjiang River basin have inherited and continuously employed traditional water management methods for site selection, settlement planning, and residential landscape design. The history of these water management and landscape design practices can be traced back to the Ming Dynasty (1371AD) and have persisted to the present days. Actual cases demonstrate the sustainability of water cultural heritage, namely: these water management strategies have exhibited continuity and resilience historically, spatially, and socially.

THESIS 2 - Design strategy: Philosophical background

In my exploration of the philosophical underpinnings of traditional water-related cultural landscapes in China, I have discovered that the traditional Chinese philosophies (Confucianism, Buddhism, Taoism) have had an important influence on the design of traditional water management. I established, that the traditional design strategies are driven by internal (spiritual) elements and influenced by external (physical) ones, together forming a harmonious design philosophy system.

I find how cultural, societal, religious beliefs, and traditional philosophies profoundly influence the formation and sustainability of water cultural landscapes. This aspect illustrates the multifaceted impact of non-physical factors on the practical applications of traditional water management strategies.

Taking as case study the cultural landscape formed along the Xiangjiangg River's basin, we can observe, that the traditional Chinese philosophies of Confucianism, Buddhism, and Taoism have had an important influence on the values, customs, and beliefs of the

Chinese people, which in turn has helped form a solid and sustainable concept of landscape planning. This is of great value for the promotion of sustainable development. By proposing the perspective of "*internal elements driven, external elements influenced*" I introduced a multi-layered analytical framework that aids in deepening the understanding of the design philosophy behind traditional water-related cultural landscapes. Providing specific examples, historical document support, to demonstrate how internal and external elements collaboratively influence the design philosophy of traditional water management. Moreover, exploring how these elements specifically impact the design outcomes and the details of the socio-cultural environment further enhance the depth and breadth of the argument.

THESIS 3 - Water related landscape interpretation

Through an interdisciplinary approach I discussed the significance of historic water management from the perspective of the landscape, on the basis of which water management is a landscape that transcends time, space and culture. The interpretation “the landscape transcends time, space and culture" is not attributed to my proposal, but has gradually formed through the fusion of multiple disciplines such as landscape studies, geography, history and cultural studies. This concept reflects a deep understanding of water-related landscapes from a multidisciplinary perspective, emphasizing water landscapes as a product of the interaction between humans and nature, representing both the physical environment and a carrier of culture and social history. (picture 43 Appendix A)

Several academic backgrounds are related to the development of this concept.

Landscape ecology emphasizes the relationship between ecological processes at different scales and landscape patterns. Early works (Forman and Gordon (1986)) initiated systematic studies on the spatial structure and functions of landscapes. This research draws on landscape ecology's definition of different scales.

Cultural geographers focus on cultural expressions and identity within space and place, such as Yi-Fu Tuan's "Topophilia" (1974) and Edward Relph's "Place and Placelessness" (1976), which explore the deep connection between place and cultural identity. I have drawn on this concept to enhance the connection between water management and local communities for the traditional water management reuse in design.

Historical geography studies highlight how the geographical environment affects historical processes and how historical events shape geographical spaces, emphasizing the role of time in the formation of landscapes.

Environmental historians like William Cronon in "Changes in the Land" (1983), explore how human activities have transformed the natural landscapes of North America. I have drawn on this theory of the interaction between humans and nature and the historical dimension of landscapes.

Combining the above academic backgrounds, I found that water management holds significant value throughout the development of human civilization. It reflects not only the regularity expressed by water management in spatial and temporal differentiation but also a common logic and core of water management across different cultural contexts.

My study summarizes the logic and core of traditional water management as continuity in time, space, and society, that is a landscape that transcends time, space and culture.

THESIS 4 - 'Three-levels' water management

I established, that traditional (sustainable) water management as Landscape Heritage can be modelized in three different levels or scales: a. Regional scale; b. Settlement scale; c. Dwelling/object scale, and these levels are strongly interconnected.

This result draws on landscape ecology's approach to scaling, a discipline that studies the impact of landscape structure, function, and changes on ecological processes, and ecosystem services. In landscape ecology, scale is a core concept, encompassing multiple levels from micro to macro. These scales include: micro scale, regional scale and global scale.

This result categorizes traditional water management heritage according to the level of the research cases into: urban and rural areas, and residences, that is, regional, settlement, and objects scales.

At the urban/regional scale, water management practices are often designed to address the needs of extensive geographical areas, incorporating large-scale infrastructures such as dams, canals, and reservoirs. This level emphasizes the strategic allocation and distribution of water resources across diverse ecological zones, ensuring the sustainability of water supply for agricultural, industrial, and domestic purposes. The planning and implementation of such systems necessitate a deep understanding of hydrological cycles, regional climate patterns, and the socio-economic dynamics of the area, highlighting the importance of an integrated approach to landscape and water management.

The village/settlement scale narrows down the focus to community-based practices that manage water resources at a more localized level. Here, the emphasis is on the collective efforts of communities to harness, distribute, and conserve water through communal wells, rainwater harvesting systems, and small-scale irrigation channels. This level showcases the vital role of communal solidarity and traditional knowledge in sustaining water management practices that are tailored to the specific needs and environmental conditions of individual settlements.

Finally, at the dwelling/object scale, water management becomes an intimate practice embedded within the daily lives of individuals and families. This scale focuses on the architectural and design elements that facilitate water conservation and efficient usage within homes and other structures. Features such as patios, roof gardens, and water storage units not only serve functional purposes but also reflect the cultural and aesthetic values of the community. This micro-level of water management underscores the adaptability of traditional practices to contemporary challenges, promoting sustainable living through the integration of heritage and innovation.

THESIS 5 - Patios: the basic units of traditional water management

Through historical and field research of 6 settlements, I have established a strong relationship between traditional water management, vernacular architectural structures (features) and sustainability in the Xianjiang River basin. Accordingly, I defined three different types of patios playing a crucial role in the water management, which can used as prototypes for future developments：a. Village patio；b. Large family patio；c. Small family patio. I also mapped their spatial distribution and characters.

By conducting on-site observations, photography, and mapping of the water landscapes in six settlements within the Xiangjiang River Basin, and through interviews with property owners, I identified and defined 3 main types of patios (Patio as the object level of water management), The classification of patios into three distinct types—village patios, large family patios, and small family patios—offers a nuanced understanding of how these architectural features serve not only as aesthetic and social centers but also as critical components of water sustainability. Village patios, often larger and centrally located, function as communal hubs where water is collected, stored, and distributed, embodying the collective effort in water management at the community level. Large family patios, on the other hand, cater to the needs of extended family units, incorporating more elaborate water collection and storage systems that reflect the economic and social status of the household. Lastly, small family patios represent the adaptability of this traditional practice to smaller, core family structures, showcasing the scalability and flexibility of patios in water management across different social units.

THESIS 6 - The dimensions of traditional water management

I established, that traditional water management strategies has three dimensions: the time dimension, the spatial dimension and the social dimension.

a. Time dimension：

Traditional water management focuses on the cycle of the four seasons, summarizing the rhythms and patterns of nature. Seasonal water retention measures extend the water cycle time. Traditional water management has accumulated a profound perception of the rhythms of nature through experience.

b. Spatial Dimension:

Balance between water and landscape structureManaging water resources from both horizontal and vertical spatial angles with water as the axis

c. Society Dimension: (Holism)

Humans are also part of nature, hence ethically follow nature’s metaphor.these dimensions showing the sustainability

Time Dimension: The temporal aspect of traditional water management underscores a profound respect and attunement to the natural rhythms and cycles of the environment. By aligning water retention and utilization strategies with the seasonal variations, traditional societies demonstrate an advanced capability to enhance water availability and mitigate scarcity through the year. This cyclical approach reflects not only a deep-seated knowledge of local climatic patterns but also a long-term perspective on environmental management. It embodies the principle of sustainability by ensuring that water management practices do not exhaust resources but rather extend their viability across generations.

Spatial Dimension: The spatial dimension of traditional water management highlights the intricate relationship between water resources and the landscape's structural elements. By managing water in both horizontal (across the land) and vertical (through different elevations and depths) dimensions, with water serving as the central axis, traditional practices achieve a dynamic equilibrium within ecosystems. This approach demonstrates an intuitive understanding of hydrology, where the manipulation of water flows and storage is harmonized with the natural topography and landscape features. It showcases an advanced level of environmental design where water management is integrated seamlessly into the landscape, enhancing its resilience and productivity.

Social Dimension (Holism): The social dimension emphasizes the ethical and holistic perspective that humans are integral components of nature, bound to follow its laws and rhythms. This view fosters a culture of respect for natural resources, promoting sustainable practices that go beyond mere utility to encompass moral and ethical considerations. The recognition of humanity's place within the natural world encourages practices that are not only environmentally sound but also socially equitable, ensuring the fair distribution and responsible use of water resources. This dimension highlights the role of traditional water management in fostering community solidarity, intergenerational equity, and a deep-seated sense of stewardship over natural resources.

THESIS 7 - Nature Replace Solutions (NRS)

I proposed a new design concept exploring the potential for integrating traditional and modern water management practices： the Nature Replace Solutions (NRS), utilizing Budapest patios as prototypes for NRS applications.

The literature review on NBS (Nature Based Solutions) reveals a gap in deeply integrating traditional knowledge and practices with modern engineering solutions. While both approaches emphasize the use of natural processes to manage water resources and mitigate environmental challenges, there often remains a disconnect between these modern strategies and the rich heritage of traditional water management techniques. This gap can result in missed opportunities to harness the full potential of historically informed, culturally sensitive, and ecologically harmonious water management strategies.

Finally, through research by design apply the NRS concept and emphasizing the value and potential application of traditional knowledge in contemporary water management practices.

THESIS 8 - The rain harvest equation

I modelled, measured and calculated the correlation coefficient between the rooftop and courtyard (patio) catchment areas. I conducted a linear regression analysis of the catchment volumes of two types of courtyards (patios) within the Xiangjiang River Basin and those within the architectural heritage area of Budapest (V’th district), comparing their similarities and differences, and analysing the results. Through Budapest Rain Harvest equation， I determined the applicability of traditional water management strategies based on courtyard structures across different regions.

The regression formula:

$R1=6.336P1+86.63$

$R2=3.466P2+21.23$

$R3=1.224P3+1156.2$ (1)

Roof 1: Zhang Gu Ying village roof rain water harvest area

Roof 2: ShangGanTang villages roof rain water harvest area

Roof 3: Budapest roof rain water harvest area

Patio 1: ZhangGuYing village patio area

Patio 2: ShangGanTang village patio area

Patio 3: Budapest patio area

Slope Interpretation:

The slopes of the lines (6.336, 3.466, and 1.224) are measures of how much the roof area changes for a unit change in the patio area.

For Zhang Gu Ying village, a unit increase in patio area results in a 6.336 unit increase in the roof area.

For ShangGanTang village, the corresponding increase is 3.466 units.

For Budapest, the increase is much smaller, at 1.224 units.

The slope values suggest that this correlation is stronger in Zhang Gu Ying and ShangGanTang villages compared to Budapest. This could be attributed to local communities' practices, climate, or cultural heritage factors that prioritize larger roof areas relative to patios for rainwater harvesting.

Rain water amount collection

S village year average perception（roof）：1426mm/㎡ *1251 ㎡=1783.93L
August（max）：255 mm/㎡ =319L
Z village year average perception（roof）：1353mm/㎡ *4242 ㎡=5739.4L
August（max）：172.9 mm/㎡ =733.44L
Budapest year average perception（roof）:500mm/㎡* 144824 ㎡=72412L
August（max）：70 mm/㎡ =10137.6L
The evaporation: in Budapest：86%
The water amount be storage(processed):10138L
The Budapest Rain Harvest equation:

M(R)=(1.224R+115.6) × a × b

M(R) is the amount of water that roof should be processed, in units of mm or L.
1.224R+115.6 represents the roof area for rainwater harvesting and storage, presumably in square meters.
a is a dimensionless constant, replacing the specific precipitation value of 500 mm per square meter.
b is another dimensionless constant, representing the Effective Precipitation rate, replacing the specific value of 0.14.

THESIS 9 - Budapest roof-patio water management system model

Based on my research and analysis I formulated the mathematical model of traditional water management at object level

Step 1: Data Preprocessing and Analysis

Calculate Average Precipitation: First, compute the average precipitation for each month throughout the year. This step aids in understanding the seasonal variations and long-term trends of the data.

Identify Patterns and Trends: In addition to calculating averages, analyze fluctuations in precipitation data, the frequency of extreme events, seasonal patterns, and potential long-term changes (those caused by climate change).

Step 2: Constructing an Annual Precipitation Model

Determine Model Type: Based on the analysis of historical data, identify a model suitable for predicting annual precipitation. This could be a simple statistical model or a more complex time series analysis model.

Estimate Model Parameters: Use historical precipitation data to estimate model parameters. This include fitting curves, determining periodic components, and assessing trends.

Step 3: Prediction Using Markov Chains

Define States: Divide annual or monthly precipitation into different states based on precipitation amounts ("drought," "normal," "wet").

Calculate Transition Probabilities: Analyze historical data to calculate the probability of transitioning from one state to another. This requires statistics on the frequency of various states following each state.

Construct Markov Chain: Based on calculated transition probabilities, construct a Markov chain model describing changes in precipitation states.

Step 4: Model Validation and Prediction

Model Validation: Before using the model for future predictions, validate it using a subset of historical data to check its predictive performance.

Make Predictions: Use the validated model and Markov chain to predict future precipitation patterns. Predictions made for the coming months, a year, or longer, including precipitation trends and potential state transitions.

7.2 Conclusions

7.2.1 Summary of the theory and practical research

This dissertation has systematically explored the multifaceted dimensions of traditional water management as an embodiment of sustainable heritage, underscoring its profound impact on landscape architecture, cultural preservation, and sustainable development. Through a comprehensive analysis that spans across historical, philosophical, geographical, and technical domains, the research has elucidated how traditional water management practices are not only vital for achieving harmony between the economy, society, and the environment but also represent a rich tapestry of tangible and intangible landscape heritage. These practices have been identified as integral components of sustainable landscape development, rooted in the principles of circulation, environmental adaptation, and the harmonious coexistence of humans and nature.

The findings from various cultures and regions highlight the universal relevance and adaptability of traditional water management strategies, showcasing their potential in addressing contemporary environmental challenges. By integrating philosophical perspectives with practical applications, the research has demonstrated the significant influence of traditional Chinese philosophies on the design and sustainability of water-related cultural landscapes. This philosophical backdrop has fostered a holistic design philosophy that intricately links spiritual elements with physical ones, promoting a harmonious and sustainable interaction with the natural world.

The interdisciplinary approach adopted in this study has further enriched the understanding of water landscapes as transcendent entities that navigate across time, space, and culture. This perspective emphasizes the role of water management in shaping human civilization, revealing the intrinsic connection between people, their environment, and their cultural heritage.

Moreover, the conceptualization of traditional water management into three interconnected scales - regional, settlement, and dwelling/object—highlights the importance of a multi-level approach that caters to diverse ecological and social needs. The analysis of patios as fundamental units of traditional water management underscores the role of architectural features in facilitating sustainable water practices at the micro level.

The introduction of Nature Replace Solutions (NRS) as a novel design concept marks a significant stride towards integrating traditional wisdom with modern engineering practices. This approach promises a synergistic pathway to enhancing water management systems by leveraging the strengths of both realms.

Lastly, the development of the Budapest Rain Harvest equation and the subsequent modeling of the Budapest roof-patio water management system illuminate the quantitative aspects of traditional and contemporary water management strategies, offering practical insights for future applications.

In conclusion, this dissertation affirms the indispensable role of traditional water management in fostering sustainable development and cultural heritage preservation. It calls for a renewed appreciation and integration of these time-honored practices into modern water management solutions, ensuring their continuity and relevance for future generations. This research not only contributes to the academic discourse on sustainable heritage and landscape architecture but also provides a blueprint for sustainable development initiatives worldwide, advocating for a harmonious balance between human endeavors and the natural environment.

7.2.2 Future Research

Building upon the comprehensive analysis of traditional water management strategies and the exploration of Nature Replace Solutions (NRS) presented in this dissertation, there are several avenues for future research that hold the potential to further enrich our understanding of sustainable landscape practices and architectural heritage. Two particularly promising directions for future inquiry include the examination of the thermal environment of patio systems in mitigating urban heat islands and conducting comparative research of patios between Pompeii and the Southeast of China. Here is an outline for future research based on these considerations:

a.Thermal Environment Research of the Patio System. (Picture 40-41 Appendix A)

The investigation into traditional water management has underscored the significance of patio systems in sustainable architecture and landscape design. An important extension of this research would be to explore the thermal environment of patio systems, specifically their role in mitigating urban heat island effects. Future studies could:

Quantitative Assessment: Conduct quantitative assessments of the cooling effects of patio systems in various urban contexts. This could involve measuring temperature variations within patio-equipped buildings versus those without, across different times of day and seasons.

Material and Design Factors: Examine how different materials, vegetation types, and water features within patios contribute to thermal comfort and cooling efficiency. This research could help in optimizing patio designs for maximum environmental benefits.

Modeling and Simulation: Utilize advanced simulation tools to model the impact of widespread adoption of patio systems on urban temperature profiles. This would offer insights into the potential of patios as a scalable solution for urban heat island mitigation.

b. Comparative Research of Patios between Pompeii and Southeast China

The cross-cultural examination of traditional water management practices provides a rich ground for comparative studies. The contrasting climates, cultural histories, and architectural developments between Pompeii and Southeast China make them fascinating subjects for comparison in terms of patio design and usage. Future research could focus on:

Historical and Cultural Contexts: Deepen the understanding of how historical and cultural contexts influenced the development and functions of patios in Pompeii and Southeast China. This could involve a detailed analysis of archaeological findings, ancient texts, and architectural remnants.

Design and Functionality: Compare the architectural designs, water management features, and thermal properties of patios in these regions. Such a study could illuminate how different environmental challenges and societal needs led to unique adaptations in

patio systems.
Sustainability and Modern Applications: Explore how ancient patio designs from Pompeii and Southeast China can inform modern sustainable architecture. This research could identify design principles that are applicable to contemporary challenges, such as climate change adaptation and urban sustainability.

c. Broader Implications for Sustainable Development and Cultural Heritage Preservation

In addition to these focused areas, future research could also explore the broader implications of traditional water management practices for sustainable development and cultural heritage preservation. This could include:

Policy Frameworks: Developing policy recommendations for integrating traditional water management strategies, including patio systems, into contemporary urban planning and heritage conservation efforts.

Community Engagement and Education: Investigating methods to engage communities in the preservation and revitalization of traditional water management practices, enhancing public awareness and participation in sustainable and heritage practices.

Conclusion

These proposed areas for future research build upon the findings of this dissertation, aiming to expand our knowledge of traditional water management practices and their relevance to contemporary environmental and architectural challenges. By exploring the thermal environment benefits of patio systems and conducting comparative analyses of patio designs across cultures, future studies can contribute valuable insights to the fields of sustainable development, urban planning, and cultural heritage preservation. Engaging with these research directions promises to not only deepen our understanding of historical practices but also to illuminate paths forward for addressing modern-day challenges through the lens of traditional wisdom and innovation.

7.2.3 Policy recommendation

Integration into Urban Planning Policies:

Governments and urban planners should integrate traditional water management principles into contemporary urban development and zoning regulations. This does not imply replicating the physical heritage of traditional water management in urban or rural construction. Instead, it emphasizes integrating the time-tested concepts and practices of traditional water resource management with the contemporary demands of water management and landscape design in specific regions. This includes incorporating water-sensitive urban design (WSUD) that utilizes traditional methods for water capture, storage, and reuse within modern urban environments, particularly in areas vulnerable to water scarcity and urban heat islands.

Climate Adaptation Strategies:

Incorporate traditional water management strategies into national and local climate adaptation plans. Recognizing their potential to enhance resilience to climate variability, these practices should be integrated into efforts to reduce the impact of extreme weather events and changing precipitation patterns.

Promotion of Traditional Practices in Sustainable Development:

Policy frameworks should encourage the adoption of traditional water management practices as a component of sustainable landscape development. This could involve financial incentives for projects that incorporate traditional techniques such as rainwater harvesting, natural water purification, and the use of patios and courtyards for microclimate control. Furthermore, traditional water management systems often embody holistic approaches that align with contemporary goals of environmental resilience and climate adaptation. Incorporating features such as stepwells, qanats, or ancient irrigation channels (like the Mediterranean acequias) can not only enhance water conservation but also reconnect communities with their cultural heritage, fostering a sense of place and environmental stewardship. These methods, when adapted to modern contexts, can complement advanced technologies by providing low-energy, low-cost solutions to pressing environmental problems.

Additionally, governments and planning departments could encourage interdisciplinary collaboration between urban planners, landscape architects, and environmental historians to identify region-specific traditional practices that meet modern sustainability goals. Public awareness campaigns and educational initiatives can also help bridge the gap between historical wisdom and contemporary design, ensuring that traditional water management practices are not merely preserved as relics of the past but are dynamically integrated into the future of sustainable development.

Cultural Heritage Preservation and Documentation:

Enhance efforts to document, preserve, and promote traditional water management systems as both tangible and intangible cultural heritage. This could include UNESCO World Heritage nominations for outstanding examples and the development of digital archives and databases that catalog these practices.

To achieve this, one potential strategy is pursuing UNESCO World Heritage nominations for outstanding examples of traditional water management systems, such as ancient aqueducts, irrigation networks, and reservoirs. By elevating these systems to World Heritage status, we can ensure international recognition and protection, fostering global awareness of their cultural, environmental, and technical importance. Successful examples of such nominations, like the Persian Qanats or the historical hydraulic system of Shushtar in Iran, demonstrate the role of these structures in both human development and ecological balance. Recognition on this scale can also draw attention to the communities that maintain these systems, encouraging their preservation through tourism, education, and cultural pride.

In addition to such international efforts, the development of comprehensive digital archives and databases is critical. These platforms could serve as repositories for research, imagery, oral histories, and technical documentation, making this knowledge accessible to scholars, policymakers, and the public alike. Digital preservation tools like 3D modeling, geographic information systems (GIS), and drone-based surveys can help capture the architectural and ecological complexity of these systems, while also providing a means for their virtual restoration or replication. Such tools can enable governments and researchers to share best practices across regions and disciplines, ensuring that local innovations can be adapted and applied globally.

Moreover, these preservation efforts should include the intangible aspects of water management systems—rituals, knowledge-sharing practices, and the communal governance of water resources. These traditions often represent a holistic approach to water use and conservation, integrating spiritual, social, and ecological dimensions. By documenting the narratives, customs, and social structures that accompany these systems, we preserve not only their physical form but also their cultural essence, which is often passed down through generations via oral tradition. Collaborative projects with local communities, anthropologists, and historians are essential to ensuring that the full spectrum of these practices is captured and transmitted.

Educational Programs and Public Awareness:

Implement educational programs and campaigns to raise awareness about the value of traditional water management practices. These programs should target schools, universities, and the public, highlighting the environmental, cultural, and social benefits of these practices.

In primary and secondary schools, curricula can be designed to introduce students to the history and science behind traditional water management systems. Through interactive activities, such as field trips to local heritage sites or hands-on projects like designing simple rainwater harvesting systems, students can gain practical insights into how ancient techniques can be applied to solve contemporary water management challenges. Lessons could also emphasize the importance of water conservation and ecosystem management, encouraging students to view water as a precious and shared resource, while also promoting environmental stewardship from a young age.

At the university level, interdisciplinary programs can explore the intersection of traditional water management with fields such as landscape architecture, environmental engineering, anthropology, and urban planning. Courses could focus on case studies of specific water systems—like the Roman aqueducts, or the terraced irrigation of Southeast Asia—to analyze their design, functionality, and sustainability. Such academic initiatives could also encourage research projects aimed at innovatively integrating traditional practices into modern contexts, particularly in regions facing water scarcity or climate-related challenges. Collaborations between academic institutions and local governments could further bridge theory and practice, encouraging students to apply their knowledge in real-world settings.

Public awareness campaigns, on the other hand, should aim to demystify traditional water management practices for the broader population. This could be achieved through community workshops, exhibitions, and media initiatives. For example, local governments and NGOs could organize events where local artisans and engineers demonstrate the construction of traditional water storage structures, such as cisterns or stepwells, alongside modern sustainability advocates who explain their environmental benefits. Public art installations, documentaries, and social media campaigns could also serve as powerful tools to generate interest and pride in these heritage systems, particularly if they showcase the tangible benefits these practices offer in terms of climate resilience, biodiversity conservation, and community cohesion.

Moreover, incorporating traditional water management practices into urban development plans and public spaces, such as parks and green infrastructure projects, can help raise awareness among city dwellers about their practical applications. Cities can install interpretive signs, plaques, and mobile apps that explain the historical significance of these features, while also engaging the public in discussions about their potential to address modern challenges such as flood control, heat mitigation, and water scarcity.

Such public outreach efforts should also emphasize the social and cultural dimensions of traditional water management, highlighting how these systems have historically supported community cooperation and equitable resource distribution. This can inspire contemporary water governance models that prioritize collective responsibility and sustainable management practices, encouraging communities to draw upon their own heritage to develop locally adapted solutions to water challenges. By connecting cultural heritage with modern environmental issues, these educational programs and campaigns can help bridge the gap between past and present, fostering a shared sense of responsibility for the future.

Research and Development Support:

Increase funding and support for interdisciplinary research on traditional water management, focusing on its application in addressing contemporary challenges such as climate change adaptation, urban heat island mitigation, and sustainable urban development. This should include support for pilot projects that test the integration of traditional and modern water management solutions.

Cross-Cultural and Comparative Studies:

Foster international collaboration for the study and exchange of traditional water management practices across different cultures and regions. This could involve comparative research projects, exchange programs, and the establishment of international networks dedicated to the study and promotion of sustainable heritage practices. These practices, shaped by diverse climatic, topographical, and social conditions, present valuable lessons that can be adapted to address contemporary challenges such as climate change, urbanization, and water scarcity. By facilitating comparative research projects, academic exchange programs, and the establishment of international networks, we can create a platform for knowledge-sharing that transcends geographical and cultural boundaries, promoting innovative solutions based on time-tested methods.

Exchange programs between universities, research institutes, and cultural organizations can further enhance the cross-cultural study of traditional water management practices. These programs could facilitate the movement of students, researchers, and practitioners across borders, enabling them to engage directly with traditional systems in site. For instance, landscape architecture students from Europe might spend time studying the water management systems of ancient China or Africa, while engineers from America might visit the Middle East to learn about qanat construction and maintenance. Through such hands-on experiences, participants would not only gain technical knowledge but also develop a deeper appreciation for the cultural and historical significance of these systems within their respective communities. These exchanges could also foster collaborations on joint research and design projects, encouraging the blending of traditional and contemporary methods to create innovative solutions for water management in both urban and rural contexts.

Finally, promoting cross-cultural understanding through these collaborations can help foster a more inclusive approach to global water management. Traditional water management systems are often embedded in local governance structures, rituals, and community practices, making them powerful examples of how decentralized, community-based approaches can offer sustainable solutions. By learning from diverse traditions, we can develop hybrid models that combine the strengths of traditional systems—such as resilience, low environmental impact, and community involvement—with modern technological innovations. These models can inspire policies that are not only technically but also socially equitable and culturally sensitive.

In conclusion, fostering international collaboration through cross-cultural and comparative studies of traditional water management practices not only enriches our understanding of sustainable water resource management but also builds bridges between cultures, encouraging mutual respect and shared problem-solving in the face of global environmental challenges.

Policy Development for Nature Replace Solutions (NRS):

Develop and implement policies that support the application of Nature Replace Solutions (NRS), which blend traditional knowledge with modern engineering and ecological design. Policymakers should encourage the use of NRS in public and private sector projects through guidelines, standards, and incentives.

Policymakers should take a proactive role in promoting NRS by establishing comprehensive guidelines, standards, and incentives that encourage their use in both public and private sector projects. These policies could outline best practices for incorporating traditional techniques such as rainwater harvesting, terraced agriculture, and wetland restoration into urban and rural landscapes, alongside modern ecological designs like green roofs, permeable pavements, and bioswales. To ensure widespread adoption, governments could introduce financial incentives such as tax breaks, grants, and low-interest loans for developers, municipalities, and businesses that incorporate NRS into their projects. For instance, urban developers who integrate green infrastructure for stormwater management could benefit from tax incentives, while farmers using traditional irrigation systems that conserve water could receive subsidies or grants to support the maintenance of these systems.

AppendixA Pictures

AppendixB Tables

AppendixC Reviews

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