Evaluation on Sustainable Development of Scenic Zone Based on Tourism Ecological Footprint: Case Study of Yellow Crane Tower in Hubei Province, China

LI Huiqin\textsuperscript{a}, HOU Linchun\textsuperscript{b}

\textsuperscript{a}Economy and Management School, China University of Geosciences, China, 430074
\textsuperscript{b}Earth Science Faculty, China University of Geosciences, China, 430074

\textbf{Abstract}

Tourism Environmental Carrying Capacity (TECC) is an important index to judge sustainability of scenic zone, which is calculated by Tourism Ecological Footprint (TEF) and Tourism Ecological Capacity (TEC). Based on theories and models of TEF, this paper calculated TEF, TEC, and TECC in Yellow Crane Tower scenic spot. In 2008, TEF per capita was 0.0570hm$^2$, footprint of transportation and waste were large, occupied 55.89\% and 33.20\% respectively. TEC of Yellow Crane Tower was 108.45hm$^2$ in 2008 and it will be 176.80hm$^2$ in 2012. Therefore, TECC was 3 804 tourists per day and it will be 6 204 tourists per day in 2012. Actually, TECC reached 3 354 tourists per day in 2008, which showed that tourists were under Carrying Capacity, but it is in vigilant situation of sustainable development. Finally, this paper put forward some suggestions on tourism sustainable development in Yellow Crane Tower.

© 2011 Published by Elsevier Ltd. Open access under CC BY-NC-ND license.

Selection and peer-review under responsibility of RIUDS

\textbf{Keywords:} Scenic zone carrying capacity; Tourism ecological footprint (TEF); Yellow Crane Tower

\section{1. Introduction}

With the rapid development of tourism, tourism environmental problems are the core issues of tourism research. How to effectively evaluate and control of sustainable development of regional tourism is the main problems. Many scholars have systemically studied evaluation methods of tourism sustainable development, such as Carrying Capacity (CC) [1-3], Limits of Acceptable Change (LAC) [4],...

* Corresponding author. Tel:00-86-18986008659

Email address: break11@163.com
Environmental Impact Assessment (EIA) [5]. Tourism Environmental Carrying Capacity (TECC) is one of the important indicators on evaluating tourism sustainable development. Wall and Wright (1977) held out that: Tourism Carrying Capacity is tourism level of an area whose resources and environment are not subject to unacceptable damage levels [6], which is denoted by number of tourists in some tourism zone.

In recent years, tourism ecological footprint (TEF) is a new idea and method of calculating environmental capacity of regional tourism. Ecological footprint was firstly proposed by Canadian ecological economist William Rees in 1992 and improved by Wackernagel. It can be defined as: ecological footprint of any known population (for example some individual, a city or a country) is the sum of biological productive land and the water resources which produce all resources these populations consume and take in waste produced by these population. TEF was introduced into China in 2004[7]. From the view of demand and supply, TEF put the unity area indicator, that is biological productive area, with characteristics of clear thinking and operable indicators etc, it is widely used in evaluating and calculating tourism sustainable development and TECC. Based on the theory of TEF, Liu Nianfeng (2005), Hu Haisheng (2007), Zhang Yiqun (2009) studied the tourism ecological footprint, tourism ecological capacity and tourism sustainable development [8–10].

Yellow Crane Tower scenic spot, situated in Snake Hill in Wuhan City, Hubei Province, adjacent to the Yangtze River, First Revolution Square, Red House (Xinhai Revolution Museum) and other tourism attractions. It is a five-A scenic spot and one of the three famous buildings in southern Yangtze River in China. As the image card of Wuhan tourism, it has a prominent position for tourists. In 2008, it covers 25hm². There were 1.22 million tourists visited Yellow Crane Tower and revenue reached 54.91 million Yuan. Yellow Crane Tower Park began to expand in 2008. The new park will include First Revolution in 1911 Square, Red House and Snake Hill. The total area of scenic zone will be 42 hm². With the rapid development of tourists, how to evaluate and control sustainable development of this spot is vital to local tourism.

According to data in 2008 and scenic planning in 2012 of Yellow Crane Tower, used theory and model of the TEF, through calculating and analyzing tourism ecological supply (TEC) and demand of tourism (tourist ecological footprint per capita, tef), this paper got the maximum TECC in theory of Yellow Crane Tower in 2008 and in 2012. The results can give a reasonable basis for zone planning and development, which is also a good trial on sustainable development of scenic zone.

2. Evaluation Model OF Sustainability of Scenic Spot

2.1 TEC and Computational Methods

Tourist’s activities inevitably take up resources, facilities and service of tourism, then affecting the sustainable development of Tourism. According to the meanings of ecological footprint, TEF can be defined as: in certain places and time scope, the area of productive land of occupied, consumed and waste intake caused by tourist activity [11]. This ecological productive land is global unified and can be comparable directly. The steps of computing TEF as follows[12,13]:

(1) Dividing the expenditure items, calculating the per capita construction and consumption. Occasionally, tourist entire travel expense project may divide into seven sectors. They are food, accommodation, travel, touring, shopping, entertainment and waste.

(2) Using the average output data, converse each consumption quantity into biology productive land. The biological resources consumed by tourist include agricultural product and animal product and so on. Conversing formula is showed following:

\[
A_i = \frac{C_i}{P_i}
\]  

(1)
$A_i$: real ecological production land of $i$ expense item; $C_i$: consumption of $i$ biological resources; $P_i$: average output of $i$ biological resources.

Energy converging formula is:

$$A_i = C_i \times f / GM$$  \hspace{1cm} (2)

$A_i$: area land of $i$ energy; $C_i$: consumption of $i$ energy; $f$: $i$ energy conversion coefficient; $GM$: global average energy coefficient of $i$ energy consumption.

(3) Transform each kind of biological productive land area into equal productive land through the balanced factor. Then sum and calculate the per capita of average ecology footprint. Converging formula is:

$$tef = \sum \alpha_i A_i$$  \hspace{1cm} (3)

$tef$: Ecological footprint per tourist; $\alpha_i$: balanced factor of biological production land. Different land has different balanced factor, farming and construction land is 2.8, the fossil energy is 1.1, the lawn is 0.5 and the sea is 0.2.

According to the above equation, TEF models of sub-account are showed in related references [7, 8].

2.2 Tourist Ecological Capacity of Scenic Zone

Tourist ecological capacity (TEC) refers to the maximum sum of productive land supplied for human sustainably, which has no harm to related ecosystem productive forces and complete of ecosystem. Tourist ecological capacity may be understood as the maximum of ecological footprint in some natural and social conditions. Actual area of the same biology productive land can’t be compared directly, for same kind of lands in different place have different resources. Used ratio of local average output and global output, which is called “output factor”, land in different places can be standardized. For discrete consideration, computing ecology capacity, 12% biodiversity protection area should be deducted.

The steps of calculating tourist capacity are: (1) calculating area of each kind of productive land, (2) calculating output factor, (3) calculating each kind of average capacity, (4) sum of every kind of tourism land capacity and sum of tourism ecological capacity. Equation is:

$$TEC = \sum \alpha_i Q_i S_i$$  \hspace{1cm} (4)

$TEC$: Tourism ecological capacity; $\alpha_i$: balanced factor of biological productive land; $Q_i$: output factor, $S_i$: area of $i$ land use.

2.3 Evaluation Model of Sustainability of Scenic Zone

From supply and demand, evaluation on scenery zone sustainable development can be measured by tourist ecological footprint (demand) and tourist ecological capacity (supply). The maximum number of visitors of TECC is determined by the scenic ecological supply and demand. We can get the maximum capacity by TEC and tef (TEF per capita). With the comparison of the theoretical and actual tourist scale, state of sustainable development in scenic areas can be judged. If actual tourism environmental carrying capacity is more than theoretical, regional tourism is unsustainable; otherwise it is in sustainable status. The evaluation models on scenery zone can be built in figure 1.
Equation of the maximum number of tourism ecological carrying capacity in theory is:

\[
\text{TECC} = \frac{\text{TEC}}{\text{tef}}
\]  

(5)

\(\text{TECC}\): tourism ecological carrying capacity, \(\text{TEC}\): tourist ecological capacity, \(\text{tef}\): TEF per capita.

3. Research Methods and Results

3.1 Data Source and Data Collection

Calculated data of TEF and TEC of Yellow Crane Tower include three categories: ① Research data: including origin of tourists, transportation patterns, tourist stay-time, commodities of tourist shopping etc. In May and September 2008, authors handed out questionnaires in Yellow Crane Tower Park, and did sample analysis and statistics. ② Basic data: including total tourists, areas of accommodation, restaurants and energy consumption etc, which can be found from Tourism Bureau of Wuhan and management office the Park. ③ Standard data: including energy consumption of each vehicle, average calorific of world fossil fuel productive land, which can be found from some research literatures and reports.

3.2 Methods of Calculating

3.2.1 TEF of Yellow Crane Tower

3.2.1.1 TEF of Transportation

In 2008, 26.5% Tourists in Yellow Crane Tower Park came from Wuhan, 15.1% tourists are from Hubei Province except Wuhan City, and percentage of tourists from other provinces is about 58.4%. Other provinces are mainly in eastern and southern coastal provinces in China, such as Guangdong and Zhejiang Province. Overseas visitors are mainly from Hong Kong, Macao, Germany, France and other European countries and the United States, Canada. The average stay-time for visitors is half a day. To facilitate the calculation, this paper made the following assumptions: ① Among the domestic tourists, all tourists in Hubei province, reached Wuhan by buses, the average distance of travel is 367km; tourists...
arrived in Wuhan by plane from over 1,000 km provinces; other tourists came Wuhan by train; 2) transport vehicles which tourists took are standard buses, trains, aircraft. Their energy consumption are showed in related references; 3) all overseas tourists transit from Beijing to Wuhan Airport; 4) small proportion of tourists choose water transport, so it was not considered water transport. According to the calculation model of ecological footprint of tourism traffic [7], the per capita of transportation TEF of Yellow Crane Tower was 0.03186 hm².

### 3.2.1.2 TEF of Food and Accommodation
Considered the food consumption of the local residents in Wuhan as a reference data in calculation, the per capita of tourist food footprint of Yellow Crane Tower is 0.00297 hm². The tourist housing time in Yellow Crane Tower scenic is 1 d. They accommodated in entire three-star hotels in Wuhan. In 2008, Wuhan has 54 three-star hotels including 12,337 beds, the room occupancy rate was 61.03%. The per capita of accommodation TEF was 0.00303 hm².

### 3.2.1.3 TEF of Entertainment and Traveling
The Yellow Crane Tower Park is composed of buildings, green lands, water body, roads etc. The per capita of entertainment TEF was 0.10*10⁻⁴ hm².

#### Table 1. Per capita of TEF of entertainment in Yellow Crane Tower

<table>
<thead>
<tr>
<th>Item</th>
<th>Area (hm²)</th>
<th>Land type</th>
<th>Balanced factor</th>
<th>Per capita of TEF (hm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buildings</td>
<td>0.0044</td>
<td>farm land</td>
<td>2.8</td>
<td>0.99*10⁻⁵</td>
</tr>
<tr>
<td>Roads</td>
<td>0.7100</td>
<td>farm land</td>
<td>2.8</td>
<td>0.16*10⁻⁵</td>
</tr>
<tr>
<td>Green land</td>
<td>17.00</td>
<td>lawn</td>
<td>0.5</td>
<td>0.69*10⁻⁵</td>
</tr>
<tr>
<td>Water body</td>
<td>1.1908</td>
<td>water</td>
<td>0.2</td>
<td>0.19*10⁻⁶</td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td></td>
<td></td>
<td>0.10*10⁻⁴</td>
</tr>
</tbody>
</table>

### 3.2.1.4 TEF of Shopping
Shopping street in the park is the main spot for tourist shopping, covering 0.55 hm². Model of “Yellow Crane return” and “copper mirror” are the two popular souvenirs. Each souvenir weighs average 0.5 kg, and the price is about 150 Yuan. Production capacity of copper is 2631 kg/hm². Therefore, the per capita of TEF of shopping was 0.00021 hm².

### 3.2.1.5 TEF of Waste
Travel is an Eco-consumption activity, which not only consumes resources but produces waste, such as gas, water and solid waste. According to the characteristics of tourism consumption, the calculation of waste of TEF consists of three parts: the solid wastes generated during travel, liquid wastes including sewage and excrements, gas such as CO₂. The per capita of waste TEF in Yellow Crane Tower scenic was 0.01892 hm².

### 3.2.1.6 Sum of TEF
Add seven accounts of the per capita TEF, the total TEF of Yellow Crane Tower was 0.0570 hm². Transport TEF and waste TEF are major components, which account for 55.89% and 33.20% respectively. Therefore, the key factors impacting TEF include tourists and consumer behaviour, such as transportation, catering, quality of ecological civilization. The results show that tourism waste account is a larger proportion, so waste impact on tourism can’t be ignored.

### 3.2.2 TEC of Yellow Crane Tower
According to the expansion plan of Yellow Crane Tower Park, results of TEC in 2008 and in 2012 are showed in table 2.

#### Table 2. TEC of Yellow Crane Tower Park in 2008 and in 2012
<table>
<thead>
<tr>
<th>Land type</th>
<th>output factor</th>
<th>balanced factor</th>
<th>area</th>
<th>balanced area</th>
<th>area</th>
<th>balanced area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>3</td>
<td>2.8</td>
<td>6.8</td>
<td>57.12</td>
<td>9.4</td>
<td>78.96</td>
</tr>
<tr>
<td>Forest</td>
<td>3.5</td>
<td>1.1</td>
<td>17</td>
<td>65.45</td>
<td>31.5</td>
<td>121.28</td>
</tr>
<tr>
<td>Water body</td>
<td>2.8</td>
<td>0.2</td>
<td>1.0908</td>
<td>0.672</td>
<td>0.672</td>
<td>0.672</td>
</tr>
<tr>
<td>TEC</td>
<td>123.242</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Biodiversity protection area (-12%)  

Total TEC  

108.45  

176.80  

* Output factor is adjusted by local reality.

### 3.2.3 TECC and Sustainability of Yellow Crane Tower

According to the calculation Model of TECC, the theoretic environmental capacity of Yellow Crane Tower Scenic was 3804 tourists per day in maximum. In 2012, it can be accommodated 6204 tourists per day. Actually, visitors of the Yellow Crane Tower were 3354 per day in 2008. Although tourists are endurable, TEC reached an alter state of sustainable development.

### 4. Suggestions

#### 4.1 Reduce Transportation TEF by High-speed Railway

High-speed railway is a new way to travel. In December 2009, Wuhan-Guangzhou high-speed railway stared to work, which greatly changed the structure of the tourism market in Wuhan and the transportation of tourists. Contrasting airplane, high-speed railway has high capacity and comfortable and efficient environment. It is a green transportation way to save energy and meets the requirements of low-carbon economy. Therefore, it is very important to let more and more tourists select high-speed rail, trains and other modes of transport with low energy consumption so that to reduce the huge TEF caused by traffic and promote sustainability.

#### 4.2 Control the Number and Distribution of Visitors through Comprehensively Applying Price Leverage

Price is an efficient lever to control tourists. There is no doubt that rising price limit a certain number of visitors effectively, especially in the "golden tourism week". Price leverage can realize the diversion of tourists, and reduce tourist huge pressure on tourism environment. Meanwhile, the scenic spot can also implement a variety of pricing strategies to control the tourist activities orderly. For example, local people can visit this park by purchasing a year-ticket and lower tickets during off seasons.

#### 4.3 Adjust the Seasonal Streaming of Tourists by Enriching Cultural Products

Enriching cultural connotation of tourism products, digging deeply the “Yellow Crane Culture”, “Chu Culture”, holding festivals and other events in off-season, these strategies can improve the problems of overloading caused by tourist activities. In busy season, the main building tower can set up a checkpoint at the entrance, in order to control the tourists’ amount strictly.

#### 4.4 Improve Quality of Ecological Civilization of Tourists by Increasing Publicity

The scenic area can improve the ecological responsibility by management, guidance, publicity. They can help visitors understand their experience will impact the environment greatly. Therefore, tourists can promote conservation and minimize consumption of energy and resources in the destination.
Acknowledgements

The paper was Supported by Youth Research Fund of Humanities Social Sciences of Educational Ministry in China (No: 09YJC790248) and the Special Fund for Basic Scientific Research of Central Colleges, China University of Geosciences (Wuhan) (No: CUGW090218).

References