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# Touristic ecological footprint in Mu Ko Surin National Park

Usaradee Phumalee [a, c, *], Noppawan Tanakanjana Phongkhieo [a], Dachanee Emphandhu [a], Somskaow Bejranonda [b]

[a] *Department of Conservation, Faculty of Forestry, Kasetsart University, Bangkok 10900, Thailand*
[b] *Department of Economics, Faculty of Economics, Kasetsart University, Bangkok 10900, Thailand*
[c] *Center for Advanced Studies for Tropical Natural Resources, Kasetsart University, Bangkok 10900, Thailand*

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**ABSTRACT**

The objectives of this study were: 1) to study the resource consumption per tourist in terms of the amount of carbon dioxide emission due to the activities per tourist, 2) to compare the difference in the touristic ecological footprint (TEF) of day-trip and overnight-stay tourists, and 3) to determine the TEF concerning the demand for forest areas to absorb $CO_2$ that is released from the activities of the tourists. Using systematic random sampling, a constructed questionnaire was collected from 397 Thai tourists who visited Mu Ko Surin National Park during October 2014–May 2015. The results showed that day-trip and overnight-stay tourists released an amount of $CO_2$ in one day from four activities that accounted for 177.62 $kgCO_2e$ and 132.06 $kgCO_2e$ per person, respectively. Regarding assessment of TEF in one year based on the statistics from tourists in 2013, it was found that the demand for $CO_2$-absorbing areas from activities of tourists was 679.59 gha, in which the average per tourist accounted for the demand for $CO_2$-absorbing areas from the activities equal to 0.033 gha per capita. Such consumption behavior required a forest area about one-fifth of all the forest in Mu Ko Surin National Park. Assessment of the TEF can be used as an indicator to assess the sustainability of tourism and as an effective interpretative tool for environmental study. Additionally, this can create and stimulate environmental awareness that may induce behavioral changes in consumption patterns, which are more environmentally friendly in the future.



## Introduction

The ecological footprint (EF) is the measurement of human demand on bioproductive land due to human exploitation resulting from tourist activities (Wackernagel & Rees, 1996). The EF can be expressed in terms of dimensions of bioproductive land demanded by humans to accommodate living and economic activities. Measurement of the EF indicates the unit of measurement at the population level, whether it is at the level of an individual, household, city, or country. Measurement of the EF usually entails a study comparing two or more different areas to determine the level of consumption activities and whether or not it is within the capacity of such areas (Haberl, Erb, & Krausmann, 2001; Rees, 2000).

Studies on the EF have been extensively performed with the conceptual application of EF analysis to various industries, including the tourism industry because tourism can be an instrument for economic development at national, regional, or even local levels. However, the increasing number of tourists can generate adverse effects on the

* Corresponding author.
*E-mail address:* usaradee.p@gmail.com (U. Phumalee).
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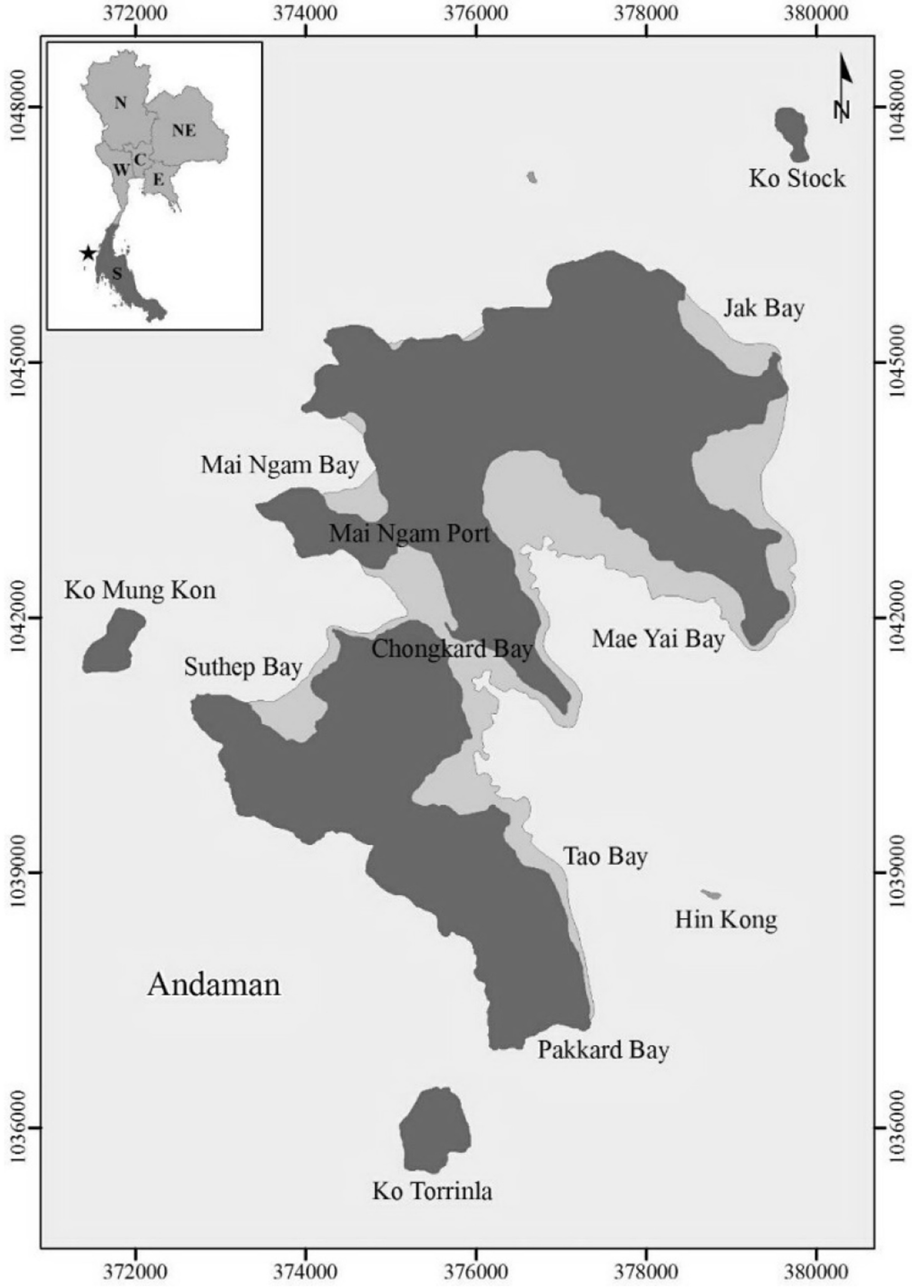


**Figure 1** Map of Mu Ko Surin National Park in Southern Thailand
**Source**: DNP (2008)

environment and ecosystem of tourist destinations, which are specifically destinations in protected areas whose primary objective is to conserve the biodiversity rather than the tourism services. Thus, it is important to develop a model of tourism in natural areas to guarantee that the security of ecosystems will not be destroyed by tourist activities (Castellani & Sala, 2008).

The touristic ecological footprint (TEF) is the conceptual application of the EF in order to assess the demand for land to accommodate the activities of tourists associated with traveling from their residence to tourist destinations, the type of accommodation, and the consumption of goods, food, and services, as well as activities performed once at each tourist destination (Li & Yang, 2011; Luo & Wu, 2011). In applying the EF approach, most researchers used a component-based approach and usually performed comparative studies of the EF levels between tourists and residents in the tourism area. The resource consumption categories popularly employed in the calculation of the EF are transportation, accommodation, food and fiber consumption, electricity consumption, water consumption, and waste disposal. Analysis of the EF can be categorized according to tourism activities, such as sightseeing, entertainment, and shopping. In calculating the bioproductive land of the TEF, most researchers compared the areas of study sites. The bioproductive land commonly used in the analysis of the EF are fossil energy land, built-up land, crop land, and grazing land (Cole & Sinclair, 2002; Gössling, Hansson, Hörstmeier, & Saggel, 2002; Johnson, 2003; Li & Yang, 2011; Luo & Wu, 2011; Meng & Yu, 2012; Peng & Guihua, 2007; Pongsakornrungsilp, 2011).

Thus, the current research focused on studying the TEF in Mu Ko Surin National Park, which is a popular marine national park for tourists. Its objectives were as follows: 1) to study levels of resource consumption of individual tourists in terms of their $CO_2$ emission whilst undertaking tourist activities, 2) to compare the different amounts of $CO_2$ emissions of day-trip tourists and overnight-stay tourists due to the activities performed by the tourists, and 3) to identify the level of the TEF which will determine the demand for forest areas to absorb the $CO_2$ that tourists released from their activities. In calculating the TEF, this study compared the area sizes at the local scale level because comparison at the local scale level is more beneficial in deciding the policy for the management plan, and in facilitating interpretation for tourists which will persuade tourists as a group to reduce their levels of resource consumption and change their behavior to conform to the concept of sustainable tourism.

*Study Site Information*

Mu Ko Surin National Park is a marine national park located in the west of Southern Thailand. The park is a famous tourist attraction, both nationally and globally, It is composed of two islands, Ko Surin Nua and Ko Surin Tai, surrounded by concave-shaped bays (Figure 1). They are the origin of the largest and most complete shallow reef in Thailand. The Royal Forest Department has indicated that most of Mu Ko Surin National Park consists of tropical rain forest, (30.71 $km^2$) which comprises approximately 93 percent of the total land area of the islands. Furthermore, there are small areas of mangrove (0.15 $km^2$) and beach (0.14 $km^2$) forests, making up approximately 0.46 percent and 0.42 percent, respectively. Mu Ko Surin National Park has the capacity to accommodate overnight-stay tourists at the following points: 1) Chong Kard Bay consists of a national park office, visitor center, welfare food shop, tourist lodging, and campsites. It has beautiful beaches and shallow reef areas for diving and snorkeling. It can accommodate about 250 tourists; and 2) Mai Ngam Bay has campsites for tourists who wish to stay overnight, with amenities such as a welfare food shop, bathroom-toilet, and a visitor center. It also has beautiful beaches and shallow coral reefs as sites for snorkeling (DNP, 2008).

## Methods

*Participants*

The population in this study was Thai tourists aged 18–65 years who traveled for recreational activities in Mu Ko Surin National Park. The day-trip and overnight-stay tourists were requested to individually answer the questionnaire. The sample size was set according to the formula of Cochran (1977) by specifying the acceptable deviation of sampling at 5 percent. According to the relevant formula, the sample in this study needed to be at least 384 people. Systematic random sampling was employed to collect data.

*Data Collection*

The instrument used for data collection was the questionnaire and field sheet concerning the consumption of tourists. The questionnaire contained four categories of questions related to the consumption behavior of tourists as follows: 1) transportation—vehicle types, number of passengers, average distance from residence to Mu Ko Surin National Park, etc.; 2) food consumption—type of food consumed at the National Park, number of meals, amount of beverage consumption, etc.; 3) outdoor recreational activities—types of recreational activities, diving spots of tourists, etc., and, 4) waste disposal based on using a form to record the weight of garbage per day and classifying garbage into food leftovers, glass bottles, plastic bottles, cans, and general rubbish. In investigating the quality of the questionnaire, the researcher examined its content validity and objectivity in order to consider the coverage of conceptual variables or objectives by consulting experts to verify the suitability of the definition and the scope of contents to be measured.

*Data Analysis*

In this research, the level of consumption in Mu Ko Surin National Park and the resulting EF were measured in terms of the forest areas required to absorb tourists' $CO_2$ emissions when performing tourist activities. The TEF levels were calculated in three steps. Step 1: identifying tourists' consumption behavior according to the components of tourism resources used by tourists. Each component was detailed as follows:

1) Transportation: this research focused on the $CO_2$ emissions released through the various forms of transportation and vehicles used by tourists. In addition, the average distance between the tourists' residence and the destination was taken into account in the footprint calculation by employing the following equation (DEFRA, 2013):

$$CO_2\ \text{emission}_{\text{transportation}} = \sum d_i e_i \tag{1}$$

where, i is the means of transportation, $d_i$ is the average of the distance between the tourists' residence and the destination, and $e_i$ is the emission factor of the means of transportation.

2) Food consumption: food consumption was estimated based on the food products consumed by tourists during their trip to Mu Ko Surin National Park. This research included the amount of food the tourists consumed and the emissions resulting from food preparation. This process estimated the typical food energy that the tourists consume in different food groups. The calculation of the $CO_2$ emission when cooking was taken from the carbon footprint database of TGO-registered products (DEQP, 2013). The detail is shown in Equation (2):

$$CO_2\ emission_{food} = \sum(CFcooked_i \times meal_i) + \sum(CFinstant_i \times meal_i) + \sum(CFbeverage_i \times meal_i) + \sum(CFcontainer_i \times meal_i) \quad (2)$$

where, i is the types of food and beverage, $CF_{cooked}$ is the carbon footprint of cooked food ($kgCO_2e$/meal), $CF_{instant}$ is the carbon footprint of instant food ($kgCO_2e$/piece), $CF_{beverage}$ is the carbon footprint of beverage ($kgCO_2e$/piece), and $CF_{container}$ is the carbon footprint of the food container ($kgCO_2e$/piece).

3) Waste disposal: this study explored the amount of waste produced by tourists. Emissions from waste disposal were mainly the result of $CO_2$ produced at landfill sites as well as from transport. The calculation principle of $CO_2$ emission caused by the landfill disposal of discarded products after use was based on MTEC (2014) as shown in Equation (3):

$$CO_2\ emission_{waste\ disposal} = \sum(Cdayuse_i \times type1) + (Covernight_i \times type2) \quad (3)$$

where i is the type of waste, Cdayuse is the carbon emission of waste disposal (per day-trip tourist), Covernight is the carbon emission of waste disposal (per overnight-stay tourist), Type1 is a day-trip tourist, and Type2 is an overnight-stay tourist.

4) Outdoor recreation activities: the calculation was divided according to the Carbonzero (2014) database of $CO_2$ emissions resulting from recreational activities consisting of photography or nature-sightseeing, visiting the Tourist Service Center, trekking, and wildlife watching. The calculation for diving was based on the distance and the vehicle type the tourists used for the activities as shown in Equation:

$$CO_2\ emission_{activities} = \sum(activity_i \times e_i) \quad (4)$$

where, i is the type of outdoor recreation activity, and $e_i$ is the emission factor of the outdoor recreation activity.

The second step involved converting the tourists' consumption into amounts to indicate $CO_2$ emissions using a specific conversion factor. The third step was determining the land area required to absorb the carbon emission. This study used the calculation guidelines and equivalence factors established by earlier studies such as Chambers, Simmons, and Wackernagel (2000), DEFRA (2013), DEQP (2013), and WWF (2002). In comparing the level of the TEF between the day-trip and overnight-stay tourists, a Mann–Whitney U test was used.

## Results and Discussion

### *General Information About Tourists*

Among the 397 tourists visiting Mu Ko Surin National Park, 57.93 percent were female; 50.38 percent were 25–35 years of age and the average age was 33.88 years (SD = 8.52); 63.22 percent were graduates holding a bachelor's degree; 28.46 percent had an income in the range THB 15,000–25,000, with the average income being THB 34,472 (SD = 24,093). Regarding transportation patterns of tourists, it was found that 62.22 percent of tourists came from Bangkok, 69.52 percent had never visited Mu Ko Surin National Park before, 48.61 percent came with a tour company, 32.75 percent came with friends, and 33.00 percent came in groups of three to six. It was found that 93.95 percent were overnight-stay tourists, 56.42 percent of whom remained for about two to three days and 70.03 percent stayed overnight on the island for two to three nights, with the average period being 3.41 days (SD = 1.54), and the average overnight stay was 2.61 nights (SD = 1.62). Furthermore, 53.65 percent had traveling costs in the range THB 5,000–8,000, with the average being THB 7,760 (SD = 3248).

### *Amount of Carbon Dioxide Released from Activities of Individual Tourists*

Most tourists who came from Bangkok traveled about 610 km to the National Park, with 35.00 percent using an air-conditioned bus, and 29.22 percent in their own large-engine car. From Equation (1), the average amounts of $CO_2$ emissions from the tourist activities the of day-trip and overnight-stay tourists were 167.28 and 121.29 $kgCO_2e$ per person, respectively.

Regarding food consumption, 62.72 percent of the tourists had meals provided by the staff of the National Park. An American breakfast and porridge were served in the morning, and four Thai dishes and fruit were served at lunch and dinner, with 27.71 percent of the tourists having cooked-to-order meals. For beverage consumption, 64.99 percent of the tourists drank 600-ml plastic-bottled water, with an average amount of 2.44 bottles per day. Using Equation (2), the average amounts of $CO_2$ emissions from food consumption by day-trip and overnight-stay tourists were 4.74 and 18.2 $kgCO_2e$ per person, respectively.

Garbage was collected from two zones—campsite zones for overnight-stay tourists and dining zones for day-trip tourists. The waste was separated into general garbage, food leftover, plastic bottles, glass bottles, and cans. The weight of waste in the calculation was just general garbage and food leftover in order to prevent repeated counts because plastic bottles, glass bottles, and cans were considered as packages of beverages already calculated in food consumption. The results of the study showed that the average weights of general garbage and food leftover by day-trip tourists per person were 0.0202 and 0.0284 kg, respectively, while the weights of general garbage and food leftover by overnight-stay tourists per person were 0.1067 and 0.0284 kg, respectively. By interviewing park officers on waste management, it was found that food leftover was disposed of by the National Park as landfill without any transportation involved. Furthermore, the park officials transported general garbage to the coast, which was about 60 km away, and then the waste was transported to the dumping areas 8 km away using six-wheeled trucks. Using Equation (3), it was found that the average amounts of $CO_2$ emissions from the activities to dispose of the waste from

**Table 1**
Comparison of average amounts of $CO_2$ emission (unit of $kgCO_2e$ per person) between day-trip and overnight-stay tourists

| Tourist activity category | Day-trip tourist | | Overnight-stay tourist | | *p*-value of Mann Whitney |
|---|---|---|---|---|---|
| | Average | SD | Average | SD | |
| Transportation | 167.28 | 215.41 | 121.29 | 118.92 | .009 |
| Food consumption | 4.74 | 2.86 | 5.42 | 2.77 | .000 |
| Waste disposal | 3.94 | 0.00 | 4.11 | 0.21 | .000 |
| Recreation activities | 1.65 | 0.87 | 1.98 | 0.80 | .000 |
| **Total** | **177.62** | **214.82** | **132.06** | **119.08** | **.080** |

day-trip and overnight-stay tourists were 3.94 and 13.36 $kgCO_2e$ per person, respectively.

The recreational activity analysis results indicated that Mu Ko Surin National Park provided four diving routes for overnight-stay tourists as follows: Route 1: Dragon Island, Suthep Bay, Mai Ngam Beach, with an average distance of 7.26 km; Route 2: Hin Kong, Turtle Bay, Mae Yai Bay, with an average distance of 13.23 km, Route 3: Jak Bay, Stock Island, with an average distance of 23.52 km; and Route 4: Pakkard Bay, Torrinla Island, with an average distance of 8.66 km. For day-trip tourists, the Park provided a route with diving spots at Mae Yai Bay, Hin Kong, Turtle Bay, Chong kard Bay, and Morgan Village, with an average distance of 8.66 km. Using Equation (4), the average amounts of $CO_2$ emissions from waste disposal resulting from day-trip and overnight-stay tourists were 1.65 and 5.28 $kgCO_2e$ per person, respectively.

### *Comparison of Amounts of Carbon Dioxide Released from Performing Tourist Activities of Day-Trip and Overnight-Stay Tourists*

This research found that each individual day-trip tourist released 177.62 $kgCO_2e$ in one day from performing four types of activities, while each individual overnight-stay tourist released 132.06 $kgCO_2e$ in one day. Comparing the average amount of $CO_2$ emission due to tourist activities in a day between day-trip and overnight-stay tourists, it was found that the average amounts of $CO_2$ emissions in a day of both groups were not statistically significant. Considering the difference in the average amount of $CO_2$ emission from all four consuming activities, it can be seen that the average amounts of $CO_2$ emission from transportation, food consumption, waste disposal, and outdoor recreational activities of overnight-stay tourists were significantly different (Table 1).

Table 1 shows that the differences in the average $CO_2$ emissions due to consumption of both tourist types were for transportation and food consumption. In terms of transportation, day-trip tourists traveled by personal cars with only two or three passengers, while overnight-stay tourists mainly traveled by bus, and some by personal cars but with more passengers (four to six in a car). Summing up, the average amount of $CO_2$ emission due to transportation from a visitor's residence to the National Park per person for the overnight-stay group was less than for the day-trip group. This result was similar to the study by Marzouki, Froger, and Ballet (2012) which indicated that the impact level on the environment varied according to the number of tourists and the distance between their residence and the destination.

The food consumption analysis revealed that the consumption patterns of both tourist types were different regarding the types of food consumed and the number of meals for day-trip tourists. This group of tourists had only two meals per day, while overnight-stay tourists had three meals per day. Although most day-trip tourists had the same set-menu lunch as the overnight-stay tourists, beverage consumption was different in that overnight-stay tourists drank more water and soft drinks in packaging than day-trip tourists because most overnight-stay tourists participated in two diving sessions, which were in the morning and in the afternoon. This conforms to the study done by Marzouki et al. (2012) which stated that that the length of stay affected the need to use the land for agriculture and farming to stratify the demands of tourists.

Although the $CO_2$ emissions from waste disposal and outdoor recreational activities were significantly different, when considering the average $CO_2$ emissions from both categories, it was found that the averages of the amounts of $CO_2$ emissions were only slightly different. Regarding waste disposal, it could be seen that the amounts of $CO_2$ emissions were slightly different between day-trip and overnight-stay tourists because of the similar weight of waste and the same waste disposal process. The $CO_2$ emissions from outdoor recreational activities were found to be little different. The recreational activities mainly consisted of snorkeling. The average distance of each route was similar (not more than 10 km). Thus, the average distance for the two tourist groups differed only slightly.

From the discussion above, it is clear that the influence of all four categories of the consumption variables affected the amount of $CO_2$ emissions of both tourist types with a clear distinction in the averages regarding transportation and food consumption, while waste disposal and outdoor recreational activities were only slightly different. In addition, overnight-stay tourists remained in the area for a longer period than the day-trip tourists, which meant the former group consumed more food and beverages which agrees with Johnson (2003) who stated “the longer the length of stay, the larger the food consumption EF”.

### *Amount of Carbon Dioxide Emissions by Tourists in One Year*

The amount of $CO_2$ emissions due to tourists visiting Mu Ko Surin National Park in one year was calculated from the number of Thai tourists visiting the National Park in 2013, which was 20,347 (DNP, 2014), but due to the limitations in the data collection in classifying tourist types, the researchers used the data collected from a sample size of 397 to determine the ratio of the two types of tourists in order to estimate the number of day-trip and overnight-stay tourists. The results of the study showed that 93.95 percent were overnight-stay tourists. Therefore, the expected number of day-trip tourists was 1,231 and that of overnight-stay tourists was 19,116. Calculation of the amount of $CO_2$ released from tourist activities in one year was calculated using Equation (5) and the results are shown in Table 2.

$$\text{Total Carbon emission in 1 year} = \sum(N_1 \times CA_i) + \sum(N_2 \times CB_i) \quad (5)$$

where, i is the consumption activities of tourists, $N_1$ is the number of day-trip tourists, $CA_i$ is the amount of $CO_2$ released due to the activities of day-trip tourists, $N_2$ is the number of overnight-stay tourists, and $CB_i$ is the amount of $CO_2$ released due to the activities of overnight-stay tourists.

*Touristic Ecological Footprint*

The TEF calculation considered only the demand on forest land required to absorb the $CO_2$ emitted by tourist activities and expressed it in units of global hectares according to Equation (6), which in turn was based on Chambers et al. (2000) and the results are provided in Table 3.

$$\text{Total TEF} = \sum(C_i \times A \times ef) \quad (6)$$

where, i is the consumption activities of tourists, $C_i$ is the amount of $CO_2$ released from tourist activities in one year, A is the areas used for absorbing $CO_2$ amounting to 1 kg per year (ha), and ef is the equivalence factor for fossil energy land.

From Table 3, it could be concluded that in one year, the area to absorb $CO_2$ from tourist activities was 679.59 gha. Thus, one tourist requires 0.033 gha of land for waste or $CO_2$ absorption due to their tourist activities. From the above results, it could be seen that the TEF of transportation has the largest proportion, which coincided with the research by Luo and Wu (2011), Patterson, Niccolucci, and Marchettini (2008), and Peng and Guihua (2007). They identified that the TEF of transportation had the largest proportion because the TEF of transportation varied according to the travel distance, which had a direct effect on the increase in the TEF.

**Table 3**
TEF for Mu Ko Surin National Park

| Tourist activity category | $C_i$ ($kgCO_2e$) | A[a] (ha) | ef[b] | Total TEF (gha) | TEF per capita (gha) |
|---|---|---|---|---|---|
| Transportation | 2,524,501.32 | 0.00019 | 1.1 | 527.62 | 0.025 |
| Food consumption | 353,937.30 | | | 73.97 | 0.004 |
| Waste disposal | 270,239.90 | | | 56.48 | 0.003 |
| Recreational activities | 102,963.63 | | | 21.53 | 0.001 |
| **Total** | **3,251,642.15** | | | **679.59** | **0.033** |

Remark:
[a] WWF (2002);
[b] Chambers et al. (2000)

In order to convey the interpretation to regular tourists so they could understand the level of impact of their use on the ecosystem and environment at tourist attractions, this study calculated the ecological carrying capacity of the Mu Ko Surin National Park considering only the demand on forest areas to absorb the $CO_2$ released by the tourist activities with details for the calculation of ecological carrying capacity, as shown in Table 4.

Tables 3 and 4 show the interaction between the capacity of forests and the demand on areas to absorb the $CO_2$ released from tourist activities. The statistics on Thai tourists visiting Mu Ko Surin National Park in 2013 suggest that the 20,347 tourists would require 679.59 gha of forest areas to absorb $CO_2$, while Mu Ko Surin National Park had 3,000.8 gha of forest areas that could support tourist consumption. Thus, based on the study levels of $CO_2$ tourist consumption, approximately one-fifth of the total forest areas of Mu Ko Surin National Park, would be required which is equivalent to 0.23 times.

Wackernagel et al. (1999) studied the national ecological footprint based on collecting data from 52 countries to determine the measurement of levels of consumption appropriate for sustainability of the environmental ecosystem, which specified the ecological possession appropriateness levels in five levels ranging from “Especially Appropriate” with an ecological possession ratio (EPR) less than 0.382 to “Inappropriate” with an EPR of more than 1. The results of the current study indicate that the EPR of Mu Ko Surin National Park was at the Especially Appropriate level with an EPR of 0.23 times.

However, this study investigated the minimum level of the demand on bioproductive land area because the calculation of tourist consumption levels considered only transportation, food consumption, waste disposal, and outdoor recreational activities. In addition, this study did

**Table 2**
Amount of $CO_2$ emissions from tourists in one year ($kgCO_2e$ per year)

| Tourist activity category | Day-trip tourist | | | Overnight-stay tourist | | | Total carbon emissions per year |
|---|---|---|---|---|---|---|---|
| | $N_1$ | $CA_i$ | Total carbon emissions | $N_2$ | $CB_i$ | Total carbon emissions | |
| Transportation | 1,231 | 167.28 | 205,921.68 | 19,116 | 121.29 | 2,318,579.64 | 2,524,501.32 |
| Food consumption | | 4.74 | 5,834.94 | | 18.21 | 348,102.36 | 353,937.30 |
| Waste disposal | | 3.94 | 14,850.14 | | 13.36 | 255,389.76 | 270,239.90 |
| Recreation activities | | 1.65 | 2,031.15 | | 5.28 | 100,932.48 | 102,963.63 |
| **Total** | | | **228,637.91** | | | **3,023,004.24** | **3,251,642.15** |

**Table 4**
Ecological carrying capacity of Mu Ko Surin National Park

| Bioproductive land | Area (ha) | Equivalence factor | Total ecological carrying capacity (gha) |
|---|---|---|---|
| Fossil energy land | 3100 | 1.1 | 3,410 |
| 12% deducted for biodiversity conservation | | | 409.2 |
| **Total** | | | **3000.8** |

not identify the consumption behavior level of foreign tourists. In 2013, the number of foreign tourists was 31.57 percent of all tourists visiting Mu Ko Surin National Park. This means that the level of demand for land to support tourism activities must be increased. This information could convince the National Park officials that they must be aware of the impact resulting from tourist behavior, as well in planning their potential capacity to accommodate tourists in order to maintain the appropriateness and security of the EPR.

## Conclusion and Recommendation

The TEF is one of the indicators that can be used to assess the sustainability of tourism and can be an effective interpretative measurement because it provides a statistic that makes it easy to understand the relationship between humans and the ecosystem. The TEF is also a tool that can create and stimulate the environmental awareness of tourists. This study was conducted to study the TEF at the individual level. It can also be considered as a study of the personal ecological footprint by investigating the demand on forest areas to absorb $CO_2$ released from the tourist activities and comparing the area at the local scale level or the size of the study area to benefit policy making in management planning for the Mu Ko Surin National Park.

The research revealed that day-trip tourists generate carbon dioxide emissions within one day from four activities that accounted for 177.62 $kgCO_2e$ per person, while overnight-stay tourists generated 132.06 $kgCO_2e$ per person for the same period. The area required to absorb the $CO_2$ from the tourist activities was 679.59 gha. Such consumption behavior required about one-fifth of the forest areas of Mu Ko Surin National Park. However, this study did not include all actual impacts, such as accommodation, electricity, and water consumption. In addition, the calculation of the ecological footprint in this case did not determine the complexity, the dynamics of nature, and the restoration of ecosystems, although these indicators are required to approximate the complexity of the ecosystem. However, simple assessment indicators can be beneficial for policy making, developing a decision support system, and to follow-up on impact in the area.

The recommendations for park management to support tourism are: 1) the development of a system to monitor the actual impact based on appropriate levels between the EF and the ecological carrying capacity; 2) the development of EF measurement in the form of an application on a smart phone so that tourists can themselves calculate their level of impact from their tourist activity; 3) the development of interpretive programs to inform tourists about their TEF and to make them aware of the impact resulting from their behavior which will lead to consumption behavior changes corresponding to sustainable tourism development; and 4) waste management in the park should be reconsidered and improved in order to eliminate waste problems on the islands. Moreover, further study should investigate a comparison with the TEF values of other national parks for the sake of national park management as a whole.

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