WATER BALANCE AND ENVIRONMENTAL FOOTPRINT ANALYSES FOR RESOURCE MANAGEMENT OF ELEPHANT CAMPS, CHIANG MAI PROVINCE, THAILAND

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ABSTRACT

This study focuses on evaluating the water balance and environmental footprints of four elephant camps in the Mae Taeng and Mae Wang districts of Chiang Mai Province, Thailand. The study assesses the environmental impact of human activities in terms of natural resource usage, consumption, and waste. The results reveal that while the elephant camps generally have sufficient water resources for their needs, certain camps may need to enhance their water storage and wastewater treatment capabilities. The ecological footprint analysis indicates that the resource consumption in elephant camps exceeds the average in Thailand and worldwide, emphasizing the importance of sustainable resource management. This study contributes valuable insights into developing efficient water management models and promoting sustainable tourism practices in the context of elephant camps.

Keywords: Ecosystem Service, Ecological Footprint, Water Footprint, Water Balance, Elephant camp

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INTRODUCTION

The Elephant Camp is one of the businesses that uses both direct and indirect water. Elephant camp is a popular tourist attraction in Thailand, particularly in Chiang Mai, and attracts visitors from around the world. The use of natural resources such as soil, water, and forest from elephant camp has significant environmental impacts. To assess the ecological footprint and impact of human activities, consider natural resource usage, consumption quantities, and waste. Effective management and allocation of resources in elephant camp are essential for maintaining a balanced ecosystem that meets the needs of elephants, staff, and tourists. The consumption of the elephant camp may affect the water resources and the ecosystems surrounding the camp. Elephant camp is considered a business that benefits directly and indirectly from water usage; a single elephant requires approximately 150-200 liters per day (Baskaran et al., 2010) for bathing and spraying water on the body. However, the needs of water in the elephant camp include not only elephants but also staff, tourists, and villager. Water-use activities impact water resources and environmental systems. The study of water balance and ecological footprints helps identify problems and efficiently develop natural resource management systems for sustainable tourism.

An accounting of water's inputs and outputs is called the water balance. The intake, outflow, and storage changes of surface water can be used to calculate the water balance of any area, i.e., residential area, industrial area, agricultural field, or watershed. The major input of water is from precipitation and output can be evapotranspiration and human usages. A calculation of water balance in hydrology can be used to explain how water enters and exits a system (Thompson, 1999). Environmental footprint can be used to qualify and quantify the exploitation of natural resources from human activities in several aspect, e.g., water footprint and ecological footprint (Martinez et al., 2019). The freshwater use indicator known as water footprint, a consumer's or product's direct and indirect water usage per unit of production, is considered recently (Hoekstra et al., 2011). The size of the water footprint lets us know how much of our limited water resources that product has claimed and whether it could be made more efficiently (Water Footprint Network, 2023). The ecological footprint, or the amount of nature required to support humans and their economies, is a metric for measuring human demand on nature (Global Footprint Network, 2017).

To develop an efficient and sustainable water management model for tourism, studying the water balance and environmental footprint analyses as important information to quantify and qualify the impact of elephant camp activities is needed.

LITERATURE REVIEWS

Water Balance

The water balance represents the equilibrium or equality between the natural water supply and the demand for water consumption and usage in both domestic and industrial sectors. Water management should prioritize achieving equilibrium and efficiently managing water resources in harmony with nature and stakeholders (Hydro-Informatics Institute, 2012). In Thailand, over 70% of agricultural water comes from surface water, primarily rainfall. Farmers frequently encounter challenges related to drought in agriculture, prompting the creation of irrigation systems to reserve water for agricultural use. It is essential to research the water balance in each area since these aids in the development of customized water reserve systems and promotes the sustainable management of water resources.

To study water balance in a particular area, it is essential to know the overall water system in the area. It is necessary to be aware of the water budget in the area, including the water source and the water demand for various activities. This enables efficient management of existing water resources and ensures a balanced approach, promoting water conservation and utilization in different activities. For instance, water balance assessments have been studied in certain water resources, e.g., Bueng Boraphet and Tonle Sap Lake (Saraphin et al., 2014; Mab & Kositsakulchai, 2020). These involve the calculation of the water budget and water demand. The water budget considers the amount of rainfall in the area and the size of the water catchment area for that community. Water demand needs to be calculated separately for different purposes, such as plant or animal needs. In the case of elephant camp, where water demand might not be fully covered, additional tools such as water footprints can be utilized to estimate water use in the area.

Water Footprint (WF)

A water footprint is a measurement unit that indicates the volume of water used in the production of goods and services, both directly and indirectly. The calculation involves assessing the water quantity at every stage throughout the entire supply chain of the product or service, expressed in terms of water footprint size. The unit can be either in cubic meters per year or cubic meters per person per year. The water footprint not only reveals the amount of water consumed but also serves as a tool to evaluate the environmental impact resulting from the production of goods or services in terms of water usage. Additionally, it provides insights into the quantity of wastewater generated, along with details on the time and location of water consumption (Chapagain et al., 2006; Hoekstra et al., 2011).

Water footprints can be divided into three parts: green water footprint (WF_{green}), blue water footprint (WF_{blue}), and grey water footprint (WF_{grey}). WF_{green} refers to the quantity of rainwater and soil moisture utilized in the production of goods and services, especially in agriculture. WF_{blue} represents the volume of water sourced from natural water bodies, such as surface water (rivers, lakes), reservoirs, and groundwater. It is used in activities like irrigation, industrial processes, and domestic consumption. WF_{grey} signifies the amount of wastewater generated during the production of goods and services. It is calculated based on the water used for treating and managing the generated wastewater, considering the standard quality that allows its release back into the environment. Common pollutants include fertilizers, toxins, and pesticides (Hoekstra et al., 2011).

The case study of the water footprint in Thailand is about the production of goods rather than services. For instance, studies have investigated the water footprint of energy crops, crops with economic significance, and products derived from these crops, such as rice, corn, sugarcane, etc. (Wangmuang & Sajjakamol, 2011; Tewapuchom, 2016). Additionally, research has been conducted on the water footprint of the hotel industry in Phuket province (Siduka, 2020). The study of water footprint in process of water consumption from the customer service in the hotel (Van Oel et al. 2008). Understanding water footprints not only reveals the actual water usage concealed in the production of goods or services but also aids in assessing the environmental impact of production on water resources. This knowledge contributes to a clearer understanding of water scarcity issues and water pollution, leading to improved water resource management. Therefore, utilizing water footprint measurement tools is crucial for evaluating water usage in production and services.

Ecological Footprint

The ecological footprint is a measurement unit that indicates the number of resources consumed through the production of goods and services, including the quantity of waste generated. It is measured in global hectares per capita. The concept is based on the idea that all forms of life require resources from the ecosystem to sustain life. A larger ecological footprint implies a greater consumption of resources compared to a smaller footprint. This concept was introduced in 1992 by William Rees, gained widespread global attention, and has been continuously studied. Research on the ecological footprint has been conducted on various scales, including national, regional, and local levels (Global Footprint Network, 2020).

Case study in European countries of ecological footprint (Alola et al., 2019) and Southeast Asian nations such as Thailand and neighboring countries (Suteethorn, 2011; Ahmed et al.,

2019; Nathaniel, 2020; Weeranakin, 2020). In Thailand, studies have evaluated the ecological footprint to assess its environmental impact. For example, research has been conducted on the ecological footprint in the Pong River basin, an economically significant industrial area in Khon Kaen province (Weeranakin, 2020). Other studies have focused on the transportation impact on the ecological footprint of food production in Bangkok (Suteethorn, 2011). Additionally, studies have explored the ecological footprint to indicate the urbanization trend in Malaysia (Ahmed et al., 2019) and to assess environmental quality in Indonesia (Nathaniel, 2020).
However, research on the ecological footprint at the local scale is less common due to the need for systematic data collection, which is time-consuming. Neglecting studies at the local level may lead to inaccuracies in broader-scale calculations, such as regional and national scales. Therefore, this study focuses on investigating the ecological footprint of elephants and related activities in the study area of Mae Taeng and Mae Wang districts, Chiang Mai province, known for their elephant-related activities in the context of the broader study area of Mae Wang and Mae Taeng districts, Chiang Mai province.

RESEARCH METHODOLOGY

Sites study were four elephant camps in Mae Taeng (sites A and B) and Mae Wang Districts (site C and D), Chiang Mai Province (Figure 1). The data were collected during November 2020 to October 2021, i.e., geography data and water pathways (e.g., irrigation system and water storage reserves) using GPS with Satellite Imagery. These data were used to prepare water maps in the area of each elephant camp. For water balance and water footprint, the water consumption was assessed by questionnaires and interviews regarding amount of water resource use, waste management and disposal, transportation, and others. Additionally, the water quality of wastewater from cleaning the elephant housing was measured. To analyze the water balance and water budget, this study used the equations of the community water balance manual (Hydro-Informatics Institute, 2012) as follows;

Water balance (elephant camp) = Water budget-Water demand (TWF)
Water budget (m^3) = Watershed (rai) x Annual rainfall (mm) x 0.8 x 0.3 x 1,600 /1,000

Where the watershed is the area including rainwater, annual rainfall is the volume of precipitation in area, 0.8 is the precipitation ratio, 0.3 is the runoff coefficient, 1,600 is 1 rai, and 1,000 is convert the value to m^3
For water footprint, this study considered only WF_{blue} and WF_{grey} analyses. WF_{blue} (m^3/camp/year) for tourism activities in the elephant camp included water consumption per capita in elephant camp, cleaning purposes, and management. WF_{grey} (m^3/camp/year) of elephant camp is volume of freshwater that is needed to dissolve impurities that are excessive for water-carrying capacity from cleaning the elephant housing. The calculation formula is as follows: $WF_{grey} = V_w \times (\max(\rho_i/\rho_o) - 1)$. V_w stands for wastewater discharge, which is not meeting the required standards; ρ_i and ρ_o refer to the measurement value and water standard concentration of i pollutant, respectively; ρ_i/ρ_o is the dilution coefficient. Here, the maximum dilution is needed ($\max(\rho_i/\rho_o)$) to get the overall dilution volume in order to handle all contaminants. This implies that all other pollutants will also be adequately diluted if this pollutant is appropriately diluted (Hoekstra et al., 2011; Zhang et al., 2017). In this study, the measuring of the chemical oxygen demand (COD) of wastewater from cleaning the elephant housing in each camp was defined as ρ_i, while ρ_o referred to the surface water quality standards (PCD, 2020).

The ecological footprint assessment was investigated using online database; www.footprintcalculator.org, which all data for field surveys and interviews were used following the Life Cycle Analysis (LCA) concept.

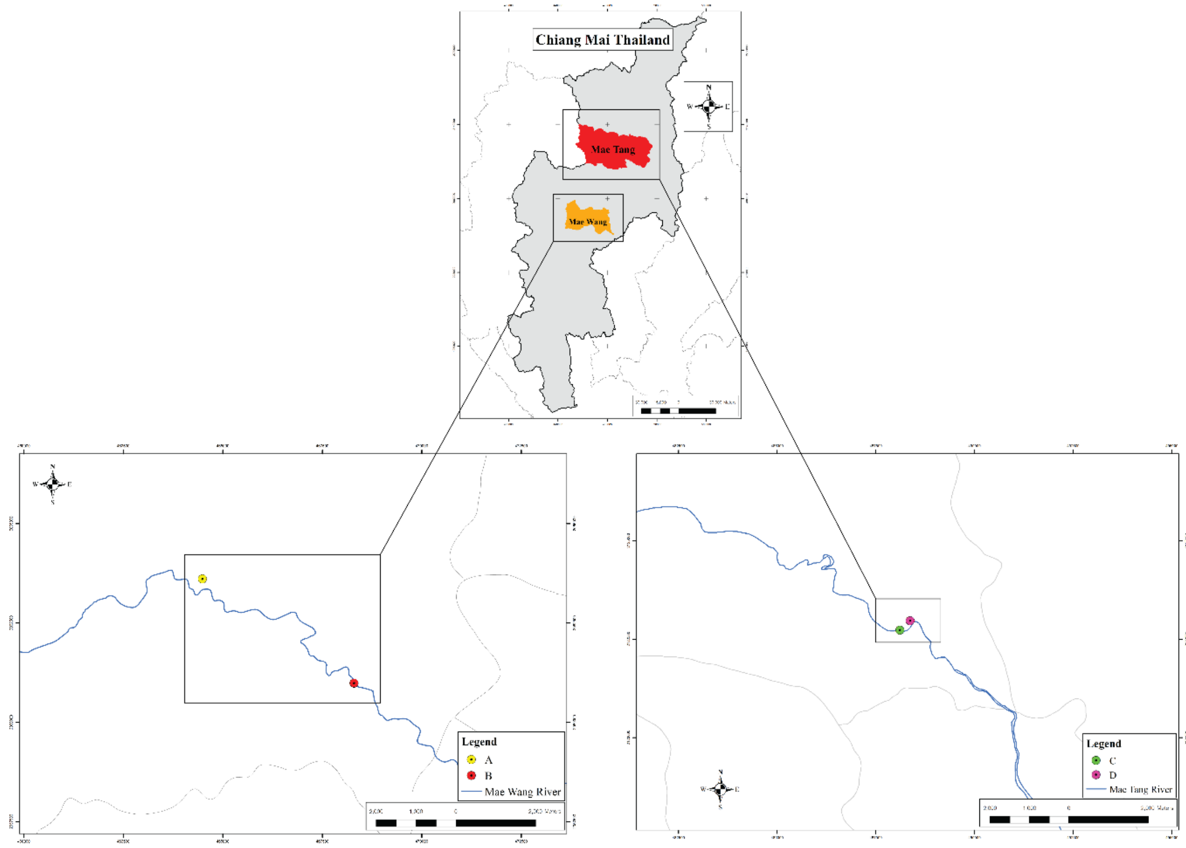

Figure 1 Four elephant camps as study sites in Mae Taeng and Mae Wang District, Chiang Mai Province

RESEARCH RESULTS

The water balance of elephant camp is divided into two types: 1) The quantity of water demand according to general water usage (or actual water use) based on actual consumption, including consumption, household cleaning, and other water uses; 2) The quantity of water demand according to water usage to meet environmental standards (including hidden water, or grey water footprint). The assessment of water balance in the elephant camps revealed that elephant camps A, B, C, and D have sufficient water to meet their water demand indicating by the lower WF_{blue} requirement than water budget. Elephant Camp A showed the smallest size of WF_{blue}, followed by camps B, D, and C, indicating the size of water demand. Moreover, the elephant Camp A showed the smallest size of WF_{grey}, followed by camps B, C, and D, indicating the size of water requirement for environment. When assessed against environmental standards, only elephant Camp C has a sufficient water budget (Table 1).

Table 1 Water balance and water footprint analyses of elephant camps

Elephant Camps	Water budget (m^3/yr)	Water footprint (m^3/camp/yr)		Water balance (m^3/camp/yr)	
		WF_{blue}	WF_{grey}	For general usage	For general use and environment
A	9,865	832	31,943	9,032	-22,079
B	20,434	2,539	40,628	17,895	-20,194
C	427,942	8,844	180,651	419,097	247,290
D	24,634	8,534	239,253	16,100	-214,618

Regarding the ecological footprint, data were gathered through surveys on resource usage from each elephant camp. The resource utilization of each elephant camp was then categorized into two groups, including the usage by the elephant camp itself (Mahout and staff) and the tourists who utilize services within the elephant camp area. This classification is based on four aspects: accommodation, food, transportation, and goods and services. The ecological footprint is calculated and presented in the Figure 2.

The ecological footprint in the elephant camp A, B, C and D have higher than the average in Thailand and Worldwide are 2.30 and 1.70 gha/person, respectively. Specifically, the ecological footprint of the mahout and staff in the elephant camp is as high as 1.87, 2.48, 2.57, 2.51 and 2.57, 3.35, 3.47, 3.41 times, respectively, and of tourists who come to use the services in the elephant camp area which have values as high as 2.30, 2.13, 2.57, 2.22 and 3.12, 2.88, 3.47, 3.00 times, respectively. The major consumptions of four elephant camps were about food, and accommodation, whereas the minor consumptions were transportation and goods and services in the elephant camps.

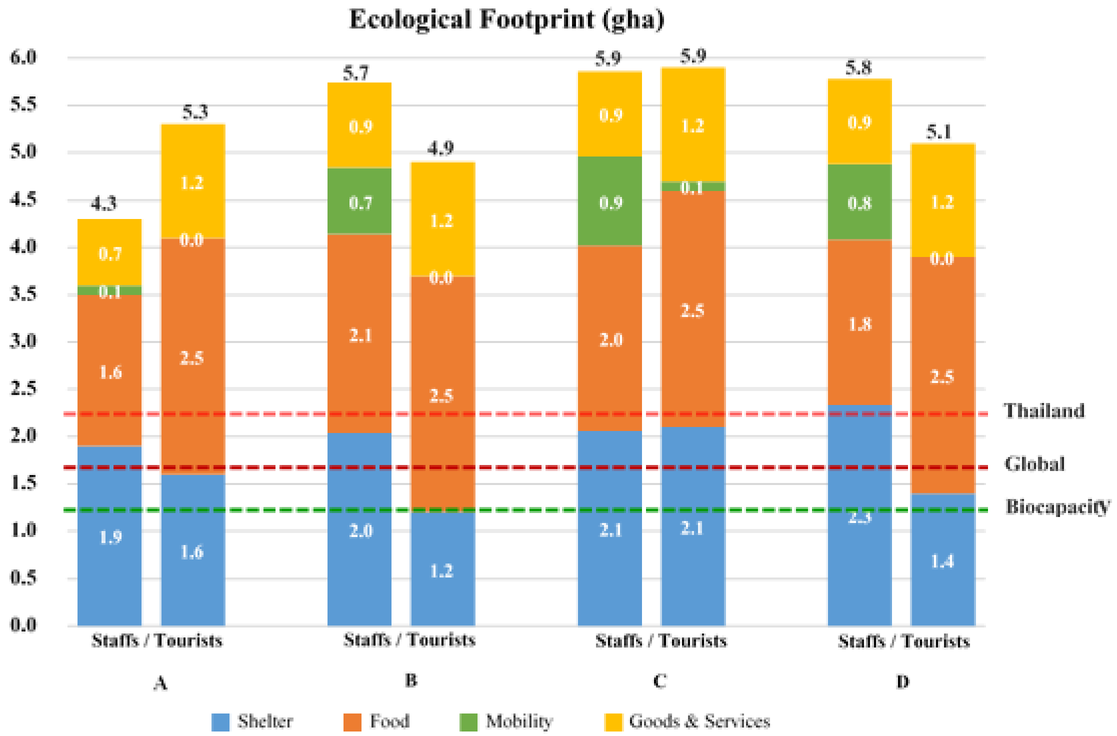

Figure 2 The Ecological footprint ratio of the staffs and the tourists in the elephant camps

DISCUSSION & CONCLUSION

Utilizing water footprints to assess and calculate water usage in various production and service processes is a crucial measure, providing both producers and consumers with a comprehensive view of actual water consumption, encompassing both clean and hidden wastewater within various processes (Chapagain et al., 2006; Hoekstra et al., 2011; Chuenwongarun, 2022). Upon evaluating four elephant camps' water balance, it was observed that elephant camps A, B, C, and D have adequate water resources to meet general consumption needs. However, when considering environmental standards, elephant camps A, B, and D exhibit considerably higher water demands. Only elephant camps C has a water surplus that is sufficient to meet environmental standards because it has its own water resources such as water storage, and pond. The other camps may need to enhance their water storage capabilities. Additionally, this study suggests that all elephant camps may need to manage water storage capacity, explore water transfer options from other areas, and prioritize wastewater treatment to meet environmental standards. This aligns with Tewapuchom's (2016) study on water footprints in cultivation processes, indicating that blue and grey water footprints are disproportionately large, potentially impacting soil surface water quality and future water scarcity. Therefore, it is essential to increase water storage in the area, including reservoirs and check dams. Due to the elephant camp's location near rivers and their utilization of natural water resources without adequate regard for water scarcity, it is crucial to treat wastewater before discharging it into natural water sources to adhere to environmental quality standards. This analysis underscores the significance of evaluating the water balance and footprint to comprehend the overall water usage in various processes and advocate for water conservation. This awareness can foster a deeper appreciation for water conservation and sustainable resource utilization.

For ecological footprint assessment, from the on-site survey and data collection of resource usage in each elephant camp, there were two groups of studies, i.e., staff of the elephant camp and tourists. Notably, most elephant camps do not provide overnight accommodation for tourists in the study, except elephant camp B, which offers overnight accommodation services. When analyzing the ecological footprint of the resource usage by tourists in elephant camp, encompassing residential, food consumption, travel, and goods and services, it was found that elephant camps A, B, C, and D have ecological footprints higher than the average in Thailand and globally. The larger ecological footprints of elephant camp activities indicating an excessive utilization of natural resources. This aligns with the study by Weeranakin (2020) on the ecological footprint in the Nam Pong River Basin, Khon Kaen Province, which found that the ecological footprints are strongly related to the benefits derived from natural resources, especially soil and water resources, leading to a continuous degradation of valuable environmental areas (Suteethorn, 2011). To manage natural resources in the limited elephant camp area and promote sustainable resource use, there should be a campaign to use environmentally friendly materials and a shift in the resource use pattern to consider the amount of waste that will occur in the elephant camp area. This can help reduce the size of the ecological footprint and lead to sustainable resource management in the elephant camp area in the future.

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