sustainability

Review

Progress and Prospects for Tourism Footprint Research

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Abstract: The tourism footprint family comprises the tourism ecological footprint (TEF), the tourism carbon footprint (TCF) and the tourism water footprint (TWF). The tourism footprint represents an important tool for quantitatively assessing the impact of tourism activities on the ecosystem of a tourist destination. This paper systematically reviews the relevant literature on TEF, TCF and TWF, analyses and summarizes the main progress and failures in the analytical frameworks, research methods, measurement results, environmental impacts and reductions in the tourism footprint. This paper also proposes areas for further developing the tourism footprint research, including unifying the analytical frameworks and boundaries of the tourism footprint, distinguishing the geographical scope of the tourism footprint effectively, improving the process of analyzing the environmental impact of the tourism footprint, measuring the tourism footprint scientifically and roundly, performing space-time calculations of the tourism footprint, and expanding the tourism footprint family by introducing new members. Accordingly, this paper is devoted to the continued study of the tourism footprint.

Keywords: tourism ecological footprint; tourism carbon footprint; tourism water footprint; research review; research prospect

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1. Introduction

Tourism activities, as a part of the human lifestyle and a form of ecological consumption, have a profound impact on ecosystems (such as soil erosion, air and marine pollution, and natural habit loss) in tourist destination areas by appropriating and consuming sightseeing resources, travel facilities (such as roads and airports), and tourism services (such as resorts, restaurants, hotels, marinas, shops, and golf courses). Therefore, the rapid growth in tourism might cause major problems in terms of environmental sustainability [1–3]. In the early stages of tourism research, studies paid comparably little attention to the impact of the overall industry on the natural environment, and research in important fields, such as those analyzing tourism energy consumption, food consumption and water supplies, rarely assesses the sustainability of tourism products and tourist destination areas [4]. However, increasing numbers of researchers, governments and international organizations have been considering the impacts of large-scale tourism industries on the environment in light of the rapid development of the global tourism industry and the burgeoning environmental issues of climate change and water resource scarcity. Consistent with this focus, many tourism footprint analyses have emerged in recent years, including tourism ecological footprint (TEF) analysis, tourism carbon footprint (TCF) analysis, and tourism water footprint (TWF) analysis, which share the research target of better integrating tourism industry development with the protection of the ecological environment. TEF analysis emphasizes the comprehensive assessment of tourism activities' impact on the environment, which has the advantage of being a comprehensive evaluation. TCF and TWF analyses emphasize specific evaluations (TCF analysis focuses on the effects of carbon emissions from tourism activities on climate change, and TWF analysis focuses on the effects of water consumption from tourism activities on water resources), which have the advantage of being thorough evaluations. According to Galli et al. [5], Fang et al. [6], and Stoeglehner and Narodoslawsky [7], the footprint family consists of a number of members (each of which is a single-dimensional footprint) that can reflect human pressure on the planet and address research questions, rationales and methodologies. We argue that TEF, TCF and TWF analyses have gradually built the structure of the tourism footprint family, which not only measures the tourism industry footprint but also assesses the footprint of tourism products, tourist destination areas, and even tourism companies. As important and effective tools to evaluate a potentially sustainable tourism industry, TEF, TCF and TWF analyses are unique approaches to examining sustainable tourism, and they can scientifically measure the impact of the tourism industry and tourist activities on the environment. In addition, some studies, such as those on the tourism figure footprint (a virtual footprint), cannot assess the impact of tourism activities on the environment, and this is outside the scope of our analysis. The purpose of this paper is to review the relevant achievements of the tourism footprint family, summarize its progress, analyze its shortcomings, and propose areas for further research on the tourism footprint.

2. Research Progress of the Tourism Footprint Family

2.1. Roots

TEF analysis first received attention from researchers as an extension of ecological footprint theory, and it is based on the ecological footprint analytical framework. Rees [8] was the first to propose the concept of the ecological footprint, and Wackernagel and Rees [9] improved on the idea. The ecological footprint is an estimate of the area of biotically productive land and water that are appropriated exclusively to produce the natural resources used and assimilate the wastes generated. The ecological footprint can quantitatively estimate regional sustainability by comparing natural resource consumption with the ecological capacity of the biosphere [10]. Based on the theory of the ecological footprint, Hunter [1] formally introduced the TEF concept to show the actual consumption of natural resources and waste generation by tourists in terms of the appropriated area of land and water in the relevant ecosystem in a certain area. Empirical TEF measurements, such as those for the town of Manali [11]; the regions of Val di Merse, Italy [12]; Shangri-La, China [13]; Lanzarote Island, Italy [14]; and the countries of the Seychelles [15] and Tunisia [16], have been analyzed to account for the environmental externality of tourism growth.

Tourism, as an economic activity, has one of the largest effects on climate change [17] and is estimated to have contributed to 5% of global CO_2 emissions in 2005, with an approximately 8% contribution to radiative forcing (including the impact of both short- and long-lived greenhouse gases on global warming) [17]. Against this background, TCF analysis focuses on environmental issues caused by large-scale tourism, particularly its energy consumption and CO_2 emissions (defined as the amount of $CO_{2\text{-eq}}$ emissions caused directly and indirectly by tourism activity), which have been widely researched at various scales, such as analyses for the countries of New Zealand [18], Sweden [19], Australia [20], Spain [21,22], Iceland [23], and China [24–26]; the regions of Taiwan [27–29], Wales [30], and Poole [31]; and even the scenic locations of the Penghu Islands [32] and Huangshan National Park [33]. TCF analysis excels at assessing the impact of tourism greenhouse gas emissions on climate change and identifying the contribution of tourism carbon emissions to climate change at the global scale, which has become a key research field.

In recent years, the tourism industry has been increasingly recognized as a significant water-consuming sector at the local, regional and global scales [34,35]. Against the background of freshwater availability, which is increasingly under pressure [36], the conflict between increasing tourism water demands and shortages in water supply has become progressively more serious. Therefore, TWF (the total volume of water that is used to produce a unit of a good or service that a tourist consumes [35]) analysis has received attention from not only tourism researchers but also international organizations, such as the United Nations World Tourism Organization (UNWTO), the United Nations Environment Programme (UNEP) and the Organizations for Economic Co-operation and Development (OECD). TWF studies in recent years have analyzed the regions of Zanzibar, Tanzania [37], Hong Kong, China [38], Sarigerme, Turkey [39], and the western Mediterranean [40]; the country of Spain [41]; and the world [42]. TWF analysis has the advantage of measuring the impact of water consumption from tourism on the balance of water supply and demand as well as water pollution in certain regions (especially in arid regions with water resource shortages) at the local scale, which has been viewed as a key local sustainability issue in water-scarce destinations. Compared with TEF analysis and TCF analysis studies, there are fewer TWF analysis studies in the literature, and this is an often overlooked area [42,43].

2.2. Analytical Framework

Overall, defining an analytical framework is the key issue in tourism footprint research. The current framework is more complete than earlier ones. In the early stages, only a few data were included in the analytical framework. For example, the first analytical framework of TEF, by Gössling et al. [15], included four parts: tourism transportation, accommodations, recreational activities and food consumption. In empirical analyses, Patterson et al. [12] and Peeters and Schouten [44] noted that tourism transportation should include two segments: transportation from the origin to the destination and local transportation. This improvement was helpful for determining suitable allocations in estimating the tourism footprint at the national, regional and local scales and obtaining reasonable results. Since then, additional content has been added to the analytical framework. For example, Zhang and Zhang [45] constructed an analytical framework for TEF that comprised six parts of tourism: transportation, accommodations, catering, shopping, entertainment, and sightseeing. Li and Yang [13] added waste disposal to the TEF measurement and constructed a seven-part analytical framework—including tourism transportation, accommodations, catering, shopping, entertainment, sightseeing, and waste disposal—which is comparatively complete for scientifically measuring the TEF.

Becken and Patterson [18] proposed an analytical framework of the TCF based on three components—tourism transportation, accommodations, and recreational activities—to estimate the energy use of New Zealand tourism. Additional studies performing TCF measurements, such as Kuo and Chen [32] for the Penghu Islands, Bruijn et al. [46] for The Netherlands, and Tang et al. [47] for China, adopted the analytical framework for empirical analyses. Generally, analytical frameworks contain only three tourism-related sectors that are unable to roundly assess the TCF and produce smaller results in comparison to reality. More content has been added to analytical frameworks to address this issue. For example, Sharp et al. [23] proposed a four-part framework that includes local transport, accommodation and restaurant services, retail goods, and recreation and leisure services. The analytical framework by Sun [27] includes eight components: air transport, land transport, shopping, food, lodging, entertainment, travel service, and car-rental service. No unified analytical framework for the TCF has been created and widely accepted by the majority of researchers. However, a review by Gössling [48] argued that a framework for a comprehensive emission assessment in tourism should include seven parts: transports, accommodations, attractions, food and beverages, infrastructure (planning and construction), marketing and sales, and shopping and services. Such an analytical framework would be relatively complete. In addition, TCF analysis should include both direct and indirect impacts [48,49], and some studies [20,21,27,50] have followed this principle. However, some assessments [51,52] have been restricted to direct carbon emissions and have excluded indirect emissions, causing inaccurate results.

Early TWF studies mainly emphasized the direct water footprint calculations for tourism accommodations, swimming pools, spas and water parks [37–40,53–56]. In contrast, later studies have paid more attention to the comprehensive analysis of the TWF by including direct tourism water consumption and indirect tourism water consumption. The TWF analytical framework created by Yang et al. [57] includes only three components: water for direct use, food service and waste dilution. Hadjikakou et al. [43] provided a more detailed analytical framework that includes direct water consumption by accommodations and tourist activities and indirect water consumption through food consumption and tourism energy consumption. Contemporary studies have developed the earlier tourism footprint analytical frameworks, making them more complete and substantial with more content and details. Gössling [35] further expanded the TWF analytical framework and included direct water use for accommodations and activities in addition to indirect water use for infrastructure, fossil fuels for transportation, energy use at hotels, biofuels, food and other forms of consumption. This analytical framework can effectively measure tourism water consumption at various scales; however, it is not entirely complete because it excludes tourism marketing, shopping and other tourism services.

In case studies, because of complexities in defining the extent of tourism in the context of the economy (of which there remains no single definition [48]) as well as difficulty in data acquisition, TEF, TCF and TWF analytical frameworks have often been simplified according to the collected data. Most studies include only partial information when they assess the tourism footprint, leading to difficulties comparing the results of these studies.

2.3. Research Methods

Generally, both "top–bottom" and "bottom–top" methods are used to collect and analyze data to calculate the tourism footprint. The top–bottom method directly estimates the proportion of tourism resource consumption or waste emissions that account for a holonomic system (an entire country or state) based on the monitoring data of tourism resource consumption and waste emissions. Input–output (IO) analysis provides a theoretical foundation for this approach. Incorporating IO analysis with the tourism footprint analysis is helpful for comparability and veracity, but challenges such as repetitive counting and difficulty in data collection usually emerge in practical studies [58]. The bottom–top method directly calculates resource consumption by tourism products or services and waste emissions in a step-by-step fashion, starting with tourist activities. The bottom–top method is based on life cycle assessment (LCA) theory and includes a four-part process of that includes the following features: study, inventory analysis, impact assessment and interpretation of results [59]. As a method that is used in combination with tourism footprint analysis to perform environmental impact assessments, LCA can completely evaluate tourism products or the service footprint, which is an advantage of this approach [18,31,60]. However, LCA is not feasible for all indicators in all sectors of tourism, and the boundary definition and data selection of LCA usually reflect researchers' subjectivity, which can lead to instable and conservative research results [32,58].

The top–bottom method uses statistical and satellite tourism data to measure the tourism footprint at the regional, national, and global scales, and these widely available data are not difficult to obtain. This method has been adopted by research in Taiwan, China [28]; Wales, the UK [30,50]; Hawaii, the USA [61]; New Zealand [62]; and South West England [63]. In contrast, the bottom–top method is suitable for measuring small regions, such as the tourism footprint of local or scenic spots, without statistical or satellite tourism data. Visitor surveys can be customized to reflect greater levels of detail [28], as in studies on the Penghu Islands, China [32]; the city of Whistler, Canada [64]; and Antarctica [65]. Some exceptions in the literature include a study that measured tourism carbon emissions for Huangshan National Park, China [33], using the top–bottom method because it is a developed park with a complete database. Measurements for The Netherlands and China have also been conducted following the bottom–top method to collect information by surveying residents or visitors [46,47]. Combining the two methods can effectively provide more comprehensive and accurate results, as observed in tourism footprint calculations that have been performed in New Zealand [18], Australia [20] and Switzerland [52] (Table 1). In addition, Cadarso et al. [22], Zhong et al. [25], and Zhou et al. [58] combined IO analysis with an LCA to build the IO-LCA joint model, which reduces truncation errors and superpositions and simplifies the calculation process. Overall, comprehensive methods will make tourism footprint results more dependable and less contestable.

Table 1. Research methods of the tourism footprint.

Methods	Areas	Sources
Top–bottom	Taiwan, China	[28]
	Wales, UK	[30,50]
	Hawaii, USA	[61]
	New Zealand	[62]
	South West England	[63]
Bottom–top	Huangshan National Park	[33]
	China	[25]
	Penghu Islands, China	[32]
	Whistler, Canada	[64]
	Antarctica	[65]
	The Netherlands	[46]
	China	[24,47]
Both top–bottom and bottom–top	New Zealand	[18]
	Australia	[20]
	Switzerland	[52]
	Queensland, Australia	[66]

2.4. Measurement Results

TEF analysis is designed to focus on a certain area. In contrast to studies performing TEF analysis, TCF studies contain two measurement criteria. The first criterion is based on the TEF analytical framework to explain the TCF as a fossil fuel footprint, which is equal to the land area that is necessary for assimilating CO_2. The second criterion is the direct measurement of the amount of tourism carbon emissions, presented as a unit of mass and no longer translated into land area for assimilating CO_2; it mainly evaluates the impact of tourism carbon emissions on the environment under the condition of climate change. Broadly, compared with the first measurement criterion, the second criterion has received more attention in relevant empirical studies. The TWF directly measures tourism water consumption and presents it as a unit of mass instead of a unit of area. Without being translated into a unit of area of land or water, the TCF and TWF indexes do not exhibit substantial uncertainty and avoid the mistakes that are induced by various hypotheses in the process of translation [67].

The tourism footprint can be measured at various scales, ranging from a scenic spot scale to a global scale. However, there are some differences among the various results for the same type of objects because different analytical frameworks contain different content, and different development stages of tourist destinations induce different types of consumption. For example, the TEF per capita measurement is 3.07 global hectares (gha) in Manali [11], whereas in Val di Merse, it is 5.28 gha [12]. There are also differences among various traveling routes from the single travel angle. For example, the TEF is 0.21 gha from Shanghai to Shangri-La [13], and it is 0.5286 gha traveling to Tunisia [16]. Compared with the results from Yang et al. [57], an average tourist leaves behind a daily footprint of 5.2 m^3 (5200 L) on local water resources. Based on the results from Hadjikakou et al. [43], the TWF ranges between 5790 and 8940 L per tourist per day in semi-arid eastern Mediterranean destinations. Generally, based on the relevant literature, direct water consumption from accommodations and activities ranges from 94 to 2030 L per tourist per day. If the indirect water use of tourism-related infrastructure, fossil fuels, biofuels, and food is considered, the amount of direct and indirect water consumption ranges between 2000 and 7500 L per tourist per day [42].

It is widely accepted that the contribution of indirect emissions can be much higher than that of direct emissions [68,69]. Indirect carbon emissions make a substantial contribution to the total emissions [27,70]; for hotels and tourism transport, they could be as high as 20% and 65%, respectively [31]. The average amount of direct water consumption per tourist is higher than that per local resident [43]. For example, the amount of water consumption in Zanzibar is 48 L per day per resident but 685 L per day per tourist [37]. Similarly, on Lanzarote Island, tourist water consumption is four times the water consumption of local residents [71]. The results from Yang et al. [57] also support the finding that tourist water consumption is higher than local resident water consumption in Liming Valley, China.

Compared with the tourism footprint of inbound tourists, that of domestic tourists is smaller due to their shorter traveling distances. For example, a daily foreign tourist carbon footprint for southwestern England is 196 kg of $CO_{2\text{-eq}}$ [63]. Hanandeh [72] indicated that on average, each Hajj religious tourist contributes 60.5 kg of $CO_{2\text{-eq}}$ per day. The inbound tourist carbon footprint of Iceland is 1.1–3.2 t of $CO_{2\text{-eq}}$, and the average is 1.35 t of $CO_{2\text{-eq}}$ [23]. However, in southwestern England, domestic overnight visitors account for 49 kg of $CO_{2\text{-eq}}$, and day visitors account for 48 kg of $CO_{2\text{-eq}}$ [63]. The TCF in Wales is even lower (20.72 kg of $CO_{2\text{-eq}}$ [30]). Furthermore, findings indicate that there are differences among inbound tourists due to differences in their traveling distances, transportation patterns, and activities. The daily TCF for British tourists with different transportation plans traveling to southern France for seven days is 20.1–77.1 kg of $CO_{2\text{-eq}}$ per tourist, and for 14-night tourists, it is 14.9–43.4 kg of $CO_{2\text{-eq}}$ per tourist [73]. The average per capita emissions of tourists visiting Iceland range from approximately 1.35 t to 3 t of $CO_{2\text{-eq}}$, increasing with the flight distance. An increase in the average flight distance has caused annual emissions to grow rapidly [23].

A structural analysis can effectively reflect the contribution of various types of tourism consumption to the tourism footprint, which is helpful for clarifying dominant driving factors and providing specific strategies to lower the tourism footprint. Table 2 shows that relevant studies agree that tourism transportation energy consumption is the primary component of the tourism footprint, accounting for 59–97% of it. However, this proportion is easily affected by other factors, such as travel distance [13], tourism vehicle choices, and the duration of stay. For example, the carbon footprint of short-haul tourists from the UK who travel to southern France shows that tourism transportation for 7- and 14-night vacations accounts for 40–84% and 27–75% of the total TCF, respectively [73]. In addition, tourism accommodations and tourism catering are important components of the tourism footprint, accounting for 3–21% and 2–16% of the total TCF, respectively. Furthermore, traveling by air is a dominant and increasing factor in the energy consumption and CO_2 emissions of tourism transportation [17,20,22,74], especially for isolated or island-based destinations, where tourists overwhelmingly arrive by air [18,20,48].

Table 2. Structure analysis of the tourism footprint.

Study Areas	Transportation (%)	Accommodation (%)	Recreation (%)	Catering (%)	Others (%)	Sources
Taiwan Islands	59	6	3	13	19	[27]
Mecca	60	18	—	13	9	[72]
Zhoushan Islands	60.18	10.44	—	16.03	13.35	[75]
Penghu Islands	67	17	16	—	0	[32]
China	67.72	29.92	2.36	—	0	[24]
China	68.16	12.13	0.91	—	18.8	[25]
Hawaii	69	25	6	—	0	[61]
Amsterdam	71	21	—	—	8	[44]
Anguilla	71	25	4	—	—	[76]
Global	72	24	4	—	0	[77]
New Zealand	73	17	10	—	0	[78]
Global	75	21	4	—	0	[17]
Shangri-La	82.14	2.72	0.02	12.19	2.93	[13]
Iceland	83–93	3–8	1.5–4	—	—	[23]
Val di Merse	90	3	—	6	1	[12]
Switzerland	87	10	1	2	0	[52]
Jiuzhaigou	87.16	4.63	—	7.12	1.09	[79]
China	88.65–91.10	7.62–9.33	1.28–2.03	—	0	[47]
Global	90	6	4	—	0	[51]
Amsterdam	94	4	2	—	0	[80]
Wales	96	2	2	—	0	[30]
Seychelles	97	2	1	—	0	[51]

2.5. Environmental Impacts

Generally, as a comprehensive index of tourism sustainability, TEF analysis contains plenty of content that can be used to effectively evaluate the impact of tourism activities on ecosystems by comparing regional natural resource consumption and waste emissions from tourism activities with the regional ecological carrying capacity. Many studies have shown that most tourist destination areas are unsustainable because the ecological footprint of touring backpackers is considerably higher than the average footprint of the backpackers in their home countries [2], or the ecological footprint per capita produced by tourists exceeds the ecological footprint produced by local residents [13,32], or the ecological footprint is clearly higher than the local environmental capacity [60,81]. The energy and material use that is associated with tourism and local activities has eroded natural capital foundations [82]. However, Patterson et al. [12] indicated that the tourist footprint is similar to the footprint estimated for residents, excluding arrival transport, and is also lower than the average footprint estimated for the tourists' countries of origin.

It is widely accepted that tourism carbon emissions have direct and indirect impacts on the environment at various scales. At the global scale, the tourism industry is responsible for 4.4% of global CO_2 emissions and has a growth rate of 3.2% [77]. If the current high-growth trends in emissions continue, tourism is likely to become a major source of greenhouse gas emissions [83]. The tourism industry accounts for 5–14% of anthropogenic global warming, which is predicted to increase 188% by 2035 [17]. At the national scale, the tourism industry has become an important sector for greenhouse gas emissions in some countries, such as in Australia and Switzerland, where the tourism industry contributes 3.9–5.3% and 5.2% of total greenhouse gas emissions, respectively. Generally, the tourism industry constitutes 4–150% of the total national emissions [48]. At the regional scale, many tourist destinations might have greater emissions than other similarly sized, non-tourism-based communities [20].

Meanwhile, there is little doubt that the water footprint created by tourism activities has a direct and potential impact on water resources and the environment. The amount of water that is directly consumed by tourists on vacation is estimated to be an average of 300 L per person per day, which is almost double the amount of water for home consumption (160 L per person per day); this means that tourism activities increase global water consumption and aggravate the water resource crisis to some extent. More seriously, due to climate change, tourism development has led to water security threats and has caused local water resource shortages in some tourist destination areas [42,84], especially in important or emerging ones, such as the American Southwest, southern Australia, central and coastal Brazil, the Middle East, central and southern China, and island hot spots such as Bali, Penghu, the Caribbean, and the Mediterranean [32,35,42,85]. Black et al. [86] forecasted that many important tourist destination areas, such as Tunisia, Malta, Morocco, southern Africa, Cyprus, Maldives, Singapore, Antigua and Barbuda, the Federation of Saint Kitts and Nevis, and Dominica and Barbados, will face long-term water shortages by 2050.

2.6. Reductions in Tourism Footprint

Some studies have provided suggestions for decreasing tourism energy consumption, including: (1) changing transportation from energy-extensive types to low-energy types or from private transportation to public transportation, such as changing from air and car to train or coach travel [73,87,88]; (2) promoting new policies and system designs, such as recreation activities with low energy intensity [32], carbon tax policies [89], cooperative governance policies [90], carbon emission reduction systems [91], and carbon labeling [92]; (3) reducing tourism carbon emissions, which includes decreasing carbon emissions by using advanced technology, such as designing environmentally friendly planes, increasing plane management efficiency, or utilizing biomass energy [93–96]; (4) changing tourist consumption styles, such as reducing the travel distance by localization, extending stays, buying local products and encouraging low meat-eating habits [63,87]; and (5) increasing the effectiveness of tourism administration, such as food consumption management [97] and carbon emissions reduction supervision [98]. However, tourists are largely unaware of the benefits of decreasing tourism carbon emissions or the importance of changing their vacation styles to realize the harmony between tourism activities and environmental preservation [42,99,100]. There is little willingness to reduce the environmental impact of tourism by changing vacation styles [95], and many tourists are unfamiliar with tourism carbon calculators [101].

Gössling [35] argues that there is sufficient evidence that tourism water consumption is rapidly increasing because of a growing interest in energy- and water-intensive activities, higher hotel standards (with larger pools and gardens, in-room Jacuzzis and all-inclusive arrangements with large buffets), and the planned use of biofuels for transportation. Therefore, changes or reversals in these aforementioned behaviors, e.g., lowering tourism energy consumption, reducing water-intensive activities, and reducing the luxurious consumption of food and accommodations, would help tower the TWF to a certain extent. Simultaneously, pursuing altruism [41], encouraging water saving through pricing strategies [42], lowering water consumption by installing water regulators [102], and collecting taxes on foreign tourists [103] are all recognized as effective tools for lowering the TWF. However, due to a lack of awareness regarding the need for water resource protection [104], tourists usually do not make environmentally friendly decisions in advance that involve sacrificing vacation quality [105].

3. Prospects for Tourism Footprint Research

3.1. Unifying the Analytical Frameworks and Boundaries of the Tourism Footprint

At present, due to limited tourism data, there is no agreed upon assessment framework for tourism footprint analysis [48]. Most studies have used only partial information when assessing the tourism footprint; this allows fewer calculations, produces more uncertainty, and prevents comparability among different relevant results. As a leisure activity, the tourist traveling process usually comprises six components: transportation, accommodations, catering, sightseeing, shopping, and entertainment. Therefore, TEF analysis should examine the production area for the land and water of each component, TCF analysis should investigate the carbon emissions produced by each component, and TWF analysis should study the water consumption of each component. It is also necessary to measure the absorptive area of the land or water, carbon emissions and water consumption for tourism waste disposal. This addition means that a complete analytical framework of the tourism footprint should include the seven components of transportation, accommodations, catering, sightseeing, shopping, entertainment, and waste disposal.

Accurate quantification of the tourism footprint is critical. The rational confirmation of system boundaries is the key for precisely measuring the tourism footprint. However, the system boundary between the tourism industry and other industries is obscure because of the non-independence of the tourism industry and tourism activities. Traditionally, the tourism industry is not measured as an economic sector within national accounts, and there is no national statistical system to measure it, which has led to differences in the system boundaries and research results across studies [18,27,60]. The key to solving the issue of indistinct boundaries is to establish a statistical system that includes building a tourism statistical system, establishing a TSA system and IO table, obtaining data regarding the tourism environmental economy, unifying tourism statistical data collection, and structuring a tourism IO analysis platform. Together, these methods can create a foundation for further tourism footprint research.

3.2. Distinguishing the Geographical Scope of the Tourism Footprint Effectively

The limitations of regional divisions must be resolved when measuring the footprint of tourist destination areas and comparing this footprint with the ecological carrying capacity; one limitation is misallocation in estimating the TEF at the national or local scales [106]. Most studies have analyzed the overall processes of tourism transportation, including travel from the tourism-generating region to the tourist destination and back, as well as travel in tourist destination areas. However, most tourism transportation processes do not actually occur in tourist destination areas. Therefore, recognizing the overall processes of tourism transportation as part of the TEF or TCF for tourist destination areas may be impossible. For example, Xiao et al. [75] showed that most (87.19%) of the ecological footprint of tourism transportation in the Zhoushan Islands, China, does not occur there, and Peeters and Schouten [44] argued that transportation from the tourism-generating region to the destination comprises 70% of the total TEF. A comparison of the tourism transportation ecological footprint that occurs in other regions with the local environmental carrying capacity leads to an inconsistent range that clearly overestimates the TEF or TCF. The findings of Patterson et al. [12] differ from most results, which show that the TEF is higher than the local residents' ecological footprint; they found that the TEF (5.28 gha) is lower than local residents' ecological footprint (5.47 gha) in Val di Merse, Italy, without including tourism transportation from the tourism-generating region to the destination. The same condition has been true in measurements of the TCF and the TWF, most of which do not occur at tourist destination areas. Hence, it is necessary to perform assessments with a consistent geographical scope when comparing the tourism footprint and the environmental carrying capacity in a scientific analysis. More specifically, tourism transportation should include two segments in the empirical analysis—transportation from the origin to the destination and local transportation [12,44]—which is helpful for measuring the regional tourism footprint.

Furthermore, the ecological burdens of tourist destination areas can be transferred to the productive land of other countries or regions by trading or forming an ecological hinterland [15]. Generally, an ecological hinterland supplies some tourism products to destination areas, which can be converted to a transferable TEF and TWF. Therefore, distinguishing a transferable from a non-transferable tourism footprint can allow for not only an effective evaluation of the sustainability of tourist destination areas but also an accurate assessment of the environmental impact of regional tourism development on other regions. Specifically, on the one hand, most products for tourist destination area development can be transferred to an ecological hinterland (transferred production function), which forms a transferable TEF or TWF; on the other hand, tourism waste is absorbed by tourist destination areas (non-transferred absorptive function), which forms a non-transferrable TEF or TWF. Therefore, there are different possibilities when comparing the TEF or TWF and the ecological carrying capacity due to the elasticity of a transferable TEF or TWF. Overall, any regional tourism footprint will create a global environmental impact through trading from a macro perspective: if the proportion of tourism material products that are transferred to the ecological hinterland is higher, the ecological burden of tourist destination areas will be smaller, but the environmental impact on other regions will be larger. Some empirical analyses indicate that the transferable TEF for Jiuzhaigou, China, accounts for 27.82% of the total TEF [79] and could be as high as 52.47% for the Zhoushan Islands, China [75].

3.3. Improving the Process of Analyzing the Environmental Impact of the Tourism Footprint

A complete analytical process of the impact of the tourism footprint on the environment should include three parts: the tourism footprint calculation, the ecological carrying capacity measurement, and a comparative analysis that scientifically evaluates the impact of the tourism footprint on the environment. The majority of TEF studies follow the analytical framework and emphasize a discussion of the direct impact of tourism activity on the environment in tourist destination areas at the local, regional, national scales [2,12,13,60,81]. However, there are certain deficiencies in the analysis process of the TCF and the impact of the TWF on the environment. Although, at the global scale, most studies effectively assess the impact of the TCF on climate change, TCF analyses usually only calculate the amount of carbon emissions at the local, regional, and national scales and generally ignore the process of the carrying capacity measurement and discussions on the impact of the TCF on the environment. In addition, the TWF only measures the tourism industry's water consumption from the global to the local scale, and there is no process by which to comparatively analyze the water resource carrying capacity.

As mentioned above, the tourism footprint calculation, the carrying capacity measurement, and the comparative analysis of the two comprise a complete process of analyzing the tourism footprint that can effectively evaluate its environmental impact. However, most of the relevant studies of the TCF and TWF lack any process to measure carrying capacity and to conduct a comparative analysis. Therefore, it is essential to supplement these studies in the future. Carbon carrying capacity is based on the carbon absorbing ability (carbon sequestration capacity) at the local, regional, and national scales, and carbon absorption estimates and forest yield data have been harmonized by using IPCC statistics [106]. Subsequently, comparative analysis can be conducted between the TCF and carbon absorbing ability. Water carrying capacity is based on the water resource supply from the global to the local scale, and then, a comparative analysis can be performed between the TWF and the water carrying capacity. Improving the analysis process will enrich the research on the impacts of the TCF and TWF on the environment to effectively analyze the extent to which tourism activities aggravate the local environmental burden, regardless of whether a carbon deficit or water deficit exists, and how to adopt feasible carbon balance and water balance strategies.

3.4. Measuring the Tourism Footprint Scientifically and Roundly

Local residents and tourists all consume local products and services supplied by local natural resources. Undoubtedly, tourism activity aggravates the ecological burden of tourist destination areas. Distinguishing between the baseline footprint and the tourism footprint is helpful in measuring whether tourism activity is a factor that induces environmental imbalance in tourist destination areas. One such study shows that the ecological footprint of local residents in Siena, Italy, is gradually exceeding the local ecological carrying capacity, and the TEF aggravates the local ecological deficit [82]. However, several prior studies have not effectively distinguished between the baseline footprint and the tourism footprint and even directly compared the tourism footprint with the ecological carrying capacity, resulting in erroneous conclusions. Hence, it is necessary to effectively distinguish the baseline footprint from the local population's footprint (as well as the tourism footprint from external tourists) and to assess the tourism footprint's superimposed impact on the sustainable development of tourist destination areas based on the baseline footprint. If the local carrying capacity exceeds the baseline footprint (ecological surplus), regional resources can provide local people with an ecological surplus, which means that there is sufficient development space for tourism activity.

The direct TCF and TWF have been emphasized by many researchers, but the indirect TCF and TWF have been neglected because of their obscure boundaries and the difficulty in the data collection. This neglect clearly underestimates the impact of tourism activity on the ecological environment. In fact, indirect activity is also an important part of the TCF and TWF. An empirical analysis from China indicates that aside from tourism transportation, the magnitude of indirect carbon emissions is 3–4 times that of direct carbon emissions [26]. In addition, indirect carbon emissions equivalently relate to 30–110% of direct carbon emissions [27,49]. Similarly, TWF calculations for Cyprus, Turkey, Greece and Syria indicate that indirect water consumption is higher than direct water consumption and that the former is the main component of the TWF. In particular, the indirect water consumption caused by food consumption accounts for 75–95% of the footprint [43]. Indirect water consumption is far more than one order of magnitude greater than direct water consumption [107]. Therefore, measuring only the impact of direct carbon emissions and water consumption on the environment will lead to erroneous conclusions. Hence, it is necessary to comprehensively calculate the tourism footprint, which comprises both direct and indirect parts, and to scientifically assess its environmental impact.

3.5. Performing Space-Time Calculations of the Tourism Footprint

Relevant studies of the TEF, TCF and TWF mainly emphasize the static analysis of a single point or a single year. Few longitudinal studies have examined the tourism footprint based on different regions and time series analyses, although the analyses by Cadarso et al. [22], Sharp et al. [23], Sun [29] and Tang et al. [47] are based on a time series. This deficit means that we cannot effectively understand the dynamic change trend in the tourism footprint and the impact of tourism activities on the environment across time dimensions. Additionally, the static assessment of the tourism footprint of a single point or a single year goes against the comparative analysis of different study results.

Performing space-time calculations of the tourism footprint is an important direction for further research. Such calculations are helpful for discovering the development rules of the tourism footprint and the sustainable development of tourist destination areas. It effectively compensates for a lack of static analysis, explores the relationship between the tourism footprint and driving factors, and forecasts the change trend in the tourism footprint. Regarding the time dimension, a longer time series not only makes the tourism footprint results more dependable and less contestable [106] but also reflects the long-term variation characteristics of the tourism footprint and the impact on the regional environment. It is easier to discover variations in the tourism footprint when it is compared with a single-year measurement [82]. In addition, a tourism footprint calculation based on time series data can eliminate data distortion and correct data deviation to some extent. Concerning the spatial dimension, a tourism footprint calculation based on different regions can realize horizontal comparisons of structural differences and efficiency variance. At a practical level, space-time monitoring and assessing the tourism footprint is helpful for detecting early eco-security warnings, finding ecological environment damage without delay, conducting effective ecological security arrangements, and promoting harmonious development between the tourism industry and the environment in tourist destination areas.

3.6. Expanding the Tourism Footprint Family by Introducing New Members

TEF, TCF and TWF analyses have gradually developed in the tourism footprint family, which evaluates the impact of tourism activities on the environment from various angles; however, according to two dimensions (the object, i.e., the nation, organization, product, etc.; and the theme, i.e., carbon, water, land etc.) of a footprint [108], many directions and content remain to be expanded. For example, land is central to tourism and is used in multiple ways as a resource for tourism-focused activities [109], so the expanding tourism industry and tourism activities have had obvious impacts on land use and the environment. Therefore, examining the tourism land footprint is also a new direction that can further expand the scales of the tourism footprint family. In addition, large-scale tourism activities consume considerable energy, which aggravates regional heat island effects and damages natural landscapes that are sensitive to temperature through heat radiation, such as glaciers. Therefore, the tourism heat footprint is a new direction for calculating the impact of tourism activities on the environment.

In addition, according to Fang et al. [108], a footprint can address the theme dimension in both the environmental domain and the socio-economic domain. We argue that the tourism footprint family, comprising three indicators (TEF, TCF and TWF analyses) with an environmental evaluation function, can be expanded to the socio-economic domain. Some studies have created new variations in recent years, such as the tourism figure footprint, which examines the popularity of tourist attractions [110], the use travel guide maps [111], and the space-time rule of tourist behavior [112,113]. It is obvious that the socio-economic domain will expand the tourism footprint family and contain more content to some extent by breaking through the environmental evaluation function.

4. Conclusions

The tourism footprint family comprises TEF, TCF and TWF analyses and has become an important tool for quantitatively assessing the impact of tourism activities and the tourism industry on the environment. In recent years, the tourism footprint family has received wide attention not only from tourism researchers but also from international organizations. As a comprehensive index of tourism sustainability, TEF analysis mainly emphasizes the comprehensive assessment of tourism activities on the environment, which has the advantage of a comprehensive evaluation. In contrast, TCF analysis and TWF analysis mainly emphasize specific evaluations (carbon emissions and water consumption), which have the advantage of being thorough evaluations. The tourism footprint family helps to scientifically understand the impact of tourism resource consumption and waste emissions on the environment, to advance suggestions to lower the ecological impact of tourism, to realize harmonious development between tourism activities and the environment, and to promote sustainable development in the tourism industry.

However, some limitations still exist in the relevant literature, (1) there is no agreed upon assessment framework for the tourism footprint analysis because the analytical frameworks, research methods, and research scopes are different; (2) TCF and TWF analyses of the impact of the tourism footprint on the environment are imperfect, and most relevant studies lack measurements of the carrying capacity and do not provide means for comparative analysis; (3) indirect carbon emissions and water consumption have been neglected in some research because of their obscure boundaries and the difficulty in collecting data, which leads to underestimations of the impact of tourism activity on the ecological environment; (4) certain studies have not effectively distinguished between the baseline footprint and the tourism footprint and have even directly compared the tourism footprint with the ecological carrying capacity, which leads to erroneous conclusions; (5) a comparison of the tourism transportation ecological footprint that occurs in other regions with the local environmental carrying capacity leads to an inconsistent range that clearly overestimates the TEF or the TCF; and (6) relevant studies of the TEF, TCF and TWF mainly emphasize the static analysis of a single point or a single year, and there are few longitudinal studies of the tourism footprint based on different regions and time series analyses.

Finally, this paper proposes areas for further developing the tourism footprint. We argue that: (1) a complete analytical framework of the tourism footprint should include the seven components of transportation, accommodations, catering, sightseeing, shopping, entertainment, and waste disposal; (2) it is necessary to perform assessments with a consistent geographical scope when comparing the tourism footprint and environmental carrying capacity to perform a scientific analysis; (3) distinguishing a transferable from a non-transferable tourism footprint can allow not only for an effective evaluation of the sustainability of tourist destination areas but also for an accurate assessment of the environmental impact of regional tourism development on other regions; (4) the carbon/water carrying capacity at the local, regional, and national scales and comparative analysis between the TCF/TWF and carbon/water absorbing ability should be conducted; (5) it is necessary to effectively distinguish between the baseline footprint of the local population and the tourism footprint of tourists to calculate the superimposed impact of the tourism footprint on the sustainable development of tourist destination areas based on the baseline footprint; (6) it is necessary to comprehensively calculate the tourism footprint that comprises both the direct part and the indirect part and scientifically assess the impact of the tourism footprint on the environment; (7) making space-time calculations of the tourism footprint is an important direction for further study because space-time calculations are helpful for discovering the development rules of the tourism footprint and the sustainable development of tourist destination areas; and (8) the tourism footprint family still requires the development new members to better assess the impact of tourism activities on the environment.

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