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Article

Evaluation of Tourism Water Capacity in Agricultural Heritage Sites

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Abstract: Agricultural heritage sites have been gaining popularity as tourism destinations. The arrival of large numbers of tourists, however, has created serious challenges to these vulnerable ecosystems. In particular, water resources are facing tremendous pressure. Thus, an assessment of tourism water footprint is suggested before promoting sustainable tourism. This paper uses the bottom-up approach to construct a framework on the tourism water footprint of agricultural heritage sites. The tourism water footprint consists of four components, namely accommodation water footprint, diet water footprint, transportation water footprint and sewage dilution water footprint. Yuanyang County, a representative of the Honghe Hani rice terraces, was selected as the study area. Field surveys including questionnaires, interviews and participant observation approaches were undertaken to study the tourism water footprint and water capacity of the heritage site. Based on the results, measures to improve the tourism water capacity have been put forward, which should provide references for making policies that aim to maintain a sustainable water system and promote tourism development without hampering the sustainability of the heritage system. The sewage dilution water footprint and the diet water footprint were top contributors to the tourism water footprint of the subject area, taking up 38.33% and 36.15% of the tourism water footprint, respectively, followed by the transportation water footprint (21.47%). The accommodation water footprint had the smallest proportion (4.05%). The tourism water capacity of the heritage site was 14,500 tourists per day. The water pressure index was 97%, indicating that the water footprint was still within the water capacity, but there is a danger that the water footprint may soon exceed the water capacity. As a consequence, we suggest that macro and micro approaches, including appropriate technologies, awareness enhancement and diversified tourism product development throughout the whole year that can alleviate the water pressure at critical times, could be taken to optimize the water management of the heritage sites.

Keywords: agricultural heritage systems; sustainable tourism; tourism water footprint; tourism capacity

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1. Introduction

The agricultural heritage systems covered under the GIAHS (Globally Important Agricultural Heritage Systems) program are defined by FAO (Food and Agriculture Organization of the United Nations) as "remarkable land use systems and landscapes, which are rich in biodiversity evolving from the ingenious and dynamic adaptations of a rural community to its environment, in order to realize their socio-economical, cultural and livelihood needs and aspirations for a sustainable development" [1]. Among these heritages, the Hani terrace system is one of the best examples of human wisdom to adapt to, and be in harmonious existence with, nature. The Hani terraces have formed spectacular "forest-village-terrace-river" ecological landscapes, which spread for more than 70,000 ha over 1300 years. The Hani people, their indigenous agricultural technologies and practices, their selection of settlement sites and traditional customs for environmental protection and conservation all show an adaptive relationship with nature [2–7]. These practices have been developed over time, and invariably involve the management of water.

These living heritages are valuable not only for production and ecology, but also for tourism. They are typical compound systems of nature, society and economy that present features of both natural and cultural heritage, which have become popular tourism destinations for both domestic and foreign tourists for their unique biological, cultural, aesthetic and scientific values. The development of tourism surrounding the agricultural heritages produces both benefits and challenges. On the one hand, it enhances the public's understanding and awareness of the protection of the heritage sites, yields significant economic and social benefits that improve the cultural awareness and confidence, as well as the welfare of local people. On the other hand, the biological environment of the agricultural heritage sites is highly sensitive and fragile, and vulnerable to the disruption of external activities. The situation has been worsened by climate change, which, for example, causes the continuous lowering of water reserves. Hence, traditional agriculture is facing grave resource depletion challenges. A large number of tourists would stretch even further the local water supply system, threatening the sustainable development of the agricultural heritage. Before developing tourism, a water-intensive sector [8–10], tourism water consumption should be measured, as well as the pressure on water resources.

As fresh water availability is increasingly under pressure [11], tourism water consumption has received growing attention by international scholars [9,12–15]. By reviewing studies, it gradually becomes clear that tourism water consumption is not limited in hotels, swimming pools and other tourist infrastructures. Tourism also causes indirect water consumption [10,15] because of its strong linkages with other sectors [16–19], for example, fossil fuels, diet and the construction of tourism infrastructure contain indirect water consumption [10]. Research shows that indirect water consumption of tourism activities is far more significant than direct water consumption, an insight that reverses the previous understanding that tourism water consumption can be overlooked [10,20,21].

Water footprint (WF) is widely used to measure the scarcity of water resources in the study and application of theories on tourism water consumption. It presents a comprehensive assessment of water consumption [20–23]. The concept of "water footprint", introduced by Hoekstra and subsequently elaborated by Hoekstra and Chapagain, provides a framework to analyze the link between human consumption and the appropriation of the globe's freshwater [24,25]. The WF of a product (alternatively known as "virtual water content") expressed in water volume per unit of product is the sum of the WFs in the process steps taken to produce the product [26]. It takes into account the volume and types of water consumed and of the pollutants generated. It considers the water consumed both directly and indirectly [25]. At present, the WF is mainly measured through the bottom-up component-based approach and the top-down input–output approach [21]. Both approaches have merits and weaknesses [27]. The latter tracks the entire supply chain of the sector. For example, Cazacrro *et al.* estimated the WF caused by domestic and foreign tourists in Spain based on trade data of the agriculture and industry sectors, as well as of the service industries represented by tourism [20]. The former, on the other hand, divides water consumption into direct and indirect consumption, instead of studying the supply chain of the tourism sector [10]. Because of limited data availability, researchers have mostly used the bottom-up approach. One such research, conducted by Hadjikakou *et al.*, proposed the concept of "total water footprint" and studied the tourism water use of a semi-arid area in the eastern Mediterranean [22]. The result showed that the food that tourists consumed was the largest contributor to the tourism WF. Gössling *et al.* adjusted the WF indicators to make the model more applicable, which was then tested in a case study of Rhodes, Greece [21]. Yang *et al.* calculated the tourism WF of northwestern Yunnan, China, by dividing the water use into three components, namely direct water use, catering water use, and water for diluting sewage [28].

Considerable progress has been achieved in the studies of tourism WFs. However, studies of the tourism WF of agricultural heritage sites and other specific types of tourist destinations are still lacking. They will be of great importance as they give a comprehensive depiction not only of tourism water consumption, but also of the use intensities of water resources at the heritage sites. To fill this gap, this paper studies the tourism WF indicators of the Hani Rice Terraces, a GIAHS site in China. Rice-fish-duck farming systems are water dependent, which makes the choice of research site even more appropriate. Our paper aims to assess the tourism WF and the water capacity of the subject area. To do so, this paper (1) constructs a framework for assessing the tourism WF of the agricultural heritage sites; (2) assesses the tourism WF of the Hani rice terraces using data collected through questionnaires and interviews; (3) analyzes tourism water capacity of the subject area; and (4) proposes measures that would improve the tourism water capacity of the subject area which would lend support for policies on sustainable utilization of water resources at the heritage site, and tourism development in general.

2. Materials and Methods

2.1. Study Area

2.1.1. Profile of the Study Area

The subject area of this study is the Hani Rice Terraces, a system with a history of over 1300 years, and a masterpiece of local farmers, most of whom are Hani people. The heritage system was listed as a GIAHS in 2012 and a World Heritage Site in 2013. It is the first site in China to be honored with the both titles, and the only World Heritage Site with an agricultural theme in China. The heritage site, located at the southern bank of the Honghe River, covers the typical distribution area of the Hani terraces, including Honghe, Yuanyang, Lv'chun and Jinping counties of Honghe Hani and Yi Autonomous Prefecture in Yunnan Province. This paper mainly looks at Yuanyang County, which has seen the most rapid development of tourism among the areas in recent years (Figure 1).

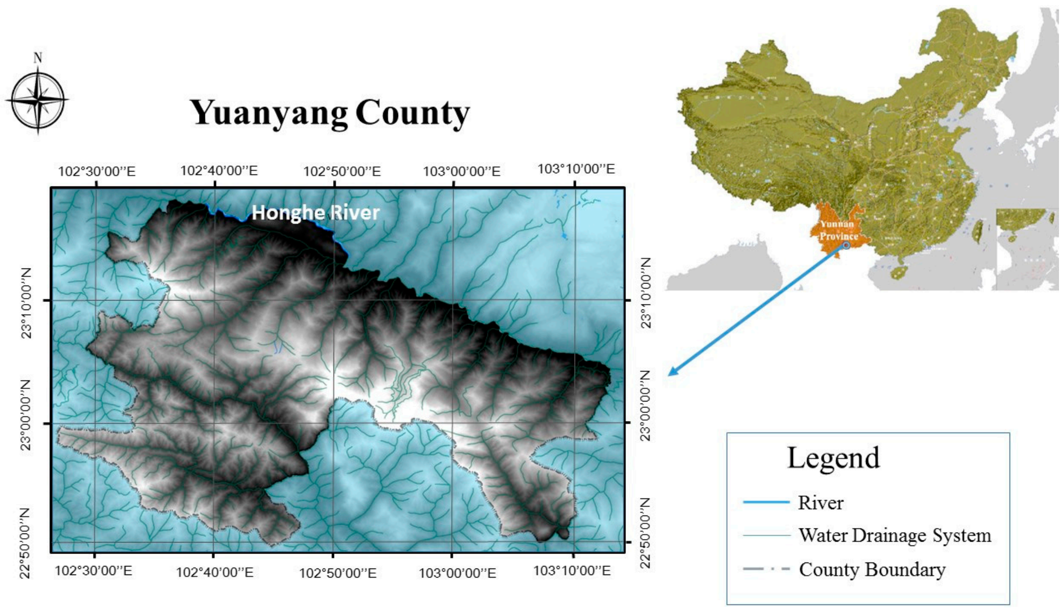

Figure 1. The location of Yuanyang County, Yunnan Province, China.

2.1.2. Tourism Development at the Heritage Site

Becoming a World Heritage Site, the Hani terraces have been rapidly gaining popularity. As a result, tourism has been greatly boosted. The number of tourists has been soaring. In 2014, a total of 1,252,590 tourists visited Yuanyang County (up by 16.65% on the previous year), bringing a tourism income of RMB 175.936 million (up by 33.75%) (Figure 2).

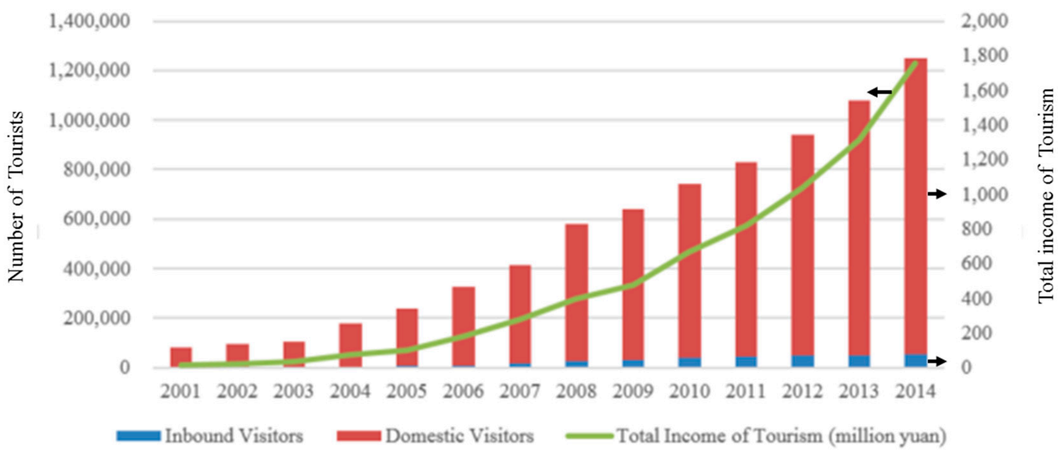

Figure 2. Trends of Tourist Arrivals and Tourism Income of Yuanyang County.

The heritage site enjoys monopolistic and quality tourism resources. However, tourism is still considered to be under-developed despite a rapid growth in tourist arrivals. The tourism market still has a relatively small volume. In 2014, the tourist arrivals of the Yuanyang County accounted for only 0.08% of the tourists in Yunnan Province, with a tourism income 0.09%. It can be seen that tourism resources of the county have not yet been highly developed, indicating promising potentials in tourism development by the tourism industry and local authorities. However, while tourism can bring positive economic benefits, it also causes biological and environmental challenges. One of them is the scarcity of water resources. Water is an indispensable and irreplaceable environmental factor for the agricultural system and an essential resource for tourism development. For the Hani terraces, it is the most important factor, and the key for protecting the heritage site. Rapid increments of tourist arrivals will cause the water demand to skyrocket. This, together with global climate change, has made water capacity a vital issue that must be sorted through before promoting further tourism at the heritage site.

2.1.3. Utilization of Water Resources at the Hani Terraces

The residents at the heritage site demonstrate great wisdom and experience in the use of water resources. In the Hani terraces, the locals have developed a complex water management system to use water resources in a sustainable way [2], such as the invention of wooden/stone water barriers, the *shuizhang* (The "*shuizhang*" is the master of the water ditches and use his knowledge about the relationship between forest and water to determine dates and flows) institution, and rice terraces water control [7]. Besides, the heritage system shows a clear vertical structure made up of forests, water system, terraces and villages on the valley sides. They make up a sophisticated system of water allocation based on controlled gravity flow (Figure 3). Water is at the center of the heritage system. It enters the system through rainfall, then flows down along the forests covers and gathers at an altitude higher than the villages. This water meets the daily demand of the villagers. The surface flows then carry the wastewater, manure of both human beings and livestock, and household waste to the rivers via the terraced fields [29,30].

Development at the heritage site has brought a large number of tourists to the area. As a result, hundreds of rural home inns and restaurants have emerged along the roads in the heritage sites and more are being built. These inns and restaurants draw water from the upland source to meet their daily demands. This results in irrational allocation of water resources, and vastly reduces the water for irrigation in the terraces. Tourism has become one of the main causes of dry-out at the terraces [31], which, ironically, is the very feature that tourists come to see. Meanwhile, the domestic sewage produced by these inns and restaurants adds pressure onto the environment of the terraces, threatening the sustainability of the heritage site.

Figure 3. Water Circulation of the Hani Terraces.

2.2. Data Sources

Basic data: The main sources including data about the residents of Yuanyang County and villages, types and average consumption of food per person per day, domestic water use, unit electricity consumption, transportation, *etc.* were taken from the Statistical Yearbooks of Honghe Hani and Yi Autonomous Prefecture (2013–2015) [32], and statistics of relevant government departments [31,33].

Survey data: Surveys were conducted during August 2014, November 2014, May 2015 and July to August 2015 in four villages in the subject area, where tourists visit and stay most often (Pugaolaozhai, Jingkou, Dayutang and Huangcaoling). Through the surveys, consumption data of the tourists were collected, such as types and average consumption of food per person per day, water and electricity consumption, origins of the tourists, transportation means, *etc.* The respondents included tourists, local residents, the county tourism bureau, tourism companies, rural home inns, hotels, *etc.*

Standard data include energy consumption of different transportation means, energy consumption of accommodation, embodied water use per unit of crude oil, embodied water use per unit of food, domestic water to sewage coefficient, sewage diluted coefficient. The data mainly came from relevant literature and official standards [21,28,34–38] (Figure 4).

2.3. Methods

Water use of accommodation, tourist activities, fuel and diet of different areas and types vary considerably (Table 1) [10,21]. In this paper, the bottom-up component-based approach is applied. Considering the components of tourism consumption at the heritage site, this research assesses the WF using four indicators, namely accommodation WF, diet WF, transportation WF and sewage dilution WF. Entertainment WF is not included in this paper in light of the variation in the characteristics of tourism resources and activities at the heritage site. The sewage dilution WF is included considering the impacts of sewage produced by tourism on the agriculture ecological environment. The four indicators add up to the WF per unit of tourism. On this basis, one can assess the tourism water capacity of the heritage site and thus measure the pressure on local water resources.

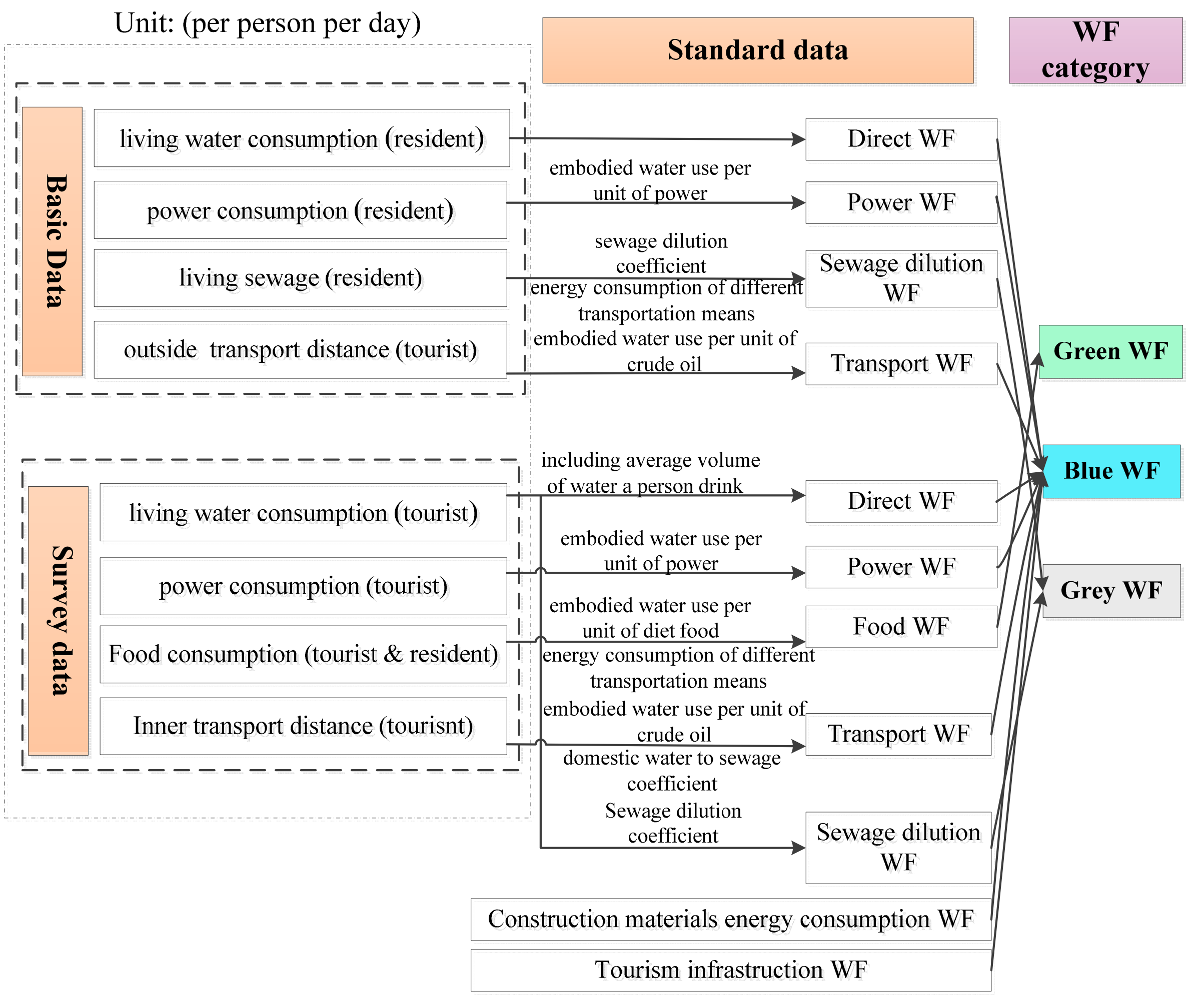

Figure 4. Data sources in this research.

Table 1. Direct and indirect water use in global tourism.

Water Use Category	Indicator	Min-Max in L/Guest Night	Estimated Average L/Guest Night
Direct water use	Accommodation	84–2425	350
	Activities	10–875	20
Indirect water use	Infrastructure	0.2	0.2
	Fossil fuels for transport	5–2500	130
	Energy use at hotel	0.3–200	75
	Biofuels	2500	-
	Food	4500–8000	6000
	Other consumption	n.a.	n.a.
Total	Total	4600–12,000	6575

Data Source: Gössling *et al.*, 2012, 2015 [10,21] (The data was gathered and updated from the literature for each category in the two papers by Gössling *et al.*).

2.3.1. Tourism WF at the Heritage Site

Step 1: Calculate accommodation WF. Accommodation water use includes direct and indirect water use. The first includes water spent on taking showers, doing laundry, for drinking and use in the kitchen. The latter includes water used to produce fuels, and in the tourism infrastructure. Accommodation WF refers to the daily average volume of water used in accommodation per tourist per day.

$$W_{\text{accommodation}} = \sum_{i=1}^{n} (\bar{V}_d)_i + \bar{V}\text{e} + \bar{V}\text{c} \tag{1}$$

where $(\bar{V}_d)_i$ is the average of i, the direct water consumption in accommodation per tourist per day; $\bar{V}$e refers to the average WF of energy use per tourist per day; and $\bar{V}$c refers to the average WF of the tourism infrastructure per tourist per day.

Step 2: Calculate diet WF. The diet WF mainly measures the average volume of virtual water embodied in the food consumed per tourist per day.

$$W_{\text{catering}} = \sum_{i=1}^{n} \left[\bar{f} \times (V_g)_i\right] \tag{2}$$

where $\bar{f}$ represents the average amount of Food i consumed per tourist per day; and $(V_g)_i$ refers to the water coefficient for growing and producing Food i.

Step 3: Calculate transportation WF. This measures the water embodied in the fuels consumed by tourists when they travel from their hometown to the tourist destinations, and within the tourist sites.

$$W_{\text{transport}} = \left(\sum_{i=1}^{n} D_i C_i + D_l C_l\right) \times \alpha \tag{3}$$

where D_i stands for the average distance that a tourist travels by Transportation Means i. C_i stands for the unit energy consumption per capita of Transportation Means i. D_l stands for the average distance traveled by one tourist by Transportation Means l within the tourist sites. C_l stands for the per capita energy consumption of the transportation means within the tourist sites. α refers to the virtual water embodied per unit of fuel.

Step 4: Calculate sewage dilution WF. The concept refers to the volume of fresh water needed to dilute the average volume of sewage discharged per tourist per day. The sewage contains a variety of pollutants, which need different amounts of water to lower their concentration to harmless levels. The largest water amount is used in the function [36].

$$W_{\text{dilute}} = \bar{V}_w \times \left[\max\left(\frac{\bar{p}_i}{s_i}\right) - 1\right] \tag{4}$$

where $\bar{V}_w$ stands for the volume of sewage discharged per tourist per day. $\frac{\bar{p}_i}{s_i}$ is the dilution coefficient, in which $\bar{p}_i$ stands for the average concentration of Pollutant i in the tourism sewage, while s_i stands for the background concentration of Pollutant i in local water.

Step 5: Calculate tourism WF at the heritage site. The tourism WF is the sum of the abovementioned indicators.

$$W_{\text{tourist}\cdot p} = W_{\text{accomodation}} + W_{\text{catering}} + W_{\text{transport}} + W_{\text{dilute}} \tag{5}$$

where $W_{\text{tourist}\cdot p}$ refers to the total WF per tourist per day.

2.3.2. Tourism Water Capacity at the Heritage Site

From the perspective of WF, the tourism water capacity of an area refers to the largest number of tourists that average local water resources can accommodate. The calculation of tourism water capacity of the heritage site is based on two assumptions. (1) The heritage site produces low yields of agricultural products with high value. Besides meeting local people's demands, they are mainly consumed by tourists. Therefore, there is no outbound transportation demand in terms of these products. Thus, transportation cost of agriculture productions can be saved. (2) Unlike in scenery tourist sites or enclosed heritage sites, residents of the Hani terraces are not only the most important components of the system, but also the producers of the tourism resources. Therefore, they should be the direct beneficiaries of tourism development. To be in line with the principle of community development, all the practitioners of tourism are local residents. Under these assumptions, the WF of the tourists and the residents can be summed to the total WF, which has to be sustained by the local water capacity.

Following is the function of daily water capacity of the heritage site:

$$N_{tourists} = (W_{total} - W_{locals}) / W_{tourist \cdot p} \; (W_{total} \leq W_{available}) \quad (6)$$

where $N_{tourists}$ refers to the number of tourists the heritage tourism destination can receipt; W_{total} is daily WF for both locals and tourists living in the area; W_{locals} is daily WF of local residents, including the accommodation, diet, transportation and sewage dilution WF of both urban and rural residents; $W_{tourist\ p}$ refers to daily tourism WF for a person; and $W_{available}$ refers to the daily available water resources for satisfying living needs in the area both locals and tourists.

2.3.3. Pressure of Water Resources of the Heritage Site

Water resources pressure is a measurement of water use intensities based on the theory of WF. The function is as follows:

$$WP = {}^{W_{total}}/_{W_{available}} \quad (7)$$

where WP refers to the index of water resources pressure; W_{total} is total WF for both locals and tourists living in the area; and $W_{available}$ is the volume of available water resources of the area for satisfying both locals and tourists living needs. When the WP is higher than 1, the water system is overloaded. When WP is lower than 1, the total WF of the area is still within the water capacity of the area, which means that there is still room for further use of the water resources.

3. Results and Discussion

3.1. Results

3.1.1. Accommodation Water Footprint

The Accommodation WF measures both the direct and indirect water use of the tourists during their stay at the hotels and guesthouses. The direct water use includes the water spent for taking showers, flushing toilets, doing laundry, cooking, drinking, washing cars, cleaning, *etc.* Indirect water use includes the water embodied in the fuels and tourism facilities (Figure 5).

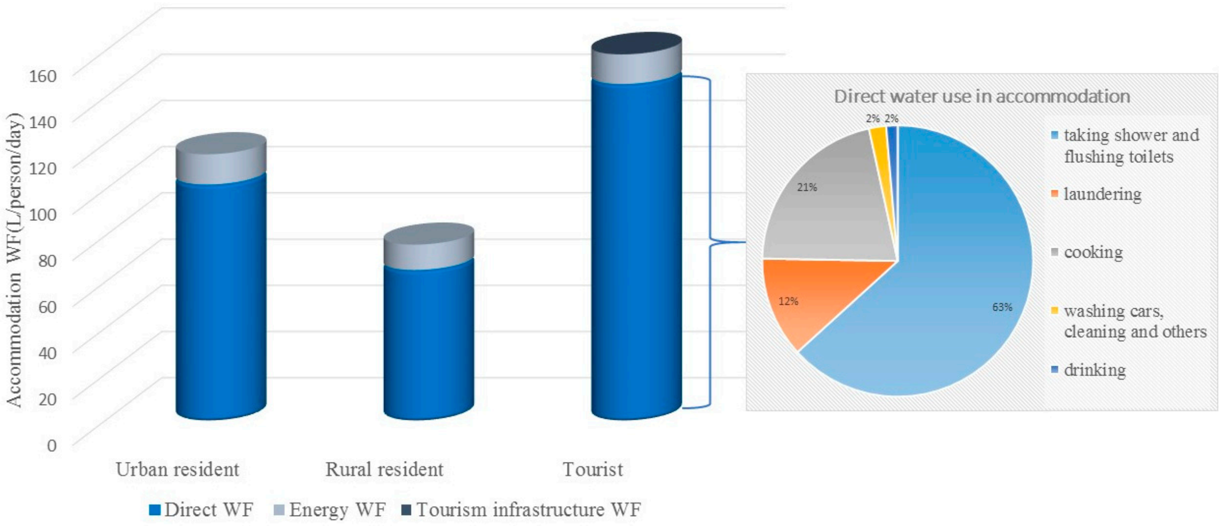

Figure 5. Accommodation water footprint in Yuanyang.

(1) Direct water use by a tourist was 146.5 L/person/day, 63.3% of which was spent on taking a shower and flushing toilets, 21.3% on cooking, 12.0% on laundry and 2.1% on washing cars, cleaning and other domestic activities. The average volume of water a person drinks was 2.0 L per day. The data were collected during August 2014 and May and July 2015 through random sampling. A total of 15 family inns at the heritage site were sampled. The average direct water use of the tourists was somewhat higher than that of the urban residents (103 L/person/day), and much higher than that of the rural residents (66 L/person/day) [33]. In fact, it was 2.2 times that of the rural residents.

(2) Energy WF: The research showed that the tourists in the Hani terraces consumed about 3.5 kWh of electricity per person per day. At an estimated 0.8 L of water per kWh [39], this suggested an energy-related WF of 2.8 L per tourist per day. The WF related to building energy consumption was 10 L per person per day if the service life of the hotels and rural inns was assumed to be 50 years [40]. Therefore, the energy related WF of the tourists added up to 12.8 L per person per day. The average energy consumption of the local urban residents was 3.9 kWh per person per day, which indicated a WF of 3.1 L per person per day. This and the WF of building energy consumption added up to a total energy-related WF of 13.1 L per person per day. The average energy consumption of the rural residents was 2.2 kWh per person per day, indicating a WF of 1.8 L per person per day. The sampling showed that about 92% of the rural residences were of masonry structure, the energy consumption of which was about 10 L per person per day. Eighteen percent of the rural residences were adobe houses with an energy consumption small enough to be overlooked. Therefore, the total energy-related WF of the rural residents was 11 L per person per day. In review, there was not much difference between the energy-related WF of the tourists, and urban and rural residents.

(3) Tourism infrastructure WF: The tourism infrastructure WF, a part of the indirect water use, was overlooked in the earlier studies of water footprints. This situation changed when Rosello-Batie *et al.* revealed that the construction of one square meter of tourism infrastructure used 85 L to 97 L of water in their studies of three hotels on the Ballearic Island [40]. The WF is considerable for tourism infrastructures such as airport, harbors, roads, museums and rinks. However, in the case of agricultural heritage sites, the demands on tourism infrastructure are relatively low, which allows the heritage site to

preserve their original appearance. For example, only several viewing decks have been set up at the Yuanyang Hani terraces. Thus, this paper sets the tourism infrastructure WF at 0.2 L per person per day, which is the basic level (Table 1) [21].

(4) Accommodation WF: According to Equation (1), the accommodation WF of the Yuanyang Hani terraces was the sum of the direct water use, the energy-related WF and the tourism infrastructure WF. The result was 159.5 L per person per day, which was higher than those of the urban and rural residents, 116.1 L and 77 L per person per day, respectively. Direct water use was the largest component of the accommodation WF of the tourists, as well as of the urban and rural residents (Figure 5). The proportions were 91.8%, 88.7% and 85.7%, respectively. Another observation was that the water used directly and the virtual water embodied in energy use was local water. Meanwhile, the water embodied in the building materials of residential and tourism infrastructure was imported water, constituting an imported WF. This meant that for the accommodation WF of the tourists, 149.3 L per person per day was local water, 10.2 L per person per day was imported water; of the urban residents and 106.1 L per person per day was local water and 10 L per person per day was imported water; and for the rural residents, 67.8 L per person per day was local water and 9.2 L per person per day was imported water.

3.1.2. Diet Water Footprint

In the Hani terraces, the consumption behavior of the tourists was different from that of the local residents. Field investigations were conducted to figure out the food consumption coefficients of the urban and rural residents of the Yuanyang County, and that of the tourists, which were used to calculate the diet WF of the three groups (Table 2).

Table 2. Diet water footprint of urban and rural residents and of tourists in Yuanyang.

Category		Grain (Rice)	Meat	Vegetable	Consumption (kg/person/day)	Diet WF (L/person/day)
Consumption coefficient ** (kg/person/day)	Urban residents	0.18	0.12	0.56	0.86	1788
	Rural residents	0.43	0.10	0.45	0.98	2047.5
	Tourists	0.14	0.10	0.14	0.38	1421
Water coefficient * (L/kg)		2000	11200	150	-	-

* The data sources of the water coefficients are from previous studies [41]; ** The data were collected during August 2014, and May and July 2015 through random sampling. A total of 20 urban households, 20 rural households and 20 tables of tourists at the heritage site were sampled.

Table 2 shows that the food consumption of the tourists was only 0.38 kg per person per day, lower than those of the urban and rural residents, which were 0.86 and 0.98 kg per person per day, respectively. Even though the total consumption amounts were quite different, the consumption of meat was similar, between 0.1 and 0.12 kg per person per day. Grain took up a high proportion of the rural residents' food consumption (43.9%), much higher than that of the tourists (36.8%) and the urban residents (20.9%). The reason was that the level of mechanization was low at the heritage site. This left much manual work to the farmers, who have to work intensively. Therefore, they need a lot of grain to keep up their strength. The urban and rural residents consumed similar amounts of vegetables, 0.56 and 0.45 kg per person per day, respectively. Tourists consumed less, only 0.14 kg per person per day. This was because the local residents favored vegetables, especially wild vegetables.

Using Equation (2), this paper estimated the WF of the food the urban residents, rural residents and tourists consumed. The results were 1788 L, 2047.5 L and 1421 L per person per day, respectively. This paper assumed that the diet WF consisted only of local WF. Though the consumption of meat was lower than those of grains and vegetables, the footprint it caused was higher for meat as it embodied more virtual water. The proportion of meat WF in diet WFs of the tourists, urban and rural residents were 78.8%, 75.1% and 54.7%, respectively, and all higher than 50%. The grain WF of the rural residents was 1500 L per person per day, taking up 28.5% of their diet WF. This was because the rural residents consumed a large proportion of grains. However, despite the fact that vegetables made up 48.7% of the diet of the urban residents, the vegetable WF accounted for only 4.7% of their diet WF. Overall, vegetable WF accounted for only 3.2% of the local diet WF. The reason was that the water content of vegetables was low.

3.1.3. Transportation Water Footprint

Transportation WF measures the water used when tourists travel from their trip origin to the destinations, and within the destinations. This is affected by the distance and the transportation means. (1). Transportation from the origins to the destinations: The statistics of the Yuanyang County Bureau of Tourism showed that, in 2014, the tourists to the county were mainly from Yunnan Province (40%), Guangdong Province (20%), Sichuan Province (10%), Guangxi Province (5%) and Chongqing City (5%). Tourists from Hong Kong accounted for 4% of the total, while those from the other areas of China took up 15%. Foreign tourists took up about 1% of the total. As to transportation means, 77% of the tourists arrived driving cars. The other 23% travelled by bus after they flew to Kunming. The average distance between the main tourist origins and the county were measured through Google Earth. The results are shown in Table 3. (2). Taking buses or driving were the common transportation means for tourists inside the heritage site. The sampling showed that the average distance a tourist travelled was 38.9 km per day.

Table 3. Energy consumption and distance from the tourist origins to the Hani Terraces, by transportation means (2014).

Transportation Means	Energy Consumption * (GJ/(Person km))	Average Distance ** (km/Person)
Airplane	0.002	83.5
Bus	0.0007	12.2
Car	0.0018	305.6

* The data sources of the energy consumption based on previous studies [10]; ** The average distances were estimated based on the number of tourists and the transportation statistics from the statistical Yearbook 2015 [32].

The virtual water content per L of crude oil was 1060 L/GJ [34]. The transportation WF was then calculated using Equation (3). The result showed that transportation WF per tourist was 844.1 L, of which 769.9 L was imported water and 74.2 L was local water. The sampling showed that the daily distance that the urban and rural residents traveled averaged only 0.05 km and they seldom used means of transport that consumed energy. The transportation WF per person was lower than 0.1 L and could be overlooked.

3.1.4. Sewage Dilution Footprint

Using the direct water to sewage coefficient and the water consumption listed in Section 4, this paper concluded that the volume of sewage produced by the tourists was 123.5 L per person per day (Table 4) [37,38]. The bathrooms produced 74% of the sewage, while the other sources produced relatively less. The statistics of Yuanyang's environmental protection authorities showed that, in 2014, the county's urban residents produced 87.3 L of sewage per person per day, while the rural residents produced 63.4 L per person per day.

Table 4. Water to sewage by the tourists of Yuanyang Hani Terraces (2014–2015).

Water Use	Water to Sewage Coefficient	Volume of Sewage (L/Person/Day)	Proportion (%)
Bathroom	0.99	91.8	74.3%
Cooking	0.50	15.0	12.1%
Laundering	0.85	15.6	12.6%
Washing cars, cleaning	0.35	1.1	0.9%
Total	-	123.5	100%

Monitoring the tourism sewage of the northwestern mountainous areas of Yunnan suggests that BOD_5 had the largest assimilative coefficient. It was as high as 12.2 and was a key indicator in the calculation of sewage dilution WF [28]. According to Equation (4), the sewage dilution WF of the tourists was 1506.7 L, the urban residents 1065.1 L and the rural residents 773.5 L. All were local WF. It could be seen that the sewage dilution WF of the tourists was by far the highest, and double that of rural residents.

3.1.5. Total Water Footprint

The tourism WF at the heritage site consisted of accommodation WF, transportation WF, diet WF and sewage dilution WF. The calculation showed that it was 3931.3 L per person per day. The figure was higher than those of the local residents, which was 2969.2 L per person per day for urban residents and 2898 L per person per day for rural villagers. The largest component of the tourism WF was the sewage dilution WF, which took up 38.33% of the total. The second largest component was diet WF, taking up 36.15% of the total. Following these were transportation WF and accommodation WF, accounting for 21.47% and 4.05%, respectively. It could be concluded that the direct water use in accommodation was not the only issue that merited attention. As most water use in tourism is overlooked, this can cause serious underestimation of the pressure on the environment exerted by tourism.

Blue WF refers to the accommodation and transportation WF together. It measures the use of surface water and underground water. Green WF refers to diet WF, including the water embodied in grain and vegetables and their preparation. Grey WF is sewage dilution WF. Blue WF was the largest component of the WF of both tourists and local residents. However, the proportions of green WF in total WF varied.

At 32.7%, it was the highest for rural residents (Table 5). This was much higher than those of urban residents (15.2%) and tourists (7.7%). Overall, 80.2%, or 3151.2 L per person per day, of the tourism WF was local WF. Imported WF was 780.1 L per person per day. As to the local residents, the water they used was almost all local water. The WFs of urban and rural residents were 2959.2 L and 2888.8 L per person per day, respectively.

Table 5. The water footprints of tourists, urban and rural residents in Yuanyang, 2014 (L/person/day).

Types of Water Footprint		**Tourists**	**Urban Residents**	**Rural Residents**
Blue WF	Accommodation	159.5	116.1	77
	Transportation	844.1	-	-
	Meat	1120	1344	1120
Green WF	Grain	280	360	860
	Vegetable	21	84	67.5
Grey WF	Sewage dilution	1506.7	1065.1	773.5
Total Water Footprint		3931.3	2969.2	2898

3.1.6. Tourism Water Capacity and Water Use Intensities

In 2014, Yuanyang County received 19,740 × 10^8 L of water from precipitation [33]. Studies show that water use should not exceed 40% of the area's water resources, without causing environmental degradation [42]. Therefore, the water that Yuanyang could use was 40% of the total, or 7896 × 10^8 L. Data showed that industry usually took up 12.30 × 10^8 of the available water, including 0.30 × 10^8 for power generation. Therefore, except 12.00 × 10^8 L industry water utilization and 2960 × 10^8 L ecological water utilization [43], the water available to meet the daily demands of the local residents and tourists was 4924 × 10^8 L for one year, or about 13.49 × 10^8 L per day (statistics of the Bureau of Water Affairs, Yuanyang County).

In 2014, the urban population of Yuanyang County was 37,828 and the rural population was 408,641[32]. Using the local Water Footprint listed above, the urban and rural residents of Yuanyang County consumed a total of 12.92 × 10^8 L water per day. The volume of water available for tourism development stood at 0.57 × 10^8 L. Using Equation (6), the maximum tourism capacity of Yuanyang Hani terraces is about 14,500 persons per day.

The calculation of Water Footprints can provide a basis for quantifying water use intensities. Qi Rui *et al.*, based on the WF theory, proposed to measure the pressure on water resources through the water resources pressure index [44]. The pressure of the water resources of Yuanyang could be calculated using Equation (7). The result was 97%. The tourism at the heritage site is a kind of community tourism. Therefore, not only the increase of tourists should be taken into consideration, but also the growth of the local population. Growth of both populations would exert a burden on the local environment. The Water Footprint of Yuanyang is still within the water capacity, but is in danger of exceeding the water capacity.

3.2. Discussion and Outlook

3.2.1. Comparative Analysis

Compared with the other tourist destinations, agricultural heritage sites attract tourists with distinct purposes. These are to experience traditional agricultural civilization, admire agricultural landscape, taste traditional food, experience local culture, *etc*. Therefore, they make different choices of food, accommodation, transportation means, *etc.*, choices that give their WF special features. First, their accommodation WF, especially direct water use, is relatively low. Accommodation categories have direct links with the WF. Normally, higher-end accommodation categories are associated with higher water consumption. The dominant accommodation category at the heritage sites is rural inns (in the case of Yuanyang, 73%), whose target customers are tourists that want to experience agro-culture. Unlike beach hotels and high-end resorts, most of them are not equipped with water intensive facilities, such as swimming pools. Thus, the direct water use was only 159.5 L per person per day, whereas the global average is 300 L per person per day [8,21,22]. The former was only half of the latter. However, it was still somewhat higher than that of the urban residents, and much higher than that of the rural residents of the study area. This suggests that there is still room for water conservation. Besides direct water use, the other accommodation-related WFs are also relatively low, such as the virtual water embodied in the tourism facilities. This could be attributed to the restriction of large-scale infrastructure construction that aims to preserve the indigenous landscapes of the heritage sites, and the lack of high demands on infrastructure from the tourists.

Second, the diet WF of the tourists is relatively low. The research of the UNESCO indicates that the production of per kg of food consumes 1 L of water [45]. Thus, the diet WF is 2000 L to 5000 L per person per day [10]. However, Gössling, Gerbens-Leenes and Nonhebel propose that human beings consume food with higher virtual water content to compensate the energy use when they travel, and thus produce higher diet footprints than usual [46,47]. Hadijiakakou points out in his study of the menu of five resort hotels that the diet WF accounts for 87% of the tourism WF. This is between 4696 and 7876 L [22]. The figures suggest that the diet WF is the most important factor in tourism WF. However, our study discovers that even though there are many differences between the diet structures of the tourists and local residents, the tourists tend to consume indigenous dishes made up of fresh local ingredients. The tourist diet footprint was only 1421 L per person per day, far less than the global average, which is 6000 L (Table 1).

Third, other WFs: The grey WF discussed in this paper is directly linked to the accommodation WF. Same as the accommodation WF, it is relatively low. Moreover, the transportation WF is higher than the global average (130 L per person per day) [21]. This is because the heritage site is remote with inconvenient transportation that causes higher energy consumption.

3.2.2. Water, a Constraint of Tourism Development in the Hani Terraces

Water is a critical factor of the heritage system. It is indispensable for the sustainable development of traditional agriculture and people’s lives. Both the volume and structure of water consumption are constantly changing because of the growth in local population and tourist numbers. This has put much pressure on the ecosystem. Water is a restraining factor for developing tourism at the heritage sites and maintaining the water-based farming system that they come to see. In this case, there are prominent conflicts between the seasonal changes of precipitation and the fluctuation of tourist arrivals, and the tourism water use and ecological water use.

First, there are conflicts between the seasonal changes of precipitation and the fluctuations of tourist arrivals. The main water source of the Hani terraces is the surface flows made up by rainwater. The surface flows are intercepted by canals and ditches (about 60%). The forests conserve about 30% of the surface flows, and can provide water throughout the year for the village and the rice-fish terraces farming system. There are few water conservancy projects, such as reservoirs [48]. The heritage site is located in the arid zone where the precipitation varies drastically over time. The rainy season is from May to October, during which 76% to 84% of the annual precipitation occurs. During November and the April of the following year, the precipitation is low and droughts occur now and then. Because of the terrace landscape is more attractive in the winter, the peak season of tourism is also from November to the April, the same time when the terraces are going through their dry season. For example, during the Spring Festival of 2014, the tourist arrivals at the Yuanyang County were as high as 70,000 per day, far more than the tourism capacity identified in this paper based on the tourism WF [49]. The water system of the heritage site is severely overloaded, which is, to some degree, hampering the sustainability of the water system and the stability of water supply to agriculture. In April 2015, the administration of the heritage site conducted a survey on the irrigation of the terraces. The survey found that about 58 mu (one mu equals to about 666.67 m^2) of terraces suffered droughts because of the competing demands of water from tourism [31]. As a consequence, future studies on the tourism WF at the agricultural heritage sites should consider the factor of seasons and dry spells; the allocation of water resources throughout the year, the time features of the irrigation water demands and the patterns of tourist arrivals.

Second, there are competing demands of tourism water and ecological water. Thanks to the water utilization patterns of the Hani people, agriculture on the terraces has lasted for over one thousand years. They are a model of the harmonious existence of human beings and nature, a healthy ecological system and sustainable utilization of resources. However, the investigations of the water management departments in recent years found that the total volume of water resources at the heritage sites had been diminishing, while the water quality also had been deteriorating [50]. The sufficiency and efficiency of the irrigation system on the terraces is being undermined. What is worse, the continuously expanding tourism WF is aggravating the problem of water use intensity and ecological degradation. The tourist arrivals have gone up by 16.65% annually. The water use intensity therefore is expected to be a challenging issue. Tourism development could easily trigger problems of environmental justice between the tourists and local people because it could bring substantial economic benefits to the areas [44]. This problem would threaten the protection of the agricultural heritage system. The benefits however may not necessarily go to the farmers who maintain the heritage system that sustains the tourism attractions. The increase of tourists would inevitably increase food consumption, especially grain consumption. However, the yield of traditional rice varieties is low, making them unable to meet the demands of the tourists. For this reason, the local people may shift to planting hybrid rice species, which would cause two problems. First, many traditional species may disappear. The loss of these core resources of the heritage sites would hamper biodiversity. Second, the growth of hybrid rice species requires a large amount of chemical fertilizer and pesticides, which would enter the water system and do harm to the ecological environment of the heritage sites. Under this situation, more water would be needed to sustain a healthy ecosystem, thus aggravating the competing demands of ecological water and tourism water.

3.2.3. Water Management of the Agricultural Heritage Sites

When managing the water resources of the heritage sites, technologies and awareness measures should be especially considered. Besides, tourism products should be designed and diversified throughout the whole year, which can alleviate the water pressure at critical times. The purpose is to realize the unified management of water supply, water utilization, water drainage, and water conservation. Both macro and micro approaches should be taken to optimize the sustainable management of water in this water-based system.

Technology improvement: Technologies are an important factor in water conservation. As can been seen above, the tourism WF is made up by accommodation WF, diet WF, transportation WF and sewage dilution WF. Water conservancy technologies could be applied to diminish these WFs. Some examples include water supply facilities, sewage processing facilities, water conservation and recycling facilities, and more environmental friendly transportation means, *etc.* To guarantee adequate water for agricultural production, water conservancy projects should be set up when the conditions are favorable. These measures would ease the soil and water erosion of the heritage sites and improve the irrigation system. Emerging technologies that reclaim resources from wastewater should also be considered. Specifically for rural areas, the oxidation pond (stabilization pond) can reduce the ammonia concentration in the stripper effluent. The wastewater can also be treated concurrently with disposal methods such as subsurface wastewater infiltration and constructed wetlands [51,52].

Awareness enhancement: First, tourists need to be educated to be more aware of water conservation. Various advertising and stimulating approaches could be taken to this end. For example, posters could be put up. The administrators and tour guides could be required to share with the tourists the tips on water conservation to encourage them to save water. Second, local farmers should be encouraged to use less chemical fertilizers and pesticides and return to using traditional manures. Pesticide free food should be one of the attractions. Traditional agricultural techniques should be passed on, especially those related to water use. In addition, the education on water conservation should be enhanced in elementary and secondary schools.

New tourism products: As mentioned in Section 3.2.2., there are competing demands of tourism water and ecological water as the main tourism season is concentrated in the winter when terraces experience a dry period. However, as an agricultural heritage tourism destination, Hani terraces are actually connected with the local traditional culture and nature during the whole year. With the terraced landscapes and functions changing throughout the year, the farming festivals of the Hani minority are celebrated in different seasons (Figure 6). Participatory experiences in agricultural activities and the lives of farm people can improve the quality of tourism; tourists are not only sightseeing and taking photographs, but are also learning about the ingenious meanings of the agricultural heritage system. Additionally, food products that are perceived to be traditional and local and the development of "alternative" food networks appeal to visitors who increasingly demand food authenticity from heritage sites [53]. The Hani terrace rice agricultural heritage system supplies rich food experiences all year long and visitors can taste featured food produced on a seasonal basis.

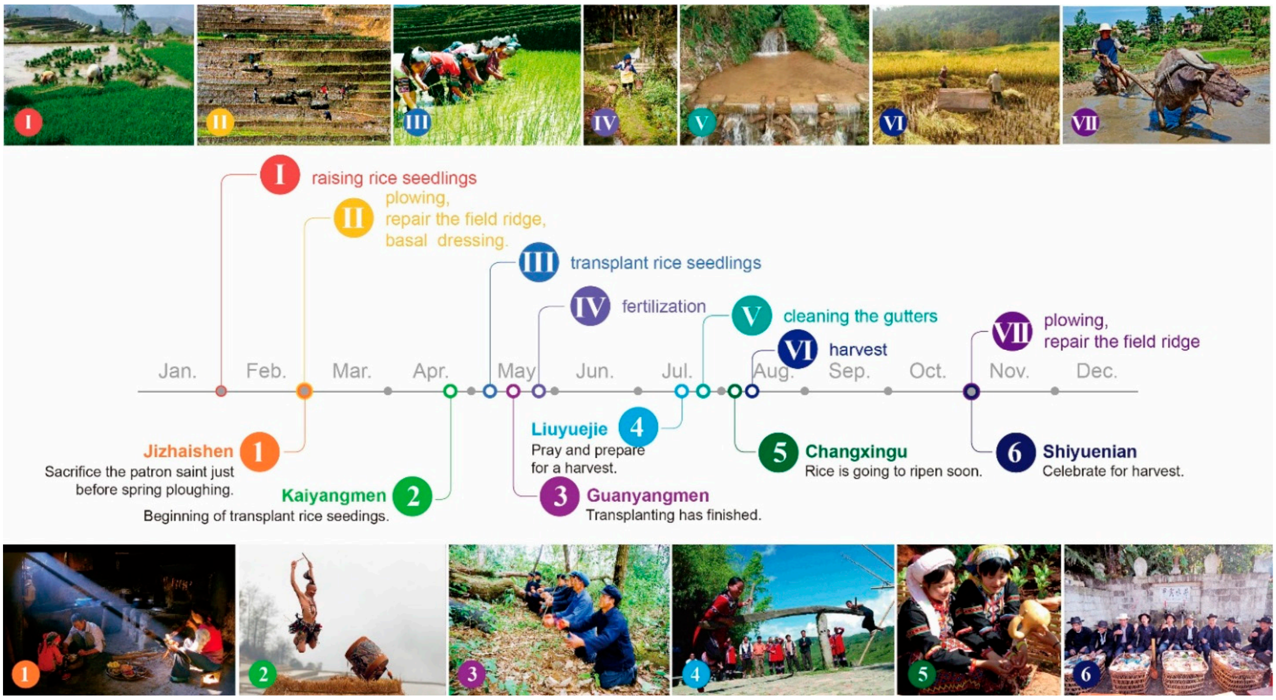

Figure 6. Festivals and Agriculture Activities in Hani terraces (Photo by Jie Zhou).

4. Conclusions

This paper uses the bottom-up approach to construct a framework on the tourism WF of the agricultural heritage site. Yuanyang County, a representative of the Honghe Hani rice terraces, was an appropriate study area. Questionnaires and interviews and other secondary data approaches have been taken to study the tourism WF and water capacity of the heritage site. The tourism WF consists of four components, namely the accommodation WF, diet WF, transportation WF and sewage dilution WF. The assessment of these WFs indicated that sewage dilution WF was the largest component, taking up 38.33% of the tourism WF. Following this were diet WF and transportation WF, accounting for 36.15% and 21.47%, respectively. The accommodation WF only took up 4.05%, the smallest proportion. It could be seen that if attention were paid only to the direct water use, the dominant volume of water use in tourism would be overlooked. In consequence, it would be hard to gain an accurate assessment of the pressure exerted by tourism development on the environment of the tourism destinations. In terms of the sources of the water, 80.2% of the tourism WF was local WF. This shows that the water resources–socio-economy–ecological environment of the heritage site form a relatively isolated system with a low dependence on the outside. The tourism water capacity of Yuanyang was 14,500 tourists per day. The water pressure index was 97%, indicating that the WF was still within, but was about to exceed, the water capacity.

The tourism WF of the agricultural heritage sites is much lower than the world's average level. However, water is already a scarce resource, a crucial factor in agriculture and a restraining factor in tourism development. Therefore, water supply, water utilization, water drainage and water conservation should be coordinated. We suggest taking macro and micro approaches, especially technologies and awareness enhancement, as well as new tourism products, to optimize the water management of the heritage sites, so that they are not irrevocably damaged by tourism.

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Author Contributions

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Conflicts of Interest

The authors declare no conflict of interest.

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