Traditional Model of Ziquejie Mountain Terraces in China and Scientificities on Irrigation Heritage Perspective

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Abstract—Terraces are an effective and common mode of mountain agriculture. Issues such as water resource storage and drainage, structural stability, impact on the conservation of soil and water, and their adaptive and influencing mechanism to the natural and social environment are important technical engineering issues in the creation and operation of terraces creating. Moreover, these issues are also the key topics in heritage research. Covering a total area of 6,416 hectares, Ziquejie Terraces located in South China is built on hills with an altitude of 460–1,540 m and a surface slope of 25°–40°. Owing to its 1,000-year history and simple but systematic irrigation and drainage system, Ziquejie Terraces has been included in The World List of ICID Heritage Irrigation Structure in 2014 as a unique type of agricultural irrigation. A systematic analysis has been conducted on its creation, influences on the ecological environment and human society, components and characteristics of irrigation and drainage system in the terraces area, and scientific and cultural values as a heritage area. Through such analysis, a traditional pattern of mountain agricultural development has been revealed under the population pressure and mechanism of background adaptation and environment response. The creation of Ziquejie Terraces has specific natural conditions. As an example of overall planning and exploitation of water and land resources, Ziquejie Terraces reflect ancient Chinese philosophy that the simplest projects could afford the largest comprehensive benefits. The successful experiences of Ziquejie Terraces should be used as reference of modern agricultural development in mountainous areas.

1. INTRODUCTION

Terraces are an effective and common mode of mountain agriculture. For thousands of years, humans have created different types of terraces in different sloping conditions, which are meant to mitigate flood risks, reduce soil erosion, and conserve water. As early as the Western Zhou period (before 771 BC), records on terracing had been documented. Considering that the total area of plateaus, mountainous, and hilly areas account for 69.24% of the continental area on earth—which is the same
case in China—and human population grew to a certain level, agricultural spaces needed to expand to mountains from plain and basin landforms. Hence, terraces were created. These anthropogenic landscapes can be found in tropical and subtropical rainforests, deserts, and arid and semiarid mountains across the globe. Terracing could also enhance the survival rate of plant seedlings, promote ecosystem restoration, and increase crop yields. Diversified forms of terraces have different engineering systems and/or crop species. Despite the long history, the roles of and the mechanisms by which terracing improves agricultural economy, human society, and ecosystem services also vary. However, fundamental principles or rules remain core matters. Issues such as water resource storage and drainage, structural stability, impact on the conservation of soil and water, its adaptive and influencing mechanism to natural and social environment, are not only important technical engineering issues in the creation and operation of terraces, but also the key topics of heritage research.

As a study case on historical terraces, Ziquejie Terraces in Hunan Province of China is representative of the traditional mode of irrigation farming. Covering a total area of 6,416 hectares, Ziquejie Terraces located in South China is built on hills with an altitude of 460–1,540 m and a surface slope of 25°–40°. Owing to its long 1,000-year history and simple but systematic irrigation and drainage system, Ziquejie Terraces has been included in The World List of ICID Heritage Irrigation Structure in 2014 as a unique type of agricultural irrigation. A systematic analysis has been conducted on its creation, influences on the ecological environment and human society, components and characteristics of irrigation and drainage system in the terraces area, and scientific and cultural values as a heritage area. Through such analysis, a traditional pattern of mountain agricultural development has been revealed under the population pressure and mechanism of background adaptation and environment response. As an example of overall planning and exploitation of water and land resources, Ziquejie Terraces reflect ancient Chinese philosophy that the simplest projects could afford the largest comprehensive benefits. The successful experiences of Ziquejie Terraces should be used as reference of modern agricultural development in mountainous areas.

2. HERITAGE IRRIGATION SYSTEM OF ZIQUEJIE TERRACES

Ziquejie Terraces is located in Xinhua, Hunan Province in South Central China. It is built on hills with an altitude of 460–1,540 m and a surface slope of 25°–40°. This area is rich in water resources with an average annual precipitation of 1,700 mm. Home to several ethnic groups, Ziquejie Terraces is the result of fishing and hunting culture evolving into agricultural civilization. In earlier times, the lack of plains in Ziquejie had forced ancient people to reclaim terraces. By the 10th century AD, Ziquejie Terraces had been developed into shape. Now, Ziquejie Terraces covers a total area of 6,416 hectares. It continues to support more than 17,000 residents of 16 villages, and the traditional way of life and cultural diversity have been retained.

The irrigation and drainage system in Ziquejie is composed of three parts: water storage project, irrigation and drainage canal system, and control devices. Ziquejie has good climate and lush vegetation, which make good conditions for water resource conservation. In the valleys of Ziquejie, many streams do not dry up throughout the year. The total length of streams and rivers has reached more than 170 km. These streams are converted into small dams using small weirs. In normal circumstances, these weirs ensure water supply for the terraces; during torrential rains, flood water can overflow and drain away from the top of the weirs. A few meters upstream from the weir is the water inlet. The angle between the mouth and the stream is larger than 60° to ensure safety. Grit chambers and flushing sluices are built behind the weirs to reduce canal silting. With ridges that are 0.2–0.3 m high, the terrace fields are the major water-retaining works. Each hectare of terrace field can retain 750–900 m³ of water, and the Ziquejie Terraces as a whole has a water-retaining capacity of 10 million m³. Coupled with abundant water retained within the soil, the water-retaining terrace fields provide adequate water supply for the terrace agriculture.
The long and narrow field blocks also serve as the major canals. Delivering water through field blocks can meet the irrigation demand of most terrace fields. For some fields, short canals are needed to divert water from small reservoirs or other field blocks. Canals are usually built along the edges of field blocks and are separated from the field by low ridges. A small irrigation unit results in a small canal section and discharge; therefore, the canals are called “hair canals” by the local people. When delivering water to the platform fields on independent hills, locals set up bamboo tubes as aqueducts. Bamboo tubes are also employed for trans-altitude water delivery to avoid erosion of the ridges. The total length of the terrace canals in Ziquejie is only 153 km, which means that Ziquejie has achieved gravity irrigation with minimal work and the simplest infrastructures.

Irrigation safety would not be possible without drainage systems. Ziquejie Terraces fully utilizes natural valleys and streams as the main drainage canals. Moreover, drainage outlets are built in the proper place in the terrace fields and canals to ensure the discharge of waterlogging and tailwater. The floor of the valley is usually erosion-resistant bedrock, whereas places with relatively thick soil layers are lined with flagstones. Perpendicular to the contours, these valleys and streams can either be dammed up to be water sources or serve as main drainage canals. Together with delivery canals and field blocks that are built along contours, the valleys and streams have formed the irrigation water network of Ziquejie Terraces.

3. TRADITIONAL MODEL AND SCIENTIFICITY
Ziquejie Terraces is an example of overall planning and exploitation of water and land resources. As a result, balance has been achieved between the scenic cultural landscape and ecological environment. Ziquejie Terraces is a perfect example of the harmonious coexistence between man and nature, promoted by traditional Chinese philosophy.

3.1. General model of the agricultural system
Systematic recognition of an agricultural system including nature and society is important for the sustainable development of the current society and economy. Based on the general agricultural civilization process and conditions, the specific connotation of an agricultural model could be revealed in the perspective of the layers and interrelationship of natural environment, human agricultural activities, and social economy (Fig. 2). Natural environment, including topography, climate, water resources and ecological system, is the basic condition of agricultural production. Environmental changes directly affect the survival and development of the agricultural society. One of the most basic natural elements of supporting agricultural development is water, which is also the most active element affecting the evolution of the natural environment. Agricultural production, especially irrigation
agriculture, ensures population survival and society development, as well as affects landscape evolution directly or indirectly. The ultimate goal of (irrigation) agriculture is always the sustainable development of human social economy and culture. Population growth lead to more requirements for agriculture, whereas the development of society promoted the scale of agricultural construction and management. Agriculture civilization should be perceived holistically from nature to society, with its characteristics mainly in corporeality, integrality and dynamic development.

3.2. Traditional model of Ziquejie Terraces irrigated agriculture system
As an example of historical irrigation agriculture heritage system, Ziquejie Terraces is the result of fishing and hunting culture evolving into agricultural civilization. The Ziquejie system is an interesting case with typical characteristics and historical development. Covering a total area of 6,416 hectares, Ziquejie terraces is an example of overall planning and exploitation of water and land resources. It is the fruit of Ziquejie people’s wisdom and hard work. As a full-fledged gravity irrigation project built using simple technology and natural materials, Ziquejie Terraces is perfectly adapted to local conditions and has provided water for the local farming system for more than 1,000 years. The model of the irrigated agricultural system in Ziquejie Terraces is an extension and concretization of the general model of agricultural civilization. The traditional modeling of Ziquejie mountain terraces irrigation farming system should be analyzed on three layers: natural environment, terrace irrigation agriculture system and social system (Fig3). Natural environment is the foundation of the system, the terrace irrigation agriculture is the central part, and society is the destination layer.

Figure 2. General model of the agricultural system based on process

Figure 3. Systematic model of Ziquejie Terraces
Ziquejie Terraces has unique characteristics. With intact section and granite as the bedrock, the hills in Ziquejie are endowed with mature soil and a thick organic layer. Enjoying an average annual precipitation of 1,700 mm, this area is also rich in water resources. As a key process, the water cycle in the terrace system deeply affects the performance of soil and water conservation. A longitudinal profile of the terrace mountain surface (Fig. 4) shows that a forest is located on top of the mountain, terraces are found in the middle, and steam lays are found at the bottom, interspersed with houses and roads of the villages. Ziquejie Terraces is built with than 500 steps on hills with an altitude of 460–1,540 m and a surface slope of 25°–40°. Rainfall flows to the groundwater with a large proportion and then transuses to different levels by gravity. Today, the 25,500 hectares of forests on the hills remain the source of water for domestic and production purposes.

![Figure 4. Process of water cycle and gravity irrigation in Ziquejie](image)

The agricultural production system with irrigation and drainage system is the most important section of the model. Rice has been the main crop in Ziquejie for more than 1,000 years. Today, 69 weirs and 153.46 km of canals irrigate the terraces in Ziquejie. Apart from irrigation, water resources in Ziquejie have also been used for living facilities, such as water-powered rollers and water mills.

Living a hilly area that lacks flat farmlands and facing a growing population that has growing need for food, the ancient people in Ziquejie were forced to reclaim terraces. By the 10th century AD, Ziquejie Terraces had been formed into shape. In the early stage of the Song dynasty (10th century AD), Ziquejie people reclaimed the terraces to address the local population growth and food shortages. By the Qing dynasty (1644–1911 AD), Ziquejie had become a well-known grain production base, and the rice produced here was sent to the imperial palace as tributes. Currently, the 6,416 hectares of Ziquejie Terraces remain the major source of food and income for more than 17,000 residents of 16 villages. The benefits brought by Ziquejie Terraces since its inception fall into two categories—socio-economic benefits and ecological benefits. Terraces have played a significant role in the development of Ziquejie. As the major means of livelihood, terrace farming is the most important component of local economic life and provides material and impetus for survival and development. One reflection of this significance is the population change in Ziquejie since the inception of this project (Fig. 5).

![Figure 5. Population growth in Ziquejie](image)
For Ziquejie people, the terraces are the source of rice, fish, shrimps, and vegetables. Apart from being the source of food, Ziquejie Terraces also hold significant value for tourism. In fact, tourism revenue has become a pillar of local economy. Ziquejie Terraces has also provided a rich soil for the emergence and growth of multi-ethnic culture. The cultural value of the terraces are well-acknowledged worldwide.

The expansion of farmlands in Ziquejie before the 10th century has facilitated the development and integration of different ethnic groups. The unique but scientific water–land development method and the simple but developed irrigation and drainage system in Ziquejie have debunked the rule that hills with a slope greater than 25° are not suitable for terraces. In building the terraces, Ziquejie people adapted their measures to local conditions and retained the forest at high altitudes to guarantee the overall balance of water resources and the environment. They built villages halfway up the mountain where climate is milder and more suitable for human settlement. At low altitudes where the climate is warm, local people reclaimed terraces and set up a water distribution system. The water conservation function of the forest and the water retention function of the terraces have brought ecological benefits: conserving soil and water, recharging groundwater, adjusting flood peak, purifying water, conserving biodiversity, and regulating microclimate.

4. CONCLUSIONS AND DISCUSSIONS
The relationship of humans and nature is the core of Ziquejie Terraces. Such relationship is not only reflected in development philosophy but also in irrigated agricultural technology. On the basis of a systematic analysis of its creation, influences on the ecological environment and human society, components and characteristics of irrigation and drainage system in terraces area, scientific and cultural values as heritage in this paper, there reveal a traditional pattern of mountain agricultural development under the population pressure and mechanism of background adaptation and environment response. The study shows that the creation of Ziquejie Terraces has specific natural conditions. As an example of overall planning and exploitation of water and land resources, Ziquejie Terraces reflect ancient Chinese philosophy that the simplest projects could afford largest comprehensive benefits. The successful experiences of Ziquejie Terraces should be used as reference for modern agricultural development in mountainous areas.

The value of the traditional model of Ziquejie Terraces is embodied in the overall planning with different natural resources, and the absence of negative effects on the environment while the capacity of the population and economy significantly enhanced. A good planning for traditional irrigation systems is usually featured with great vision and systematicness, which is the scenario when components of a system work as an organic whole instead of a stiff combination. Ziquejie Terraces has made the most of local soil, geological and water conditions, including the natural stream network and plot distribution. In the model of Ziquejie Terraces, the impact of irrigation agriculture on the environment has been minimized.

The irrigation agriculture heritage of Ziquejie Terraces has a long history. The concrete case may not be copied in all the mountains area, but the exploitation philosophy and ideas could be learnt forever. Besides, various traditional irrigation agriculture forms should be systematically studies not only for engineering value, but also for sociological and ecological values. Although slopes face severe human disturbance and can generally become more stable after terracing, negative effects of terracing may occur in poorly-designed or poorly-managed terraces. Among the reasons are the lack of environmental legislation, changes in traditional concepts and lifestyles of local people, as well as price decreases for agricultural products. All of these can accelerate terrace abandonment and degradation. In light of these findings, possible solutions regarding socio-economic changes and techniques to improve already degraded terraces are discussed.

ACKNOWLEDGMENT
This work was supported by IWHR Research & Development Support Program (JZ0199B212019、JZ0145B022020、JZ0145B572016).
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