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The study on the sustainable development of tourism based on ecological footprint theory ——taking Loudi, hunan as an example

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ABSTRACT

Recently the ecological footprint (EF) analysis has been developed into a method of assessing human being's utilization and the sustainable development of natural resource by measuring area in a quantitative way. The application of this method in tourism can be called tourism ecological footprint (TEF), which quantitatively reflects the impact of tourism on the ecological environment and the sustainable development situation of tourism. Based on ecological footprint theory and taking Loudi, Hunan as an example, the study assesses the sustainable development of tourism in Loudi by analyzing the dynamic variation of TEF and tourism ecological capacity (TEC) from 2005 to 2012. The empirical study shows that the rapid development of tourism industry has brought tremendous pressure to the tourism ecological environment and the tourism ecological contradiction between supply and demand is prominent in Loudi. So the sustainable development strategies of regional tourism are as follows: firstly, adjusting the tourism structure to promote its transforming and upgrading; secondly, changing the traditional concept of tourism planning to make plans from the perspective of ecological security and strengthening the security control to establish the ecological compensation mechanism; thirdly, improving the utilization rate of resource to control the demand of TEF; finally, promoting the land productivity to increase TEC.

KEYWORDS

Tourism ecological footprint (TEF); Sustainable development; Loudi.

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INTRODUCTION

Ecological footprint, first put forward by Canadian ecological economists William Rees and Wackernagel in the early 1990s, represents the amount of biologically productive land and sea area necessary to supply the resources a population consumes and to assimilate associated waste. It is an important indicator to measure the ecological development in a creative and practical way and has widely attracted people's attention in economic development and been applied into the assessment of regional sustainable development and with the rapid development of tourism industry, the application of TEF (first put forward by Hunter) in assessing tourism sustainable development has been the hot topic people talked. Based on previous relative research and taking Loudi as an example, the study has continued for 8 years to take empirical research on the development trend of TEF in order to provide a reference to the sustainable development of its tourism industry.

THE MODEL TO CALCULATE TEF AND TEC

Ecological footprint is a method of assessing human being's influence on ecosystem and measuring the sustainable development situation, calculated by the formula 1.

$$EF = N\text{ef} = N\sum_{i=1}^{n}(F_i C_i / P_i) \tag{1}$$

In this formula, *EF* represents the total amount of ecological footprint, *N* the number of population, ef per capita ecological footprint, *i* types of the consumption and investment, F_i the balanced factor of *i* kinds of land, P_i the average roductivity of *i* kinds of consumer goods and C_i per capita consumption amount of *i* kinds of goods. The formula tells us that the ecological footprint represents the amount of biologically productive area of every kind of consumer goods.

Tourism activities can not do without food, accommodation, transportation, visiting, shopping, entertainment and waste discharging. The TEF is calculated based on the calculation of ecological footprint. By surveying the regional tourism destination, obtaining the per capita consumption data about people's 7 activities described above, then respectively calculating their per capita building footprint and per capita consumption and converting them into the productive land area, finally adding these area up to calculate TEF [1].

$$TEF_{tourism} = TEF_{food} + TEF_{accommodation} + TEF_{transport} + TEF_{visiting} + TEF_{shopping} + TEF_{entertainment} + TEF_{waste} \tag{2}$$

Tourism ecological capacity (TEC) refers to the amount of biologically productive area that tourism destination provided for tourists, calculated as follows,

$$TEC = N\text{tec} = N\sum_{i=1}^{n}(a_i r_i y_i) \tag{3}$$

In this formula, *TEC* represents tourism ecological capacity, *i* 6 types of biologically productive land, including fossil and energy land, farmland, grassland, forest land, building land and water, *N* the number of population, tec per capita TEC, a_i per capita biologically productive land area, r_i the balanced factor and y_i the yield factor [2].

From formula 2 and 3,we can get the conclusion as follows; if *TEF-TEC>0*, it will be ecological surplus that represents the regional tourism benefiting for the sustainable development; if *TEF-TEC<0*, it will be ecological deficit that represents the regional tourism harmful for the sustainable development.

STUDY ANALYSIS

Development trend analysis

Dynamic variation analysis of the amount of TEF

The method above can be used to measure tourist's consumption demand on the ecosystem and nature's supply for human being in a macro perspective and calculate the TEF of Loudi from 2005 to 2012 to study the sustainable development situation of its tourism and calculation results are described in the following TABLE 1.

TABLE 1 : TEF in Loudi (2005-2012)

Year Item	2005	2006	2007	2008	2009	2010	2011	2012
TEF (hm2)	14928.84	19666.41	24087.33	31143.69	39776.20	54008.54	68195.06	72605.89
TEC① (hm2)	44095.79	46749.23	47485.84	50298.14	53897.64	55204.11	57924.39	60003.77
Ecological Surplus/Ecological Deficit (hm2)	+29166.95	+27082.82	+23398.51	+19154.45	+14121.44	+1195.57	-10270.67	-12602.12
Per Capita TEF (×10-5hm2)	843.44	848.09	771.29	771.27	734.01	718.46	672.61	667.52
Per Capita TEC (×10-5hm2)	2491.29	1584.77	1482.99	1245.62	994.61	734.36	571.31	551.66
Per Capita Ecological Surplus / Ecological Deficit (×10-5hm2)	+1647.85	+736.68	+711.70	+474.35	+260.60	+15.90	-101.30	-115.86
TEF per Ten Thousand GDP (×hm2/10000 yuan)	0.1756	0.1725	0.1554	0.1549	0.1441	0.1376	0.1196	0.1084
Tourism Ecological Pressure Index	0.3385	0.5351	0.5201	0.6192	0.7380	0.9783	1.1773	1.2100

①: deducting 12% of biological diversity area.

From the TABLE 1, it is known that from 2005 to 2012 the tourism ecological demand in Loudi has been continuously increased with the ecological footprint from 14928.84 hectare in 2005 to 72605.89 hectare in 2012, increased by 386.35% and about 48.29% every year (See TABLE 5-1). And we notice that during these years the speed of ecological footprint increases rapidly, representing more and more demand for the tourism resource. Compared with the year of 2005, up to 2012 the number of tourists increases by 514.5% and the annual average increase rate is 64.3%, especially in 2012 the number of tourists reaches 10.87698 million unprecedentedly. The demand increase results from the large-scale development, the expansion of tourism flow, the promoting of tourist's consumption capacity, the enlargement of tourist's spatial behavior and the rapid growth of tourism population. However, under the increasing background, the increase rate of TEF slows down in 2012, which mainly comes from the increasing of resource utilization rate that results from the government policy on building a clean city and restricting civil servant's consumption in three aspects [3].

TEC has increased by 36.1%, from 44095.79 hm2 in 2005 to 60003.77 hm2 in 2012 with the annual 1988.50 hm^2 increase per year (See Figure 1). This should be the result of the policies about

improving the ecological environment to make the city suitable for living and traveling. However, the increase of TEC is far behind the increase of TEF, which drives the ecological surplus into deficit.
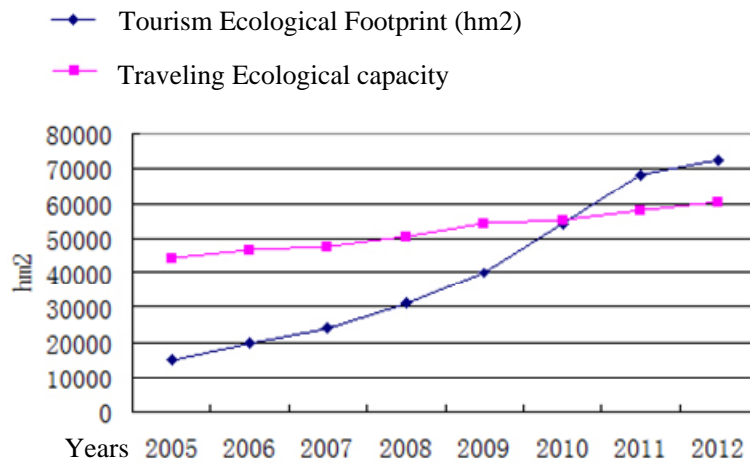

Figure 1 : Dynamic variation trend of TEF and TEC in Loudi (2005-2012)

Dynamic variation analysis of tourism ecological surplus and deficit

Tourism ecological deficit is used to directly assess to what extent the sustainable development brings pressure to tourism ecological system. From 2005 to 2012, the TEF and capacity increase continuously while the ecological surplus converts into deficit owing to the increase of capacity far less than the ecological footprint [4].

Before 2010, the tourism development environment shows the situation of ecological surplus, representing the general safe and sustainable development of ecosystem, which corresponds to the low speed development in Loudi. And the tourism product contributes little in GDP, only occupied 5.76% in 2010. But in 2011 the overall TEF suddenly increases and relatively the surplus converts into deficit with a trend of increasing continuously (See Figure 2). That the increase of TEC is far behind the ecological footprint's increase results in the ecological deficit which also reflects the severe consumption of resource and the debt increase for ecological environment. And this condition tells us that Loudi develops in an unsustainable way, by consuming the environment rather than the resource, regardless of whether the environment is degenerate or destructed [5].
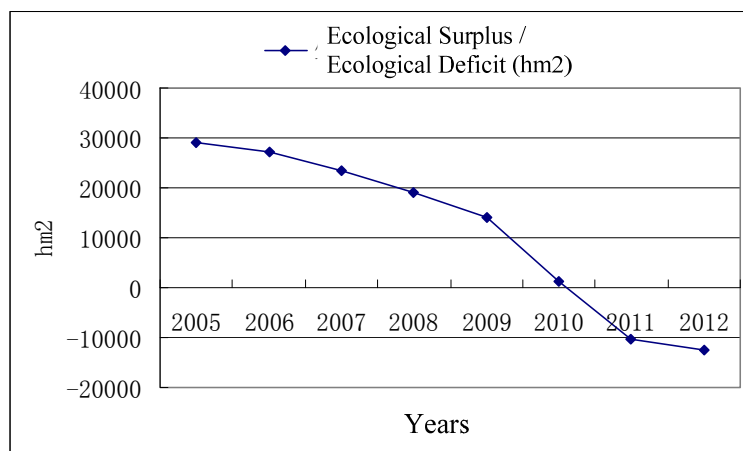

Figure 2 : Dynamic variation of tourism ecological surplus and deficit in loudi (2005-2012)

Variation tendency analysis of per capita TEF and per capita TEC

From 2005 to 2012, we notice that the total tourists increase from 1.77 million to 10.8969 million, increased by 514.5% and the annual average increasing rate is 64.3%. And per capita TEF has lowered from 843.44×10-5 hm2 to 667.52×10-5 hm2, decreased by 20.86% and the annual decreasing rate is 2.61%. Compared with other excellent tourism cities, the per capita TEF in Loudi keeps in a low level that results from the rapid growth of tourists who devote to the increase of utilization of tourism facilities and spots and also causes the large amount of overall TEF. Furthermore, we know that per capita TEC has decreased from 2491.29×10^{-5} hm^2 to 551.66×10^{-5} hm^2 with an annual average decreasing rate of 77.9%, from which we realize that per capita TEC decreases faster than per capita TEF and from 2010 the per capita tourism ecological surplus transformed into deficit. The per capita tourism ecological surplus $+1647.85 \times 10^{-5}$ hm^2 in 2005 decreased dramatically into the per capita ecological deficit -115.86×10^{-5} hm^2 with annual decreasing number as 220.46×10^{-5} hm^2 (See in Figure 3). Therefore, with the development of tourism in Loudi, the reception population overpasses its capacity, which reflects the obvious contradiction between the tourism ecological supply and its demand [6].
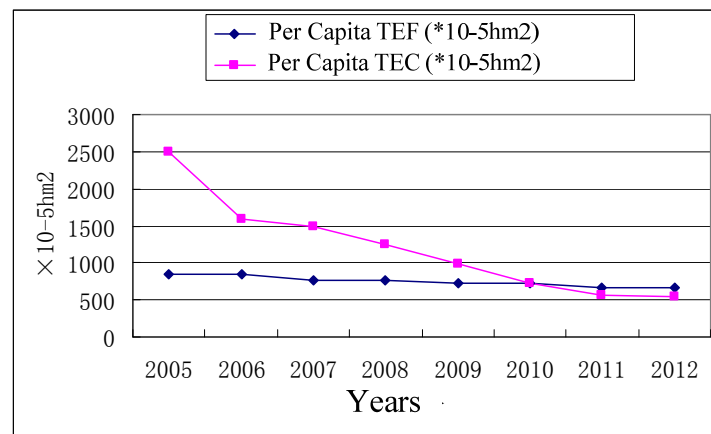

Figure 3 : Dynamic variation of per capita tef and per capita tec (2005-2012)

Viewing from the following tourism consumption structure, it can be observed that transportation and food stand inthe main position, the following is accommodation while visiting, entertainment and others almost do not work, especially entertainment, shopping and solid waste all make the least contribution (See Figure 4). There are two aspects we should know: firstly, before 2007 the indoor entertainment facilities attached into the accommodation and facilities and to avoid double-counting the indoor building land were excluded from the calculation. In addition, at that time the consumption of entertainment was so small that it can be neglected. Secondly, before 2007 in Loudi it not only had many kinds of tourism commodities but also had the overall plan about them. However, at that time most production factories were small-scale with poor technology that made their product's price lack of competitiveness. And poor technology could not contribute to the research and development of these products, most of which were agricultural products and on the other side were not promoted for lack of sufficient franchise stores and counters. The tourist spent less in shopping, therefore, the TEF in shopping can be negligible [7].
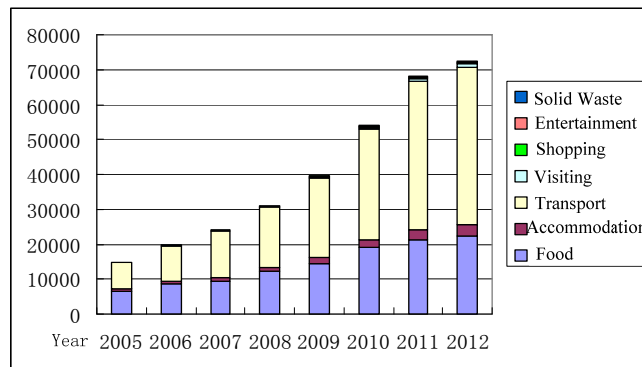
Figure 4 : Proportional diagram of TEF activities in Loudi

The first three footprints that contributes to TEF are transportation, food and accommodation, all increased continuously and at the same time the rank of their speed increase is also from transportation to accommodation (See Figure 5). This paper mainly focuses on studying the transport footprint inside the tourism spot, so the car is the main study object and self-driving tour becomes the main element of TEF in transportation. Convenient highway network provides convenience for people who have more free time and disposable income and encourages them to travel by car. And the car has higher per capita TEF and can be driven in a long distance, so it will consume more energy, which explains that transportation vehicles and distance will have direct effects on TEF in transportation[8].
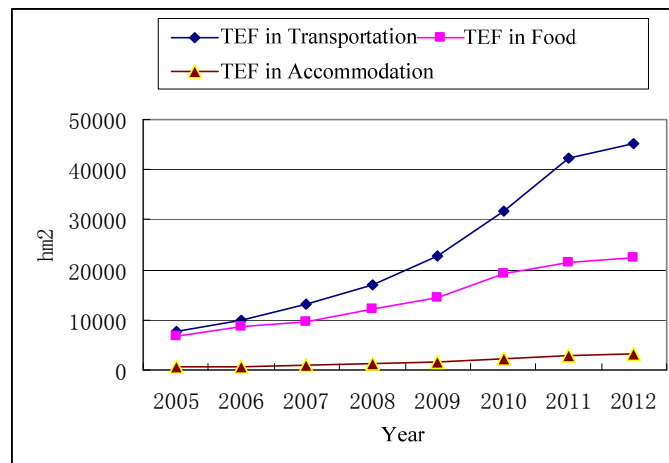

Figure 5 : TEF tendency of transportation, food and accommodation in Loudi

Meanwhile, from the following Figure 6, we should notice that the TEF in shopping and solid waste has some special characteristics, mainly reflected in the following two aspects: firstly, they have little impact on TEF; secondly, with the increasing of their total TEF year by year, per capita TEF increases annually.
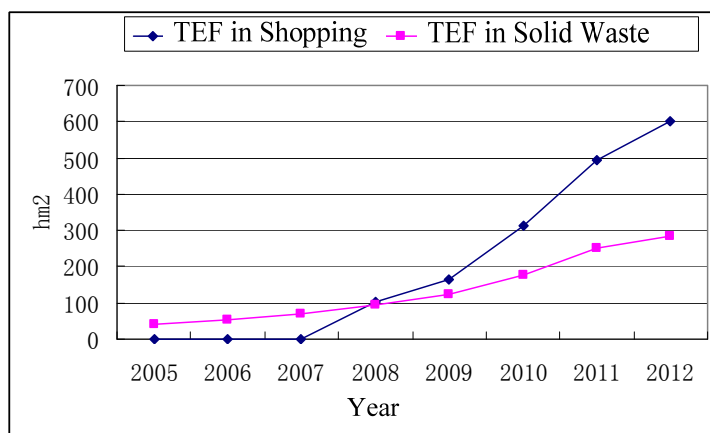
Figure 6 : TEF trend of shopping and solid waste in loudi

Productivity land analysis of TEF

Land types that contributed to the amount of TEF

The ecological footprint produced from human being's tourism activities reflects the real situation that to what extent the tourism spot bears the pressure from human being. When calculating the TEF, various consumption items about resource and energy are classified into 6 biologically productivity area types, including farmland, forest land, grassland, building land, fossil and energy land and sea water).

Viewing from the following TABLE 2, we find it reflects various land area of TEF in Loudi from 2005 to 2012, of which fossil and energy land, farmland and grassland occupy the largest proportion, followed by water, forest land and building land [9].

TABLE 2 : Land Types of TEF in Loudi (2005-2012)

Year	Farmland	Forest Land	Grassland	Fossil and EnergyLand	Building Land	Water	Total
2005	3416.0761	196.7023	2163.7259	8415.3404	189.2528	547.7390	14928.8366
2006	3910.4095	264.3362	2967.6019	11565.5980	236.6655	721.7965	19666.4077
2007	4275.2366	316.8929	3849.7098	14480.2687	410.4481	883.2584	24087.3328
2008	5283.0603	430.3747	4668.4707	19251.6293	529.7542	1145.7453	31143.6926
2009	6366.2201	550.7014	5881.6179	25077.9376	465.3815	1463.7640	39776.1971
2010	8427.3842	756.2275	7890.2153	34281.0553	631.3058	2022.3497	54008.5379
2011	10235.3964	950.1617	9970.7996	43668.5016	793.1085	2577.0913	68195.0592
2012	10604.5252	1007.9875	10179.4177	47210.5247	844.0434	2759.3867	72605.8852

Fossil and energy land is the main element of TEF, which tells us that the energy consumption determines the value of TEF and affects the sustainable development of ecological environment. The fossil and energy land includes the fossil and energy that food, accommodation and transportation consumed and most of them are from transportation, which proves that the distribution of tourism industry is not reasonable. What's more, the transportation facilities are not sound. All above explain that why the amount of TEF is so tremendous. Taking the year of 2012 as an example, we can get the fossil and energy land accounts for 65.0230% in TEF (See Figure 7).
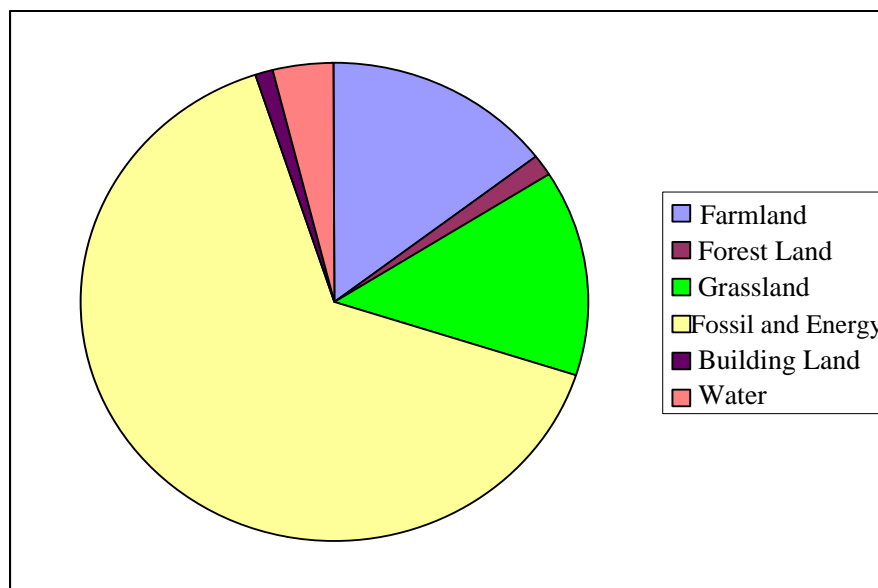
Figure 7 : Contribution rate of productivity land on TEF in 2012

Until 2012 all types of land have increased and the amount of TEF has increased by 57677.0486 hm^2, of which 67.26% is the fossil and energy land that has risen about 38795.1843 hm^2, from 8415.3404 hm^2 to 47210.5247 hm^2. Thus to realize the sustainable development of tourism industry in Loudi, the most significant we should do is to reduce the consumption of energy, that is, to reduce the ecological footprint of fossil and energy land, especially the TEF in transportation. With the improvement of people's consumption ability and the growth of visitors, respectively the consumption of energy rises, which will make the energy demand and foreign import increase and drive Loudi to depend much more on the import. To get rid of this trouble and lower the energy consumption, Loudi should improve the utilization rate of energy and use the green energy [10].

Contribution Rate of Six Kinds of Land on TEF

From 2005 to 2012, all kinds of land area increase but with different increased amount, which results in the restless change of their contribution rate as described in TABLE 3.

TABLE 3 : Contribution rate of six kinds of productivity land on TEF in Loudi

Year	Farmland	Forest Land	Grassland	Fossil and Energy Land	Building Land	Water
2005	22.8824	1.3176	14.4936	56.3697	1.2677	3.6690
2006	19.8837	1.3441	15.0897	58.8089	1.2034	3.6702
2007	17.7489	1.3156	15.9823	60.1157	1.1704	3.6669
2008	16.9635	1.3819	14.9901	61.8155	1.1701	3.6789
2009	16.0051	1.3845	14.7128	63.0476	1.1700	3.6800
2010	15.6038	1.4002	14.6092	63.4734	1.1689	3.7445
2011	15.0090	1.3933	14.6210	64.0347	1.1630	3.7790
2012	14.6056	1.3883	14.0201	65.0230	1.1625	3.8005

From the Figure 8, we notice the first three that contributed to all land area are fossil and energy land, farmland and grassland.
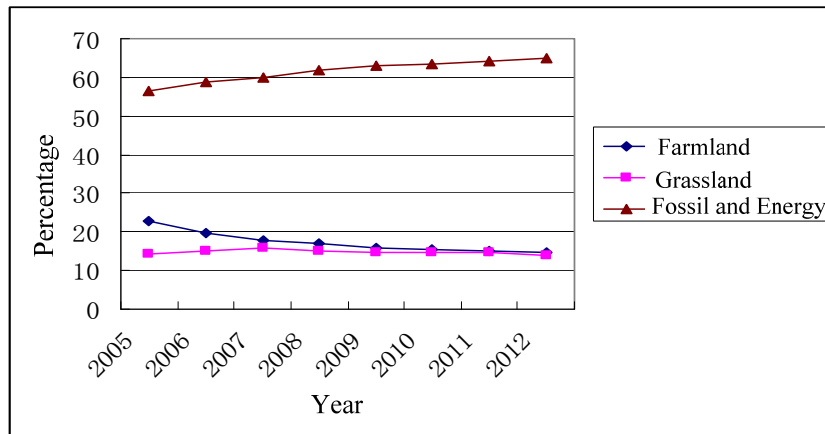
Figure 8 : Contribution rate of fossil and energy land, farmland and grassland on TEF (2005-2012)

In the diagram above, we get that the rate of fossil and energy land is always more than 55% and rises annually while that of farmland falls slowly, decreased from 22.8824% to 15.6038%, and it falls quickly then slowly before 2010 and from 2010 to 2012 it falls gently and maintains in a stable level.

The last three that contributed to the land area can be obtained from the following Figure 9.

From the Figure 9, we find that the rate of water, forest land and building land floats slightly, representing tourist needs more fossil and energy land, farmland and grassland than building land and forest land.
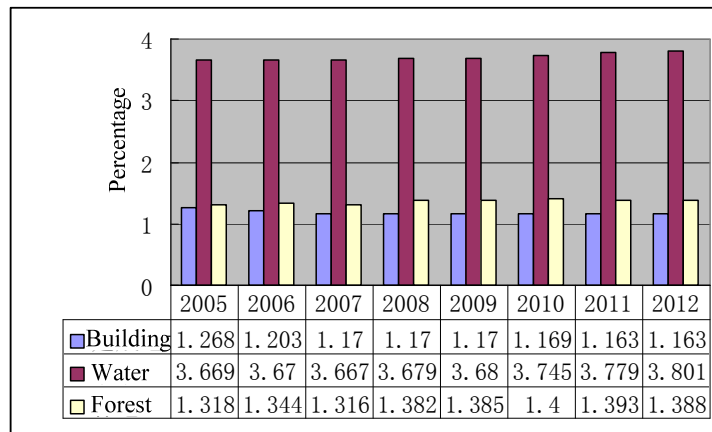

	2005	2006	2007	2008	2009	2010	2011	2012
Building	1.268	1.203	1.17	1.17	1.17	1.169	1.163	1.163
Water	3.669	3.67	3.667	3.679	3.68	3.745	3.779	3.801
Forest	1.318	1.344	1.316	1.382	1.385	1.4	1.393	1.388

Figure 9 : Contribution rate of water, forest land and building land on TEF

The consumption of fossil and energy land is the most and increases continuously, which illustrates that in the six essential elements of tourism, transportation, food and accommodation consume the most fossil and energy. The rate of farmland is more than that of water, which explains that tourists consume more grains than aquatic products. However, the falling of farmland's percentage and the growing of water shows the improvement of tourist's diet habit. At the same time, tourist's consumption about beef, mutton and dairy products keeps in a stable level, observed from the stable change of grassland. And tourism activities focus on the sightseeing, for the consumption rate of forest land and building land stays in a low level. In addition, these activities have little impact on the the ecological environment. On one hand, the number of tourists is not so large, for the tourism industry starts late, lacked high level tourism items and perfect infrastructure. On the other side, tourism activities have little

impact on environment, for the authorities put emphasis on the promoting and management of its protection.

CONCLUSION AND FURTHER DISCUSSION

During the process of the regional tourism development, we should make full use of TEF as a standard to assess and measure the development situation of tourism and according to the measure result, do some adjustments to instruct the tourism to step into a healthy and sustainable road. Therefore, if Loudi wants to develop its tourism industry, it should do as follows; firstly, adjusting the tourism structure to promote its transforming and upgrading. Specifically, standing in a higher height to understand tourism and develop the regional economy by cooperating with the development of transportation, building, forest, culture and other industries around the tourism industry; secondly, changing the traditional concept of tourism planning to make plans from the perspective of ecological security and strengthening the security control to establish the ecological compensation mechanism; thirdly, improving the building of transportation infrastructure and promoting low-carbon traveling to control TEF in transportation; fourthly, controlling the cost and promoting green hotel to control the TEF in accommodation; fifthly, adjusting the food structure to control TEF in food; finally, promoting the land productivity to increase TEC.

TEF method has attracted more attention owing to its creative and practical characteristics. However, there are still some aspects to study and improve.

(1) The research in this paper has made some assumptions and also neglected some variations, so the calculated result of TEF is smaller than the real value and the tourism ecological deficit is larger than the research result, but these have little influence on making the final conclusion.

(2) Tourists will move from one region to another, which devotes to the transfer and change of TEF and the expansion of ecological impact and responsibility among regions. Then the TEF model can assess the effect of tourism activities on environment and its sustainable development from a larger scale even around the world.

(3) TEF method prefers to measure the ecological situation rather than measure the impact of society, economy and technology, so there are some limitations when measuring the utilization of resource and the regional sustainable development and it needs a further study.

(4) With the developing of experience economy, the tourism experience has emerged. But when pursuing to develop this new emerging model, the tourism industry may neglect something that will affect the results tourist's experienced. Therefore, we should make a further study about how to reduce the TEF while the experience quality must be guaranteed.

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