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Water-tourism nexus: impact of the water footprint of inbound tourists to China

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ABSTRACT

The water footprint is a new concept used to understand the water resources uses; however, few studies have applied it to the service industry and the impact analysis are not abundant. This study explored how water footprint of tourism influenced water resources based on inbound tourists to China from 2001 to 2018. The total water footprint of inbound tourists (ITWF) was 7273.15*10^6 m^3, and showed an upward trend. The spatial pattern was agglomerated, being mainly concentrated in North China, East China, and South China. The standard deviation ellipse showed that the horizontal axis was first east, and then west. According to the background water footprint, the 'contribution' of ITWF to the background water surplus differed in each province. According to the background water stress, the impact roughly separated into large, medium, and small using overlay analysis. Based on ITWF and water stress levels, the 31 administrative regions of mainland China were separated into four types and put forward suggestions: double-high pressure type, cautious development type, double-low potential type and optimised development type. This study provided a theoretical reference for governments, and is conducive to promoting the coordinated and sustainable development of tourism and water resources.

Key words: impact analysis, inbound tourism, water footprint, water stress

HIGHLIGHTS

- First explored the impact of tourism water footprint on regional water resources.
- Impact analysis must be combined with background water footprint and water stress.
- Showing the characteristics of spatial agglomeration, and evolves from east to west.
- The provinces can be divided into four types: double-high pressure type, cautious development type, double-low potential type and optimized development type.

INTRODUCTION

Water pollution and the uneven spatial distribution of water are the main problems in sustaining the water resource environment globally. Tourism is often perceived as an opportunity for economic development in many regions, due to the special accessibility (Zapata *et al.* 2011). Therefore, in terms of taxation and resource allocation, this industry is prioritized over other sectors, including water resources (Hall & Sharples 2008). Moreover, tourism is an industry that exhibits both spatial and temporal agglomeration. The spatial flow of tourists may shift water resources from areas of water abundance to areas of water scarcity at the continental or regional level, such as from northern to southern Europe, and from inland to coastal areas (Eurostat 2009). Seasonal tourism demand means that peak tourism periods at many destinations may occur during the dry season (Gössling 2015). With the increasing demand of global available freshwater, the tourism water consumption has attracted increasing attention from scholars and international organizations.

From the perspective of supply, tourism destinations need a large supply of high-quality water resources, with any water shortages negatively impacting the image and reputation of destinations. Moreover, due to the scarcity of water resources, its effective utilization has become one of the major challenges for tourism destinations (Gössling 2006, 2015). Early studies mainly focused on direct water use in tourism, such as swimming pools, spas and guest rooms. However, direct water use by tourism only accounts for less than 1% of total global water consumption, and this figure has not changed significantly (Gössling *et al.* 2012). This is mainly because indirect water use in tourism is not considered. Comprehensive evaluations of water resources should include both direct and indirect water usage. The concept of the tourism water footprint (TWF) solves this problem. As a comprehensive sector, tourism products and services are obtained from other sectors, and transferred and imported between regions and countries. Thus, the water footprint represents a suitable approach for measuring the water consumption of tourism (Hadjikakou *et al.* 2013).

TWF refers to the amount of water resources needed to meet the needs of tourists for products and services (Cazcarro *et al.* 2014). It has become a leading field of tourism research; however, compared with the tourism ecological footprint and carbon footprint, research on the water footprint remains limited (Wang *et al.* 2019). Existing studies on the tourism water footprint primarily focused on the following aspects: (1) The accounting system of TWF. At present, the accounting of TWF is mostly carried out in relation to the six elements of tourism (Tian *et al.* 2015; Wang *et al.* 2015). (2) The measurement methods of TWF. There are two main types: 'top-down' and 'bottom-up'. The 'top-down' method calculates the TWF using input-output tables. For example, from the perspective of service trade, 16% of Spain's virtual water exports derive from foreign tourism based on input–output analysis (Cazcarro *et al.* 2014). The 'bottom-up' method uses inventory analysis to evaluate water consumption at a certain time and space, completely and systematically, and is based on life cycle assessment (Jia *et al.* 2012). The specific measurement of tourism water footprint is to incorporate the consumption of products or services over the whole process of tourism activities into the accounting system of tourism water footprint (Tian *et al.* 2015). (3) Measurement and evaluation of TWF. Most empirical studies are conducted on specific tourism destinations, different tourism sectors, and regional scales. Gössling *et al.* (2012) briefly introduced the direct and indirect water uses of tourism activities. Subsequently, studies of TWF at different regional scales and tourism sectors emerged, including evaluations of tourism destinations in the eastern Mediterranean (Hadjikakou *et al.* 2013); the water footprint of tourism in Spain (Cazcarro *et al.* 2014); and the resort hotel on Lodz Island in Greece as examples (Gössling 2015).

However, research on TWF in China is at the initial stage. In 2011, the water footprint of tourists in the Liming Scenic Area of Yunnan was calculated based on their consumption behavior (Yang *et al.* 2011). Huangshan Scenic area as the case, Wang *et al.* (2015) constructed a water footprint model from five elements and implemented an in depth analysis of the physical and virtual water. Tian *et al.* (2015) used a bottom-up approach, taking the Honghe Hani Terraces as an example. Zhang *et al.* (2017) incorporated tourism wastewater and tourism management water into the model, and conducted an empirical study on the tourism water footprint of Huangshan Scenic Area in 2012. Liu *et al.* (2018) comprehensively measured TWF of Back-mountain in Qingcheng by evaluating physical water (accommodation, catering, entertainment, landscape and ecological water) and virtual water (food and life goods).

Most existing studies are based on the static analysis of a single sample site at a small scale and for a single year. In comparison, the research results on the dynamic measurements of the TWF and its impact on water resources at multiple spatial and temporal scales remain limited. The degree of human activities is the main reason for the increasingly severe water supply (Tekken & Kropp 2015). It would exert strong demand on the water resources of tourism destinations with an increase of visitors, for example, leading to water pollution and a decline in underground aquifers. Specifically, because of the spatial and temporal agglomeration characteristics of tourists, along with the fact that tourists often aggregate in arid and island destinations, tourism presents a severe challenge for areas where water resources are already scarce and ecologically fragile (Deya Tortella & Tirado 2011). Consequently, water has become one of the determinants affecting the life cycle of tourism destinations (Rico-Amoros *et al.* 2009).

China has entered an era of rigid demand for mass tourism. The influx of a large number of international tourists not only stimulates the development of tourism, but also consumes large quantities of water resources in China. In addition, mobility is a basic characteristic of tourism. The environmental impact of tourism is characterized by interregional diffusion. The trans-space-time mobility of tourists leads to the flow of virtual water, which generates space-time diffusion of environmental impact of tourism and transfer of ecological responsibility. This study explored the spatial and temporal evolution of the water footprint of inbound tourists (ITWF) and its influence on China's water resources.

METHODS AND DATA

Methods

ITWF model

Based on the contribution of each measurement account to the overall water footprint in previous studies (Yang *et al.* 2011; Tian *et al.* 2015; Zhang *et al.* 2017), this study only measured the water footprint of tourism food consumption ($ITWF_{food}$), accommodation ($ITWF_{accom}$), and transportation ($ITWF_{trans}$).

$$ITWF = ITWF_{food} + ITWF_{accom} + ITWF_{trans} \tag{1}$$

(1) Food water footprint of inbound tourists ($ITWF_{food}$)

$$ITWF_{food} = \sum_{i=1}^{n} (W_i \times Q_i) \times N \times T \tag{2}$$

where W_i is the water footprint per unit food i, Q_i is the daily consumption of food i, N is the number of inbound tourists, and T is the stay days of inbound tourists.

(2) Accommodation water footprint of inbound tourists ($ITWF_{accom}$)

$$ITWF_{accom} = 425 \times N \times T \tag{3}$$

where 425 is per capita daily water consumption, including 350 L direct water consumption per guest per night, and 75 L virtual water consumption implied from energy utilization related to hotel accommodation per guest per night (Gössling 2015).

(3) Transportation water footprint of inbound tourists ($ITWF_{trans}$)

$$ITWF_{trans} = 130 \times N \times T \tag{4}$$

where 130 is the per capita water consumption for transportation, which was mainly the virtual water consumption generated by energy consumption (Gössling 2015).

Standard deviational ellipse (SDE)

SDE is commonly used to reveal the geospatial patterns and evolution characteristics of economic activities. It was developed by Welty Lefever in 1926, a sociology professor at the University of Southern California, and is also called Lefever's standard deviational ellipse. In this study, SDE was used to reveal the evolution characteristics of the spatial pattern of ITWF, and was implemented through using the spatial statistics tool ArcGIS 9.4.

Water stress indicator (WSI)

Evaluation of water resource stress provides data support and a reference for the comprehensive evaluation of water resources. It is also used as an independent evaluation index to detect regional water resource shortages and provide a decision-making basis for regional water resource management. In this study, the ratio of supply to demand was used to evaluate water resource stress in 31 administrative regions of China from 2001 to 2018. The index selects the proportional relationship between annual water resource availability and renewable water resources and divides stress into four levels (Table 1).

Data

The data used in this study included: (1) data to measure ITWF, and (2) data to measure the water resource stress and water surplus of each province.

$ITWF_{food}$ requires information on the food consumption, per unit water footprint of agricultural products, number of inbound tourists, and days of stay. For the types and quantities of food consumed by tourists, we used the data on food

Table 1 | Classification of WSI

WSI	<0.1	0.1–0.2	0.2–0.4	>0.4
Stress level	1	2	3	4
Stress indicates	Low	Medium	Medium-high	High

consumed by local residents as a reference, because tourists tend to 'do as the Romans do when in Rome.' Standard data for each unit of agricultural products were obtained from reports 47 and 48 published by the UNESCO-IHE Institute for Water Education (Mekonnen & Hoekstra 2010a, 2010b). Other data were obtained from the statistical yearbooks of China and its Provinces, China's domestic Tourism Sample Survey Data, Tourism Sample Survey Data, and Provincial Tourism Development Statistical Bulletin. In addition, for $ITWF_{accom}$ and $ITWF_{trans}$, per capita daily consumption was based on the average data from Gössling (2015), due to limited data (Gössling 2015).

In terms of the impact of the ITWF on the water resource environment, it is necessary to analyze the water resource stress and water surplus of each province. According to the selection of indicators, data were mainly obtained from the Statistical Yearbook of China and Provinces and Water Resources Bulletin.

RESULTS AND DISCUSSION

Spatial-temporal variation in ITWF

Total ITWF from 2001 to 2018 was 7273.15*10^6 m^3, with an average annual average of 404.06*10^6 m^3. Over time, ITWF showed an upward trend, rose from 159.02*10^6 m^3 in 2001 to 656.27*10^6 m^3 in 2018, with a 312.70% rate of increase. Chongqing, Anhui, and Ningxia were the three fastest growing provinces, with ITWF being 16.28, 15.58, and 14.50 times higher in 2018 compared to 2001. Gansu, Guizhou, and Beijing had relatively small increases over the same period, of 0.48, 1.44, and 1.72 times, respectively. Spatially, ITWF varied greatly at the provincial level (Figure 1). From 2001 to 2018, the three provinces with the highest water footprint were Guangdong, Jiangsu, and Beijing, accounting for 46% of the total. Ningxia, Qinghai, and Gansu had the lowest water footprint, with an average annual ITWF of 0.13*10^6 m^3, 0.27*10^6 m^3, and 0.37*10^6 m^3, respectively.

The spatial pattern of inbound tourists' water footprint presents an agglomeration feature, primarily in North China, East China and South China. Taking five representative years as an example, the horizontal axis was first east, and then west, while

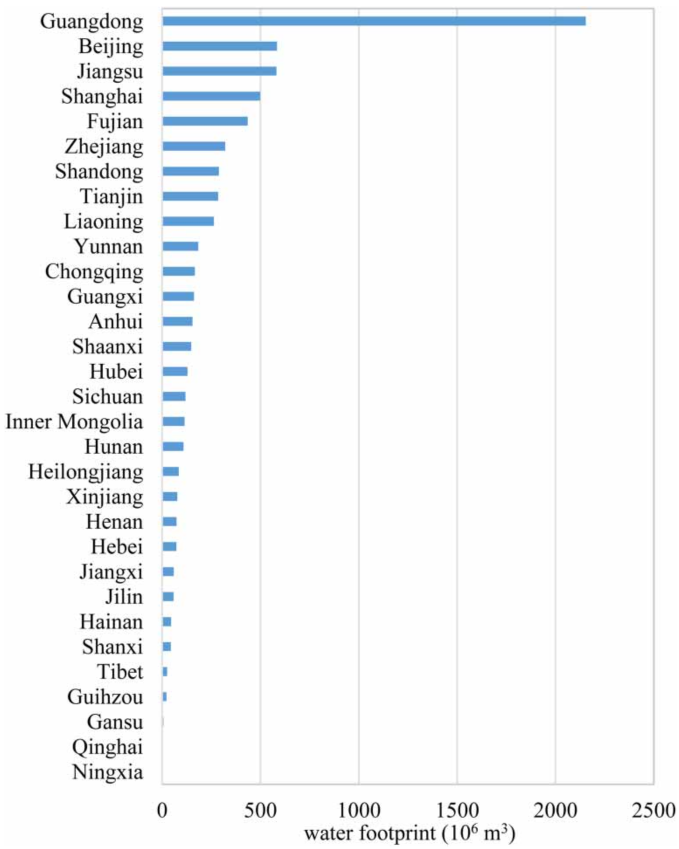

Figure 1 | ITWF of each province from 2001 to 2018.

it moved south on the vertical axis (Figure 2). The parameters in Table 2 provide the details on this trend. From the center point, X increased first and then decreased, indicating that the overall spatial layout of the water footprint migrated first to the east and then to the west. The year 2011 was the cut-off point. Before 2011, it moved to the east and then gradually moved westward. In general, the Y value was in a decreasing trend, indicating that the overall pattern of the water footprint moved southward vertically. From the lengths of the X and Y-axes, Y is longer than X. Based on the long and short axis indexes, variance along the Y-axis was significantly greater than that along the X-axis, and was determined by the spatial pattern of inbound tourists. Based on the changes in the long axis and short axis, the long axis showed a continuous decreasing trend, while the short axis showed an increasing trend, and the ellipse rotation showed a slow decreasing trend. This indicated that the spatial distribution of the ITWF in the east-west direction strengthened over time, whereas that in the north-south direction showed no clear trend. This finding was consistent with the overall pattern and trend of China's inbound tourism development, which exhibited agglomeration characteristics on the eastern coast. In recent years, with the economic development of central and western China, other provinces have also become popular destinations for inbound tourism.

Influence analysis based on the background water footprint

ITWF influences the water resources of each province through a 'superposition' effect with the background water footprint of each province. The utilization of water resources by the sector mainly includes agricultural, industrial, domestic and ecological water. The accounting of the water footprint for each province should, thus, incorporate these four dimensions. However, these four dimensions represent the measure of water quantity, with it being necessary to include the gray water footprint too.

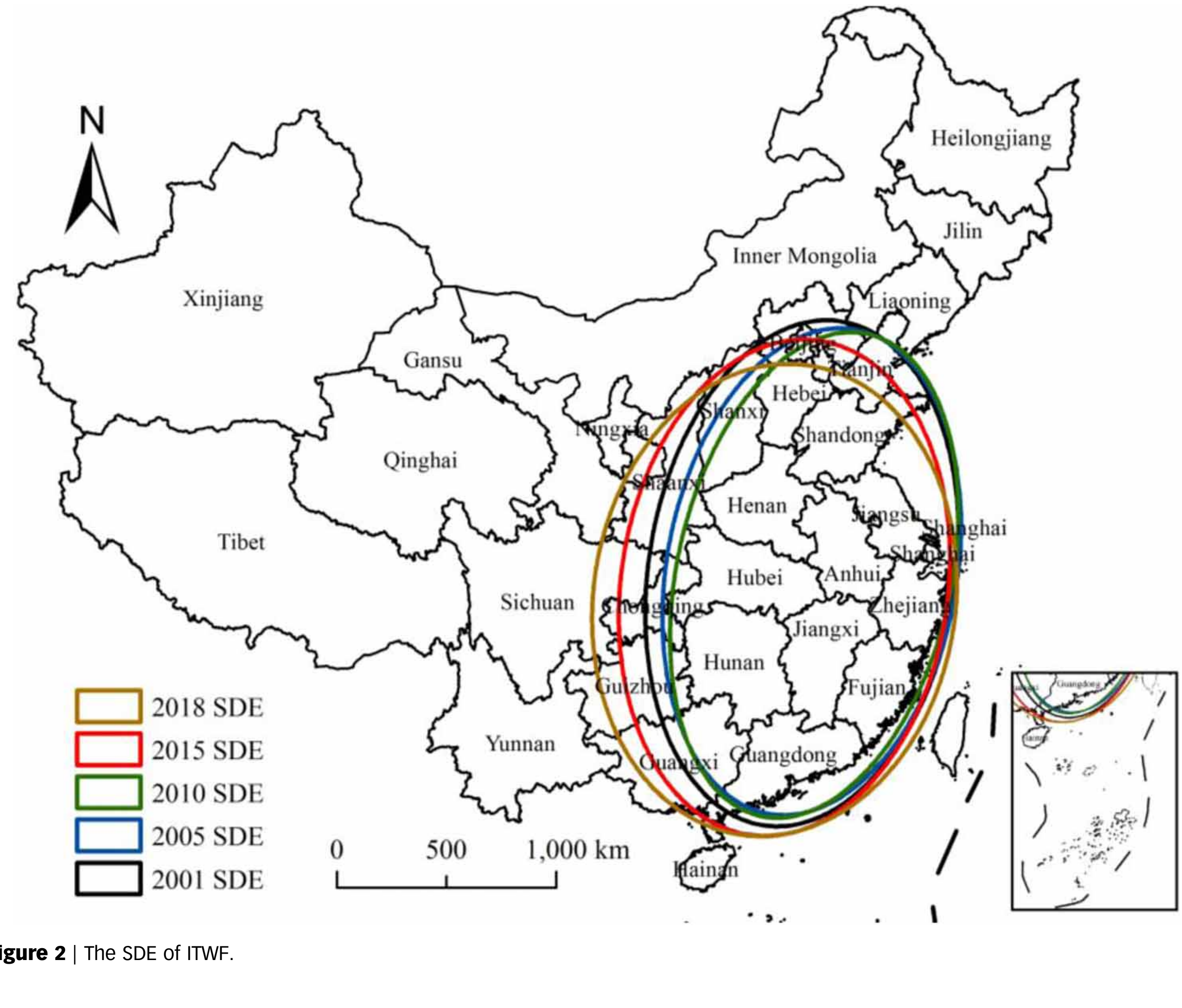

Figure 2 | The SDE of ITWF.

Table 2 | SDE parameters of water footprint, 2001–2018

Year	Center X	Center Y	XStdDist	YStdDist	Rotation
2001	946759.26	3330956.14	700085.97	1162887.08	8.75
2002	966627.35	3341811.02	688650.08	1140755.39	10.14
2003	1018724.79	3276451.13	608228.88	1134674.22	11.33
2004	998992.77	3331391.65	652641.62	1120345.86	10.00
2005	991630.06	3338211.52	661879.23	1121571.63	10.16
2006	990657.37	3329587.13	663407.20	1130268.30	11.13
2007	984356.18	3334019.10	690709.89	1130308.80	11.55
2008	1022131.46	3357001.04	608514.47	1155663.16	12.30
2009	1006551.72	3336684.55	615481.34	1131472.01	12.71
2010	1002841.73	3323167.38	624738.85	1126337.25	12.61
2011	980203.99	3331205.24	662018.67	1132137.95	12.49
2012	960628.47	3338339.81	713650.95	1124175.61	12.02
2013	904195.96	3334317.57	757420.65	1169218.24	7.35
2014	896868.37	3328831.02	739391.53	1166311.66	8.90
2015	866811.36	3264792.62	746136.38	1138301.77	7.88
2016	874039.07	3229280.37	745270.04	1102972.85	10.33
2017	865873.57	3219360.53	787536.07	1082296.12	8.91
2018	821944.41	3209241.76	826051.31	1081,249.24	8.22

Note: Center X and Center Y are the center points of the ellipse. XStdDist and YStdDist are the lengths of the X and Y axes. Rotation represents the direction and angle of the ellipse.

The gray water footprint refers to the amount of water required to dilute pollutants to meet discharge standards. On this basis of the average water footprint of each province in China and the population (Zhang *et al.* 2019), we obtained the per capita water footprint. Compared to per capita water resources, the water surplus or deficit could be obtained. The contribution rate of the ITWF was analyzed by superimposing the ITWF on background water surplus or deficit (see Table 3 for details).

As can be seen from the table, the ITWF contributes to water resources is different among provinces (Table 3). The 'contribution rate' ranged between −3.26% and 22.93%. First, provinces facing per capita background water deficit, to some extent, included: Tianjin, Jiangsu, Shandong, Beijing, Henan, Hebei, Shanxi, Ningxia, and Shanghai. The inflow of inbound tourists is bound to widen the water deficit. Secondly, the per capita ITWF in Liaoning, Gansu, and Anhui had a greater impact on background water surplus, which was relatively small. Especially for Liaoning, because of the low per capita background water surplus and high per capita ITWF, the 'contribution rate' reached to 22.93%. If no measures are taken, and inbound tourism continues to rise, the surplus would further decline, or even become a deficit. Thirdly, the per capita water footprint of tourists had relatively small impact on the per capita background water surplus in Tibet, Qinghai, Yunnan, Guangxi, Hainan, Jiangxi, Guizhou, and Sichuan provinces, with a 'contribution rate' below 0.2%. The effect of ITWF on water resources from the perspective of water surplus in each province was basically consistent with the results of the spatial superposition analysis.

Influence analysis based on background water stress

Background water stress

The spatial distribution of water resources in China is extremely unbalanced, and is spatially dislocated from national economic development. As a result, different regions face different water resource pressures, with significantly different spatial distributions, which is not optimistic on the whole. The WSI in each province represented the proportional relationship between annual water resource availability and renewable water resources. Renewable water resources in each province were the surface and underground water production generated by local precipitation. The data are from the 'National Data' of the National Bureau of Statistics. By selecting annual data by province, the data related to water resources from

Table 3 | 'Contribution rate' of ITWF to background water surplus

Province	Background water footprint (m^3/ per capita)	Water resources (m^3/ per capita)	Background water surplus[a] (m^3/per capita)	ITWF (m^3/ per capita)	Contribution rate[b]	Superimposed surplus[c] (m^3)
Anhui	780.35	1,191.61	411.27	4.38	1.06%	406.89
Beijing	697.31	141.17	−556.14	8.28	−1.49%	−564.42
Chongqing	789.18	1,765.01	975.83	6.3	0.65%	969.52
Fujian	860.9	3,306.41	2,445.51	6.54	0.27%	2,438.96
Gansu	680.91	836.49	155.58	2.63	1.69%	152.95
Guangdong	806.05	1,888.99	1,082.94	4.32	0.40%	1,078.62
Guangxi	832.96	3,968.92	3,135.96	3.17	0.10%	3,132.78
Guizhou	701.67	2,664.34	1,962.67	2.63	0.13%	1,960.05
Hainan	692.71	4,394.11	3,701.39	3.86	0.10%	3,697.53
Hebei	655.05	206.63	−448.42	4.92	−1.10%	−453.34
Henan	679.59	361.04	−318.55	3.69	−1.16%	−322.24
Heilongjiang	754.51	2,134.63	1,380.12	3.76	0.27%	1,376.36
Hubei	826.67	1,578.7	752.03	3.59	0.48%	748.44
Hunan	785.2	2,529.45	1,744.25	3.73	0.21%	1,740.52
Jilin	740.49	1,472.49	731.99	3.72	0.51%	728.27
Jiangsu	929.53	538.17	−391.36	7.76	−1.98%	−399.12
Jiangxi	776.48	3,548.34	2,771.86	3.27	0.12%	2,768.59
Liaoning	707.71	734.88	27.17	6.23	22.93%	20.94
Inner Mongolia	775.06	1,968.63	1,193.57	4.66	0.39%	1,188.92
Ningxia	804.09	155.38	−648.71	4.3	−0.66%	−653.01
Qinghai	751.24	12,729.3	11,978.06	5.54	0.05%	11,972.52
Shandong	643.99	287.51	−356.47	5.9	−1.66%	−362.38
Shaanxi	662.33	1,043.6	381.27	3.75	0.98%	377.52
Shanxi	660.48	289.15	−371.32	3.24	−0.87%	−374.57
Shanghai	1,021.88	172.97	−848.92	5.11	−0.60%	−854.03
Sichuan	705.43	2,948.18	2,242.75	3.71	0.17%	2,239.04
Tianjin	659.39	117.32	−542.07	17.69	−3.26%	−559.77
Tibet	666.01	144,104.77	143,438.76	6.05	0.00%	143,432.7
Xinxiang	776.97	4,088.45	3,311.47	8.77	0.26%	3,302.7
Yunnan	682.7	3,977.92	3,295.22	3.02	0.09%	3,292.21
Zhejiang	798.39	2,001.3	1,202.91	3.89	0.32%	1,199.02

Note: The data of per capita water resources and ITWF in the table are from 2006 to 2015 for parallel study. Background water footprint, water resources, background water surplus all refer to permanent population per capita.
[a]'Per capita background water surplus' is the difference between 'per capita water resources' and 'per capita background water footprint'.
[b]'contribution rate' is the ratio of 'per capita water footprint of inbound tourists' and 'Background water surplus'.
[c]'Superimposed surplus' is the difference between 'per capita background water surplus' and 'per capita water footprint of inbound tourists'.

2004 to 2018 and the data from 2001 to 2003 were obtained from the statistical yearbook and water resources bulletin of each province, respectively.

According to the multi-year average data of each province from 2001 to 2018, the ratio of annual water resource availability to renewable water resources was used to determine the water stress level of 31 provincial administrative regions of mainland China. The highest WSI was recorded in Ningxia (Figure 3), where the average water resource pressure value has reached 6.93 for many years, with this province facing a serious water resource shortage. The next highest regions were Shanghai, Tianjin, Beijing, and Hebei, which are among the top five regions with severe water shortages. Water resources and the

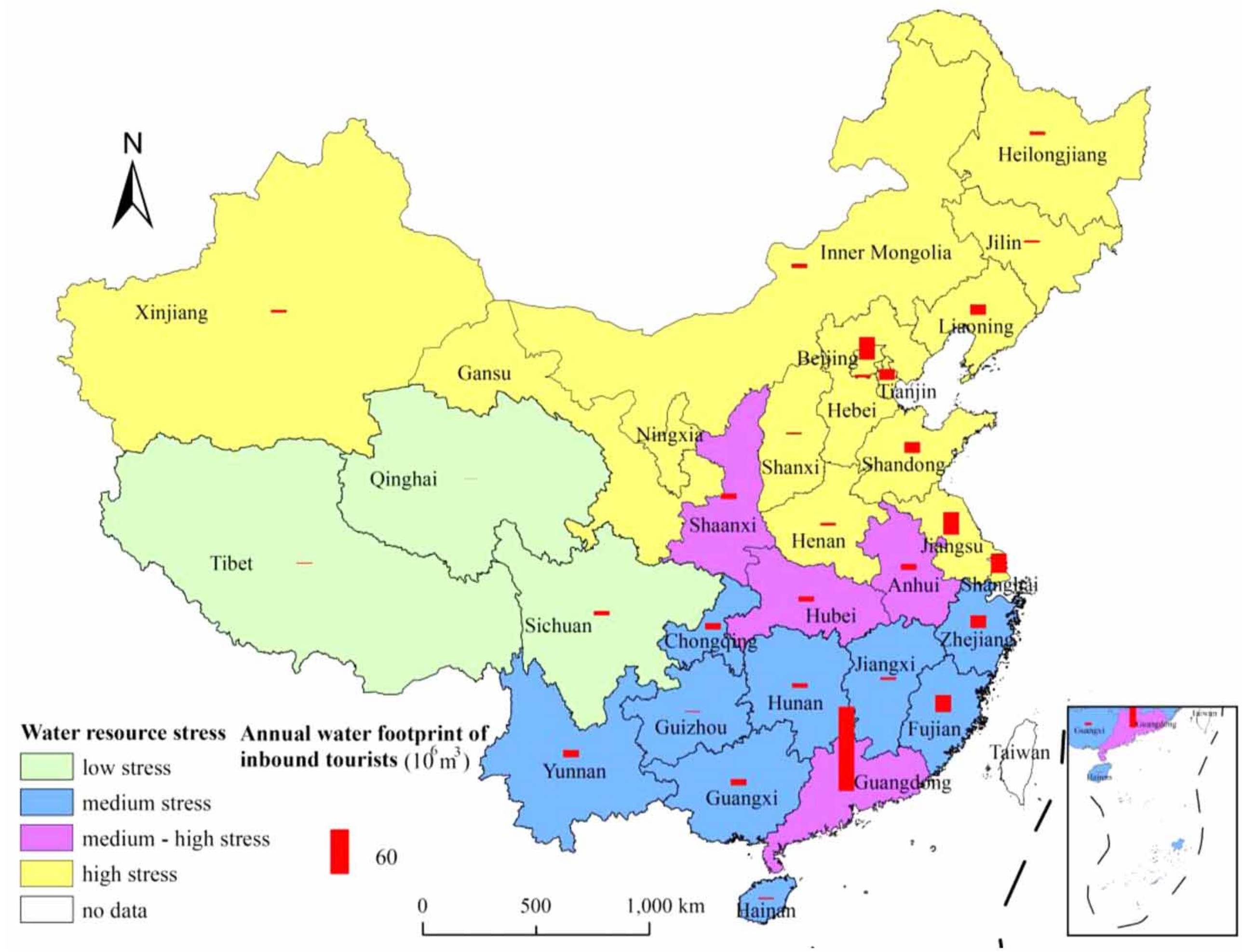

Figure 3 | Overlay analysis of annual average ITWF and water resource stress in each province.

economic environment did not match each other, with the water resource crisis being serious. In particular, Ningxia and Shanghai were far more stressed than other provinces. In contrast, Sichuan, Tibet, and Qinghai had low or basically no pressure on water resources, and significantly differed to Ningxia and Shanghai. This contrast was attributed to huge differences in the distribution of water resources in China, the gap in economic development levels across regions, especially in the eastern and western regions, and the difference in the awareness of residents on water saving and agricultural irrigation technology. Consequently, huge differences in the water resource stress index values existed across regions.

Regionally, China's 31 provincial administrative regions can be divided into eight regions according to geographical location (Figure 4). North China is the region with the highest water stress in China, with a WSI of 0.87. Southwest China has the lowest water resource stress. The WSI in North China, where stress is highest, was 12 times higher than Southwest China, where the stress is lowest. In general, the WSI in northern China was 0.44, and the stress level is 4, with it representing the high stress region. All four regions covered were high stress and medium stress areas, and the way in which water resources are utilized is extremely unhealthy. Southern China, which is rich in water resources, was in a low-stress state, with a WSI of 0.16 and a stress level of 2, and was considered a medium-stress region. The four areas covered by southern China were low stress, medium stress, and medium-high stress levels. Overall, the stress in northern China was more than double that in southern China, and the region faces severe water shortages.

Overlay analysis of the ITWF and WSI

The water footprint comprehensively identified the actual use, or 'possession' of China's water resources by inbound tourists. Whether this 'possession' has a significant or insignificant negative impact on tourist destinations must be quantified, and

Figure 4 | Overlay analysis of annual average ITWF and water resource stress in each region.

whether inbound tourism development and water resource systems are in synchrony. Therefore, the regional water resources and water resource stress of tourist destinations should be assessed and superimposed on the ITWF. To enhance contrast, the ITWF and WSI data were normalized. The ratio of these two parameters showed that the impact of ITWF on provinces generally increased, except for Gansu. This result might be attributed to a change in the structuring of food consumption reducing the water footprint of inbound tourists in Gansu Province. The ITWF in Ningxia, Yunnan, and Chongqing had the greatest increasing influence on local water resource stress.

By overlaying the average multi-year water footprint with the water stress level, the influence of ITWF on water resources could be roughly divided into three categories (Figure 3). The first category has a large impact, with an unsustainable match between the ITWF in some provinces and water resources stress. For example, Guangdong, Beijing, Jiangsu, Shanghai, Shandong, Liaoning, and Tianjin, where the annual average ITWF was relatively high, all face high water stress except Guangdong. The tourists' water footprint placed 'extra' pressure on provinces' where water resources were already overstretched. Water consumption by inbound tourists exacerbated the already fragile water resource ecosystems in these provinces and cities. The second category had little or no influence. Examples of provinces in this category included Tibet, Qinghai, and Sichuan. The ITWF and the water stress of these provinces was low. Finally, the impact of the ITWF in some provinces on water resources was moderate and still controllable. For example, Shaanxi, Hubei, Anhui, Fujian, Zhejiang, Jiangxi, and Guizhou. Although the level of water stress in each province was medium or medium-high, ITWF was relatively small, and the impact on each province was still in a controllable range.

From the regional perspective, the impact of the ITWF on the water resources of each region is different, as shown in Figure 4. It can be seen that the Southwest region has the lowest WSI and lower ITWF, and was expected to have a relatively low impact on the water resources of this region. The ITWF in the other six regions had a great impact on the regional water resources. Except for South China, the other five regions had high or medium-high water resource stress. The contribution rate of ITWF is relatively large, which would have strong impact on the water resources within the region, generating relatively large ‘extra’ pressure. Although South China is a region under medium water resource stress, it had the highest ITWF, which significantly impacted regional water resources.

In general, Southwest China had the lowest WSI, and a relatively low water footprint, indicating that inbound tourism was underdeveloped, to some extent, and had had a strong potential for development. This region should utilize characteristic resources effectively to promote the further development of inbound tourism. In regions with moderate influence, the problem of water resources should be addressed by adjusting the development strategy of inbound tourism. How to achieve a balanced and stable development of water resources and inbound tourism is a problem that needs to be solved in this type. The regions where the ITWF had a strong impact on water resources in regions with water shortages and high water footprints. Both inbound tourism and water resources must be considered to achieve long-term coupled development.

The spatial pattern of ITWF did not match the distribution of water resource stress at a regional level. In southern China, where the water stress level was 2, the ITWF represented 68.90% of total ITWF. In northern China, which had a water stress level of 4, inbound tourists accounted for less than one third of the country’s water footprint. This spatial pattern was generally reasonable. Generally, the WSI was low in southern China, and inbound tourism development also had a relatively small impact on the water supply system. However, the very high contribution rate of ITWF in southern China shows that actions must be taken to optimize the relationship between water resources and inbound tourism, rather than allowing free development. In the northern regions, where water resource stress was high, the ITWF could be catastrophic for the water resource system.

At present, water resources exhibit a reverse flow configuration in physical and virtual forms between the northern and southern regions of China. First, water flows from the water-rich area to the water-deficient area in the form of physical water (South-to-North Water Diversion). Second, water flows from the water-deficient area to the water-rich area in the form of virtual water (Grain Transportation from North to the South). The northern grain to the southern transfers precious (scarce) water resources of the north to the south, which is rich in water and land, through virtual water trade subsidy and transfer. This type of abnormal subsidy causes the severe consumption of agricultural water resources in the northern region, exacerbating the water crisis.

The development of inbound tourism in the water-scarce northern region was bound to have a significant impact on regional water. For the better management and optimization of water resources, both tourism enterprises, tourists and stakeholders in the northern regions should improve the cognition of virtual water and establish awareness of water saving actions.

Classification of provinces and implications on policy

Inbound tourists in different regions of China have different water footprints and water resource pressures; thus, future adjustment measures and pathways for development are bound to be different. Based on the ITWF and water stress levels, the 31 administrative regions of mainland China were divided into four types. The average annual ITWF was $404.06*10^6$ m^3, and the average of each province was $13.03*10^6$ m^3. When using the provincial average as the critical value, this value could be listed as low, and any values higher than this average could be listed as high. Water stress levels were divided into four grades. Grades 1 and 2 were classified as low, while grades 3 and 4 were classified as high. Thus, the 31 administrative regions were divided into double-high pressure type, cautious development type, double-low potential type and optimized development type (Table 4).

Double-high pressure type

Double-high pressure provinces had medium and high water stress levels, and they were already facing serious water shortages. With the development of inbound tourism, inbound tourists consumed a large amount of water resources, which exacerbated the problem of water shortage. We should take measures from the two aspects of inbound tourism and water resources order to generate long-term and harmonious development.

In terms of inbound tourism, for food consumption, the basic strategy is to decrease the consumption of water-intensive products and increase products with relatively low virtual water content. In parallel, food waste is an issue that must be addressed. In terms of food sources, it is necessary to improve agricultural production technology, such as adopting water-saving irrigation technology. It is also important to increase source controls over pollutants being added to water bodies,

Table 4 | Classification of provinces

Type	Tourism water footprint	Water stress	Administrative regions	Number
Double-high pressure type	High	High	Beijing, Guangdong, Jiangsu, Liaoning, Shandong, Shanghai, Tianjin	7
Cautious development type	Low	High	Anhui, Hebei, Henan, Heilongjiang, Jilin, Inner Mongolia, Hubei, Ningxia, Xinjiang, Gansu, Shanxi, Shaanxi	12
Double-low potential type	Low	Low	Chongqing, Guizhou, Sichuan, Yunnan, Tibet, Guangxi, Hainan, Hunan, Jiangxi, Qinghai	10
Optimized development type	High	Low	Fujian, Zhejiang	2

thereby lowering the need for additional dilution, such as by reducing the use of chemical fertilizers and pesticides. In terms of accommodation, unnecessary wastewater must be reduced, along with reducing the frequency of changing towels, bath towels, and bedding. In terms of transportation, low-carbon and green travel should be advocated.

In terms of water resources, these seven provinces and municipalities (Beijing, Guangdong, Jiangsu, Liaoning, Shandong, Shanghai, and Tianjin) were economically developed and had a large population. With the increasing demand for water resources and the poorly regulated development and utilization of water resources, serious water shortage problems have been generated. All regions must take strong measures to balance competing demands for water resources, improve water utilization efficiency, strictly control the water cycle in each water area, and attempt to secure adequate supply of water resources. In addition, it is even necessary to be prepared to sacrifice part of GDP for sustainable development of water supply. In addition, in the case of high water resource pressure, the management of water resource supply and consumption must be strictly strengthened. Under the guidance of flexible thinking, the ability of water resource system to withstand the disturbance of tourism system and maintain its function and control cannot be ignored. In terms of water quality, strict water quality standards should be formulated and implemented strictly and effectively. It is important to control and reduce total pollutant discharge, and eliminate the generation of new pollution sources.

Cautious development type

These areas had a high water stress and relatively low ITWF. The problem of water resources must be addressed, and the development strategy for inbound tourism should be adjusted. The 12 provinces and autonomous regions in this type were inland areas, located far from the ocean, with relatively few precipitation resources, and subject to a serious water crisis. The exploitation of groundwater must be strictly controlled, save water efficiently, and take the development approach of circular economy and water resource recycling in industry. Agriculture should adopt advanced water-saving irrigation technology to reduce unnecessary waste. In addition, sewage should be comprehensively treated and discharged to the set standard, in addition to treating and recycling reclaimed water efficiently.

These provinces have restricted traffic, economy, and tourism resources; consequently, inbound tourism in these provinces and autonomous regions has not been developed. In environment where tourism is increasingly becoming an economic growth point, it is necessary to raise the importance of tourism resource endowment in these provinces, along with integrating various types of tourism resource and associated publicity, marketing, and tourism product development from the perspective of all-region tourism. Conditions that facilitate foreign exchange and cooperation must be created, along with and drive the development of inbound tourism with international trade. Moreover, the management of water resources used by tourism requires the cooperation of stakeholders, which should be considered from the two dimensions of supply and demand (Gössling 2006). On the supply side, tourism generally has higher purchasing power than other sectors in the economy, and tourism can directly compete with agriculture or domestic water (Rico-Amoros *et al.* 2009). Therefore, ways to coordinate the development of tourism water allocation in relation to industry, agriculture, and domestic water at the province, autonomous region must be considered. In terms of the demand for tourism water resources, effective water resource management must be implemented with respect to the tourists' food, housing, transportation, travel, shopping, entertainment and other aspects of tourism. It is generally believed that tourism facilities can reduce water consumption by at least 10–50% without compromising the comfort or experience of tourist (Gössling 2006). Provinces and autonomous regions should actively learn from existing advanced experience and should use environmental management systems as part of the overall management system.

Double-low potential type

These areas had relatively low water stress and relatively low ITWF. Even though water resource pressure was relatively low, these areas were not completely free of pressure; thus, focus should be placed on water resource protection. The development strategy of inbound tourism should also be adjusted to become a potential area for inbound tourism development. In terms of water resources, out of the 10 regions in this group, Sichuan, Tibet, and Qinghai were low stress regions, while the other regions belonged to medium stress group. Awareness of limited water resources should be raised in these regions, along with implementing industrial water-saving and emission-reduction, agricultural water-saving transformation, and increasing the amount of available water resources.

In terms of inbound tourism, the water footprint was relatively low, indicating that inbound tourism was underdeveloped and has great potential for development. Moreover, most of these 10 regions belonged to the central and western economic belt, with generally poor traffic conditions, and economies lagging far behind those at of the eastern region. With the implementation of the strategy to promote central China and the grand western development program, inbound tourism has a promising future in this region.

All regions should be aware of the importance of tourism image and improve their popularity. Traditional notions must be revised, and the development of global tourism must be promoted. The development mode of inbound tourism must be transformed to the concept and mode of coordinated regional development. In addition, it is also necessary to follow the ecological development trend of tourism to reduce its impact on the natural ecology, including the water environment, and to constantly upgrade eco-tourism. The government must lead an organic combination of market players to promote the development of inbound tourism.

Optimized development type

Fujian and Zhejiang provinces were within the optimized development type. These two provinces have relatively low water resource pressure, and well-developed inbound tourism. These two provinces are important inbound tourism destinations. In an environment with abundant water resources, the development of inbound tourism has become an important economic growth point. However, the problem of water resources must be addressed, and the development pattern of inbound tourism should be optimized.

Fujian Province is located in the southeast coastal area, and has subtropical maritime monsoon climate, abundant rainfall, and relatively rich water resources. As such, the province's per capita water resources are very rich. However, due to the unbalanced distribution of precipitation, contradictions in the supply and demand of water resources have become increasingly prominent. In the future, the water resource protection and management system must be improved, and the protection of water resources should be strengthened. Coordination and a win-win goal between economic development and water resource protection must be realized. It is necessary to establish a long-term mechanism of water resource utilization and develop a compensation policy for ecological and environmental protection. Fujian Province is a major province for inbound tourism. Since 1979, the average annual growth rate of both inbound tourists and tourism foreign exchange has exceeded 10% (Ji & Chen 2013). However, there has been a serious imbalance in the regional development of inbound tourism, which is mainly concentrated in the coastal cities of Fujian. Therefore, it is necessary to narrow the regional and intra-regional differences in inbound tourism and optimize the tourist source structure of the inbound tourism market, to improve the overall competitiveness of inbound tourism in Fujian. In addition, Fujian Province is at the front line of 'The Belt and Road Initiative', and should play an important role as the starting point of the 'Maritime Silk Road' to expand and optimize the market structure of different sources of inbound tourism.

In terms of total amount of water resources, Zhejiang is rich in water resources, but the per capita level is low. In order to obtain long-term development, strategic measures and countermeasures must be formulated for water utilization in relation to overall, long-term, and sustainable development. These measures should adhere to the concept of sustainable utilization of water resources, establishing a strict water management system, promoting water saving and emission reduction in industry and agriculture, and follow the path of clean production and circular development. Over the last 30 years, inbound tourism in Zhejiang Province has risen, in general, except for a few years affected by major events. With the all-round opening of the tourism industry in Zhejiang Province and continuous improvement of the status of the tourism industry, all cities tend to attach great importance to the development of inbound tourism. Overall, differences among cities on tourism are gradually narrowing (Jin *et al.* 2009; Wang *et al.* 2016). In the future, each city should be fully aware of its own level and stage of inbound tourism development, and should delineate appropriate inbound tourism development strategies according to the actual economic strength, quantity and quality of regional tourism resources. On the whole, Zhejiang Province should further enhance the level of international tourism products, segment the source market, and carry out targeted marketing and strengthen regional tourism cooperation. While further expanding the inbound tourism market in Zhejiang Province, environmental protection should also be promoted, especially mitigating any direct impacts on water resources, so as to reduce waste and pollution.

Strengths and limitations

Tourism water footprint contains the characteristics of physical water and virtual water, and has become an important method for comprehensively measuring the water consumption of tourism. Existing studies have mostly focused on the measurement of tourism water footprint of specific tourism destinations; however, research on the impact of tourism on the water resource has remained limited. Thus, this study mainly discussed the influence of the ITWF on water resources in China, and generated management suggestions based on this new classification of provinces. This study presents a new perspective for understanding the environmental impact of inbound tourism. However, due to the limitations of available data, this study only considered food, accommodation, and transportation water footprints, which had a greater impact on the overall water footprint. We did not consider water consumption of visiting, shopping, entertainment and so on. Therefore, the final results were relatively small. Besides, due to the difficulty of data acquisition in large-scale studies, we used the average data of the water footprint for transportation and accommodation. Consequently, it was not possible to show the effects of environmental and seasonal factors, transportation distance, and transportation mode on the transportation water footprint. It was also not possible to show differences in accommodation water footprint caused by individual behaviors. Future studies should incorporate first-hand data through field research to allow a detailed and comprehensive analysis. In addition, this study did not analyze the factors affecting the water footprint, such as political, economic and social factors, which is our next research direction.

CONCLUSIONS

China is an important destination for international tourism. From 2001 to 2018, the ITWF showed a rising trend. The spatial pattern presented an agglomeration feature. Standard deviation ellipse showed that the horizontal axis was first east and then west; on the vertical axis, it moved south. In terms of the background water footprint of each province, the 'contribution rate' of the ITWF to 'water surplus' ranged from −3.16% to 29.74%. In terms of background water stress, this study adopted the water resources availability and renewable water resources to assess water stress, and superimposed it with ITWF to analyze the influence. As a result, we delineated the provincial inbound tourists water footprint impact on provincial water resources into three categories. According to the water footprint and water resource stress of inbound tourists, the 31 administrative regions in mainland China were divided into four types: double-high pressure type, cautious development type, double-low potential type and optimized development type. The classification revealed the differences among administrative regions, from which we proposed specific strategies to promote the coordinated and sustainable development of inbound tourism and the water resource system, so as to realize the 'harmony between human and water'. In conclusion, this study divided administrative regions from the ecological dimension of water resources, which differed to traditional economic and political divisions.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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