Chapter 16
Resilience of the Human-Water System at the Southern Silk Road: A Case Study of the Northern Catchment of Erhai Lake, China (1382–1912)

Anning Xu, Liang Emlyn Yang, Weibing Yang and Aubrey L. Hillman

Abstract This study focuses on the northern catchment of Erhai Lake that lies in the heart of the ancient Southern Silk Road (the Tea-Horse Roads) in southwest China. The hydrologic environment of this region is complex and evolved under significant human impacts, especially after large populations migrated after 1382 under the policy of military tillage. This led to increased pressures on the human-water relationship of this region but also stimulated social resilience to water stresses. This paper investigates the manner in which local people addressed the conflicts of utilizing limited water for people, livestock and irrigation until 1912. The approaches of statistical analysis, spatial analysis and correlation analysis were adopted, and historical data on floods, water conservation projects, plants, and disease were collected to support a detailed examination of the evolution of the human-water relationship in the study area. The results indicate that: (1) the evolution of the hydrologic environment, including the river system and the hydro-chemical environment, had a close correspondence with human activities; (2) local people constructed various water conservation and engineering facilities and changed their farming structures to cope with water stresses, which partly contributed to the break out and spread of Schistosomiasis japonica; (3) the resilience of the human-water relationship became weaker as the management of water projects diminished; (4) the sustainable development of the human-water relationship could be maintained through regular water management and environmental governance. These findings emphasize the influences of social policy and human activities on the resilience of the catchment and improve our understanding of resilience theory.

A. Xu (✉) · W. Yang
Center for Historical Geographical Studies of Fudan University, Shanghai, China
e-mail: anxu16@fudan.edu.cn

L. E. Yang
Graduate School of Human Development in Landscapes, Christian-Albrecht-Universität Kiel, Kiel, Germany

A. L. Hillman
School of Geosciences, University of Louisiana at Lafayette, Lafayette, USA

L. E. Yang et al. (eds.), *Socio-Environmental Dynamics along the Historical Silk Road*,
https://doi.org/10.1007/978-3-030-00728-7_16

Keywords Human-water relationship · Water environment
Agriculture production · Resilience theory · Schistosomiasis japonica
Erhai lake · The Tea-Horse Road · Southwest china

16.1 Introduction

Water, as a basic element of the environment, has a close relationship with humans. The human-water relationship occupies an extremely important position in the development of society. In its long history, China has been a country frequently and seriously affected by natural disasters such as floods and droughts (Liu and Yang 2012; Ji et al. 2015). Water governance strategies aimed at combating these disasters are linked with political, social and economic developments in Chinese history. There have been many famous water management projects that made a contribution to successful water governance. For example, Dam Dujiangyan and Canal Lingqu were built 2000 years ago and are still in use today (Wang et al. 2017). At the same time, the Chinese people have experienced several changes in understanding and utilizing water, including fear, worship, control, and conservation (Wang 2009a, b). In these human-water relationships, humans had made great achievements, created various cultures and religions focused on water, developed water related habits, and created rich water-related theories (Yuan 2014; Zhang and Wang 2014).

Here, the hydrologic environment refers to the formation, distribution and transformation of both water quantity and quality in the natural environment (Wu and Zhang 2009). The hydrologic environment plays an essential role for humans to survive and for society to develop. However, it has also been seriously disrupted by human activities (Harper and Snowden 2017) from the past to present. In the future, the human-water relationship will experience increased tension due to many challenges such as population growth, increased urbanization, higher standards of living, and climate change (Ding et al. 2014a, b). Faced with these challenges, modern society has begun to rethink its water use activities and social development strategies, and reexamine the human-water relationship to emphasize the sustainable utilization of water resources and the harmony between humans and water (Liu et al. 2012; UN-WWAP 2015). Understanding the evolution of this human-water-relationship during the historical period is therefore of significance for its current and future management planning.

This paper aims to understand the resilience and evolution of historical human-water relationships in the northern catchment of the Erhai Lake in southwest China. The focus is on key changes that reflect water impacts and social responses during the Ming and Qing Dynasties (1382–1912 A.D.), in which a combination of qualitative and quantitative approaches are adopted. It is expected that the findings from this study can help understanding local human-water relationships in the past and their implications for future water governance at basin scale.

16.1.1 Relationships Between Human and Water in the Long Historical Period

The concept of the human-water relationship has been a topic of research for many years (Turner II et al. 1990; Simmons et al. 2007). Recently it has become clear that the increase of population and the intensification of human activities are leading to increased tension between humans and water resources, which calls for macro control to maintain a harmonious relationship (Lautze et al. 2005; Ding et al. 2014a, b).

Ji (1981) emphasized that the development of water conservation projects brought about a high level of agricultural production and prosperity to ancient China (before 1860 AD). By analyzing the developmental processes and geographical distribution of ancient water conservation projects, Ji put forward the concept of a "basic economic zone". A basic economic region with superior agricultural production and water conditions was the main support of a centralized feudal Chinese dynasty, which relied closely on water. The main inland economic areas were usually the "basic economic zone" which the central dynasty relied on, including the lower Yellow River plain and the Yangtze River basin. Meanwhile, remote border areas were regions in which the control of central feudal power was relatively weak, and the economic development was limited compared to the main inland economic areas. These regions include the mountainous Yunnan area, during the Ming and Qing Dynasties.

Research has been done on the relationships between humans and water during historical periods, with a large amount of focus on the Chinese heartland, of which the middle and lower Yellow River is an important basic economic zone. Tan (2000) suggested that soil erosion is directly related to vegetation coverage on the Loess Plateau and that the vegetation is dominated by the agricultural production of the people living there. Due to the varying types of land use in these areas during the historical period, the amount of sediment entering the Yellow River has changed significantly. After the Eastern Han Dynasty (25–220 A.D.), the development of animal husbandry in the Loess Plateau, especially in the Shanxi-Shaanxi Gorge and the upper zone of Jing River, Wei River and Luo River, greatly reduced the amount of sediment transported downstream and resulted in long-term stability of the Yellow River (Tan 2000).

Another basic economic area is south of the Yangtze River, which has also been researched extensively. Wang (2013) believed that water conservation technology had a great impact on the water environment, which was reflected in social development levels and resulted in the emergence of new water conservation units. Further research has revealed the effects of culture and disease on the hydrologic environment. Wang (2015) found that as water space was divided into smaller sections, there were less poems that mentioned "girls picking lotus" while more mentioned "girls picking water chestnut".

According to the division of main inland economic areas and remote border areas by Ji (1981), many studies focused on the former but relatively less on the later, and with no comparison of the two. In the late imperial periods of the Ming and Qing Dynasties, both the main inland economic areas and the remote border regions experienced huge pressures with a surge in population. The land use mechanism in basic economic zones crumbled under the weight of huge populations (Li 2006). With the rapid expansion over the border regions of China by Han culture during the Ming and Qing Dynasties, a significant influence was exerted on existing local societies and cultures, though how this influenced the basic land use and associated water management remains unclear. Basins within the mountains of these southwest border areas are significant regions of grain production, making them critical regions of study.

One such example is the Erhai catchment. Recent years have seen an increasing number of studies on the Erhai water environment, especially with regards to water quality problems during historical periods (Crook et al. 2008). Physical geographic studies have been focused on the water quality of Erhai Lake, but over a relatively short-time span. Dearing et al. (2008) undertook a series of studies on this area and examined the mechanisms of sustainability in this area. Though fascinating, these studies are somewhat less systematic in their historical perspective, as historical changes cannot merely be explained through data whilst neglecting the specific adjustments or processes of society.

Yang (2007) studied floods in the Erhai Basin by summarizing the character, causes, and solutions relating to flooding in ancient times. Even though research has been done on this subject, the historical materials used were incomplete, and the reliability of these analyses depends highly on the integrity of the data. For example, the records of floods in The Veritable Records of the Qing (清实录) are far more abundant than sources used in previous research. Consequently, the attempt by Yang (2007) to rebuild the historical database and to reconstruct the sequence of floods in time and space is very informative, but the theories and effects of river harnessing are still unclear.

Due to the limitations of existing studies, a detailed and rigorous study of the Erhai Basin is necessary. This research on the human-water interrelationship in historical times would yield useful findings to help manage the water problems that still bother local people now. This study would further broaden vision and enhance the understanding of the importance of solutions to hydrologic challenges for both the present and future.

16.1.2 Resilience Theory in Human-Water Relationships

Resilience originates from the Latin word 'resilio' (re = back, silio = to leap) From the concept of mechanics, resilience is the ability of a material to deform and store potential energy without breaking or becoming completely deformed (Pelleg 2012, 27). Since the 1970s, the term resilience has been extended to encompass the ability of a system to restore itself and to return to its initial state. The development of Resilience Theory over the last few decades has undergone three phases since Holling put it forth in the 1970s (Holling 1973): Engineering Resilience, Ecological Resilience and Socio-ecological Resilience.

Specifically with regards to coastal complex systems, Klein et al. (1998) divides resilience into three parts: (1) natural resilience, (2) ecological resilience and (3) socioeconomic resilience. This suggests that there is no initial or equilibrium state in coastal systems, and that coastal resilience maintains the ability to self-organize in a constantly changing hydrological and geomorphological environment. This ability is derived from the dynamic processes of natural, ecological and socioeconomic conditions, and is limited by the maintenance of functions. Berkes (1998) further identified four aspects of resilience research: (1) learning to coexist with changes and uncertainties; (2) fostering diversity for renewal; (3) integrating different categories of knowledge; (4) creating opportunities for self-organization, restoration, and construction of a socio-ecological system.

According to Resilience Theory as described by Holling (2001), the adaptive cycle as a fundamental unit of dynamic change comprises a forward and backward loop in four phases: exploitation, conservation, release and reorganization, which may provide the potential foundation to assess human-water system changes. Adger et al. (2005) further put forward that restoring resilience is the ability of a system to absorb periodic disturbances, such as hurricanes or floods, while maintaining its basic structure, process and functions. Adger et al. believe that the diversity of means of livelihood, societal knowledge, and local emergency agencies can all be important resources to buffer extreme natural disasters and to recover from them. Accordingly, some ecologists believe that the resilience of an ecosystem will change if disturbed, and cannot be fully restored to the state before interference (Sun et al. 2007). Therefore, it is the aim of resilience researchers to find ways to enhance the system's resilience by studying it, in order to avoid an undesirable state even if it might be stable.

With particular focus on the Erhai Basin, Dearing (2008) adopted Resilience Theory to compile a relatively complete temporal series of environmental evolution and human activity over the past three millennia, with analysis of historical data and sediment sequences from the basin. The results indicated that the resilience and sustainability of the modern agricultural land system of the Erhai area depends on reducing the use of high altitude and steep slopes for grazing and cultivation. Unfortunately, this research had a coarse temporal resolution and didn't make full use of available historical materials, leaving a need for further analysis.

Through the literature review above, we identified two shortcomings of existing research on the human-water system resilience: for one, the historical evolution of the human-water relationship in the Erhai catchment has not been studied systematically; second, the human-water relationship in history is far more complex than just an "adaptive cycle" and there are still many unknown interactions. Previous research has been mainly introductory in both interpretation and analysis. The lack of specific historic details has led to a deficiency in scientific rigor. For example, what role did anthropogenic disruption play in flooding process or as a triggering factor? These are essential problems that are necessary to be addressed in order to reveal the change in the hydrological environment from a historical perspective. The aim of this article lies in analyzing the evolution of the human-water relationship in the Erhai catchment and improving resilience theory when applied to research on human-water relationships.

16.1.3 The Research Objectives and Materials

This paper introduces several innovations to address existing problems of past research and addresses several new problems arising from this study. The study takes the northern catchment of the Erhai Lake as a case study area that is of significance in terms of historical geography, water environment, anthropology, social development and other aspects along the well-known Southern Silk Road, also called the Tea-Horse Road (details in Sect. 2). This research assumes ongoing change in the hydrologic environment of the case study area and aims to reveal the evolution of the water system and determine which factors dominated, on the one hand, the change of the hydrologic environment, on the other hand, human activity and its influence. The goal of this study is to reveal the interactive dynamic of the human-water relationship in the study area and to understand its resilience.

Specifically, this study utilizes historical profiles, including documentary, gazetteer, local chronicles and epigraphic records, and archaeological records of human activity. Integration of these various data resources is supported by further analysis including comparison, statistical modelling, and classification. Overall, the study contributes understandings of the following issues:

– What were the essential characteristics and changes of the water environment in the northern catchment of Erhai Lake during the Ming and Qing Dynasties (1382–1912)?
– What were the interaction effects of the human-water system in this basin?
– How did the resilient state of human-water systems evolve in this basin and how could it be promoted?

16.2 The Southern Silk Road and the Erhai Basin

16.2.1 Introduction of the Southern Silk Road (the Tea-Horse Road)

The Silk Road is a modern concept for an ancient network of trade routes that for centuries facilitated and intensified processes of cultural interaction and goods exchange between West China and its neighbors (Yang et al. 2017). It generally includes the Northern Silk Road (also called oasis Silk Road and desert Silk Road), Maritime Silk Road and the Southern Silk Road. Though the former two are more generally well-known, the Southwest Silk Road was the earliest one to come into being. The Southern Silk Road is often known as the "Ancient Tea and Horse Road" (茶马古道), also called "Road between Shu and Shendu (Ancient India)" (蜀-身毒道) (Fig. 16.1). It was partly formed during the Qin Dynasty (BC221–BC207) when the first Emperor Qin Shihuang conquered the region of Yunnan, about 200 years before the development of the traditional Northern Silk Road via Central Asia. It

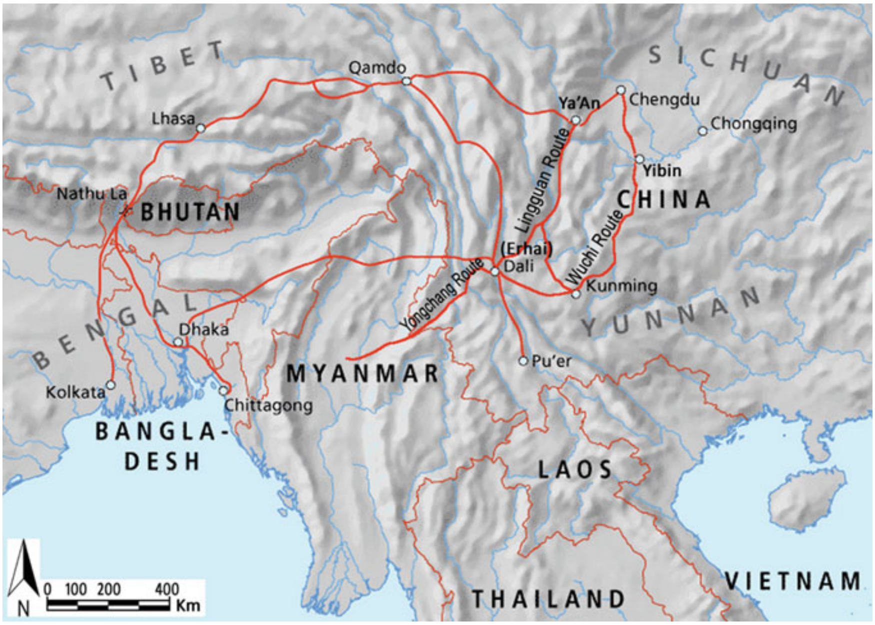

Fig. 16.1 A brief illustration of the ancient Tea-Horse Roads network (Southern Silk Road). Edited by Liang Emlyn Yang based on a figure from the "WikiPedia Tea Horse Road"

was active around 2200 years BP, with Dali becoming a regional center in the Erhai Lake basin in the Tea Horse Road networks (Xu et al. 1987).

The Tea-Horse Road was not only an important road network for early regional and international trade, but also the channel of interactions among ethnic groups and political, economic and cultural exchanges. The formation and development of this road promoted the development of commerce, the handicraft industry, mining and metallurgy, and the salt industry in the southwest mountain area in ancient times. During the last two decades, research on the Tea-Horse Road has been characterized by complexity and diversity, and has resulted in many achievements in historical geography, archaeology, anthropology, economic history, the history of transportation, tourism and other aspects; however, there has not been detailed research on specific sectors (Lan 2008). As a typical basin area in the center of the Tea-Horse Road network, the research on the Erhai catchment is therefore of great significance.

The Tea-Horse Road network consists of three major routes: Lingguan Route (灵关道), Wuchi Route (五尺道), and Yongchang Route (永昌道), with an entire length of more than 5000 km (Fig. 16.1). This network of routes links many major cities such as Yibin (宜宾), Kunming (昆明), Chuxiong (楚雄), Dali (大理), Yangbi (漾濞), Baoshan (保山), Tengchong (腾冲), Yongping (永平), Qamdo (昌都) and Lhasa (拉萨). It further connects southwest China to central China (Xi'An) in the East and to Myanmar and India in the south and west.

For the past two thousand years, people of different ethnic groups including the Zang (藏), Yi (彝), Naxi (纳西), Lisu (傈僳), Hani (哈尼), Jinuo (基诺), Qiang (羌), Pumi (普米), Bai (白), Nu (怒), Jingpo (景颇), A'chang (阿昌) connected with each other economically and culturally through the Tea-Horse Road. Along the development of the routes network, horse caravans (马帮) played a significant role in transporting goods, such as tea, salt, cotton, gemstones, and opium.

Dali became a regional center of the Erhai Basin largely due to economic activity along the Tea-Horse Road, sustaining a large immigrant population, as well as other complex social factors. Before the Ming Dynasty (1368–1644 AD), the population in Dali and the Erhai Badin was limited and the social economical system was less developed. The evolution of the hydrologic environment in the northern catchment of Erhai Lake was also slow. Beginning with the large number of Han Chinese migrating into the area at the start of the Ming Dynasty, the local economy was gradually developed. At the same time, these developments led to disturbance of the natural environment, with rapid and obvious changes to the hydrologic environment in the form of frequent floods and droughts. Because of this, the Miju River (弥苴河) was called "the Small Yellow River".[1]

16.2.2 Erhai Lake at the Tea-Horse Road

The Erhai Basin is located in the central part of the Tea-Horse Road connecting Sichuan, Yunnan and Myanmar (Fig. 16.1). Erhai (25°36′–25°58′N, 100°05′–100°18′E) is China's seventh largest lake with a surface area of 250 km^2 at the present time. It lies in an intermontane basin between the Tibet-Yunnan fold belt and the Yangtze para-platform (Zhang et al. 2000) (Fig. 16.2). It is about 1974 m a.s.l. (above sea level) with a combined lake and catchment area of ~2500 km^2. The lake basin is geologically dominated by Palaeozoic metamorphics (gneiss/granite and marble) on the west side and Mesozoic basic volcanic and sedimentary rocks on the east side (Lin 1982). The catchment of Erhai Lake is composed of four parts (Fig. 16.2) with the majority of discharge coming from the north, supplying more than 59% of the 5.18×10^8 m^3 inflow annually.[2]

The north catchment is composed of the basins of Mici River, Fengyu River, and Miju River (A and B in Fig. 16.2) with continuous hills and deep river valleys. The river drops substantially from 2050 to 1987 m a.s.l. and empties into Erhai Lake with a rapidly aggrading delta at the Miju River mouth.

The basins A and B (Fig. 16.2) together are often called the Miju River basin, which is divided into upstream and downstream regions by the Putuo Gorge (蒲陀

[1]"The small Yellow River" is a quote from the local chronicles of Eryuan County (1996), which means it was similar than the Yellow River with big floods, high sediment concentrations, and over ground riverbed.

[2]This data is quoted from Erhai Management Chronicles (2007), edited by Erhai Protection Administration of Dali.

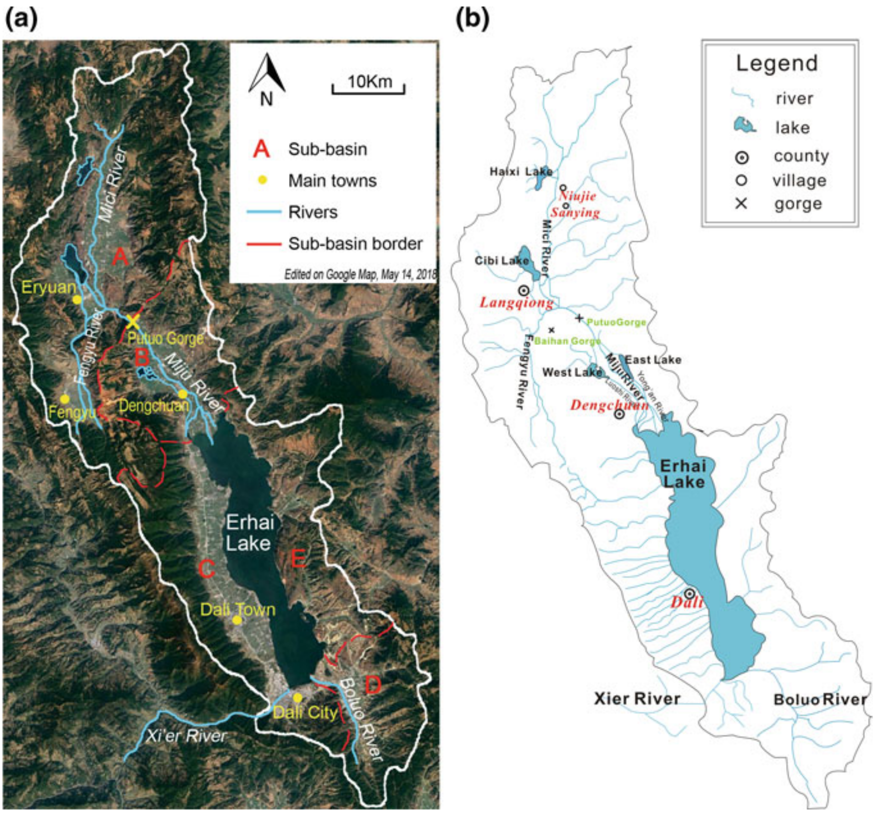

Fig. 16.2 Brief illustration of the topography (left) and river system (right) of the catchment of Erhai Lake

崆). The upstream (A) consists of two major branches, the Mici River (43.4 km) and Fengyu River (36 km). Cibi Lake (茈碧湖) and Haixihai Lake (海西海) merge at the beginning of the Putuo Gorge in an area called Sanjiang Port (三江口) and empty into downstream through the Putuo Gorge (Fig. 16.2, right). There are two smaller lakes (West Lake and East Lake) and three channels flowing in parallel at the downstream area (Fig. 16.2, right), which look similar to the Chinese word "chuan" (川). The main channel is the Miju River, while the other two have local names, the east is called Yong'an River (永安江) and the west called Luoshi River (罗时江). The three river channels flow into Erhai Lake separately, but they are often together called the Miju River basin.

The total length of the main stream system in the north catchment (the areas A and B in the left pattern of Fig. 16.2) is 71.08 km, with a catchment area of 1259.43 km^2. The heavily embanked and elevated Miju River provides irrigation water for intensive agriculture on the floodplain. The sub-basin A (Mici River and Fengyu River) is surrounded by mountains with one only outlet at the Putuo Gorge. The elevation is much higher at the villages of Niujie (牛街) and Sanying (三营) at the north of Mici River, while it is lower in the Fengyu River basin in the south, between 2060 and 2200 m a.s.l.. Both of them join with the Cibi Lake outlet (2055–2100 m a.s.l.) and flow via the Putuo Gorge to the mainstream Miju River. As the downstream region, the elevation of sub-basin B sits between 1965 and 1987 m a.s.l.. The population is dense and the fields are better fertilized in this sub-basin, which makes up more than 70% of the whole county's population and at the same time demands a larger amount of water for drinking and irrigation.

16.2.3 Social Economic Characteristics of the Erhai Lake Basin

Agricultural production is the dominant economic activity in the Erhai Lake basin, and the land use is mainly comprised of woodland, grassland and farmland, which respectively accounted for around 33.5, 35 and 24.1% of land coverage around the year 2000 (Yang 2004).

In the 15th year of Hongwu in the Ming Dynasty (1382), the Army General, Mu Ying (沐英), was ordered to conquer Yunnan Province. He brought in 200 thousand garrison troops and peasants (mainly people of Han ethnicity) to reclaim land and grow food grain in the areas surrounding Dali and Erhai.[3] The sudden influx of large numbers of people made a great contribution to the economic development of the area, but also brought considerable land pressure and people began to move up to the mountainous areas.

For example, a village named after a leader, Dawa (大娃), was filled with immigrants from Jiangsu and Jiangxi Province and settled close to the transportation line and the center of the north catchment (Fig. 16.3). The native people of Bai ethnicity who lived there since the Nanzhao (南诏) and Dali (大理) Periods (748–1254) had to move to the surrounding higher hilly regions (Yang and Li 1996). In order to attain self-sufficiency in grain production with the natural growth of the population, the military population and their families made efforts to expand cultivation areas by reclaiming land from wasteland, slopes, and desolate marshes. Han villagers settled densely at both sides of the Miju River where there was an abundance of water (Liu 2013), which eventually developed into the present town Dengchuan (Fig. 16.3).

[3]Record of the Ming Dynasty《明实录》.

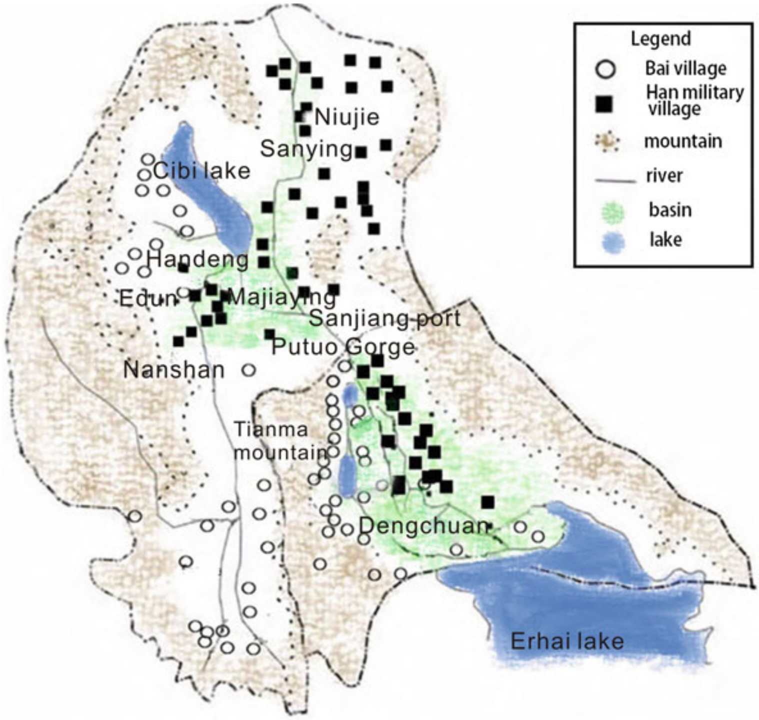

Fig. 16.3 The distribution of villages in north catchment of Erhai Lake in the Ming and Qing Dynasties. Re-edited by Anning Xu based on Liu (2013)

16.3 Human-Water System in the Northern Catchment of the Erhai Lake

16.3.1 The Water Problem in the Northern Catchment of Erhai Lake

As mentioned above, the hydrologic challenges in the northern catchment of Erhai Lake are mainly concentrated at the Miju River (sub-basin B in Fig. 16.2). The Miju River is called "the Small Yellow River" for its high sediment load and pronounced fluctuations in seasonal precipitation. The surface runoff supplied through precipitation varies largely with the seasons, and is the main reason for floods in the summer or autumn and droughts in springs. Additionally, this runoff contributes to the deterioration of water quality (Wu et al. 2012). With continuous hills and deep river valleys, the topography of the northern catchment changes greatly, leading to substantial elevation drops along the river from 2050 to 1987 m a.s.l. Consequently, the river empties into Erhai Lake at high velocity (ECC 1996). Under these circumstances, the standing time of the water is short and rainfall is not stored for long periods; therefore scarcity of rainfall may easily lead to droughts.

The population is dense and fields have been fertilized in this region since the large migration in 1382, resulting in high water demand for drinking and irrigation all the year round. Therefore, tension exists between the huge demand and the short supply of water for most of the time. In addition, population pressures have caused the increased cultivation of unstable mountain surface soils on the slopes of the upstream areas, which was detailed in the gazetteer.[4] The result has been a massive increase in sedimentation of the river. Additionally, the dykes in the downstream rose to a level above the farmland. When heavy rains occur and break the banks, this often results in floods.

Several scholars have done detailed research on the floods and droughts of the northern catchment of Erhai Lake (Yang 2007), but the materials used were not comprehensive. By collecting historical materials in the Ming Dynasty and the Qing Dynasty (1382–1912), the present study built a database of floods (Table 16.1) and droughts (Table 16.2). Particular attention was paid to a few key sites in the research area, including Langqiong (浪穹) and Dengchuan (邓川) as basic local administrative regions of the Qing Dynasty.

Floods were so frequent in the north catchment that the records of floods are very common in historical archives. Torrential floods exerted a tremendous influence, the most serious one being in 1905 (the 31st year of Guangxu in the Qing Dynasty). According to the record, the flooded field area was up to 321 qing (顷) in Dengchuan, whilst the entire paddy field area was only 400 qing, leading to over 80% of the paddy fields failing, a particularly rare situation in southwest China. Additionally, the bursting of banks leading to floods was also quite common. In 1691, the Miju River burst its banks and the chief of the prefecture, Liang Dalu, led the local people to plug the leaks. It seemed like a normal event in the record, with the area submerged by flood sediments being over 79 qing(顷); this means that a quarter of the paddy field failed to grow rice. Additionally, the estuary was often blocked by sediments, resulting in poor drainage and overflowing lake conditions. For example, in 1694 (the 33rd year of Kangxi in the Qing dynasty), there was a flood from the Baihan Gorge (Fig. 16.3), which resulted in sand blocking the river and flooding of the fields and houses.

The climate of the northern catchment is mainly affected by the southwest summer monsoon. Weak summer monsoons lead to a scarcity of precipitation and subsequently droughts. In early 20th century, droughts in Dengchuan lasted for years due to a lack of precipitation. Additionally, delays in the timing of rainfall may also cause droughts. In the May of 1747, the rice seedlings could not be planted because of the late arrival of rainfall in Dengchuan. In years when the strength of the monsoon is highly variable, seasonal change may induce both droughts and floods within the same year. In 1859, it barely rained in the summer in Dengchuan, leading to drought. However, it rained too much in the autumn, which caused floods. Overall, the frequency of droughts was much lower than that of floods.

[4]Eryuan County Committee (ECC) (1996). Local Chronicles of Eryuan County.

Table 16.1 Selected records of floods in the northern catchment of Erhai Lake during the Ming and Qing Dynasty

Time (B.C.)	Location	Original record in Chinese documents	Material resources in Chinese
1501, August	浪穹 Langqiong	八月"浪穹淫雨,山崩水溢冲圮,居民溺死百余人,公署文案尽漂没" Flood in August of the lunar calendar, over hundred people were drowned	天启《滇志》卷三十一"灾祥" Yunnan Province Gazetteers in Tianqi Years
1663, July and August	East Lake, Dengchuan	邓川七八月间红石泛滥,倒灌东湖,淹没田庐。Flood in July & August of the lunar calendar, inundated the field and houses	咸丰《邓川州志 》[a] (Xianfeng) Dengchuan Gazetters
1691	Dengchuan	"弥苴河决,知州梁公大禄塞之。" Miju River burst its banks; The prefecture chief Liang Dalu lead the local people to plug the leaks	咸丰《邓川州志 》 (Xianfeng) Dengchuan Gazetters
1693	Baihan Gorge of Langqiong	白汉涧水发,沙石填河,湖水横流,冲田宅无算。Flood from Baihan Gorge and sand block the river	《浪穹县志略》 The Langqiong County Gazetteers
1694	浪穹,邓川 Langqiong, Dengchuan	洱源"白汉涧水发,沙石坝河湖水横流,冲田宅无算。" Flood from Baihan Gorge, sand block the river and flooded the field and houses	《浪穹县志略》 The Langqiong County Gazetteers
1732	浪穹 Langqiong	浪穹县羽河等处。筑堤四十余丈。但补苴一时。急宜委勘加修。Build dam of Yu river in Langqiong for the flood	清世宗实录 The Record of Shizong Emperor in Qing Dynasty
1749	邓川 Dengchuan	除云南邓川州、水冲沙压民屯田地额赋米、二十二石有奇。银、二十五两有奇。 Exempted from taxation of affected people in floods	《清高宗实录》 The Record of Gaozong Emperor in Qing Dynasty

(continued)

Table 16.1 (continued)

Time (B.C.)	Location	Original record in Chinese documents	Material resources in Chinese
1760	Fengyu River	夏秋之间,每淤塞倒漾,淹浸田庐。The water submerged the field and houses in summer and autumn	清世宗实录 The Record of Shizong Emperor in Qing Dynasty
1782, February	邓川 Dengchuan	弥苴河…河高湖低。遇夏秋潦发,青不涧、九龙涧等处之水,会冲入河。河水宣泄不及,回流入湖,附近粮田俱被淹没。The field were flooded in summer and autumn along the Miju River	清高宗实录 The Record of Gaozong Emperor in Qing Dynasty
1801	Miju River at she Gorge, Ning Lake	浪穹之宁东、宁南、宁北各村田亩,均被冲淹。The field on east, south and north of Ning Lake were flooded in Langqiong	咸丰《邓川州志》卷五"灾祥志" (Xianfeng)The Dengchuan Gazetters
1806, Jume	Langqiong	奏报查明浪穹县被水田亩情形,请分别赈抚事。Report and find out the situation of fields were submerged	《军机处全宗》 Record of Military Aircraft Department
1808	浪穹 Langqiong	嘉庆十三年灾益甚,南北城垣尽圮,请赈,除田赋五百余石。The flood were so serious that request help	道光《浪穹县志》(Daoguang) The Langqiong County Gazetteers
1859, July	Dengchuan	邓川淫雨经旬,淹没禾苗无算。 The field were flooded countless after rain for months in Dengchuan	新纂云南通志 The New Yunnan Province Gazetteers
1906, March	邓川 Dengchuan	豁免云南邓川州属上年被水地方银米。 The tax of Denghcuan were exempted because of the flood	清德宗实录 The Record of Dezong Emperor in Qing Dynasty

[a]Hou Yunqing, (Xianfeng) Dengchuan Gazetters, reprint by Chengwen Press, 1976
[b]Qing (顷) is a unit of area that equals to 6.67 ha

Table 16.2 Selected records of droughts in the northern catchment of Erhai Lake

Time (B.C.)	Locations	Original record in Chinese documents	Material resources
1606	浪穹 Langqiong	是岁洱源旱甚,南水浸沟,不能注下。Heavy drought in Eryuan	康熙浪穹县志 (Kangxi)The Langqiong County Gazetteers
1665	洱源Langqiong	大旱heavy drought	洱源县志 The Eryuan County Gazetteers
1692, spring to summer	洱源 Langqiong	康熙三十一年,自春月不雨至夏五月不雨,民益惶惶。It has no rain from spring to summer	康熙大理府志 (Kangxi)the Dali Prefecture Gazetteers
1747, from May	洱源、邓川 Dengchuan	雨泽愆期,秧苗不能全栽。The Rice seedling cannot plant because of the late of the rain	张允随奏稿 The memorial to the throne from Zhang Yunsui
1792, summer	邓川Dengchuan	壬子 (1792年)之夏,邓 (川)境乏雨 it was lack of rain in summer of Dengchuan	咸丰邓川州志 (Xianfeng)The Dengchuan Gazetteers
1817, autumn	浪穹Langqiong	夏雨雪,秋大旱,民复饥。It was drought in autumn	道光浪穹县志 (Daoguang) The Langqiong County Gazetteers
1837, summer	邓川Dengchuan	邓川夏旱。Drought in summer of Dengchuan	咸丰邓川州志 (Xianfeng)The Dengchuan Gazetteers
1859, summer	邓川Dengchuan	邓川夏旱,秋淫雨。Drought in summer but flood in autumn of Dengchuan	云南通志 Yunnan Province Gazetteers
1893, summer	邓川Dengchuan	邓川夏大旱。Drought in summer of Dengchuan	柿坪记述 Description of Shiping
1905	邓川Dengchuan	邓川等州"大旱连年,赤地千里"。Drought for years in Dengchuan	云南通志荒政草稿 Yunnan Province Gazetteers

Floods occurred 41 times upstream (sub-basin A in the left pattern of Fig. 16.2) and 58 times downstream (sub-stream B) of the Miju River basin during the Ming and Qing Dynasties (1382–1912), as summarized from available records. When dividing the collected flood events into different periods according to Yang (2007), there were 20 downstream floods before the channel diversion of the Fengyu River during the period 1659–1760 as the first phase, while only 9 floods occurred upstream during the same time frame. In the second phase (~1760–1860), a period of one hundred years after the twenty-fifth year of Qianlong in the Qing Dynasty (1760), the frequency of upstream and downstream floods were similar—20 and 21 times respectively. This finding differs from the previous opinion of Yang (2007), that the floods in Langqiong were more frequent than in Dengchuan. During the third phase

(1851–1912), the number of upstream floods was 12 while the number of downstream floods was 17, showing that the floods in Dengchuan were actually more frequent than in Langqiong. These results are roughly consistent with previous findings, except for the second phase. Although the outbreaks of drought were less frequent than floods, the occurrence of droughts downstream were more often than that in the upstream area; therefore, we conclude that the droughts in Dengchuan were more serious than in Langqiong.

As floods in this area are far more serious than droughts, the following sections will focus on the causes of and local responses to the floods.

16.3.1.1 Climate Impacts

The northern catchment of Erhai Lake has a typical humid monsoon climate that is often found in the north subtropical Yunnan Plateau where there is a clear distinction between dry winters and wet summers. The average annual rainfall is 742.4 mm and 90% falls from May to October. Runoff into Erhai is mostly made up of this rainfall. Relative humidity averages around 66% with an average annual temperature of 15.1 °C and an annual sunshine duration of 2354 h. In addition, the microscale climate within the basin varies with topography and altitude.[5]

Huang et al. (2014) found that the main synoptic systems giving rise to heavy rainfall in the Erhai Basin were shear line, Bay of Bengal storms, a low vortex, a convergence zone of two high-pressure south branching troughs, and a westbound low-pressure typhoon. These meteorological features often facilitate rain storms. Combined with previous research on the summer monsoon and the rainy season in the Yunnan Province during the Qing Dynasty (Yang et al. 2006), analysis indicates that there were obvious inter-annual and inter-decadal fluctuations of the starting date of rainy seasons in Yunnan, as well as long-term fluctuations on the decadal and centennial scale. The monsoon arrived earlier in the beginning of the 18th century, later in the 19th century and earlier again in the 20th century (Huang et al. 2014). The variability of the summer monsoon therefore leads to great changes in precipitation and thus brings floods and droughts.

16.3.1.2 Topographic Factors

Some scholars believe that the location of burst banks and collapses are not random (Yang 2007). The location of such events shifted downstream, which was closely related to the evolution of sedimentation in downstream areas. According to historical records, burst river banks were not the only reason for the severe flooding in Dengchuan. There were 7 burst banks in 61 years (1851–1911), with 21 recorded floods, indicating that burst banks were not an inevitable cause of the floods.

[5]Eryuan County Committee (ECC) (1996). Local Chronicles of Eryuan County.

As stated in The Record of Gaozong in the Qing Dynasty: “Whenever it rains too much in summer, a lot of water accumulates in the low-lying land”, it reveals that the occurrence of excessive rainfall was the main cause of flooding in Dengchuan, which corresponds to a phase of *exploitation (rapid growth)* in resilience theory. For example, “in the third year of Kangxi in the Qing Dynasty (1663) there was a flooding outbreak and the water invaded into East Lake and submerged farmland and villages in July and August” (Eryuan County Water Conservancy and Electric Power Bureau 1995). In the seventeenth year of Qianlong in the Qing (1752) “[Dengchuan] standing grains were flooded in rural areas” (Yunnan hydrology and Water Resources Bureau 1997). In the ninth year of Xianfeng in the Qing Dyansty (1857), “after rains for months, the grains were flooded countless times in Dengchuan by the time of July in autumn” (Zhou and Zhao 2007). Excessive rain often led to floods since the basin is large and flat while its outlet is too small to accommodate the inflow from the surrounding mountains (Fig. 16.4). If the riverbanks were strong enough and the river was sufficiently deep and wide, floods may not have occurred. However, technology was limited in the Ming and Qing dynasties and cannot compare to modern reinforced concrete engineering measures,[6] so dams were often unable to withstand the floods.

Compounding the problem is that the natural channel of the Miju River is quite shallow; the river bed was even higher than the adjacent ground in times of heavy

Fig. 16.4 The flat landscape of Dengchuan Basin surrounded by mountains (taken by Weibing Yang in 2012)

[6]The reinforced concrete engineering measures was first invented by Aspdih in 1824; and China built the first cement plant in Shanghai at the late 19th centuries.

sediment flow. The breaching of the dyke can therefore hardly be avoided as the channel cannot accommodate even slightly excessive runoff. Dengchuan used to be an area of "swamp and shallow lake beach" before the time when the riverbanks of the Miju River were built by Deng Danzhao (邓赕诏) in the year 649 and before Luo's brothers excavation of the Luoshi River in the year 785.[7]

The dykes were built to prevent the river from brimming over, but the channel was relatively fixed by these dykes after being constantly repaired and renovated for hundreds of years (the *conservation phase* of resilience theory). When it rained excessively and there was inadequate drainage, "the water would backflow into the lake and the grain nearby would all be submerged" (the record of Gaozong Emperor in Qing Dynasty) (the *release phase* of resilience theory). Excessive sediment deposition exacerbated the already serious problem of flooding.

16.3.1.3 Characteristics of the Water System at the Cibi Lake

The Cibi lake basin is naturally shallow and has a low capacity to adjust to water levels in both cases of drought and flood. This has been documented in many historical materials. In 1762 (the 27th year of Qianlong in the Qing Dynasty), the governor of Yunnan Province, Liu Zao (刘藻), wrote the reason and response to the flood in the memorials to the emperors[8]:

> The water from Cibi Lake (also called Ning Lake), Feng Yu River and Mici River in Langqiong County joins with other inflows at the point of Sanjiang Port, and drains downstream in Dengchuan through Putuo Gorge with sands and sediment. When it comes to summer and fall, the river would be blocked and water overflowed, flooding lands and villages. The crib and pile were arranged from the east bank at the Old Dam located at the north end of the gorge, in order to block sand and stones from rushing into the river. But both the dam body and dam crest are only five feet high and thick, which is difficult to withstand the flood challenge. The dam should be built in the size of twelve feet in height and ten feet thick, while the foot of the dam should be thicker than three feet. In addition to the old earth dam of 903.5 zhangt(丈), a new dam was added spanning 5768.5 zhang(丈) in all. As for the west riverbank where the Creek of Baihan Gorge flow into river, the sands should be excavated to build the dam.

The floods of Eryuan were mainly caused by the water rising in Cibi Lake. As early as in 1692, it was recorded in the local chronicles that once in water of the Baihan Gorge (Fig. 16.3) rose, sand filled the river, resulting in the floods and the submergence of countless fields and houses (Zhou 1976). In 1765, as the water rose and flowed out of Cibi Lake, the northern, southern and eastern walls of the city Eryuan were washed away by the water. In 1801 (the Sixth Year of Jiaqing (嘉庆) in the Qing Dynasty), "The Ning Lake is so shallow in Langqiong County (Eryuan) that there is dredging of mud from the lake bed every year, so whenever it rains

[7]Local records of river and lakes in Eryuan County (1994). P91.

[8]Memorials to the Qianlong Emperor of Qing Dynasty. Reprint by Palace Museum in Taipei Press in 1982.

heavily, the eastern, northern, southern villages would be flooded".[9] In June of 1805, "villages and fields near the lake were flooded, where water cannot drain out."[10] This kind of flood situation was so frequently seen in local chronicles that we conclude that the fundamental cause of the flood lies in its shallow lake basin, which restricts water storage capacity.

16.3.1.4 Sediment Deposition

The accretion of lake sediment reduced lake water storage and also deposited silt resulting in river blockage, which led to dam bursts and floods. It has been mentioned above that because the basin of Cibi Lake is relative shallow, small increases in precipitation could raise the water level and lead to floods. In 1760 (the twenty-fifth year of Qianlong in the Qing Dynasty), the Fengyu River was diverted into Cibi Lake. Although the floods subsided gradually in the short term, sediment brought by the Feng Yu River was deposited in the lake, reducing the basal depth of Cibi Lake, leading to reduced water storage, increasing the risk of flooding. Floods at upstream areas brought serious problems to the silted up riverbed in Sanjiang Port and Putuo Gorge, restricting the stream flows. Thus, whenever the Sanjiang Port area was blocked, the local government would put efforts to dredge it, so that the water blockage was addressed immediately.

Yang (2007) attributed the major cause of floods in the north catchment (sub-basin A in Fig. 16.2) to the development of the sensitive area of the Fengyu River catchment. He believed that the floods of the Fengyu River and Cibi Lake were previously infrequent and that floods only occurred when the Sanjiang Port was silted up by sediment from the Baihan Gorge after the 25th year of Qianlong (1760). A comprehensive analysis of data in this study (in Table 16.1) also shows that the frequency of floods increased from 1760 to 1850 (the end year of Daoguang in Qing Dynasty), supporting Yang's view. It is also found that floods subsided again after the years of Xianfeng (1861). We could detect a full resilience loop during the process above, but cannot not attribute the *reorganization* process to natural functions, but rather to governing activities. The deposition of sediment in rivers and lakes increased the risk of flooding and exacerbated the risk of dyke break. By dredging the sediment, the drainage was improved, the moisture storage capacity was increased and the floods were alleviated to a certain degree, which can be identified as *reorganization*.

An infilling of lake floor leads to a decrease of lake water storage, and, of course, reduces the regulating function of the lake. In dry seasons, drought can be easily triggered if precipitation is insufficient. For instance, "*In the 31th year of Kangxi in Qing (1692), it barely rained from spring to summer [in Eryuan] and aroused the*

[9]The Dengchuan Gazetteers during the Xianfeng periods of Qing Dynasty.

[10]Historical materials of floods and droughts in Yunnan Province.

public panic".[11] Without adequate water reserves in rivers and lakes, people were unable to irrigate farmland.

16.3.2 Human Impacts on the Human-Water System

To address flooding issues, the local people made great efforts to construct water projects, which had remarkable but inconsistent effects. The increased need for maintenance led to the restructuring of parts of the system of government and the lives of the local people. Specific principles, ideas and characteristics of flood control and river planning and harnessing in Dengchuan are presented according to data, experiences and lessons recorded in various archives.

16.3.2.1 Watercourse and Dams

Due to the frequent and serious flood impacts along the Miju River, especially in the lower reaches where the channel is shallow and riverbed accumulated over ground, local people have developed various measures to address the problem. Most significant solutions were water conservation projects (Table 16.3). In 1732 (the 10th year of Yongzheng in the Qing Dynasty), the governor of YunGui and Guangxi, E'Ertai (鄂尔泰), reported to the Emperor Yongzheng and proposed six suggestions for water conservancy projects in the Erhai Lake catchment. His report "*Suggestions on the Construction of Water Conservancy*" included a specific proposal on "*embankment and dredging engineering of the Fengyu River in Langqiong County*". The Ministry of Works immediately replied "*it is appropriate to build an embankment of 40 feet for the Fengyu and other rivers in Langqiong County quickly*".[12] However, the dykes were only a temporary measure and the effect was not as expected.

In addition to reinforcing dykes and excavating sediments in the river, local people tried to open up new channels. For example, in 1782 (the 47th year of Qianlong in Qing Dynasty), the Governor of Yunnan Province, Liu Bingtian (刘秉恬), presented a memorandum to the Emperor regarding the flood problems in the Miju River basin at Dengchuan County.[13] The problem was that the riverbed was high while the East Lake was low, and that when it rained in the summer, a flash flood in the upper reaches could expand into a more general river flood. If the water could not drain out effectively, it would flow back to the lake and flood the surrounding fields. The local officers and inhabitants advocated donations to build a dam at the end of East Lake and construct a new channel to drain out the water directly into the Erhai Lake. A few years after the new causeway was built and a stone watergate was established

[11] (Kangxi) Local chronicles of Dali prefecture.

[12] Memorial to the Emperor by E'Ertai.

[13] The Record of Gaozong Emperor in Qing Dynasty.

Table 16.3 Some collections of the water management projects during Qing Dynasty (1644–1912)

No.	渠 Channel	堤 Dam	河道疏浚 river dredging	闸 Sluice
1	西堤十四渠 Fourteen channels to the west	弥苴佉江堤 Mijuqv River dam	三江口 Sanjiang Port	上东西二闸 two sluice at upstream on east and west
2	东堤六渠 Six channels to the east	罗时江堤 Luoshi River dam	白汉涧 Baihan Gorge	下西闸 sluice at downstream on west
3	驿东乾沟渠 Yindong Gangou Channel	圆井堤 Yuanjing dam	凤羽河 Fengyu River	
4	南怒地江渠 Nan Nudijiang Channel	上七里公堤 Up Qiligong dam	瀰茨河 Mici River	
5	溪登渠 Xideng Channel	下七里公堤 Down Qiligong dam	真珠涧 Zhenzhu Gorge	
6	东源沟 Dongyuan Channel	旧东闸堤 Old Dongzha dam	南涧 Nan Gorge	
7	山根渠 Shangen Channel	卧虹堤 Wohong dam	北涧 Bei Gorge	
8	红山渠 Hongshan Channel	普陀河堤 Putuo River dam	永济河 Yongji River	
9	安民沟 Anmin Channel		罗凤溪 Luofeng Stream	
10	山关渠 Shanguan Channel		九龙泉 Jiulong Spring	
11	三江渠 Sanjiang Channel		金龟山涧 Jingguishan Gorge	
12	大波渠 Dabo Channel		沂水河 Yishui River	

to constrain the river, more than 11,000 acres of previously flooded farmland were dried out and could be cultivated again.

Drought in the lower reaches was much more severe than the upper reaches of the river because the river was straight and the riverbed was high so that water could hardly be stored for long time use. Water rushed into Erhai Lake quickly after flow out of the Putuo Gorge, even though there was sufficient precipitation. When there were extreme precipitation events, either droughts or waterlogging would occur, which would affect both the production of agriculture and people's lives and property. Therefore, the construction of the artificial canals played a significant role in regulating water storage during periods of uneven water conditions.

In order to keep the river calm over the long-term, the people of Langqiong County developed the "Maintenance Regulations for the Sanjiang Canal" in the 26th year of Qianlong (1761) and received funds from salt-tax income. Thus, financial resources of 20 Liang (两)[14] were available annually for minor maintenance and 120 Liang for major repairs and silt removal every three years. As shown partly in Table 16.3, local people excavated over 30 channels, built 8 dams, dredged 12 river sections and opened more than 2 sluices during the Ming and Qing Dynasties (1644–1912). There is an old saying that "Dengchuan is small, while the canals are countless like stars", which is a direct reflection of this situation. The implementation of these hydraulic facilities had a significant effect on water management and benefited the life, property and safety of surrounding people. However, once political interest waned and the funding stopped, serious river blockages occurred again. Details of the maintenance regulations can be referred to in Dearing et al. (2008).

16.3.2.2 Water Diversion

The floods of the Fengyu River were especially serious since sands were gradually accumulating due to the relatively flat terrain. The old downstream area of Fengyu River turned into a field of sediment around 1762 (the 27th year of Qianlong in

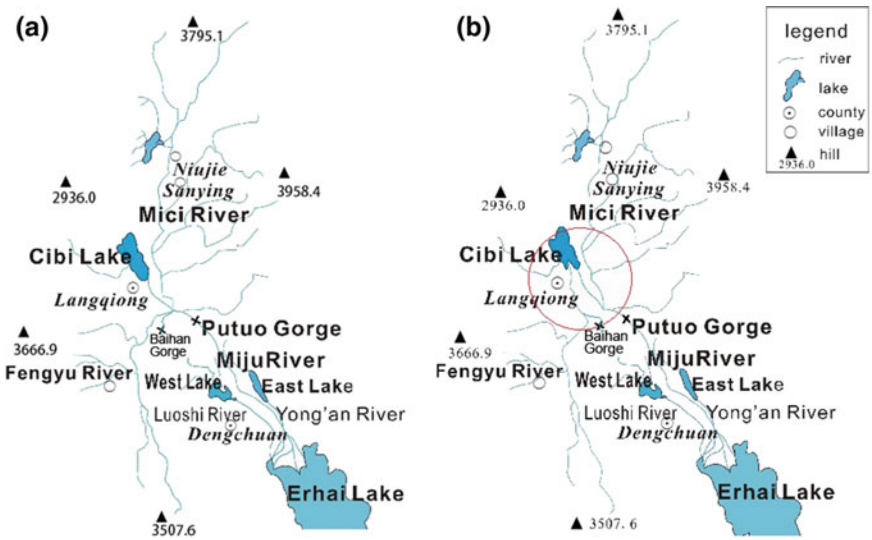

Fig. 16.5 A comparison of two maps showing significant changes (area in the blue circle) of the river system in 1368 (**a**) and 1820 (**b**)

[14]A concrete measurement unit of weight in ancient China, that 1 Liang is 31.25 g.

Qing Dynasty) when local people reached a consensus to divert water, as it was more efficient to excavate new artificial canals rather than clean up the silted stream sections. The outlet of Fengyu River was diverted northwards to the Cibi Lake and the floods at the old outlet area subsided (Fig. 16.5). From local people's point of view, if the riverbank of Fengyu River were thick and high enough, there would be no flooding of the river or stresses relating to annual maintenance. These maintenances included repairing the dam regularly, dredging sediment, and guiding the water into the lake. However, the effect was not as expected due to the natural constraints of the river terrain and limited engineering capacities. As a result, the river still broke its banks and flooded vast areas when the water rushed down from upstream every autumn.

Another technique to harness the river was to maintain the overflow channels created by flooding. For example, local people allowed a diversion channel out of Baihan Gorge, which guided the northern ravine flow down from the mountain to the mainstream of Fengyu River. Although this reduced the flood damage around the original riverbanks, it increased sediment delivery to the Fengyu River.

16.3.2.3 Separation of Sand from Water

In response to the difficulties mentioned above, a new idea was to separate the sand and water to control soil erosion at the source and prevent sediment influx to the river. The representative governors of this new river-training approach were Lin Zhonglin (林中麟) and Chen Wei (陈炜) who used to be the chancellors of Langqiong County. As early as in 1753 (the 18th year of Qianlong in Qing Dynasty), Chancellor Lin advocated for building a dry dam of stone at the mouth of Baihan Gorge, which had the effect of separating sands and water, and mitigated flooding within a few years. However, during three days of heavy rain in June 1808, the dry dam collapsed into the due to years of disrepair. Under these circumstances, the new chancellor Chen took over. He realized that the old systems didn't discharge water with enough energy, and consequently the flow was too slow to move sand. He decided to reconstruct the dry dam one hundred feet high and two feet wide and also lengthened it from the foot of the mountain to the southwest. They made use of the uncultivated lands to settle the sands from river dredging. A drought bank was also built around the dam for about a hundred Zhang (丈[15]), and hundreds of willows with strong root-nets were planted behind to strengthen the bank. Water was released at the end of the bank while mud and sand were deposited inside the dam to prevent river siltation.

It is no wonder that the local people all praised "the construction plan [which] was very good for controlling the river, which was no longer harmful for many years thereafter".[16] However, with sediment accumulation over time, the risk of dyke breaching increased, indicating that the need for the establishment of maintenance regulations. The changes correspond to the *release phase* in the resilience theory introduced by

[15] A traditional measurement unit of length in China, 1 Zhang (丈) equals to 3.33 m.

[16] (Daoguang) The Langqiong County Gazetteers".

Holling (2001) that a process loses its former tight organization. It is particularly worth mentioning that this approach was so effective that it was continuously used and maintained for centuries until the present. Due to the building of a recent sand factory in 1980s to intercept sediment upstream at Baihan Gorge, the sediment load and suspended sediment entering the estuary has decreased in both wet and dry seasons. Since then, the permanent goal of mitigating river floods has been certainly attained, and the frequency of flooding has been properly controlled.

16.4 Impacts of the Water Environment Changes

16.4.1 Impacts on Waterways

The evolution of the hydrological system is a basic aspect of the water environment change in the north catchment of Erhai Lake. It includes two factors: one is the movement and change of the river channel and the other is the contraction of the water surface area, both of which changed dramatically during the Ming and Qing Dynasties.

River changes were mainly concentrated in the upstream reaches of the Mici River and Fengyu River. In the seventeenth century, both the Mici and Feng Yu Rivers flowed around the county town of Eryuan, and did not run into Cibi Lake. The Mici River flowed along the east coast of the lake, while the Fengyu River flowed south of the town along the foothills. The Mici and Fengyu Rivers entered the confluence at Sanjiang Port and flowed into the Dengchuan basin through the Putuo Gorge (Fig. 16.5, left). In 1760 (the 25th year of Qianlong in Qing Dynasty), the embankment of Fengyu River broke at Nanshan village, resulting in diversion of the river toward Majiaying; consequently, a new river channel had to be built. Since then, the Fengyu River has flowed northeast, passing by Majiaying, Langqiong County Town, then into Cibi Lake at E'dun village. In addition, numerous artificial canals were excavated for irrigation, as shown in Table 16.3, which greatly changed the appearance of Miju River system.

The other aspect of the river system change is the contraction and expansion of water surface area of Cibi Lake, demonstrating that great changes have taken place many times (Deng et al. 1995). Through analysis of raw historical data and previous studies, this study has also found that there were four phases in this process over the past three hundred years.

- The first phase is during the early Hongwu years of the Ming Dynasty (1382–1398) when the Cibi Lake was relatively large with an area of almost 20 km^2. This was evidenced in "The Travels Journal of Xu Xiake" (徐霞客游记).
- The second phase is during the Hongwu years of the Ming Dynasty (1398) to the Kangxi years of the Qing Dynasty (1654–1722). During this period, the lake's inflow stagnated and the water level gradually decreased. The surface of Cibi Lake

was about 14.2 km^2 and remained stable at about 2055.20 m a.s.l.[17] At that time, the terms "outer sea" were locally used to represent the large and shallow south part while "inner sea" was commonly known for the small and deep north part.[18]

- The third phase began in the Jiaqing years of the Qing Dynasty (1760–1820). The transition into the third phase was mainly caused by continuous flooding. The frequent floods from 1803 to 1808 caused the lake surface to rise. The silt in the lower reaches blocked the river and impeded drainage, which also resulted in the continued expansion of the lake area and increased floods, causing disasters in an extensive area for decades. These high lake levels persisted for a long period of time, until the 1870s at least, and the area of the lake may even have been much larger than the area when Xu Xiake visited in the first stage (Deng et al. 1995; Geng 2015).
- In the fourth phase during the Guangxu years of the Qing Dynasty (1871–1908), the water in the southeast region of Cibi Lake retreated again and the area was just less than 8 km^2 until the middle of 20th century (Deng et al. 1995).

The diversion, storage and siltation situations in different sections of the Miju River system reflected changes of the hydrological and hydro-chemical environments in the past. These changes further influenced other aspects of local environment and society, including the changes in land use pattern and the spread of waterborne diseases.

16.4.2 Impacts on Land Use

The Dengchuan basin in the northern catchment of Erhai Lake is one of the basic economic regions of the Yunnan province, with the average altitude at around 1900 m a.s.l. The runoff area recently contributes to 44% of the total area and 70% of the population in Eryuan County. Crop differentiation in this area shows vertical zonality across the varied topography. As mentioned above, soil erosion has become a serious issue and the vegetation in the mountains has declined over the past six centuries due to increases in human populations and intensified agricultural activities. Areas of natural mountainous vegetation declined to 54% in the middle of the 1950s and lower to 28.6% by the end of the 20th century (Eryuan County Committee 1996). According to the research by Dearing et al. (2008), terrace technology has allowed for the continuous development of this region over the long-term, even under severe water stressed conditions.

Mitigating flood waters and opening up vegetative lands into farmland is not a modern creation. As early as the Tang Dynasty (around the year 785), the Luo brothers donated fields and money to construct a channel along the west foothills, changing the outlet of the West Lake from the Miju River to the Erhai Lake.[19] For over

[17] River and lake chronicles in Eryuan County,1995.

[18] River and lake chronicles in Eryuan County,1995.

[19] (Xianfeng) The Gazetters of Dengchuan.

1200 years the local inhabitants have benefitted from these changes, and accordingly named the river as Luoshi River.

According to previous research on the farming by garrison troops in the Ming Dynasty (Wang 2009a, b), the land they reclaimed was mainly abandoned, rather than in already cultivated lands. The land configuration of three rivers with two lakes (the East and West Lakes) in Dengchuan basin enables the basin to maintain an abundant source of water in the long-term. Liu (2013) found that the indigenous groups who had settled there earlier were mainly living in the piedmont area with higher terrain around the basin, while the garrison troops of the Han People concentrated mainly in the low-lying areas of the central basin. Although the low area of the basin is wide and flat with fertile soil, it was not an ideal area for cultivation because of frequent flood disasters at both sides of the Miju River. Since the Ming Dynasty, the settlement of garrison troops in the center of the Dengchuan basin has brought hydraulic engineering technologies to control floods, drain water and reclaim farmlands near the East and West Lakes.

In 1781 (the 46th year of Qianlong in the Qing Dynasty), an engineering approach was put forward by Gao Shanggui (高上桂), a successful candidate in the highest imperial examinations who was born in Dengchuan. Gao received support from the chief of Dengchuan prefecture and opened up a new channel known as the Yong’an River (Fig. 16.2, right), that diverted the East Lake directly to the Erhai Lake (instead of drainage into the Miju River). This artificial channel (Yong’an River) helped dry out more than 11,200 acres fields for crop planting.[20] The whole basin thereafter became a rich land of breeding fish and rice on the plateau, and Gao’s contribution was rewarded by the Qianlong Emperor.

The low-lying Dengchuan basin is still an important region today, with its 160,629 acres of cultivated land, of which 98,815 acres are paddy fields, accounting for the vast majority of Eryuan County.[21] In the historical period, the land here has undergone anthropogenic transformation that greatly changed the local water and soil features. The migration of large populations in the Ming Dynasty led to tense water conflicts. The local people had to reclaim parts of lake coasts and river beaches for farmland. They also excavated some river channels to not only reduce flooding but also to drain lake water for farming the margins. This had many consequences including the transformation of crop planting structures, as aquatic farming and aquaculture in the newly exposed shallow swamp areas were developed. In the 1980s, there were 2870 acres of aquatic crops, 2340 acres of lake margins and marsh ponds for fishing, and 3790 acres of shallow water for rice and fish farming.[22]

[20](Xianfeng) The Gazetters of Dengchuan.

[21]Eryuan County Committee (ECC) (1996). Local Chronicles of Eryuan County.

[22]See Footnote 21.

16.4.3 Impacts on Waterborne Disease Schistosomiasis Japonica

The Miju River Basin has experienced several epidemics of Schistosomiasis japonica in its history. Outbreaks of this waterborne disease did not happen frequently, but its impacts are broad and deadly. Schistosomiasis japonica is usually associated with sewage-contamination or inadequately treated water. As existing studies have indicated, the water-environmental condition, climatic characteristics and associated biological conditions in the Miju River basin provide a beneficial habitat for *Oncomelania hupensis* (Yang 2004), a particular type of snail hosting Schistosoma japonicum. The density, quantity and spatial distribution of *Oncomelania hupensis* corresponds closely with that of Schistosoma japonicum.

The five conditions necessary for the spread of schistosomiasis are host populations, feces with eggs, snails, water contamination by feces and human contact with contaminated water (Ma et al. 2011). The entry of a large number of immigrants led to a changes in the water chemistry through increased influxes of human and livestock wastes, and thus provided ideal conditions for *Schistosomiasis*. Provision of safe water and sanitation is critical to reduce the outbreak of Schistosomiasis japonica, cholera and other waterborne diseases.

The breeding environment, and consequently the largest area of habitat for the snail is a shallow water zone with slow flow, while other common habitats are grasslands and ponds. The proportion of snails in ponds is decreasing while the proportion of snails in grasslands is on the rise. A possible reason for this trend may be that the grassland proportion of land area in the basin is the largest. The epidemic of schistosomiasis in Eryuan County is closely related to floods in the historical period (Hu 2014). In the process of fighting against floods and droughts, such as the construction of water management projects, harnessing river courses, the construction of bur-rock and the excavation of canals and ditches, the change in the hydrologic environment led to a change in schistosomiasis prevalence.

The excavation of water ditches helped to reduce flood hazards and alleviate pressure on the main channel, yet at the same time, water velocity slowed. The water in ditches was stored for irrigation and improved for water availability in dry seasons or years. On the other hand, the ditch provided suitable habitat for the oncomelania snails. A large number of channels were excavated in a crisscross pattern throughout the whole basin, again increasing the habitat area for oncomelania.

In the chorography of Eryuan County (1996), the epidemic history of schistosomiasis is as recorded:

> In the Tongzhi years of the Qing Dynasty (1862–1874), in Eryuan County, there were "timpanists" and "Shau Kei swelling", "hematochezia" and "dry shake disease" among the doctors of traditional Chinese medicine and the general public, which showed similar symptoms to advanced schistosomiasis ascites. At the beginning of the 1960s, an old farmer from the third battalion of the Yongsheng commune brigade, named Dai Qiyou (66 years old), said that his father saw a patient of "Shau Kei expansion" whose stomach was badly swollen like a Xiaoqi (a basket for washing rice) at the age of 20 when he moved into the Sanying basin,

Table 16.4 Records on the schistosomiasis situation in Eryuan County during the period 1953–1979 (*sources* from the Annals of Eryuan County Schistosomiasis Control)

Villages with recorded schistosomiasis	Situation of schistosomiasis in records
Niujie commune	According to a Chinese memory who are more than 70 year old, his grandfather died of schistosomiasis and one of his daughter is suffering this disease now
Xidian village of Niujie commune	There are 500 mu of land in the Xidian basin, which are full of wild grass which no one is cultivating [due to the disease]
Yichang village of Sanying commune	More than 60 years ago, there were over 70 households and 370 lives, … while there were only 18 households and 66 lives till the mid of 20th. The villager named Cun Bingnan had married three wives but 10 of his family members died of schistosomiasis. Yang Ruxiang's family had 17 persons, while 16 of them died of schistosomiasis
Xunzhuang village of Niujie commune	There used to be over 160 households and more than 300 lives, but there were only 33 households and 120 lives left until the mid of 20th. An old man named Zheng said 14 of his 16 family members died of schistosomiasis
Yousuo commune	Ruan Yuting was only 30 years old, when due to the torture of schistosomiasis he killed himself
Yunxi village of Jiangwei commune	There were over 70 households, but only 20 households left until 1952
Wenyi village of Jiangwei commune	The survey in 1950 reported an 11-year-old girl with potbellied, which is a typical patient of advanced schistosomiasis… the girl married at the age of 18, but finally got pregnant at the age of 30 and the baby was stillborn due to schistosomiasis

Annals of Eryuan County Schistosomiasis Control (1953–1979). A preliminary survey on the prevalence of schistosomiasis in the coastal areas of Erhai, Yunnan. Eryuan County of advanced schistosomiasis control materials—Niujie Xiang

which had already existed among the local farmers in legend. His father died of "Shau Kei expansion" in the end.

Hu (2014) found that the distribution of schistosomiasis in Eryuan County was mainly along the Mici River system in the upstream areas, including the villages of Niujie and Sanying, rather than in downstream where the floods were more severe. Overall, she concluded that the epidemics of schistosomiasis were negatively associated with the frequency of floods (Table 16.4).

As the link between flood and schistosomiasis, *Oncomelania hupensis* is the intermediate host of Schistosoma japonicum. However, the distribution of the snail can be affected by the hydrodynamic conditions of the river. Schistosomiasis is distributed mainly along the main river channel and the center of the basin in low-lying flat terrain where the water has a slow velocity. The population is dense and feces and other waste is dropped into the water, causing water pollution and eutrophication. The blocking of the Miju River upstream resulted in poor drainage, gradual sediment deposition, and slow flow, all of which formed an environment suitable for snail breeding and the outbreak of schistosomiasis in the basin. In contrast, locations where the river course was dredged and the sediment was frequently cleaned up, the occurrence of Schistosomiasis japonica was infrequent because the snail could not survive and thus the transmission of the disease was more difficult.

16.5 Resilience Theory of the Human-Water Relationship

The existence of different development stages could be represented by distinct and relative steady states of adaptive cycle, as indicated in the resilience theory of Holling (2001). From 1482 to 1912, we can identify stages where floods were relatively serious, then diminished in severity by various water control measures. This can certainly be explained as following an evolutionary cycle of the human-water relationship, including exploitation (increasing floods), conservation (control measures), release (slack management) and re-organization (redevelopment of agriculture), but without a clear division of the four phases.

Due to the difference of topography and development degrees in sub-regions of the north catchment of the Erhai Lake, the four stage of resilience theory are not synchronous. As for the Baihan Gorge stream, the evolution was somewhat extreme. The water system of the stream collapsed when the dam burst into the stream and blocked the channel. The stream diverted toward west and flow into Fengyu River, a channel which was maintained thereafter. In this case, the former Baihan Gorge stream changed completely and could not evolve into the *re-organization* stage as stated in adaptive cycle of the resilience theory.

In the case of the Fengyu River, resilience theory can be applied appropriately to the sediment deposition and river diversion. The water velocity dropped quickly when the river flowed to Eryuan County and thus sediment accumulated gradually in the riverbed. The continuous deposition of silt resulted in a dam collapse, and people diverted the river directly into Cibi Lake in the 25th year of Qianlong in the Qing Dynasty (1760). After the excavation of this newly diverted channel, the floods of Fengyu River gradually subsided. Though the diverted channel sediments no longer entered the Sanjiang Port, they continued to silt up in the new channels and in the Cibi Lake. However, after a period of accumulation the siltation affected the water storage capacity of the Cibi Lake, especially during rainy seasons, leading to regular overflowing of the lake. Thus, we argue that the evolution of Fengyu River and its water environment was consistent with the four stages of the adaptive cycle in the resilience theory.

The situation of Miju River was far more divergent from the description of change in resilience theory. The natural Miju River flowed randomly with changing channels (no main stream) before the Ming Dynasty (1368–1744). Following the settlement of military migrants, the random channels were controlled and riverbanks were constructed gradually. Over time, local people opened up many sluices and branch channels in order to both irrigate farmlands and separate floodwater. A dense river network was formed in Dengchuan basin, thus the flow accessibility and water controlling capacity was greatly improved. We can identify the stages of *exploitation* (naturally frequent floods) and *conservation* (channel constructions) in the water governance history of Miju River, though these didn't develop into the *release* stage (slack management) and *re-organization* stage with the continuous maintenance measures.

For the upstream Mici River, the water environment with deep and broad river channels that rarely lead to floods, gave rise to a rich environment for human activity. However, the stable river environment benefited the breeding of Oncomelania Snails that induce schistosomiasis. As described above, local people along the Mici River suffered serious Schistosomiasis japonica outbreaks for over six centuries due to the lack of knowledge regarding the links between river environment and the disease. The disease was better controlled only when research provided allowed for targeted countermeasures from the 1960s. The process over six centuries corresponds well to the stages of *exploitation* (naturally increasing disease conditions), *release* (disease outbreaks) and *conservation* (knowledge and counter measures), but the relationship between human disease and water environment probably won't evolve into the *re-organization* or subsequent *release* stages due to the development of local knowledge regarding prevention of infection.

From the case analysis of these sub-basins, we argue that the adaptive cycles of resilience theory may not be general or universal regarding human-water relationships in the studied area. Especially in a socio-ecosystem where humans can grasp the systemic principles and develop appropriate management capacities by learning and practicing, resilience of the system can be continuously improved in a positive trend.

16.6 Summaries and Outlooks

16.6.1 Summaries on the Human-Water Relationships in the Study Area

It is undeniable that the water environment in the northern basin of Erhai either deteriorated or improved as a response to human activities. Large numbers immigrants greatly changed the hydrologic environment, not only through the construction and excavation of dams, banks and canals, but also through hydro-chemical pathways. Human activities and water management measures changed the drainage system and land use structure, and also changed the hydro-chemical environment to some extent, resulting in the outbreak and spread of typical waterborne disease.

The results of this research indicate that the evolution of the hydrologic environment, including the river system and the hydro-chemical environment had a close interaction with human activities during the last six centuries. Local people constructed various water engineering and conservation projects, and also changed their farming structures to cope with water stresses, which partly contributed to the outbreak and spread of Schistosomiasis japonica. In addition, the study reveals that resilience of the human-water interrelationship weakened under lax or mismanagement of water engineering projects. The sustainable development of the human-water relationship in the Erhai Lake basin could be maintained by regular water management and environmental governance, which is of high relevance for decision making on water management in the present day.

16.6.2 Human Impacts on Evolution of Resilience of Human-Water System

Through the discussions above, it can be found that the hydrologic environment in the northern catchment of Erhai Lake fits in generally with parts of the adaptive cycle in resilience theory described by Holling (2001). After a large number of immigrants moved in, the water environment was subject to a period of rapid development. Meanwhile, the development of the region also brought about a sharp deterioration of the environment and associated water disasters, which was called a serious ecological crisis in the Ming and Qing Dynasties (Zhou 2015). However, with a large number of water management projects, favorable environmental conditions were gradually restored and maintained. In some cases, these projects diminished and coping measures proved to be ineffective, leading to a new loop of the deterioration of the human-water system.

There are certainly some inconsistencies identified in our study. According to resilience theory (Holling 2001), the adaptive cycle as a fundamental unit of a dynamic process is comprised of a forward and backward loop with four phases, however, we cannot identify complete cycles in the sub-basin cases of Erhai Lake. A lack of consideration of social processes and man-made adjustment may lead to deviations. The evolution process of the human-water system did not necessarily follow this cycle of four phases, and if so, they could likely also occur at the same time rather than being distinct or defined separately.

In our Erhai Lake case study, these four phases were largely effected by human activities and could be modulated to a certain degree with front-loops or even back-loops. In other words, without human activities, such as water conservation works, the adaptive cycle of resilience may not finish a complete circle but instead Remain in an undesirable situation. Therefore, the evolution of resilience theory may need to be further articulated by considering the factors of human activities when it is applied to a long-term human-environment evolution process. Humans are not often ineffectual in response to the degradation of the natural environment particularly if we develop a set of effective measures and follow an appropriate management framework.

16.6.3 Outlooks

There are many aspects related to hydrologic challenges that are worth looking into deeper, including the limitations of administrative maintenance and the adjustment by local people in their cooperation during the construction of river projects. The mechanism of river engineering projects and expertise in the Erhai Lake basin has lasted for 530 years, from 1382 when the military migrants settled into 1912 when the Republic of China was established, which formed a mature institutionalization of maintenance. In this period, the human-water relationship has undergone several cycles, while river training and water management measures have mitigated the magnitude of negative impacts. However, the construction and management of engineering projects deteriorate in correspondence with lax governance and management for some sub-periods. Thus, it is necessary to raise awareness among both decision makers and local inhabitants that a resilient and sustainable human-water relationship requires continuous concern and effort.

In addition, folk religion has been deeply influenced by hydrologic challenges in the Erhai basin. Such influences in this region has resulted in a specific "water culture" where the Dragon King became one of three deities worshipped by the local people. These folk religious beliefs have been important through history and are closely related to the daily life and national consciousness of the local Bai people. It would be interesting and meaningful to investigate this cultural perspective of human-water relationships in the tradition of the Bai people. Such research could be informative to the broader concerns on human-environment interactions under present global changes and local governance, and to broader areas in the mountainous regions China and South Asia.

References

Adger, W. N., Hughes, T. P., & Folke, C. (2005). Social-ecological resilience to coastal disasters. *Science, 309*, 1036–1039.

Berkes, F., & Seixas, C. S. (2005). Building resilience in jagoon social-ecological systems: A local level perspective. *Ecosystems, 8,* 967–974.

Crook, D., Elvin, M., Jones, R., Ji, S., Foster, G., & Dearing, J. (2008). The history of irrigation and water control in China'S Erhai catchment: Mitigation and adaptation to environmental change. In: E. Wiegandt (Eds.). *Mountains: Sources of Water, Sources of Knowledge*. Advances in Global Change Research (Vol. 31).

Dearing, J. A. (2008). Landscape change and resilience theory: A paleo-environmental assessment from Yunnan, SW China. *The Holocene, 18*(1), 117–127.

Dearing, J. A., Jones, R. T., Shen, J., Yang, X., Boyle, J. F., Foster, G. C., et al. (2008). Using multiple archives to understand past and present climate-human-environment interactions: The lake Erhai catchment, Yunnan Province, China. *Journal of Paleolimnology, 40*(1), 3–31.

Deng, H., Zhu, J. H., & Li, X. F. (1995). The research on the change of Cibi Lake for recent 300 years based on Xu xiake's travel. *Geographical Research, 1,* 36–43.

Ding, Y., Tang, D., Dai, H., & Wei, Y. (2014). Human-water harmony index: A new approach to assess the human water relationship. *Water Resources Management, 28*(4), 1061–1077.

Ding, Y. F., Tang, D. S., Dai, H. C., & Wie, Y. H. (2014). Human-water harmony index: A new approach to assess the human water relationship. *Water Resources Management, 28*(4), 1061–1077.

Eryuan County Committee (ECC). (1996). *Local Chronicles of Eryuan County*.

Eryuan County Water Conservancy and Electric Power Bureau (ECWCEPB). (1995). *Eryuan County Rivers and Lakes Collection*.

Geng, J. (2015). The evolution of lotus community in Cibi Lake and the change of water environment in Ming and Qing Dynasties. *Journal of Guizhou Education University, 31*(10), 6–14.

Harper, C., & Snowden, M. (2017). Environment and society: Human perspectives on environmental issues. *Taylor & Francis,* 466.

Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics, 4,* 1–23.
Holling, C. S. (2001). Understanding the complex of economic, ecological and social system. *Ecosystems, 4,* 390–405.
Hu, Q. (2014). *The epidemic history of schistosomiasis—A case study of Eryuan county and Weishan County*. Master's thesis of Shanghai Jiao Tong University.
Huang, H. J., Li, Q. H., & Gao, Y. Z. (2014). Analysis on influence system of regional heavy rainfall and its circulation characteristics in Dali. *Plateau and Mountain Meteorology Research, 3,* 45–50.
Ji, C. D. (1981). *The basic economic zone in Chinese history and the development of water conservancy*. China Social Sciences Press.
Ji, Y. H., Zhou, G. S., Wang, S. D., & Wang, L. X. (2015). Increase in flood and drought disasters during 1500–2000 in Southwest China. *Natural Hazards, 77*(3), 1853–1861.
Klein, R. J. T., Smith, M. J., & Goosen, H. (1998). Resilience and vulnerability: Coastal dynamics or dutch dikes? *The Geographical Journal, 164,* 159–268.
Lan, Y. (2008). Reflections on the research status of the Southern Silk Road. *Forum on Chinese Culture, 2,* 44–45.
Lander, B., Mostern, R., Sun, J. H., Xiong, Y. B., & Lu, X. Q. (2017). A conversation on the study of water in environmental history. *Journal of Zhejiang University (Humanities and Social Science), 3,* 47–57.
Lautze, J., Reeves, M., & Vega, R. (2005). Water allocation, climate change, and sustainable peace: The Israeli proposal. *Water International, 30,* 197–209.
Li, B. Z. (2006). *Agricultural development in the Yangzi Delta,1620–1850*. Houndmills, England: The Macmillan Press Ltd.; New York, USA: St. Martin's Press, Inc.
Li, S. Q., Huang, Y. Z. (1998). *Kangxi "Dali's history"*. Republished by Beijing Library Press.
Lin, J. Y. (1982). Study on the geology and petro-chemistry of Permian basalts, Ehenghai-Erhai district, Yunnan. *Bulletin of the Chengdu Institute of Geology and Mineral Resources, The Chinese Academy of Geological Sciences*, 49–59.
Liu, C. M., Wang, Y., Shao, M. G., & Hou, X. Y. (2012). *Water science and technology in China: A Roadmap to 2050*. Springer Science & Business Media, 22.
Liu, L. P. (2013). *National governance in Erhai Area and the identity to Bai People in Ming and Qing Dynasties*. Fudan University.
Liu, Y., & Yang, Y. (2012). Spatial distribution of major natural disasters of China in historical period. *Acta Geographica Sinica, 67*(3), 291–300.
Ma, W., Liao, W. G., & Feng, S. X. (2011). *Hydrology influence mechanism and risk assessment method of schistosomiasis transmission*. China Water Conservancy and Hydropower Press.
Palace Museum in Taipei. (1982). *Memorials to the throne in Qianlong of Qing dynasty*. Palace Museum in Taibei Press.
Pelleg, J. (2012). Mechanical properties of materials. *Technology & Engineering, 634*.
Simmons, B., Woog, R., Dimitrov, V. (2007). Living on the edge: A complexity-informed exploration of the human–water relationship. *World Futures, 63*(3–4), 275–285.
Sun, J., Wang, J., & Yang, X. J. (2007). An overview on the resilience of social-ecological systems. *Acta Ecologica Sinica, 27*(12), 5371–5381.
Tan, Q. X. (2000). *Reasons of long term safety of the Yellow River after the Eastern Han Dynasty*. Collection of Changshui (长水集) (pp. 481–517), Hebei Education Press.
Turner II, B. L., Clark, W. C., Kates, R. W., Mathews, J. T., Richards, J. F., & Meyer, W. B. (1990). *The earth as transformed by human action: Global and regional changes in the biosphere over the past 300 years* (p. 713). Cambridge University Press.
United Nations World Water Assessment Program (UN-WWAP). (2015). *The United Nations World Water Development Report 2015: Water for a sustainable World*. Paris: UNESCO.
Wang, J. G. (2013). *Water ecology and the society of the south of the Yangtze River (9–20 century).* Peking University Press.
Wang, J. G. (2015). The Change of Water Environment in Jiangnan and the literati style change in history—Centering the analysis of the poetry on the girls pick water-chestnuts. *Folklore Studies, 5,* 125–135.

Wang, J. H., Wei, Y. P., Jiang, S., Zhao, Y., Zhou, Y. Y., Xiao, W. H. (2017). Understanding the human-water relationship in China during 722 B.C.-1911 A.D. from a contradiction and co-evolutionary perspective. *Water Resources Management, 31*(3), 929–943.
Wang, P. J. (2009). Some thoughts on the Chinese traditional culture of water. *China Water Resources, 11*.
Wang, Y. Q. (2009). Farming by garrison troops in Ming Dynasty. *Zhong Hua Book Company,194*.
Wu, B., Qin, J., Wang, Q., Gao, T., & Liu, Z. L. (2012). The variation in the water quality along the Miju River on the North Bank of Lake Erhai. *Journal of Yuxi Normal University, 28,* 26–29.
Wu, J. C., & Zhang, J. F. (2009). *The water environmental chemistry* (p. 259). China Water Power Press.
Xu, Z., Wang, Q. H., Duan, D. Z. (1987). *Southern Silk Road*. Yunnan National Press.
Yang, G. G., Li, W. Y. (1996). *Chronicles of Eryuan County*. Kunming: Yunnan People's Press.
Yang, H. G. (2004). *The land chronicles of the Dali Bai Autonomous Prefecture*.
Yang, L. E., Wiesehöfer, J., Bork, H. R., Hoo, M. (2017). The role of environment in the socio-cultural changes of the Ancient Silk Road Area. *Past Global Changes Magazine, 25*(3), 165.
Yang, Y. D. (2007). *Human-land relationship and environmental changes in small and medium river basins: The research on the flood of Miju River in Qing Dynasty* (pp. 28–53). Shanghai Jiao Tong University press.
Yang, Y. D., Man, Z. M., & Zheng, J. Y. (2006). Reconstruction of series in later or earlier starting date of rainy season in Yunnan Province and Evolvement of Summer Monsoon in Qing Period. *Acta Geographica Sinica, 7,* 705–712.
Yuan, B. (2014). *A historical investigation of water culture in modern China*. Master's thesis of the Shandong Normal University.
Zhang, J. Y., & Wang, X. J. (2014). Knowledge and reflections on the construction of aquatic ecological civilization. *China Water Conservancy, 7,* 1–4.
Zhang, Z. K., Wu, R. J., Zhu, Y. X., Pan, H. X., Wu, Y. H., Xia, W. L., et al. (2000). Lacustrine records of human activities in the catchment of Erhai Lake, Yunnan Province. *Acta Geographica Sinica, 55*(1), 66–74.
Zhou, H. (1976). *Local Chronicle of Langqiong County*. Republished by Taipei County dome, written press.
Zhou, Q. (2015). *Research on ecological frontier in the view of environmental history*. *Thinking, 41*(2), 85–96.
Zhou, Z. Y., Zhao, S. M. (2007). *The new compilation compilation of Yunnan Tongzhi, volume eighteen "weather test"*. Yunnan People's Press.