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Impacts of rural tourism-driven land use change on ecosystems services provision in Erhai Lake Basin, China

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ABSTRACT

Tourism is an expanding activity worldwide, with vital implications for local economies but also for ecosystem management. Rural tourism in particular drives land use change, which results in ecosystem services provision being altered. We performed a comprehensive temporal and spatial assessment of the impact of tourism-driven land use change on ecosystem services and sought to identify tradeoffs between tourism income and provision of multiple ecosystem services in Erhai Lake Basin (ELB), China. The results show that constructed area in ELB, especially in the lakeside zone, increased strongly from 2000 to 2015 due to a tourism boom (in which tourism revenues increased 12-fold), at the expense of farmland, grassland, and forest. With these land changes, ecosystem services also changed greatly, to the detriment of ELB as a whole and especially the lakeside zone. By 2015, soil retention had decreased and nitrogen and soil export had increased, compared with the levels in 2000, while there was only a slight fluctuation in carbon storage and water yield. The nitrogen and soil exports are impairing water quality in Erhai Lake and causing severe environmental problems. This study provides empirical evidence of the important impact of tourism-driven land use change on provision of multiple ecosystem services. For environmentally friendly tourism in ELB and beyond, a form of sustainable tourism should be established. Tourism development and ecosystem services provision should be fully weighed up and considered in future tourism planning and land use management.

1. Introduction

Ecosystem services are the benefits that humans obtain either directly or indirectly from ecosystems (Millennium Ecosystem Assessment, 2005; Bai et al., 2011; Wong et al., 2015). Governments and non-government organizations worldwide are considering ecosystem services as a useful approach to address sustainable challenges and maintain human wellbeing (Crossman et al., 2013; Wong et al., 2015). Given the importance of ecosystem services in sustainability science and action, research on ecosystem services provision has been growing rapidly in recent years. Such research indicates that, globally, at least two-thirds of ecosystem services are currently decreasing and that this trend might be exacerbated in coming decades (Millennium Ecosystem Assessment, 2005; de Groot et al., 2012). Local studies indicate that most ecosystem services, such as water regulation, carbon storage, and soil erosion control, are declining at temporal and spatial scale (Fiquepron et al., 2013; Bai et al., 2019). Furthermore, increases in some ecosystem services may cause a decline in others that are also important for human benefits, which is particularly the case for provisioning services and regulating services (Bai et al., 2011). Therefore, straightforward, user-friendly information is needed to better understand the mechanisms of ecosystem services change, and enable accurate and sustainable decision making (Honey-Rosés and Pendleton, 2013). The purpose of the present literature review was to assess progress in identifying ecosystem services change mechanisms and actual ecosystem services change, information which is critically important for sustainable land management.

Land use and land cover is one of the most important factors for provision of ecosystem services. The capacity for ecosystem services provision is directly related to ecosystems, i.e., land use types and their spatial arrangement (Styers et al., 2010; Kindu et al., 2016). Changes in land use that have influenced biophysical and biochemical processes

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(Lambin and Ehrlich, 1997) have markedly affected the provision of multiple ecosystem services worldwide (Polasky et al., 2011). For example, many studies have shown that land use change can decrease ecosystem services provision (Gao et al., 2017) by e.g., decreasing biodiversity maintenance (Maes et al., 2012; Bai et al., 2011; Sun and Li, 2017), degrading water availability and quality (Fiquepron et al., 2013; Gómez-Baggethun and Barton, 2013; Song and Deng, 2017), decreasing carbon storage and sequestration, and decreasing recreational and esthetic values (Nahuelhual et al., 2014; Song and Deng, 2017). Therefore, land use change is considered a significant driver of change in ecosystem services (de Groot et al., 2010; Gao et al., 2017). A better understanding of how land use changes affects ecosystem services provision is key for sustainable ecosystem management (Huang et al., 2019).

However, the real question is what lies behind land use change. Many studies examining the impact of land use change on ecosystem services have attributed observed land use changes to increased human activities (de Groot et al., 2010; Kindu et al., 2016; Sun and Li, 2017), urban sprawl (Mendoza-González et al., 2012; Arowolo et al., 2018), agricultural activities and mining (Haines-Young et al., 2012; Kindu et al., 2016; Tolessa et al., 2017), or climate change (Bai et al., 2019). However, few studies have analyzed what is really driving land use change, especially as the drivers are location-specific at most cases (Kindu et al., 2016). This makes identifying these drivers even more complicated, but nevertheless important for decision making.

A tourism boom in many places is one of the main factors behind changes in land use, which can result in serious ecosystem services losses. Tourism is an expanding activity worldwide, both in terms of changing land use and as a growing market, with vital implications for local economies and for ecosystem management (Andereck et al., 2005; Riensche et al., 2015). According to the latest annual report from the World Tourism Cities Federation (WTCF), global tourism revenue totaled $5.34 trillion, or 6.1% of global gross domestic product (GDP), in 2018 (WTCF, 2019). Increasing tourism benefits the local economy and also benefits the tourists involved, by refreshing them physically and mentally. Whether carefully planned or not, tourism inevitably changes ecosystems through converting land from forest and farming uses to construction land, which results in loss of ecosystem services. For example, in the state of Veracruz in eastern Mexico, tourism activities have increased along the coast, resulting in serious soil erosion and loss of natural ecosystems (Mendoza-González et al., 2012). More seriously, some development policies do not consider the ecological and ecosystem services impacts of tourism driving land use change (Mendoza-González et al., 2012). A sustainable form of tourism is urgently needed worldwide, to protect natural resources and provision of ecosystem services (Riensche et al., 2015). For this to be achieved, the ways in which how tourism, especially rural tourism, drives land use change, resulting in ecosystem services changes, need to be identified.

Rural tourism has ushered in a flourishing period in China, but can have potential impacts on local ecosystems. In 2018, China issued a new national policy called the Strategy of Rural Vitalization. It aims to build a beautiful countryside and improve wellbeing for Chinese farmers (SPRR, 2018). Rural tourism is considered by Chinese central government to be one of the most important rural development actions. The concept of rural tourism has many interpretations and can vary worldwide (Wang et al., 2013). In China, rural tourism refers to a new form of tourism that relies on the beautiful natural landscape, architecture, folk culture and other unique resources of rural areas. It is characterized by no interference from humanity, no damage to ecology, and simple enjoyment of leisure and entertainment. Since 2018, rural tourism has experienced an unprecedented boom in China and it is expected to expand even more vigorously in the coming five years. Rural tourism is characterized by its scattered distribution and large number of enterprises. Local policy makers should weigh tourism income against ecological outcomes in terms of ecosystem degradation, in order to make better decision making. However, many rural governments only consider the short-term tourism benefits and ignore the potential long-term ecological impacts (Broadbent et al., 2012).

Erhai Lake Basin (ELB) is a typical rural tourism area in China. It is an important destination for national and international tourism, with attractions such as historic metamorphic rocks formed 2.1 billion years ago, a beautiful alpine lake landscape, and a unique minority culture. Rural tourism in the region has been experiencing a boom since 2005, with tourism revenue increasing from 2.39 billion RMB in that year to 29.26 billion RMB in 2017 (ESSB, 2017). However, in parallel with this boom, water quality in Erhai Lake has significantly deteriorated, severely affecting local residents' lifestyle. This undesirable ecological outcome and the social pressure on rural ecosystems in ELB reveal an urgent need to: (1) identify land use changes due to local tourism; (2) evaluate ecosystem services in ELB; and (3) assess the impact of tourism-driven land use change on these ecosystem services. These were the objectives of the present study, the aim of which was to help policy makers understand the impact of ecosystem services change caused by tourism-driven land use change and the tradeoff between the two.

2. Materials and methods

2.1. Study area

Erhai Lake is the seventh largest freshwater lake in China (Zhong et al., 2018). Its basin is located in the upper part of Lancang-Mekong river basin, and covers an area of approximately 2608 km^2 (Fig. 1). The region belongs to the subtropical southwest monsoon climate zone, with mean annual precipitation of approximately 850 mm and mean annual temperature of 16 °C (Hu et al., 2018). The elevation of ELB is 1697–4072 m above sea level (asl), with mean altitude of 1796 m asl. The terrain is low in the center of the basin, where Erhai Lake is located (called 'lakeside zone' in this study), and high in the surrounding areas ('mountainous zone'). Lakeside zone was defined as land with slope less than 8 degrees around Erhai Lake. Tourism infrastructures are concentrated around the lake for the best lake views, on land with slope less than 8 degrees. Therefore, we excluded the flat areas in the northern part of the basin from the definition for better detection of tourism-driven land use change. The mountainous zone was defined as all other land in the basin area.

Erhai Lake is known as a 'mother lake' because of its great role in supporting local residents' life and economic development, including tourism, fresh drinking water, and irrigation (Zhong et al., 2018). However, water quality in Erhai Lake has been deteriorating in recent years. It has changed from low to moderate nutrient content, and has failed to meet the secondary water quality standard since 2006 (Ji et al., 2017; Hu et al., 2018) (Fig. S1). Agricultural non-point (extensively distributed) source pollution has been shown to be the main source of water pollutants in Erhai Lake, contributing almost 32% of total nitrogen in lake water (Guo et al., 2001; Hu et al., 2018). In addition to these non-point sources, point sources from tourist accommodation facilities (homestay, minshuku, or hostel), mainly along the western shores of Erhai Lake (with the best views), have dramatically increased with the tourism boom and have recently become a considerable source of pollution to Erhai Lake.

Tourism revenues in ELB increased 20-fold from 2000 to 2017. At roughly the same time, total nitrogen in lake water increased by 100%, from 0.3 mg/L in 1993 to 0.6 mg/L in 2009 (Ma and Dong, 2011). Indirectly, this shows that tourism was the factor with the greatest influence on land use change in ELB. At the present time, Erhai Lake is already in a state of eutrophication and algal blooms occur every year (Ji et al., 2017; Hu et al., 2018). This has significantly deteriorated local ecosystems, severely affected local residents' lifestyle and culture, and is having repercussions for tourism. There is therefore growing pressure on Chinese central and local government to protect Erhai Lake ecosystems, and action is urgently needed.

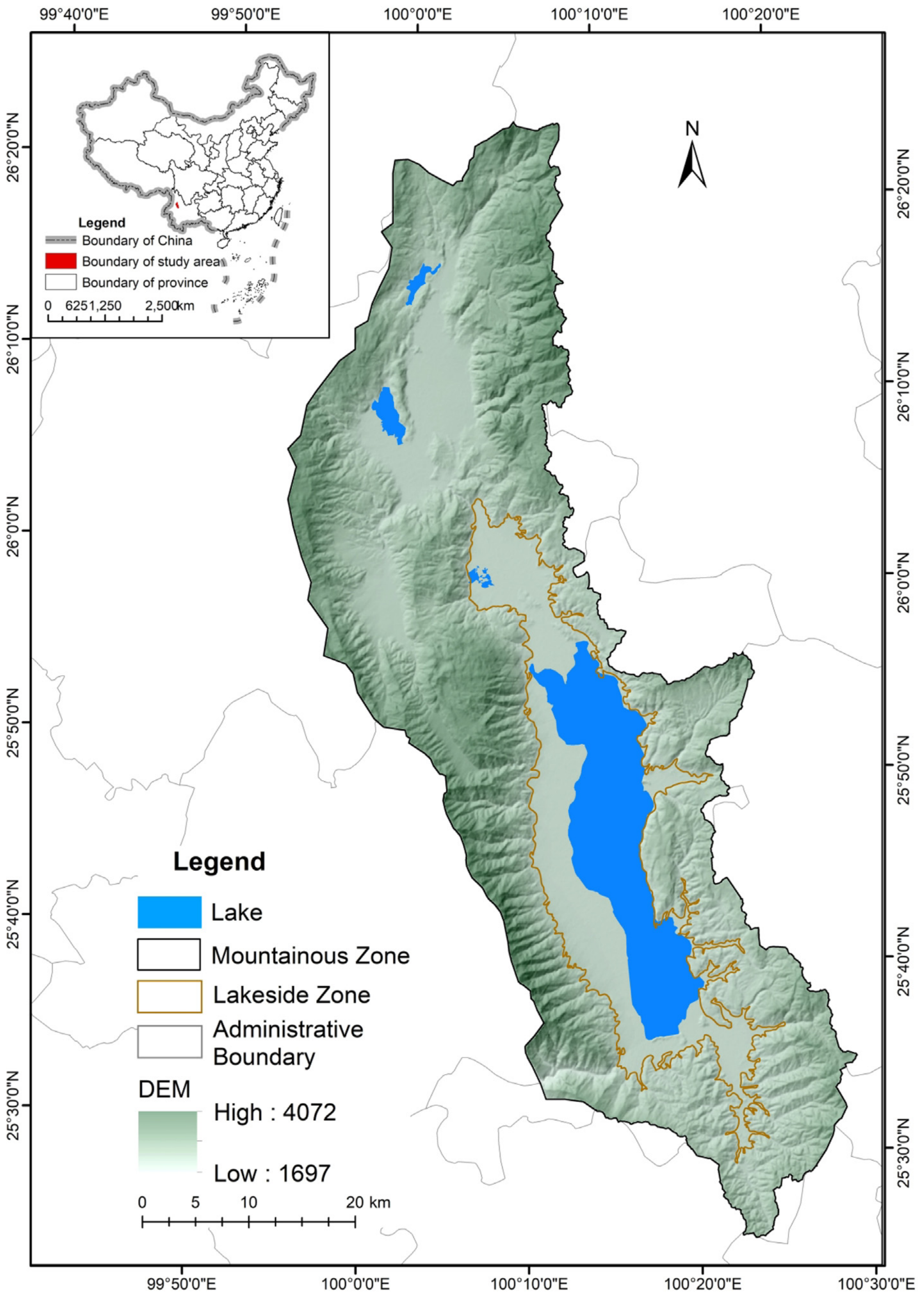

Fig. 1. Location of Erhai Lake Basin (ELB) in southern China.

2.2. Ecosystem services assessment

2.2.1. Ecosystem services selection

Ecosystem services indicators in this study were selected based on four criteria: (1) A generally accepted ecosystem services classification framework, with ecosystem services defined based on types in the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005) and Common International Classification of Ecosystem Services (CICES) (Haines-Young and Potschin-Young, 2018) as provisioning, regulating, and cultural services. (2) Stakeholder concerns, where the selected ecosystem services reflected the specific preferences and concerns of governments, enterprises, and individuals (Bai et al., 2018). (3) Social and services connections, where the selected ecosystem services indicators linked to social variables and human wellbeing. (4) Good data availability. Four key regulating ecosystem services were selected based on these criteria, namely: carbon storage, water yield, soil retention, and nitrogen export. These are important for ELB mainly because of global climate change mitigation requirements and the need to meet water availability and water quality demands from local residents and governments (see Supplementary Information 1 for more justification of the selected ecosystem services).

2.2.2. Ecosystem services evaluation

Carbon storage, water yield, soil retention, and nitrogen retention in ELB were evaluated using InVEST models (Version.3.3.3) at a temporal scale of 15 years (2000–2015). The InVEST software is designed for spatially mapping ecosystem services provision and assessing tradeoffs between different ecosystem services (Sharp et al., 2016). The carbon storage and sequestration model (for carbon storage), the water yield model, the sediment delivery ratio model (for soil retention/export), and the nutrient delivery ratio model (for nitrogen retention/export) in InVEST were used to assess the corresponding ecosystem services in ELB. A detailed explanation of the assessment process can be found in Supplementary Information 2, while InVEST model parameterization is described in Supplementary Information 3. Data availability and sources are summarized in Table S2 in Supplementary Information, while other related input parameters and settings can be found in Tables S3 and S4.

The carbon storage and sequestration model in InVEST uses land cover maps and stocks in carbon pools to estimate the amount of carbon stored in a landscape (Sharp et al., 2016). The input data include a land cover map and carbon pools (see Tables S2 and S3 for details). The water yield model estimates the amount of water running in each pixel in a landscape, simplified to precipitation minus evapotranspiration (Sharp et al., 2016). To run the water yield model, data are needed data on annual precipitation, annual reference evapotranspiration, soil depth, and plant-available water content (see Tables S2 and S4 for details). For soil retention, the sediment delivery ratio model calculates overland sediment generation and delivery to the stream. The outputs of the model include the amount of sediment eroded in a given area and retained by the vegetation (Sharp et al., 2016). The model input data include a map of land cover, data on precipitation and soil texture, a digital elevation model (DEM), and a biophysical attributes table related to soil retention based on land use and land cover (Tables S2 and S4). For nitrogen export, the nutrient delivery ratio model uses a mass balance approach and estimates the transportation of nutrient mass through a landscape. The input data include a map of land cover, precipitation data, a DEM, and biophysical attributes related to the nutrient loading and retention efficiency based on land use and land cover (Tables S2–S4).

Here we used literature data and monitoring data to calibrate the models and validate the results. The literature data for carbon storage shown in Tables S3 and S4 were used to calibrate the carbon storage model. We then validated our simulated results with other reported data. The total amount of forest carbon storage in ELB was reported to be 4.05 million t in 2015 (Cha, 2018), which was quite similar to our modeled amount of 4.44 million t in the same year. The monitoring data showed water yield to be within the range 0.41–0.89 billion m^3 from 2000 to 2015 (Li et al., 2017). Our modeled yield was 0.47 billion m^3 in 2000 and 0.48 billion m^3 in 2015, i.e., within the observed range. Our modeled soil retention was 0.18 million t in 2000, which is quite similar to the 0.15 million t reported for that year (Chen et al., 2012). Average yearly nitrogen export from ELB according to monitoring data varied from 169.40 t to 351.50 t in the study period (He et al., 2018). Our modeled values were 174.90 t in 2000 and 188.63 t in 2015, which were within the measured range.

2.3. Statistical analysis

To estimate the impact of different factors on land use and land cover change in ELB, we used regression analysis across time (2000, 2005, 2010, 2015 and 2018). We selected constructed area as the dependent variable and also as the indicator for land use change, because constructed area changed greatly during the study period and was closely related to rural tourism expansion (Malek and Boerboom, 2015). We selected as independent variables: tourism development, industry development, intensification of agriculture, and extensive livestock, because these have been reported as major factors in land use change (Keys and McConnell, 2005; Cocca et al., 2012; Malek and Boerboom, 2015; Kalumba et al., 2018), and because data on these variables were readily obtainable (see Table S1 in Supplementary Information for more details).

To estimate the relationship between land use change and ecosystem services, we used correlations (Person's *r*) across time (2000 and 2015) and spatial scale (lakeside zone, mountainous zone, whole basin) in ELB. We randomly generated 500 points each in the lakeside zone and mountainous zone, and extracted the corresponding values of all indicators to those points. Doing so enabled the correlations between ecosystem services to be best analyzed. We then aggregated the tradeoffs between tourism and ecosystem services and analyzed them for lakeside zone, mountainous zone, and the whole basin.

2.4. Data requirement and preparation

The InVEST models require spatial map datasets and specific biophysical tables as inputs (Bai et al., 2019). Land use layers and DEM data with spatial resolution 30 m were provided by Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences (http://www.resdc.cn/). The overall accuracy of the land use layer was 92.27%, according to the accompanying data description document. Seven land use classes were used in this study, namely agriculture, bare, constructed, forest, grass, open water, and shrub (Table S5). All the spatial data for ELB and other relevant data collected for this study are listed in Table S2, which includes summaries of each dataset by source, a short introduction, and the associated models. Tables S3 and S4 list key parameters used in the InVEST models. All layers were used or resampled to 90 m resolution and assigned to the WGS 1984 Albers reference system.

3. Results

3.1. Land use types and changes

Forest, agriculture, and grass were the three main land use types in ELB as a whole during the study period (2000–2015) (Fig. 2; Tables S6 and S7). The total area of forest increased slightly, from 912.75 km^2 in 2000 to 918.20 km^2 in 2015 (Table 1). This was mainly due to conversion of 4.59% of shrub and 3.11% grass land uses to forest in 2000–2015. Agriculture increased in area from 411.45 km^2 in 2000 to 503.40 km^2 in 2015, largely due to conversion of grass to agriculture, which accounted for 22.88% of the total area of agriculture in 2015. In contrast, the total area of grass decreased sharply, from 581.43 km^2 in 2000 to 387.03 km^2 in 2015, with 19.81% of grass converted to agriculture and 18.00% of grass converted to shrub during the study period. The total constructed area increased from 139.64 in 2000 to 174.59 km^2 in 2015, mainly by conversion of agriculture and grass to constructed area, with 15.63% of the constructed area in 2015 being converted from agriculture and 10.50% from grass.

In the lakeside zone, agriculture and constructed were the two main land use types during the study period, without considering the area of Erhai Lake. The area of agriculture decreased from 182.14 km^2 in 2000 to 180.77 km^2 in 2015, while the constructed area increased from 93.38 km^2 in 2000 to 103.50 km^2 in 2015. For agriculture, the loss was mainly due to conversion to constructed (15.49 km^2) and shrub (2.26 km^2). For constructed area, the increase mainly came from agriculture (15.49 km^2) and grass (3.97 km^2).

In the mountainous zone, forest and grass were the two main land use types during the study period. The area of forest in the mountainous zone increased slightly, from 909.12 km^2 in 2000 to 915.13 km^2 in 2015. However, the area of grass in this zone decreased dramatically, from 549.03 km^2 in 2000 to 365.82 km^2 in 2015. The lost grass area was mainly converted to agriculture (19.86%), shrub (18.27%), forest (5.17%), and constructed (2.62%). The area of constructed and agriculture expanded, mainly at the expense of grass.

Furthermore, statistical analysis revealed that tourism development had a higher regression coefficient with constructed area than other factors such as industry development, intensification of agriculture, and extensive livestock ($n = 5$, $P < 0.01$; Table S1). This indicates that tourism development was the factor with the greatest influence on land use change in ELB in the study period (2000–2018).

3.2. Ecosystem services in ELB

In the entire basin, the total amount of carbon storage, water yield, and nitrogen export all increased during the study period (2000–2015), while the amount of soil retention decreased. Carbon storage increased

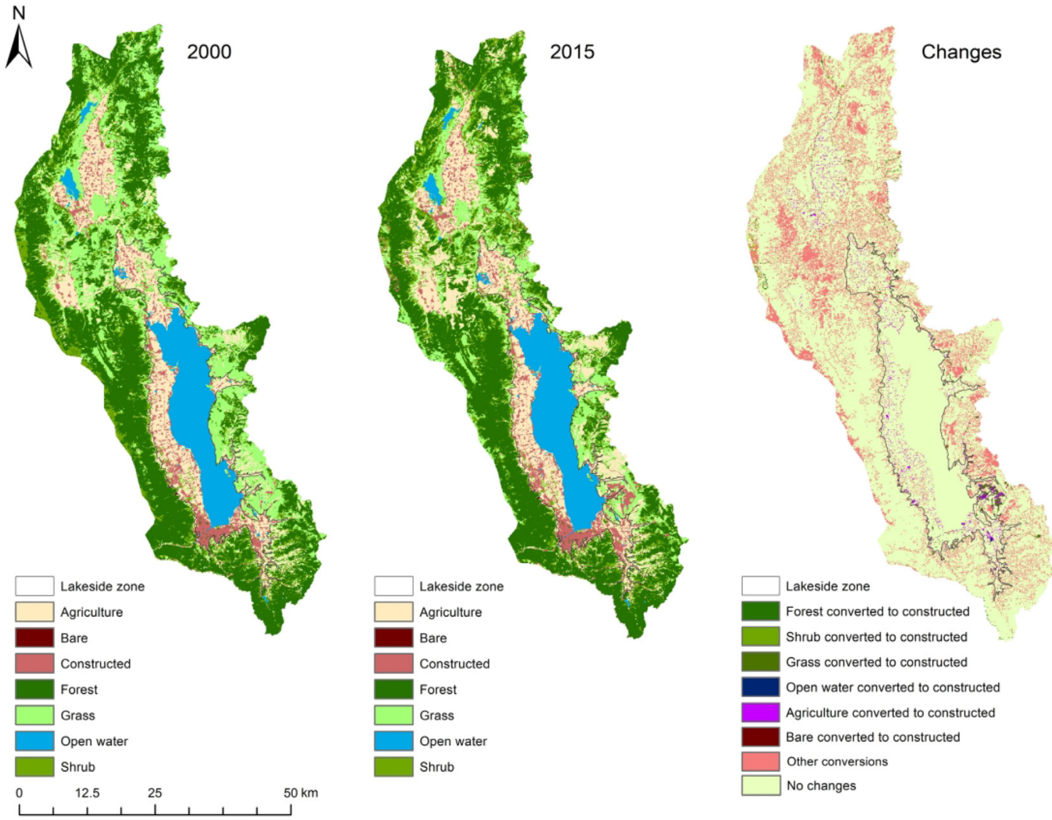

Fig. 2. Spatial maps showing land use and land cover in Erhai Lake Basin in 2000 and 2015.

from 16.53 million t in 2000 to 16.63 million t in 2015, total water yield increased from 0.47 billion m^3 in 2000 to 0.49 m^3 billion in 2015, nitrogen export increased from 174.88 t in 2000 to 188.48 t in 2015, and soil retention decreased from 463.02 million t in 2000 to 462.80 million t in 2015.

The mountainous zone showed a similar pattern of change to the whole basin, with the amount of carbon storage, water yield, and nitrogen export increasing and soil retention decreasing. In this zone, carbon storage increased from 15.55 million t in 2000 to 15.67 million t in 2015, water yield increased from 0.36 billion m^3 in 2000 to 0.37 m^3 billion in 2015, nitrogen export increased from 109.70 t in 2000 to 121.28 t in 2015, and soil retention decreased from 455.30 million t in

Table 1
Land use conversion matrix in Erhai River Basin, 2000–2015.

Land types area, km^2		2015							
		Forest	Shrub	Grass	Open water	Agriculture	Constructed	Bare	Total
Whole basin, 2000	Forest	841.83	47.19	12.72	0.19	5.92	4.90	0.00	912.75
	Shrub	42.10	188.56	41.17	0.25	14.25	6.42	0.00	292.76
	Grass	28.53	104.64	312.78	1.97	115.16	18.34	0.01	581.43
	Open water	0.17	0.32	0.76	266.27	1.08	1.11	0.01	269.72
	Agriculture	4.48	11.27	16.99	1.35	350.03	27.30	0.03	411.45
	Constructed	1.09	1.75	2.62	0.73	16.94	116.51	0.02	139.64
	Bare	0.00	0.02	0.00	0.02	0.02	0.01	0.25	0.32
	Total	918.20	353.75	387.03	270.77	503.40	174.59	0.32	2608.06
Lakeside Zone, 2000	Forest	1.99	0.25	0.15	0.11	0.36	0.77	0.00	3.63
	Shrub	0.21	8.78	0.78	0.11	2.58	1.32	0.00	13.79
	Grass	0.14	4.36	17.12	0.67	6.14	3.97	0.00	32.39
	Open water	0.04	0.11	0.32	250.84	0.86	0.96	0.01	253.13
	Agriculture	0.28	2.26	1.85	1.11	161.13	15.49	0.02	182.14
	Constructed	0.41	0.68	1.00	0.62	9.68	80.98	0.02	93.38
	Bare	0.00	0.00	0.00	0.02	0.02	0.01	0.19	0.24
	Total	3.07	16.43	21.21	253.47	180.77	103.50	0.24	578.70
Mountainous zone, 2000	Forest	839.84	46.94	12.56	0.08	5.56	4.13	0.00	909.12
	Shrub	41.89	179.78	40.39	0.14	11.66	5.10	0.00	278.97
	Grass	28.39	100.29	295.67	1.30	109.02	14.37	0.01	549.03
	Open water	0.13	0.22	0.45	15.43	0.22	0.15	0.00	16.59
	Agriculture	4.20	9.01	15.14	0.24	188.91	11.81	0.01	229.31
	Constructed	0.68	1.07	1.61	0.11	7.26	35.53	0.00	46.26
	Bare	0.00	0.02	0.00	0.00	0.00	0.00	0.06	0.07
	Total	915.13	337.32	365.82	17.30	322.63	71.09	0.07	2029.36

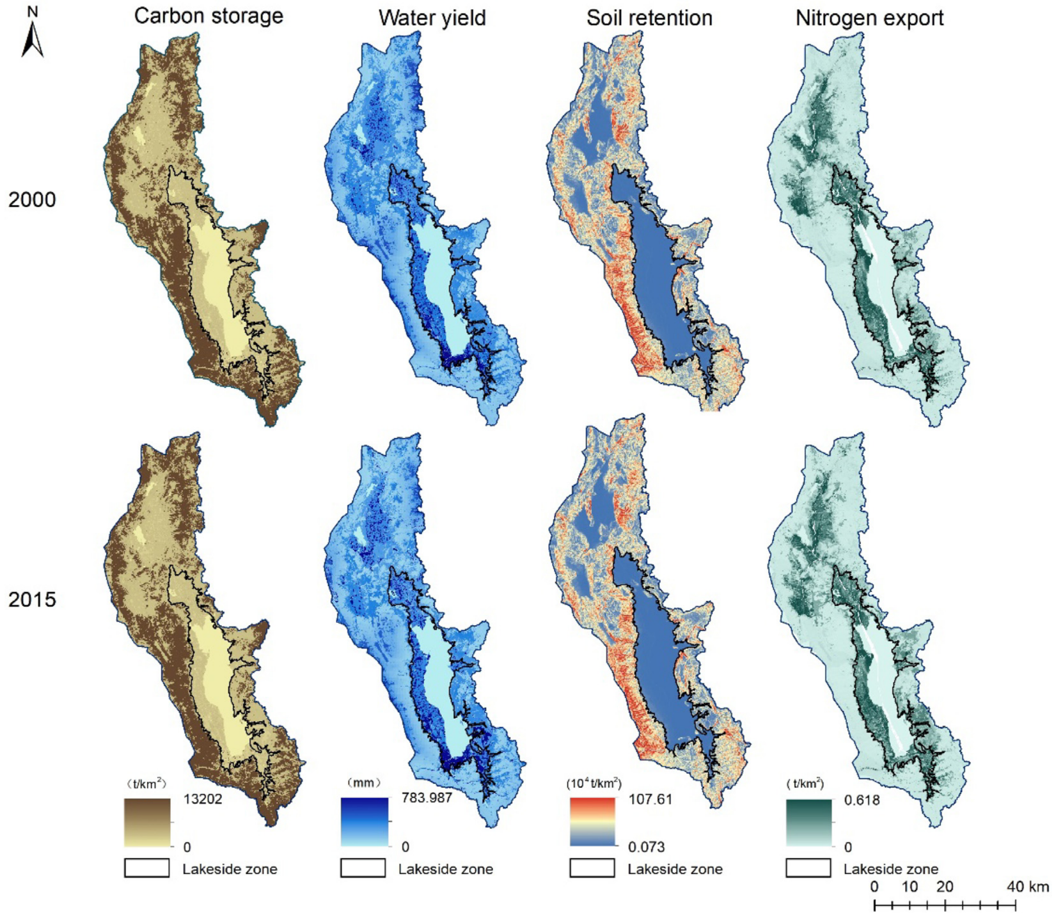

Fig. 3. Spatial provision of the four ecosystem services studied in Erhai Lake Basin in (upper diagrams) 2000 and (lower diagrams) 2015.

2000 to 455.51 million t in 2015.

The pattern of change in the lakeside zone was slightly different, with the amount of water yield and nitrogen export increasing and carbon storage and soil retention decreasing. In the lakeside zone, water yield increased from 0.11 billion m^3 in 2000 to 0.12 m^3 billion in 2015, nitrogen export increased from 65.18 t in 2000 to 67.21 t in 2015, carbon storage decreased from 0.98 million t in 2000 to 0.96 million t in 2015, and soil retention decreased from 7.51 million t in 2000 to 7.50 million t in 2015.

Spatially, the high-provision areas for carbon storage and soil retention services were identified as being mainly located in the surrounding mountainous area in ELB (i.e., the mountainous zone), while the high-provision areas for water yield and nitrogen export were identified as being mainly located in the central part of ELB (i.e., the lakeside zone) (Fig. 3). The spatial changes in carbon storage and water yield mainly took place in the north and east of the mountainous zone, while the spatial changes in soil retention and nitrogen export mainly took place in the north and east of the mountainous zone and the north and west of the lakeside zone (Fig. 4).

3.3. Tradeoffs between ecosystem services

For the whole basin, extremely significant correlations between the four ecosystem services studied were observed in the period 2000–2015 (Pearson correlation; $df = 998$, $p < 0.01$) (Table 2). Carbon storage showed highly significant negative correlations with water yield and nitrogen export ($p < 0.01$), and highly significant positive correlations with soil retention ($p < 0.01$), from 2000 to 2015. Water yield showed highly significant negative correlations with soil retention ($p < 0.01$), and highly significant positive correlations with nitrogen export, over the period ($p < 0.01$). Soil retention showed a highly significant negative correlation with nitrogen over time ($p < 0.01$). In the mountainous zone, the situation was rather similar to that in the whole ELB.

In the lakeside zone, the correlations between the four ecosystem services displayed a different pattern (Table 2). Carbon storage only showed a highly significant negative correlation with water yield from 2000 to 2015 (Pearson correlation; $df = 498$, $p < 0.01$). Carbon storage showed a significant correlation with soil retention in 2000 ($p < 0.05$), but not in 2015 ($p > 0.05$). Carbon storage showed a non-significant correlation with nitrogen export over time in the lakeside zone ($p > 0.05$). Water yield was significantly correlated with soil retention over time and was significantly correlated with nitrogen export in 2000 ($p < 0.05$). Soil retention showed a highly significant correlation with nitrogen export in 2000 ($p < 0.01$) and a significant correlation in 2015 ($p < 0.05$) (Table 2).

The tradeoffs between tourism and ecosystem services in ELB are shown in Fig. 5. Tourism revenue increased dramatically in the study period, from 1.48 billion RMB in 2000 to 17.38 billion RMB in 2015. Along with this great increase in tourism, ecosystem services also changed greatly, in a negative direction for ELB as a whole and especially for the lakeside zone. There was only a slight fluctuation in carbon storage and water yield, but soil retention decreased and nitrogen export and soil export were higher in 2015 than in 2000 (Fig. 5).

4. Discussion

4.1. Impact of tourism on ecosystem services

Land use change, in terms of changes in structure, composition, and intensity, has been identified as an important factor leading to changes

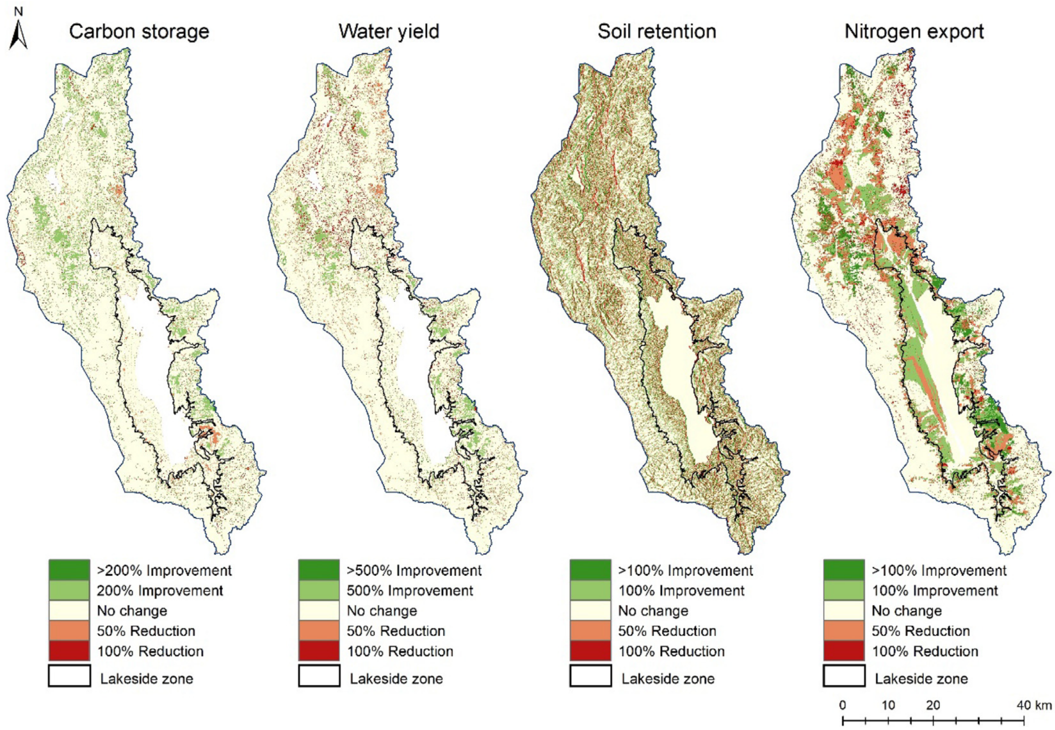

Fig. 4. Spatial change in the four ecosystem services studied in Erhai Lake Basin between 2000 and 2015.

Table 2
Tradeoffs over time between ecosystem services in the lakeside and mountainous zones of Erhai Lake Basin and in the basin as a whole.

		Carbon storage	Water yield	Soil retention
Lakeside zone	Water yield	$-0.959^{**,a}$		
		$-0.659^{**,b}$		
	Soil	0.109^{*}	-0.122^{*}	
	retention	0.042	-0.089^{*}	
	Nitrogen	0.02	-0.11^{*}	-0.237^{**}
	export	−0.055	−0.033	-0.179^{*}
	Water yield	-0.702^{**}		
Mountainous zone		-0.676^{**}		
	Soil	0.492^{**}	-0.427^{**}	
	retention	0.475^{**}	-0.406^{**}	
	Nitrogen	-0.496^{**}	0.419^{**}	-0.382^{**}
	export	-0.545^{**}	0.513^{**}	-0.402^{**}
	Water yield	-0.599^{**}		
Whole basin		-0.617^{**}		
	Soil	0.653^{**}	-0.482^{**}	
	retention	0.653^{**}	-0.483^{**}	
	Nitrogen	-0.523^{**}	0.389^{**}	-0.565^{**}
	export	-0.576^{**}	0.418^{**}	-0.572^{**}

Note: $n = 500$ in lakeside zone and mountainous zone, respectively; $n = 1000$ in the whole basin. [a,b]For each ecosystem service indicator, the upper value represents 2000 and the lower 2015. $^{**}p < 0.01$; $^{*}p < 0.05$.

in ecosystem services (Tolessa et al., 2017; Bai et al., 2019; Huang et al., 2019). Understanding the relationships between land use change and ecosystem services provision can be a useful way of understanding and guiding sound landscape management (Quintas-Soriano et al., 2016). Previous studies have primarily focused on evaluating biophysical and monetary changes in ecosystem services under different historical land use or future land use scenarios (Polasky et al., 2011; Bai et al., 2018). However, an urgent challenge to ensure good policy making is to identify the mechanisms driving land use change and the ultimate influence on ecosystem services provision (Quintas-Soriano et al., 2016).

Tourism is a widespread activity worldwide and has recently expanded dramatically in many countries like China, Singapore, Japan, Indonesia, and Switzerland. However, the links between tourism and local land use change and ecosystem services changes remain underestimated and unrevealed (Buckley, 2012; Riensche et al., 2015). The sustainability of tourism worldwide urgently needs to be impoved, in order to protect natural resources and ecosystem services (Riensche et al., 2015). By integrating InVEST models and socio-economic data in a novel approach, in this study we revealed the impact of tourism-driven land use change on local ecosystem services provision in a lake basin in southern China. This broadens current knowledge on the need for taking ecosystem services into account for decision making, and indicates a new direction for strategic land management.

Using ELB as a case study, we observed that land use changed to varying degrees from 2000 to 2015, especially for the lakeside zone. In both the whole ELB and the mountainous zone, only the area of grass decreased in 2000–2015, while the area of all other land use types increased (Tables S6 and S7). In the lakeside zone, there was not only a decrease in the area of grass, but also in the areas of forest and agriculture in 2000–2015, mainly due to conversion to constructed land (Table 1). Tourism development was observed in this study to have a greater influence on land use change in ELB than other factors such as industry development, intensification of agriculture, and extensive livestock. The tourism boom resulting in constructed area expanding for 34.95 km^2, at the expense of farmland, forest, and grassland, as the dominant land use change in the lakeside zone of ELB and the whole basin. Tourist accommodation facilities in ELB are mainly located along the west side of Erhai Lake, which affords the best views, and have dramatically increased in extent with the demand created by tourism since 2000. Some landowners have built tourism facilities themselves, others have leased or sold their land to developers. In both cases, the facilities are characterized by a scattered distribution, large quantity of units, and disordered spatial planning.

The changes in land use characterized by conversion of forest and agriculture into constructed land increased nitrogen export and soil export from the whole basin in 2015 compared with 2000, but with only slight fluctuations in water yield. In the lakeside zone, in addition to the above changes, carbon storage decreased due to loss of forest during 2000–2015, whereas in the mountainous zone carbon storage

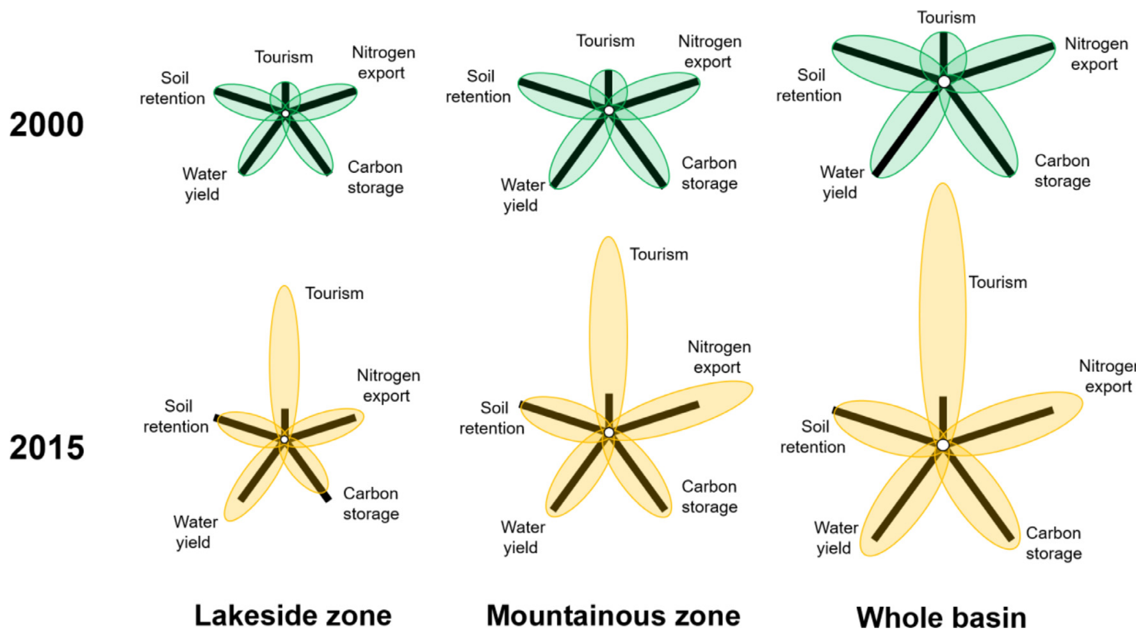

Fig. 5. Tradeoff between tourism and ecosystem services in (left) the lakeside zone, (center) the mountainous zone, and (right) the whole of Erhai Lake Basin in (upper diagrams) 2000 and (lower diagrams (2015). The black line in each segment represents the value in the base period (2000), while the length of each colored ellipse in relation to this indicates the magnitude of the change by 2015.

increased during 2000–2015 (Fig. 5). Soil retention in both lakeside zone and mountainous zone showed a decreasing trend during 2000–2015. A tradeoff between tourism and ecosystem services was observed. For the whole ELB and the mountainous zone, the tradeoff relationships were mainly between tourism and soil retention and nitrogen export. For the lakeside zone, the tradeoff relationships were mainly between tourism and soil retention, carbon storage and nitrogen export (Fig. 5). With the great increase in tourism, soil retention decreased, and there was an increase in nitrogen export from the whole basin, and especially from the lakeside zone. The overall provision of ecosystem services in ELB between 2000 and 2015 was shown to be highly affected by the expansion in constructed area driven by tourism, which is in line with other findings elsewhere (Martínez et al., 2009; Kindu et al., 2016; Tolessa et al, 2017). The increased nitrogen export and soil export are having great negative impacts on water quality in Erhai Lake, which is causing severe environmental problems for ELB (Hu et al., 2018).

Appropriate but urgent actions to reduce the nitrogen and soil loads to lake water should be implemented, and future tourism developments should be carefully weighed against ecosystem service tradeoffs in land use planning and activities.

4.2. Management implications

Erhai Lake Basin is one of the most popular rural tourism destinations in China, due to its unique rock formations, beautiful alpine lake landscapes, and unique minority culture. However, Erhai Lake is already undergoing eutrophication, and algal blooms occur every year since the expansion in tourism (Ji et al., 2017; Hu et al., 2018). This has significantly deteriorated local ecosystems and severely affected local residents' lifestyle and culture.

China's Strategy of Rural Vitalization, issued in 2018, aims to build a beautiful countryside and improve wellbeing for Chinese farmers (SPRR, 2018). Rural tourism is mentioned as one of the most important actions to achieve these aims. With such central government plans and a growing list of rural tourism development projects, it is anticipated that rural tourism will expand further in the near future (SPRR, 2018). Since 2018, rural tourism has been undergoing an unprecedented boom in China. However, Chinese central and local governments are under great pressure to protect Erhai Lake ecosystems and other similar tourism locations, and action is urgently needed to achieve this. Our study showed that tourism-driven land use change in ELB has had an important impact on the provision of multiple ecosystem services. This in turn has three major implications for optimal ecosystem management and decision making.

First, since rural tourism boom is unavoidable, we suggest developing rural tourism in a sustainable way, which we call sustainable rural tourism. Before implementing any actions, local policy makers, including governments, landowners, and other stakeholders, should consider the tradeoffs between tourism income and ecological outcomes in terms of ecosystem degradation, to enable better decision making. The sustainable rural tourism approach requires participation by central government (in the short term) and local stakeholders (in the long term). Local residents' perceptions of tourism development are reported to vary, with some locals believing that new tourism projects will provide new employment and help them sell their specialty products, while others have concerns about the negative impacts on water availability and water contamination (Riensche et al., 2015). In addition, many rural governments and landowners only consider the short-term benefits of tourism and ignore the potential long-term ecological impacts. Disorderly and environmentally damaging tourist reception facilities have been built randomly along the main scenic area in ELB. In this case, central government should use strong forces to create opportunities that include long-term ecosystem maintenance and sustainable livelihoods. Central government is very powerful in China. For example, the Chinese national natural forest conservation program and the Grain for Green project have effectively protected existing forest and facilitated afforestation (Qi et al., 2019). In fact, the local government in ELB took coercive measures and closed more than 2000 hotels along Erhai Lake in 2017, reflecting the determination, strength, and ability of central government to protect local ecosystems. We believe that only sustainable rural tourism has the capacity to create a "win-win" situation entailing small losses and large gains.

Second, we suggest establishing an effective reward and punishment system (RPS) and environmental change monitoring system (ECM). We advise the ELB local government to invest in building an RPS to ensure equity and better tradeoffs between economic development and ecosystem conservation. This RPS can set strict thresholds for the ecological protection boundary, environmental pollution discharge, and maximum resource utilization (Bai et al., 2016). The local government should then invest in building a long-term ECM for timely understanding and monitoring of changes of environmental conditions in space and time. Once the RPS is established, the local government can legally use strong forces to reward/punish stakeholders (e.g., individuals, communities, companies, or even government agencies) who protect/harm the local environment according to the ECM (Liu et al., 2019).

Third, we suggest creating buffer strips for tourism infrastructure. Our results show that tourism-driven land use change has increased nitrogen and sediment export in ELB, leading to serious deterioration of water quality in Erhai Lake. Buffer strips have proven to be effective in agricultural and urban areas for their capacity for reducing runoff, decreasing nitrogen and soil exports, increasing landscape connectivity, and propagating biodiversity (Goldstein et al., 2012; Gao et al., 2017). For example, one study reported that a 100-m buffer strip significantly improved water quality, achieving a 4.9% reduction in nitrogen export and a 9.6% reduction in soil export compared with an area with no buffer strip (Gao et al., 2017). Creating buffer strips is a well-known best management practice for agriculture to alleviate non-point pollution (Goldstein et al., 2012). Given the ecological importance and functional effectiveness of buffer strips, we suggest that they be established around tourism infrastructure in ELB to alleviate point-source pollution from tourism.

4.3. Strengths and limitations

The novelty of this study is that we provide empirical evidence that tourism has critical impacts on local land use and land cover in a landscape like ELB, resulting in changes in ecosystem services by e.g., increasing nitrogen and soil export and deteriorating water quality. Based on these findings, we suggest that governments should carry out tourism activities in a sustainable way, build protection systems (involving RPS and ECM), and create buffer trips to optimize ecosystem services management.

However, the study had three major limitations, which need to be resolved in future research steps in order to continue broadening our knowledge in the field: i) the causal relationships between tourism development and land use change need to be further analyzed. ii) The analysis only focused on carbon storage, water yield, nitrogen export, and soil export, but tourism would also affect other ecosystem services that were not considered here, e.g., expanded tourism could decrease the ability for biodiversity maintenance, pollination, and climate regulation. By fully considering all impacts of tourism-driven land use change on ecosystem services, decision makers can optimize the tradeoffs between tourism development and environmental protection. iii) There are some limitations and assumptions involved in using InVEST models, as described in the software documentation (Sharp et al., 2016), but we acknowledged the importance of careful calibration and validation of the InVEST models, as described in the methodology.

5. Conclusions

By integrating InVEST models and socio-economic data, we performed a comprehensive temporal and spatial assessment of the impact of tourism-driven land use change on ecosystem services and examined the tradeoffs between tourism income and provision of ecosystem services in ELB. The results showed that constructed area increased in ELB from 2000 to 2015, especially in the lakeside zone, at the expense of agriculture, grass, and forest, due to the recent tourism boom. Tourism revenue increased dramatically between 2000 and 2015, but nitrogen and soil exports increased significantly in the same period, resulting in deteriorating water quality in Erhai Lake and causing severe environmental problems in ELB.

The factors behind land use change should be considered as a priority in future land use management. However, land use change drivers can differ between cases, so the causal relationships between these drivers and land use changes should also be further addressed. Despite some limitations in the methodology and the need for some assumptions, this study demonstrated the negative impact of tourism-driven land use change on provision of multiple ecosystem services. For development of environmentally friendly future tourism in ELB, a sustainable form of tourism should be established. Before any land development activities, the tradeoffs between tourism development and ecosystem services provision should be fully considered in future land use planning and management. If properly designed, we anticipate that sustainable rural tourism can create a win-win situation involving small losses in ecosystem services provision and large monetary gains.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecoser.2020.101081.

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