

## Research on tourism water resources carrying capacity engineering in Hainan Province

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### Abstract

Tourism water resources carrying capacity is an important restriction factor for sustainable development of tourism engineering, also is the key and the difficulty of tourism engineering sustainable development research. This paper constructs the theory and method the tourism of water resources carrying capacity engineering comprehensively and firstly, and makes an empirical study of Hainan Province. The results of the study show that: ①From 1998 to 2008 the available water resources of Hainan Province have changed from 9.8652 billion tons to 16.764 billion tons, tourism available water supply of Hainan Province has increased from 48.9577 million tons to 206.4160 million tons, the proportion of tourism available water supply to the total available water resources vary from 0.5% in 1998 to 1.23% in 2008; tourism water resources carrying capacity ranges from 17.9169 million in 1998 to 73 million in 2008 in Hainan Province; the figures of tourists climbs from 8.5597 million to 20.60 million, fewer than tourism water resources carrying capacity. ②The figures of tourism water resources carrying capacity calculated in 2008 are respectively 19.3039 million in Sanya City, 17.4297 million in Wanning City, 11.9911 million in Haikou City, the total is 66.15% of the provincial available water supply, the percentage of other regions is relatively small. The carrying capacity of eastern areas is larger than that in the west. ③Peak season is the dry season in Hainan Province. ④The main factors of spatial-temporal differences of tourism water resources carrying capacity are the total water resources and the level of tourism development. Finally, some internal and external suggestions are put forwarded for the improvement of the tourism water resources carrying capacity engineering of Hainan Province.

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Selection and/or peer-review under responsibility of the Organising Committee of The International Conference of Risk and Engineering Management.

*Keywords:* tourism water resources; tourism water resources carrying capacity engineering; tourism water resources carrying index; Hainan Province

### 1. Introduction

Tourism water resources carrying capacity is an important restriction factor in sustainable development of tourism engineering, also is the key and the difficulty of sustainable development research of tourism engineering. Wang Qun<sup>[1]</sup> studied the imbalance between water supply and demand of Mount Huangshan scenic spot. The concept of water park carrying capacity was proposed by Liu Huiping<sup>[2]</sup>, which was determined by yacht's capacity, velocity and the suitable activity area. Zhou Jinxing<sup>[3]</sup> points out that the water supply restricts the scale of tourist arrivals. Yuan Jiyu<sup>[4]</sup> points out that the water environment carrying capacity equals to the ratio of wastewater treatment

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Co-supported by National Soft Science Research Project "Forecasting the Influence of Constructing Hainan International Tourism Island on Its Tourism Natural Environment and Countermeasures Study" (2009GXS5D120); Hainan Provincial Natural Science Foundation Project "Influence of Constructing Hainan International Tourism Island on Its Tourism Natural Environment and Countermeasures" (70899); Study Project of the Education Department of Hainan Province "Influence of Constructing Hainan International Tourism Island on Its Natural Tourism Environment" (Hjkj2009-2).

capacity to the wastewater output per capita. Tourism water resources carrying capacity in these studies is described as space carrying capacity of water resources, water supply capacity and assimilative capacity of wastewater. Luo Yanju<sup>[5]</sup> has studied the impact of tourism water consumption of the cities and counties in Hainan Province, points out that water resources in Sanya City is affected most significantly by tourism. So far, the concept of tourism water resources carrying capacity has not been raised, related studies are few. Papers of scenic areas as the research objects have been reported, while papers of provincial tourism water carrying capacity engineering have not been reported.

Water resources are rich in Hainan Province, but the spatial-temporal distribution is unbalanced. As the Qiongzhou Straits, Hainan Province cannot draw water from the mainland. In recent years, with the rapid development of Hainan tourism industry, the figures of tourists increases from 8.56 million in 1998 to 20.60 million in 2008, the increasing figures bring great pressure to the water resources in Hainan Province. The construction of Hainan international tourism island has been a national strategy. With the further development of the international tourism island construction, tourism activities scale will expand and the figure of tourists will increase. What the amounts of tourism water supply, i.e. tourism water resources, are in Hainan Province. Taking water resources as limiting factors, how many the tourists can be carried in Hainan Province every year. What the methods are to improve tourism water resources carrying capacity engineering in Hainan Province. These problems are needed to solve for Hainan international tourism island construction.

This paper aims at constructing tourism water resources carrying capacity engineering theory and method, calculating and analyzing tourism water resources carrying capacity in Hainan Province from 1998 to 2008 and the regions in 2008, revealing changing characteristics and causes of the tourism water resources carrying capacity in Hainan Province, and then putting forward the countermeasures and suggestions to improve the tourism water resources carrying capacity engineering in Hainan Province.

## 2. Theory and Method

### 2.1. Theoretical analysis

#### 2.1.1. The concept and connotation of tourism water resources

Tourism water resources are the total water resources quantity which can be used by tourism engineering under the level of science and technology and in certain space-time scope.

The connotation of tourism water resources: ①Tourism water resources are the water resources which can be used by tourism engineering. Tourism water resources are the component of water resources and with the general properties of water resources, i.e. they can be used by tourism engineering, which have two meanings: one has been used by tourism engineering, the other can be used but still unused. ②It is a kind of water resources, and its quantity will be affected by water resources quantity in one region. ③It has certain spatial-temporal disparity because of geographical or season differences.

#### 2.1.2. The concept and connotation of tourism water resources carrying capacity engineering

Tourism water resources carrying capacity is defined as the tourism activities scale the water resources which can be used by tourism engineering, which is tourism water resources can support. The restrictive conditions are as follows: in certain period of a certain country (region), under certain economic, social and scientific development level, on the premise of ecology environment healthy development and sustainable social and economic development to be coordinated (including the tourism sustainable development). It is usually described by the number of tourists that tourism water resources can accommodate.

The connotation of the tourism water resources carrying capacity: ①Tourism water resources are the decisive factor of tourism water resources carrying capacity. In a sense, tourism water resources carrying capacity equals to tourism water resources quantity. ②The natural ecological environment restricts the amount and distribution of tourism water resources. It will cause damage to the ecological environment and influence the water resources in the area if the use of tourism water surpasses ecological environment threshold, in turn affect tourism water resources carrying capacity. ③Unit water consumption standard of tourism is the key factor of tourism water resources

carrying capacity. If tourism water resources are certain, the lower the unit water consumption standard of tourism is, the larger the tourism water resources carrying capacity is. It is determined by the tourism water resources management level and the scientific and technological level. ④Tourism water resources carrying capacity is objective. Region's water resources are objectively existing and limited, tourism water resources are objectively existing and limited, tourism water resources carrying capacity is inevitably objectively existing and limited. ⑤Tourism water resources carrying capacity has spatial-temporal differences, because tourism water resources and tourism unit water consumption standard change with the space and time.

Tourism water resources carrying capacity engineering is an organic whole, which comprises the interdependent and interactional components (sub-engineerings) of tourism water resources capacity. Its specific components include water resources sub-engineering, economic sub-engineering, social sub-engineering, ecological sub-engineering, tourism sub-engineering and so on.

### 2.1.3 Related conception

#### (1) Tourism water resources and water resources

Tourism water resources are a part of regional water resources, water resources decide the quantity of tourism water resources. The difference between water resources and tourism water resources is whether it can be used by tourism engineering or not.

#### (2) Tourism water resources carrying capacity and water resources carrying capacity

Tourism water resources carrying capacity is a part of regional water resources carrying capacity, regional water resources carrying capacity decides tourism water resources carrying capacity, and both can be described by the population which water resource can accommodate eventually. Water resources carrying capacity is the carrying ability of all production activities and population in an area, tourism water resources carrying capacity is the carrying ability of tourism engineering's activities and tourists.

### 2.2. Tourism water resources carrying capacity calculation method

#### (1) Tourism available water supply (abbr: TWS)

Tourism available water supply is tourism water resources. ①It makes sure regional available water resources. Research shows that the water use in a particular district cannot exceed 40% of local total water resources, otherwise it would bring the deterioration of ecological environment<sup>[6]</sup>. Therefore, regional usable water resources equal to the total water resources multiplied by 40%. ②It makes sure tourism available water supply. In regional usable water resources, for each industrial engineering, the distribution depends on the government's development strategy and management policy. Possible distribution methods are: the contribution of GDP, the distribution of industrial engineering's employees, the former distribution proportion, etc. According to the annual data of water consumption in Hainan Province, the province is rich in water resources, water use equals to water supply. Therefore, tourism available water supply can be described as:

$$TWS = \text{regional total water resources} \times 40\% \times (\text{tourism actual water supply} / \text{regional total water supply}) = \text{regional total water resources} \times 40\% \times (\text{tourism water consumption} / \text{regional total water consumption}) \quad (1)$$

#### (2) Tourism water consumption (abbr: TWC)

Tourism water consumption is the actual water consumption of tourism, including tourism life water consumption ( $TWC_L$ ) and tourism production water consumption ( $TWC_P$ ).

Tourism life water consumption includes tourists' life water consumption ( $TWC_{L1}$ ) and tourism employees' life water consumption ( $TWC_{L2}$ ), which can be calculated as:

$$TWC_{LI} = \text{number of tourists} \times 4 \text{ days} \times 0.3 \text{ tons/day. per capita} \tag{2}$$

$$TWC_{L2} = \text{the number of tourism employment} \times 0.25 \text{ tons/day. per capita} \times 365 \text{ days} \tag{3}$$

Where, 4 days is each tourist’s average stay in Hainan Province, 0.3 tons/day, 0.25 tons/day respectively are each tourist’s and each tourism employee’s water consumption standard every day.

Tourism production water consumption ( $TWC_P$ ) (mainly including hotels water use ( $TWC_{PH}$ ) and scenic spots water use ( $TWC_{PS}$ ). The water use standard of tourism hotels’ washing, greening, swimming pool and fire protection every day is 0.3 tons for each accommodation tourist<sup>[7]</sup>.

$$TWC_{PH} = \text{number of tourists received by tourist hotels} \times 0.3 \text{ tons/day per capita} \times 4 \text{ days} \tag{4}$$

Scenic spots water use is mainly considered golf courses’ greening, fire protection and other production water<sup>[8]</sup>.

$$TWC_{PS} = 3000 \text{ tons/each} \times \text{number} \times 150 \text{ days} \tag{5}$$

(3) *Tourism water resources carrying capacity (abbr: TWRCC)*

TWRCC is tourism water resources divided by each tourist’s water consumption standard, calculation model:

$$TWRCC = TWS/W_{PC} \tag{6}$$

Where, TWRCC is tourism water resources carrying capacity ( $10^4$  person/a); TWS is tourism water available supply ( $10^4$ tn/a);  $W_{PC}$  is tourist’s water consumption standard per capita (tn/d). It is the tourism water consumption (including water consumption of tourist’s living and water consumption of production) divided by each tourist.

(4) *Tourism water resources carrying index (abbr: TWRCI)*

TWRCI is the ratio of tourism water consumption(TWC) to tourism available water supply(TWS),i.e. the ratio of the figure of tourists( $Pa$ )to tourist water resources carrying capacity(TWRCC), this index can measure the disparity of tourism water consumption and tourism available water supply in the area, calculation model:

$$TWRCI = Pa/TWRCC \tag{7}$$

Where, TWRCI is tourism water resources carrying index;  $Pa$  is the number of tourists ( $10^4$  person/a).

According to the conditions and experience, tourism water resources carrying index can be assessed by the grading evaluation standard according to Table 1:

Table.1 Classification of tourism water resources carrying degree TWCI

range	(2, ∞)	(1.5,2]	(1,1.5]	(0.6,1]	(-∞, 0.6]
score	severe overload	moderate overload	mild overload	able bearing	completely bearing

2.3 Data sources

Related data comes from Hainan statistical yearbook yearly, China tourism statistical yearbook yearly, Hainan water resource bulletin yearly.

3. Hainan Tourism Water Resources Carrying Capacity Calculation and Analysis

3.1. The calculated results and analysis of the total province

The calculated results of Hainan Province tourism water resources carrying capacity from 1998 to 2008 calculation are in Table 2.

Table.2 Tourism available water supply, consumption, tourism water resources carrying capacity and tourism water resources carrying index of Hainan from 1998 to 2008

year	TWS (10 <sup>4</sup> tn)	useable water resources (10 <sup>8</sup> tn )	TWS/ useable water resources (%) )	TWC (10 <sup>4</sup> tn)	TWC/ total water use (%)	TWRCC (10 <sup>4</sup> person)	Pa (10 <sup>4</sup> person)	TWRCI
1998	4895.77	98.652	0.50	2323.67	0.50	1803.45	855.97	0.47
1999	7777.71	135.004	0.58	2611.85	0.58	2766.69	929.09	0.34
2000	12922.21	183.256	0.71	3104.12	0.71	4194.44	1007.57	0.24
2001	16097.55	185.66	0.87	3775.98	0.87	4794.98	1124.75	0.23
2002	11736.68	133.248	0.88	3882.63	0.88	3793.61	1254.97	0.33
2003	10083.11	116.72	0.86	4000.59	0.86	3110.45	1234.11	0.4
2004	6553.32	68.456	0.96	4381.58	0.96	2098.22	1402.88	0.67
2005	12172.40	122.916	0.99	4361.29	0.99	4232.47	1516.47	0.36
2006	9030.04	91.036	0.99	4608.46	0.99	3144.96	1605.02	0.51
2007	12747.29	113.408	1.12	5248.05	1.12	4551.33	1873.78	0.41
2008	20641.60	167.64	1.23	5773.59	1.23	7364.86	2060	0.28

### (1) Tourism available water supply

Tourism available water supply has increased from 48.9577 million tons in 1998 to 206.4160 million tons in 2008 (Table 2) in Hainan Province. The proportion to available water resources have increased from 0.50% in 1998 to 0.88% in 2002, but it drops to 0.86% in 2003, then rises to 1.23% in 2008. Hainan's tourism water resources consumption has climbed from 23.2367 million tons in 1998 to 57.7359 million tons in 2008. It shows that tourism available water supply increases with tourism water consumption, the proportion to the useable water resources increases at the same time. It demonstrates that: Hainan's available water resource is abundant and Hainan's tourism position has been maintained on a steady rise.

### (2) Tourism water resources carrying capacity

Hainan tourism water resources carrying capacity has fluctuated from 1998 to 2008 (Table 2). The general trend is increasing. Except in 2002 it decreases to 37.9361 million person and in 2005 decreases to 43.6129 million person, it rises from 18.0345 million person in 1998 to 73.6486 million person in 2008. Further analysis results shows that the trend of tourism water resources carrying capacity is basically the same as that of water resources in Hainan Province. From 1998 to 2008, the maximum amount of Hainan's total water resource is 46.415 billion m<sup>3</sup> in 2001, while the minimum is 17.114 billion m<sup>3</sup>. The main reasons are as follows: the related coefficient analysis of the EXCEL software shows, ①the correlation coefficient of Hainan tourism carrying capacity and Hainan water resources is 0.68, ②the correlation coefficient of Hainan tourism carrying capacity and the ratio of tourism water resources consumption to total water consumption is 0.73.

### (3) Tourism water resources carrying index

The carrying index is between 0.23 and 0.67 (Table 2) from 1998 to 2008, within the range of completely bearing and able bearing level. It has been declining from 0.47 in 1998 to 0.23 in 2001 and then keeps going up to 0.67 in 2004, reaching to the peak during these 11 years. However, it then begins to decline to 0.36 in 2005, after that, it increases slowly in 2006, but then begin to decline, until down to the lowest value 0.28 in 2008. The carrying index of Hainan tourism water resources is less than 0.6 (mostly between 0.23 and 0.51), which is in the fully bearing state,

except the year 2004, in which the index exceeds 0.6. The data clearly shows that tourism water resources are abundant in Hainan Province. The reasons are: ① the natural conditions of rich water resources and the social conditions of tourism as the pillar industry of Hainan Province cause large tourism water resources carrying capacity. ②insufficiency in tourism products, tourism service quality and tourist promotions result in the big space for improvement of Hainan's tourism reception

### 3.2. The calculated results and analysis of the region in Hainan

The calculated results of Hainan's tourism water resources carrying capacity of the regions in 2008 are In Table 3.

Table.3 Tourism water supply, consumption, tourism water resources carrying capacity and tourism water resources carrying index of the regions in Hainan in 2008

region	TWS (104tn)	TWS/total province (%)	TWC (104tn)	TWRCC (104 person)	TWRCC/total province (%)	Pa (104person)	TWRCI
Haikou	3522.26	17.06	1600.32	1199.11	16.28	544.81	0.45
Sanya	5386.59	26.09	2165.98	1930.39	26.21	776.22	0.4
Wuzhishan	601.59	2.91	50.51	257.86	3.50	21.65	0.08
Wenchang	637.94	3.09	130.35	177.60	2.41	36.29	0.2
Qionghai	1346.94	6.52	329.93	407.27	5.53	99.76	0.24
Wanning	4537.92	21.98	837.46	1742.97	23.66	321.66	0.18
Dingan	237.26	1.15	66.63	101.13	1.37	28.4	0.28
Tunchang	112.29	0.54	17.26	48.47	0.66	7.45	0.15
chengmai	135.75	0.66	40.43	55.53	0.75	16.54	0.3
Lingao	18.72	0.09	14.47	8.05	0.11	6.22	0.77
Danzhou	183.44	0.89	129.25	78.85	1.07	55.56	0.7
Dongfang	89.14	0.43	36.24	38.54	0.52	15.67	0.41
Ledong	41.73	0.20	13.44	17.26	0.23	5.56	0.32
Qiongzong	170.90	0.83	8.68	72.85	0.99	3.7	0.05
Baoting	649.76	3.15	89.15	138.70	1.88	19.03	0.14
Lingshui	698.49	3.38	206.39	302.02	4.10	89.24	0.3
Changjiang	81.06	0.39	28.17	34.59	0.47	12.02	0.35

Note: due to the lack of data, Baisha County has no calculation.

#### (1) Tourism available water supply and tourism water resources carrying capacity

In 2008, tourism available water supply of Sanya City, Wanning City, Haikou City are 54 million tons, 45 million tons, and 35 million tons respectively, and each of them respectively occupies 26.09%, 21.98% and 17.06% of the total tourism available water supply of the whole province, namely, these three cities take up of 65.13% of the total water supply in Hainan Province. Tourism water resources carrying capacity of Sanya City, Wanning City, Haikou City are 19 million person, 17 million person, 12 million person respectively, the total of which occupies 66.15% of the total carrying capacity of the province, proportion of carrying capacity in other regions is relatively small. The differences of tourism water resources carrying capacity are significant, which can be seen from the fact that the tourism water carrying capacity in the eastern areas is bigger than the western. There are two reasons: ①The eastern area is rich in rain and water resources, the western is relatively dry, which results in differences in tourism water resources carrying capacity. From the related coefficient analysis of the EXCEL software, the correlation coefficient of tourism carrying capacity and the total amount of water resources of the regions is 0.94. ②The tourism engineering in the eastern Hainan Province is developed, the ratio of tourism water consumption to the total water consumption is higher in eastern regions, thus the ratio of tourism water available supply to the total water resource



is undoubtedly higher in eastern regions, therefore, eastern tourism water resources carrying capacity is higher than that in the Midwest.

## (2) Tourism water resources carrying index

Completely bearing state of tourism water resources carrying regions in Hainan Province accounts for 88 % (Table 3), the total state is good, the development and utilization of water resources still has large space, and the tourism water using is sustainable.

### 3.3. The calculated results and analysis of the seasons in Hainan

The calculated results of Hainan tourism water resources carrying capacity in different seasons are in table 4.

Table.4 Tourism water resources carrying and the actual tourists of Hainan in 2008

month	TWC (10 <sup>4</sup> tn)	TWS (10 <sup>4</sup> tn)	TWRCC (10 <sup>4</sup> person)	Pa (10 <sup>4</sup> person)	TWRCC
Jan.-Apr.	2046.63	2476.99	884.64	750.94	0.85
May-Dec,	3659.54	18164.61	6487.36	1308.98	0.20
total	5706.18	20641.60	7372.00	2059.92	0.28

As can be seen from table 4, the differences of Hainan's tourism water resources supply and demand in 2008 are outstanding. The TWRCC of Jan.-Apr. (Dry season and peak tourist season) is 0.85, however is only 0.20 of May-Dec. (rainy season and low season).

## 4. Conclusions and Suggestions

### 4.1. Conclusions

This paper constructs the tourism water resources carrying capacity engineering theory and method comprehensively and firstly, and makes an empirical study of Hainan Province. The results of the study show that: ①From 1998 to 2008 the available water resources of Hainan Province have changed from 9.8652 billion tons to 16.764 billion tons, tourism available water supply of Hainan Province has increased from 48.9577 million tons to 206.4160 million tons, the proportion of tourism available water supply to the total available water resources vary from 0.5 % in 1998 to 1.23 % in 2008; tourism water resources carrying capacity ranges from 17.9169 million in 1998 to 73 million in 2008 in Hainan Province; the figures of tourists climbs from 8.5597 million to 20.60 million ,fewer than tourism carrying capacity. ②Tourism water resources carrying capacity calculated in 2008 are respectively 19.3039 million in Sanya City, 17.4297 million in Wanning City, 11.9911 million in Haikou City, the total is 66.15 % of the province' available water supply, the percentage of other regions is relatively small. The carrying capacity of eastern areas is larger than that in the west. ③Peak season is the dry season in Hainan Province. ④The main factors of spatial-temporal differences of tourism water resources carrying capacity are the total water resources and the level of tourism engineering development. Finally, some internal and external suggestions are put forwarded for the improvement of the tourism water resources carrying capacity of Hainan Province.

### 4.2. Countermeasures

#### 4.2.1. Tourism engineering internal control countermeasures

##### (1) Devote major efforts to developing tourism

The contribution of various production activities to regional GDP can decide the water resources distribution, so the higher the proportion of tourism to the regional economy, the more water supply tourism will get.

(2) *Upgrade the level of tourism water resources management*

Hotels, travel service facilities engineering, should try to be energy conservational and environmental friendly, on the premise of not decreasing tourists' tourism quality, reduce tourist's water consumption standard, thus improve tourism water resources carrying capacity.

(3) *Optimize space layout*

East is rich in water resources, has developed economy and high water resources utilization efficiency, some water-wasting tourism projects can be put into eastern; tourism's increasing development of central regions in Hainan Province should be put onto agenda; the western tourism water resources are scarce, the water-saving tourism projects should be developed, while the water-wasting tourism projects should be suspended.

4.2.2. *Tourism engineering external control countermeasures*

(1) *Improve water resources development level*

We should accelerate water source engineering and water conservancy project, increase water storage ability in the rainy season and improve water transfer ability in the dry season, construct water transfer in the water-scarce western region, speed up the level of desalination engineering and seawater direct use. We should also increase available water resources through improving the level of water resources development and utilization to improve tourism water resources and tourism water resource carrying capacity.

(2) *Optimize industrial engineering structure*

Agriculture water consumption in Hainan Province is great, accounts for about 80% of the total water consumption. The GDP of agriculture is about 30% of the total GDP, agriculture water consumption and its GDP contribution are disproportionate, so we should continue to increase industrial engineering structure adjustment, develop high-efficiency water-saving agriculture, go agricultural intensification development road.

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