DEVELOPMENT OF AN ECOLOGICAL FOOTPRINT FOR ACCOMMODATION FACILITIES IN TAROKO NATIONAL PARK, TAIWAN

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ABSTRACT

This study uses the Ecological Footprint (EF) Model to calculate the EF of different levels of accommodation facilities in Taroko National Park (Taiwan) from 2002 to 2011. The result shows that accommodation food consumption footprint ($ACCEF_{FO}$), accommodation built-up land footprint ($ACCEF_{BU}$), and accommodation *fossil energy land* footprint ($ACCEF_{EN}$) constitute the major components of the accommodation EF. In 2012, the heat values per bed night were calculated as 405, 176, and 60 MJ for international tourist hotels, boarding apartments, and ordinary hotels, respectively. These findings are in agreement with those of other studies that higher accommodation levels entail higher energy consumption.
Keywords: Carbon footprint, ecological footprint, national park, tourist accommodation.

1 INTRODUCTION

According to the Construction and Planning Agency of the Ministry of the Interior [1], the number of tourist visits to recreational sites in Taiwan's national parks increased by 77% (from 9.75 to 17.3 million) between 1999 and 2011. Taroko National Park is a popular location for leisure and recreation attractions, and an important asset to develop international tourism and attract foreign tourists, by virtue of its special terrain and landscape combined with the unique cultural heritage of the indigenous Truku people. However, regulatory restrictions on land usage/division prevent the authorities from acquiring land to build additional hotels within the Taroko National Park. The only such edifices present in the park at this time include those built early on, such as the Tienhsiang Youth Activity Center, Silks Place Taroko, and Leader Village Taroko, as well as any cabins and camping sites that were already planned before the restrictions were imposed. In order to meet demand, local residents provide accommodation to tourists by way of bed and breakfast (B&B). The mountainous areas within the park are characterized by deep terrain and fragile geology. Building B&B facilities is certain to have severe negative impacts on the ecological environment, leading to the degradation of water and land resources [2].

For the tourism sector among several negative impacts is biodiversity loss with potential severe consequences for the region's expanding ecotourism industry [3]. Therefore environmental management must be an integral component of tourism development, especially for sustainable tourism development in sensitive or protected areas, and more broadly for greening of the tourism travel sector and the tourism accommodation sector [4,5]. The concept of sustainable development points to the need for the development of tourism, albeit with lower impacts. The travel and tourism industry – or more specifically, the hotels in the park – utilize available resources effectively by undertaking green initiatives, such as increasing operational efficiency. This would allow the industry to grow and benefit the cause of ecological conservation simultaneously [6].

The EF Model was put forward by Rees [7]. Its primary feature is its ability to compare human demands from the environment with the biosphere's ability to regenerate resources and provide services. Wackernagel and Rees [8] suggested that the EF magnitude is directly proportional to

ISSN: 1755-7437 (paper format), ISSN: 1755-7445 (online), http://journals.witpress.com
DOI: 10.2495/DNE-V10-N2-165-173

environmental impact (the greater the EF, the greater the environmental impact), and is inversely proportional to the per-capita usable area of biologically productive land (the greater the EF, the smaller the per-capita usable area of biologically productive land). It is a widely used measure in the field of ecological economics, because it is a quantitative indicator that is easy to understand and calculate.

Since the introduction of the EF theory, scholars have attempted to dissect the concept from various angles, such as theoretical reviews [9] and methodological improvements [10–14]. However, a few studies have concerned themselves with the EF of restaurants in particular; Hunter [15] was the first to propose the extension of the EF to restaurants, and other researchers [16] followed suit by suggesting its application toward accommodation facilities and catering services in the travel industry. Usually, such studies have merely calculated the land over which the accommodation facilities were built and the resource consumption associated with them [17]. Zhang and Zhang [18] also included the energy and food consumption of tourists in selected restaurants. Peeters and Schouten [19] alone have presented a comparatively extensive calculation of the EF of accommodation facilities while studying the EF of inbound tourists to Amsterdam.

In conclusion, this study plans to use the EF model to calculate the EF of accommodation facilities at the Taroko National Park from 2002 to 2011. The findings will serve as a measure of the sustainability of the accommodation facilities in the park and also as a guide toward reinforcing the same.

2 RESEARCH METHOD

2.1 Items included in the calculation of the accommodation EF

This study devises an accommodation EF model using five evaluation items: accommodation built-up land footprint ($ACCEF_{BU}$), accommodation fossil energy land footprint ($ACCEF_{EN}$), accommodation food consumption footprint ($ACCEF_{FO}$), accommodation fiber consumption footprint ($ACCEF_{FI}$), and sewage treatment ecology footprint (WWEF). All items pertaining to resource and energy consumption are classified under six fundamental productive land areas: agricultural cultivated land, pastureland, forestland, built-up land, land containing fossil resources, and the fishing ground. The items considered in the calculation of the accommodation ecological footprint (ACCEF) are shown in Table 1.

This study only includes tourist accommodation facilities within the boundaries of the Taroko National Park. Due to the broad range of accommodation facilities located outside the boundaries of the park, it is difficult to pinpoint the purpose of such accommodation, and therefore, I exclude them from our evaluation. According to the information provided by the official website of the National Park Association in Taiwan (NPAT) [20] on the results of a survey on tourist satisfaction with the recreational facilities at Taroko National Park (2010), there are eight tourist hotels within its boundaries (Table 2).

1. In order to calculate the total area of the accommodation facilities, I follow Gössling *et al.* [17] and classify the facilities into six categories: hotels (five-star hotels and motels), camping sites and cabins, boarding apartments (guesthouses and B&B), resort villages, and luxury guesthouses.
2. The level of service and facilities (e.g. the lack or availability of a dining hall, kitchen, garden, swimming pool, social hall, etc.) differ depending on the type of accommodation. This brings about differences in the calculation mode as well. Thus, Gössling *et al*. [17] used per-bed area as a unit to estimate the area of the built-up land for each type of accommodation. This study sources information pertaining to the average per-bed area from a The United Nations World Tourism Organization (UNWTO) survey [21] conducted in 121 countries for about 32.59 million beds, in order to estimate the said value for hotels for which I could not source the exact building land area.

Table 1: The calculation of the ACCEF.

Category	Equation	Description
$ACCEF_{BU}$	$ACCEF_{BU} = A_{bu} \times YF_{bu} \times EQF_{bu}$	A_{bu} = sum of accommodation construction area, YF_{bu} = yield factor of built-up land, EQF_{bu} = equivalence factor of built-up land
$ACCEF_{EN}$	$ACCEF_{EN} = E_{bu} \times YF_{fo} \times EQF_{fo}$	E_{bu} = total energy consumption of accommodation, YF_{fo} = yield factor of forest land, EQF_{fo} = equivalence factor of forest land
$ACCEF_{FO}$	$ACCEF_{FO} = \Sigma\,(Q_i \times YF_i \times EQF_i \,/\, P_i)$	Q_i = food consumption amount of land subject to category i, YF_i = yield factor of category i, EQF_i = corresponding equivalence factor, P_i is subject to category i
$ACCEF_{FI}$	$ACCEF_{FI} = P_{fo} \,/\, GY_{fo} \times EQF_{fo}$	P_{fo} = annual consumption amount of wood, GY_{fo} = yield of average global hector (gha), EQF_{fo} = equivalence factor of forest land
WWEF	$WWEF = EC \times 0.625 \div 3.6666 \times EQF_{FL}$	The yearly electricity consumption amount of sewage factory provided by the Taroko management office is converted to CO_2 discharge amount (0.625), The carbon footprint is measured in tons of CO_2-quivalents (3.6666) and the equivalent factor of forest land (EQF_{fo})

Table 2: Built-up land area of accommodation facilities in Taroko National Park.

Name	Accommodation type	Rooms	Per-bed area	Area of built-up land
Liwu Hotel	Boarding apartment	18	50	900
Taroko Hotel	Boarding apartment	15	–	779.9
Sakadang B & B	Boarding apartment	4	50	200
Leader Village Taroko	Resort village	124	–	25,000
Silks Place Taroko	Hotel	160	–	9,956
Tianxiang Youth Activity Center (Youth Hostel)	Boarding apartment	65	50	3,250
Guanyun Youth Hostel	Boarding apartment	17	50	850
Sunghsuehlou Lodge	Boarding apartment	32	50	1,600
Total				42,535.9

Note: Unit: m^2.

3. According to data for the hotel industry and the B&B information system maintained by the Tourism Bureau, the Ministry of Transportation and Communications (MOTC), the actual operational area is 7,799 m^2.
4. Leader Village Taroko, with a rentable area of 25,000 m^2, is a build–operate–transfer entity of the Taroko Management Office (pers. comm.).
5. The built-up land area of Silks Place Taroko was provided by the Regent Hotel Group (pers. comm.).

In addition to these, there are cabins and shelters for tourists along the climbing paths on the mountain (Table 3).

2.2 Methods for calculating yield and equivalence factors

The calculation of the accommodation EF involves two major transformation parameters – equivalence factors (EQF) and yield factors (YF). EQF is the ratio of the potential biological productivity of a certain land type to the average potential biological productivity of all global lands and it is used to evaluate the difference between the six types of productive lands on the globe. As shown by eqn (1), the EQF γ_k of type-k biologically productive land is the average productivity $\overline{Y_k}$ of such a type of lands on the globe divided by the average productivity $\overline{Y}$ of all types of lands on the globe.

$$\gamma_k = \frac{\overline{Y_k}}{\overline{Y}} \quad k = 1, 2, \ldots, 6 \tag{1}$$

Because different countries or regions have different resource endowments, the biological productivity varies according to different land types and even that of the same type of land varies from region to region. Similarly, biocapacity calculation use YF to take into account national differences in biological productivity and equivalence factor to take into account differences in world average productivity among land types. YF λ_k of type-k land in a certain region is the ratio of the average productivity $\overline{y_k}$ of this type of land in this region to the global average productivity $\overline{Y_k}$ of the same type of land, and the computational formula is eqn (2).

$$\lambda_k = \frac{\overline{y_k}}{\overline{Y_k}} \quad k = 1, 2, \ldots, 6 \tag{2}$$

Table 3: Built-up land area of camping sites and cabins in Taroko National Park.

Camping sites	Capacity (persons)	Built-up land area
Heliu Campground	240	2,500
Lüshui Campground	100	800
Cabins	Beds	Built-up land area
Heishuitang Cabin	10	20.35
Chenggong Cabin	40	118.08
Chenggong I Cabin	8	16.75
Qilai Cabin	12	12.42
Duojiatun Cabin	5	9
Yuleng Cabin	50	540
Shenmazhen Cabin	12	12.81
Nanhu Cabin	40	79.2
Nanhu River Cabin	15	16
Zhongyangjian River Cabin	15	16
Total		4,140.6

Note: Yuleng Cabin was built in 2008. Unit: m^2.

Table 4: EQF and YF for a given land type.

Land type	EQF	YF
Carbon uptake land	1.26	1.2
Crop land	2.51	1.15
Forestland	1.26	1.2
Grazing land	0.46	1.6
Built-up land	2.51	1.15
Fishing ground	0.37	0.9

Source: Global Footprint Network, Ecological Footprint Atlas (2010).

As for a given region, the physical area of its type-k land multiplied by λ_k is the area with the global average productivity of such a type of land and on multiplying by r_k gives the equivalent area with global average productivity, which has global comparability, and its measurement unit is known as global hectare (gha). Each country has its own set of YF, one for each type of biological productivity area [22]. This article refers to Ref. [23] and the Global Footprint Network for the values of EQF and YF (Table 4).

3 DISCUSSION

3.1 Calculation and analysis of the EF

Table 5 shows the proportions of the various constituent items of the accommodation EF, the largest (in terms of magnitude) being the $ACCEF_{FO}$, followed by the $ACCEF_{BU}$ and the $ACCEF_{EN}$. The remaining two constituents, namely the $ACCEF_{FI}$ and the sewage treatment ecological footprint ($WWEF_{CU}$), make up a miniscule amount of the total. The $ACCEF_{BU}$ increased from 5.6392 gha in 2002 to 13.4732 gha in 2011. In 2009, there was a decrease in $ACCEF_{BU}$, the major reason being the closure of renovation of Silks Place Taroko. Moreover, Leader Village Taroko was still undergoing renovation and did not reopen before 2005, thus leading to relatively low $ACCEF_{BU}$ values between 2002 and 2004.

Because the land application planning in national parks should take protection of natural landscape, ecological system, and the humanity historical sports from destruction as the premise, generally speaking, appropriate planning should be made to measure recreational demand, the application principle, and open as well as development decree of travel service facilities. Thus, the approval and development of accommodation facilities have been strictly controlled, and therefore, the ACCEF has fallen within a fixed range in the past decade (Table 5).

3.2 The Carbon Footprint of Accommodation Facilities ($ACCEF_{CU}$)

Figure 1 shows the energy consumed by all accommodation levels between 2002 and 2011. Tourist hotels (e.g. Silks Place Taroko) show the highest values of energy consumption compared to the other accommodation levels, mainly because these facilities consume more energy per bed night and also have more rooms. In 2012, the heat value per bed night of ordinary hotels (60 MJ) was very similar to the heat value per bed night (40 MJ) mentioned by Gössling *et al*. [17] for two-star hotels. However, the corresponding values for the international (high-end) tourist hotels (405 MJ) and

Table 5: The ACCEF and its constituents.

Year	$ACCEF_{BU}$	$ACCEF_{EN}$	$ACCEF_{FO}$	$ACCEF_{FI}$	ACCEF	WWEF
2002	5.6392	12.5035	86.8529	0.4333	105.42885	0.4343
2003	5.6392	14.2124	98.7141	0.5330	119.09864	0.4343
2004	5.6392	10.8121	94.7354	0.4264	111.61309	0.4343
2005	12.8555	13.1920	112.6879	0.5377	139.27299	0.4343
2006	12.8555	13.3022	96.7484	0.4438	123.34992	0.4343
2007	12.8555	12.9652	113.2157	0.4234	139.45973	0.4343
2008	13.0113	11.9110	96.7134	0.3684	122.00416	0.5068
2009	10.5994	6.75620	75.4350	0.2729	93.06347	0.4306
2010	13.4732	10.6215	92.6378	0.2201	116.95257	0.4799
2011	13.4732	12.4323	90.2797	0.4126	116.59778	0.4815

Note: Unit: gha.

boarding apartments (176 MJ) are quite different from Gössling *et al*. [17] values for five-star (110 MJ) and four-star hotels (70 MJ). Such findings might result from the division of energy components in accommodations. Regarding energy use in hotels, electricity is a primary source of energy, while the shares of gas and diesel are much smaller. For this reason, we include electricity consumption in the calculations of the accommodation EF. Gössling *et al*. [17] included the energy consumed by air conditioning, heating/freezing, food processing, lightning, cleaning, and the desalination treatment of salt water. For star hotels, however, Gössling *et al*. [17] ignored the energy consumption by motor equipment, such as large-scale water pumps and elevators. Thus, as admitted by the authors, the results are relatively conservative. However, generally speaking, the higher the accommodation level (e.g. tourist hotels versus camping sites), the higher the energy consumption per unit bed, and the differences in consumption among the various levels are significant.

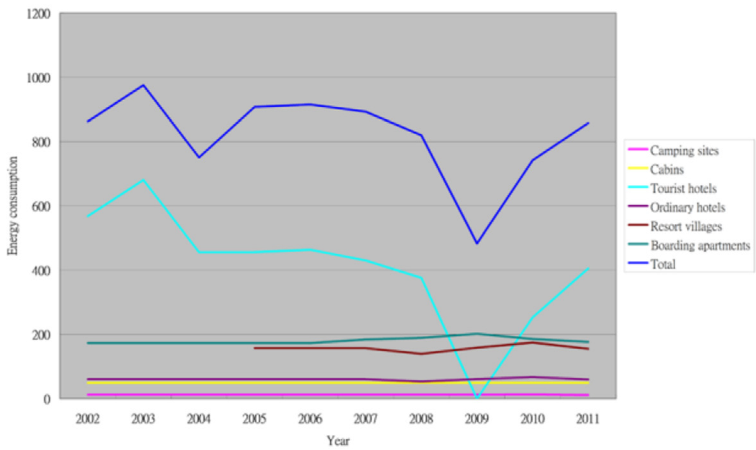

Figure 1: Energy consumption of all accommodation levels between 2002 and 2011. (*Note*: *The Silks Place Taroko closed for renovation in 2009, and reopened in 2010; so the 2009 statistics is N/A. Unit: MJ.)

3.3 Accommodation EF per guest for each accommodation level

In terms of the accommodation EF of each accommodation type, barring 2002–2004, the EF per guest of resort villages is higher than that of hotels (Fig. 2). Typically, the level of services provided by resort villages is higher than that of ordinary hotels and the guests tend to stay longer; thus, the overall consumption is higher. Taking 2011 as an example, the accommodation EF per guest of the resort villages in this study is 0.01358 gha. Although the number of visitors to Taroko National Park has increased every year, the accommodation EF per guest shows a gradually declining tendency, from 0.04920 to 0.04275 gha. The reason for this can be deduced from the recreational satisfaction survey of visitors to NPAT [20], which indicated that the average stay at Taroko National Park has been decreasing: the tourism residence time up to 3–4 hours (27.6%), followed by 2–3 hours (23.2%) and 4–6 hours (20.5%); a shorter stay translates into lower demand for accommodation.

4 CONCLUSIONS

This study used EF analysis to evaluate the sustainable development status in a national park context, leading to several conclusions. In general, the higher the level of accommodation, the higher the resource consumption, thus leading to a bigger EF and a larger environmental impact. Looking at the magnitudes of the components of the overall accommodation EF, $ACCEF_{FO}$, $ACCEF_{BU}$, and $ACCEF_{EN}$ constitute the major components in descending order. The proportions of $ACCEF_{FI}$ and WWEF in the overall accommodation EF are very minor. Regarding resource consumption, the major components of the EF are electricity consumption, accounting for 80% of the total. Resource consumption rose in accordance with the increase in the level of services or, in other words, the accommodation level. In terms of the EF of an average bed, it is possible to decipher obvious differences depending on the accommodation level; the higher the level, the bigger the EF of the bed.

The findings of this study suggest that the National Park Law and other relevant regulations pertaining to land planning must be implemented rigorously in order to protect the pristine nature of the park as well as to ensure that its carrying capacity is not overloaded due to the EF of the

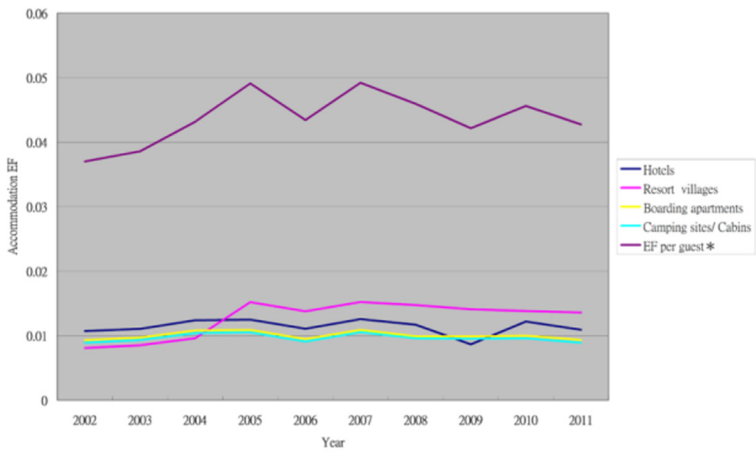

Figure 2: Accommodation EF per guest for each accommodation level. [*Note*: Unit: gha; *EF per guest = (ACCEF ÷ accommodation visitors).]

accommodation facilities in the park. The following suggestions may be of use to hotels' managements/policy makers:

1. The hotel industry can institute a reward system for guests so as to encourage them to implement simple but far-reaching environmental measures.
2. Hotel managements are likely to shy away from implementing certain high-cost albeit environmentally friendly measures, such as the installation of condensate recycling systems. The government may help by reducing taxes on such equipment or providing other favorable solutions to encourage hotel operators to implement such high-cost initiatives.

ACKNOWLEDGMENT

The research work was supported by the R.O.C. Government's National Science Council (NSC 100-2410-H-040-014).

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