Ecosystem Services 43 (2020) 101100

Contents lists available at ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser

Complementing conventional environmental impact assessments of tourism with ecosystem service valuation: A case study of the Wulingyuan Scenic Area, China

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ARTICLE INFO

Keywords:
Environmental impact assessments
Ecosystem service valuation
Integrated assessment
Tourism
Protected areas

ABSTRACT

In order to assess environmental impacts from tourism in the Wulingyuan Scenic Area, China more thoroughly, this study complemented conventional environmental impact assessments (EIAs) with ecosystem service valuation (ESV). It did so by assessing changes in ecosystem services (ESs) and their values, based on changes in environmental components already assessed by existing conventional EIAs. The ESV method was benefit transfer. Tourism can enhance aesthetic and recreational ESs, but some existing damage to vegetation reduced ES value by $1.2 million/yr in the worst situations. While reforestation that generates ES value at $1.8 million/yr can offset the damage, the cost of existing population decline of macaque monkeys was $728 million in 2010. Potential land encroachment would cause permanent and temporary environmental costs at $0.5 million/yr and $0.09 million/yr, respectively. Nevertheless, potentially artificial soil treatment system would increase ES values by $0.25 million/yr. Surface runoff and waste gas have negligible impacts. While complementing conventional EIAs with ESV has limitations, doing so can assess environmental impacts more comprehensively, link environmental impacts to human wellbeing, and improve information. Sustainable tourism requires conserving biodiversity and culturally valuable ecosystems.

1. Introduction

1.1. Background

The debates on whether the Chinese government should enhance tourism development in protected areas have been heated since the government started to create "a protected area system mainly composed by national parks" in late 2015 (National Development and Reform Commission, 2017). A major reason for this concern is that creating such a system will convert some national nature reserves with strict conservation into national parks relatively more open to tourism (Su, 2016). While tourism development can generate jobs and financial revenues by providing recreation, education, and aesthetic enjoyment to visitors, it may also generate negative environmental impacts (Donázar et al., 2018; Eagles et al., 2002; Liu et al., 2016; Pan et al., 2018; Tolvanen and Kangas, 2016; Zhong et al., 2011). Environmental impacts refer to changes in the biological, physical, or chemical state of the environment that determine the quantity and quality of ecosystems, and eventually affect human health and socioeconomic performance (Kristensen, 2004). Accordingly, tourism can be a trade-off and a controversial issue in protected areas. Addressing this trade-off needs to comprehensively weigh-up the benefits and costs of tourism. This requires integrated assessments that take into account environmental, socioeconomic and cultural factors (UNEP, 2017).

Environmental impact assessments (EIAs) have been undertaken worldwide to integrate environmental consideration with decision-making for economic and social development (Chang et al., 2018; Kumar et al., 2013; Wu et al., 2014), including tourism development. China issued *the Environmental Impact Assessment Law of People's Republic of China* in 2002 (National People's Congress, 2018) which requires EIAs to be conducted prior to approving or rejecting a development proposal that may have non-negligible potential environmental impacts. In the law-context, an EIA is the assessment of the potential impacts of development proposals on the environment prior to major decisions being taken and commitments made. The process of assessment consists of identification, prediction, evaluation and mitigation of such impacts (IAIA and IEA, 1999). In the field of environmental studies, Fischer et al. (2015) found that most publications on 'environmental impact assessment' in the Scopus Database were not predictive EIAs, but assessments of existing environmental impacts caused by current human activities. To provide a broader view of environmental impacts from tourism, the term EIA in this paper includes assessments

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https://doi.org/10.1016/j.ecoser.2020.101100
Received 18 January 2020; Received in revised form 20 March 2020; Accepted 23 March 2020

on both existing and potential environmental impacts, unless otherwise specified.

Along with the development of environmental studies and refinement of EIAs, the scope and content of EIAs has been expanded and enriched (Chang et al., 2018), and there has been some guidance (Landsberg et al., 2013; OECD, 2008; Slootweg et al., 2006; UNEP, 2017) on integrating ecosystem services (ESs) into EIAs. ESs are the benefits humans directly and indirectly derive from functioning ecosystems, while the process of assessing the contributions ecosystem functions, processes and characteristics provide for human wellbeing is termed ecosystem service valuation (ESV) (Costanza et al., 1997; Costanza and Liu, 2014; Millennium Ecosystem Assessment, 2005).

Conventional EIAs tend to assess direct impacts on environmental components (soil, water, air, sound, vegetation, animals, and landscape) separately, and hence (1) neglect indirect impacts (e.g., changes in recreational value resulted from changes in water quality) and value of non-marketable ESs (e.g. air purification), underestimating environmental costs and external diseconomies; and (2) fail to explicitly explain why environmental impacts matter to human wellbeing (e.g. how does soil quality change matter to humans) (Baker et al., 2013; Honrado et al., 2013; Karjalainen et al., 2013; Wang et al., 2010). Moreover, (3) conventional EIAs cannot compare environmental costs with financial benefits in the same unit of measurement (Chen, 2020). ESV identifies direct, indirect, marketable and non-marketable ESs (Costanza et al., 2014; Kumar et al., 2013), and hence overcomes the first shortcoming of conventional EIAs. The concept of ESs links ecological functions, processes and characteristics to human wellbeing, and highlights the fact that human wellbeing depends on the wellbeing of the rest of nature (Hernández-Blanco and Costanza, 2018). Accordingly, valuing changes in ESs overcomes the second shortcoming. Also, ESV can monetize environmental costs and benefits, and so can overcome the third shortcoming.

Many studies have conducted ESV to inform environmental management, such as visualizing nature's value, raising awareness of conservation, and offering stronger arguments to address ecological degradation (Costanza et al., 2014; Grizzetti et al., 2019; Guerry et al., 2015). Despite that ESV can potentially benefit EIAs, EIAs have rarely explicitly integrated the concept of ESs in practice (Honrado et al., 2013). An investigation of assessment methods used in EIAs of tourism in China did not mention any application of ESV (Zhong et al., 2011). Chen (2020) reviewed 30 EIAs on tourism in China's protected areas, but did not identify any EIA explicitly using ESs, typologies of ESs (e.g., regulating service), or ESs' values as objects of assessment. Thus, there was no empirical evidence demonstrating ESV's benefits to EIAs. This study complemented existing conventional EIAs of tourism with ESV, making EIAs more comprehensive and providing empirical evidence of ESV's benefits and limitations in terms of assessing impacts.

1.2. Aim

This study aimed to more thoroughly assess environmental impacts from tourism development in China's protected areas. It did this by using a case study of the Wulingyuan Scenic Area, China. The hypothesis is that assessing impacts on ESs and their values can improve conventional EIAs. The objectives include: (2) linking ESs and their values to changes in environmental components; (2) discussing the benefits from, and limitations of, complementing conventional EIAs with ESV; and (3) making recommendations on addressing the limitations and developing sustainable tourism.

1.3. Study area

The Wulingyuan Scenic Area is a protected area in Zhangjiajie, Hunan Province, China (Fig. 1). Approximately located at 110 degrees east longitude and 29 degrees north latitude, it has a humid mid-subtropical monsoon climate. With a total area of 397 square kilometers, it shelters over 400 fauna species and over 750 ligneous plants, including some endangered species, such as macaque monkeys, clouded leopards, Chinese dova trees and Magnolia officinalis (Official Website of Wulingyuan Scenic Area, 2018). The landscape (Fig. 2) is characterized by over 3000 quartzite peaks. Their altitudes range from 500 to 1100 m, while their heights range from 20 to 400 m (State Bureau of Cultural Relics, 2006). With natural beauty and rich biodiversity, the area was listed as a World Natural Heritage Site and Global Geoparks by UNESCO in 1992 and 2004, respectively. It was also selected by the National Tourism Administration as one of China's best tourism destination in 2006 (Zhangjiajie Wulingyuan Scenic Area and National Forest Park Administration, 2015).

Tourism in Zhangjiajie has been developing rapidly, and has become a dominant driver for local economic growth. From 1989 to 2017, annual visitations in Zhangjiajie increased from less than ¥1 million to ¥73.36 million, whilst annual tourism revenue increased from ¥1.4 million to ¥62.38 billion yuan, contributing to more than 50% of local GDP (Xie et al., 2010; Zhangjiajie Government, 2019). In particular, annual visitations in the Wulingyuan Scenic Area increased from 0.38 to 26.33 million during the same time period, whilst annual tourism revenue increased from ¥6.84 million to ¥21.87 billion yuan (Zhangjiajie Government, 2019; Zhong et al., 2008). Nevertheless, environmental researchers (Chen and Nakama, 2013; Wang et al., 2012; Zhong et al., 2015; Zinda, 2017) are concerned about environmental impacts from tourism the scenic area. Changing the biomass, biodiversity, process, functions or characteristics of ecosystems can simultaneously change ESs (Chan et al., 2012; de Groot et al., 2010b; Xie et al., 2017). Accordingly, potential factors affecting ESs and their values include, but are not limited to, infrastructure construction (e.g., encroachment of natural lands), tourism activities (e.g., hiking on grasslands), individual behaviors (e.g. disturbance to wildlife, littering), and discharge of pollutants (e.g., waste water and gas, rubbish).

2. Method

This paper did not undertake a full EIA, which normally involves several stages: screening, scoping, reporting, reviewing, decision-making, and monitoring (CBD, 2019). Instead, based on changes in environmental components already screened, scoped and reported by conventional EIAs, this paper assessed changes in ESs and ESs' values as complementary information to the conventional EIAs. In order words, I summarized (rather than originally assessing) changes in environmental components from existing conventional EIAs, and inferred what changes occurred in ESs accordingly. Then, I valued the changes in ESs using benefit transfer.

2.1. Selection of ESs

Forests, grasslands, dry farmlands, paddy fields, ponds and 'unused lands' have been or would be impacted by tourism in the study area, so these types of ecosystems are selected. Notably, 'unused lands' (Fig. 3) here refer to lands with sparse vegetation. They are not protected, constructed, directly used nor cultivated, so are referred to as unused lands in some studies (He et al., 2001; Hunan Jingxi Environmental Protection and Scientific Technology Company, 2017; Zhao et al., 2009).

Main services of the ecosystem types above are listed in Table 1. Supporting ESs were taken into account, but were not valued, because their values were already included in the other three types of ESs according to their definition. Cultural ESs were also considered, but it was not feasible for me to value cultural ESs. Valuation of cultural ESs (e.g. travel cost method, contingent method) requires investigation of the stakeholders' preferences, which is costly in terms of time, funding, human resources (Johnston et al., 2017; Pascual et al., 2010). If one wants to understand the existing and potential changes in cultural ESs' value from an area, one not only needs to value current cultural ESs, but

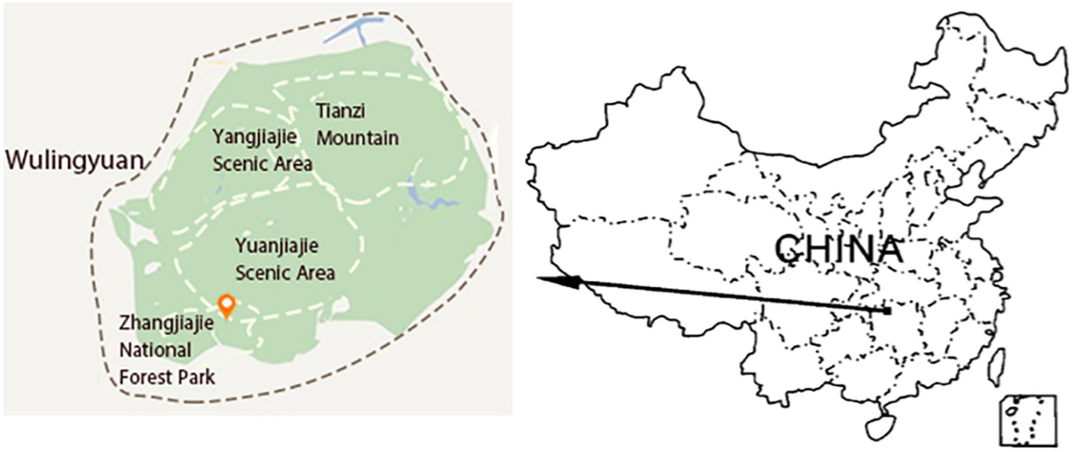

Fig. 1. Location of the Wulingyuan Scenic Area. Source: (China Discovery, 2020; Zhong et al., 2008).

Fig. 2. A snapshot of the area's landscape. Photo by Ida Kubiszewski.

Fig. 3. A section of the unused lands. Source: (Hunan Jingxi Environmental Protection and Scientific Technology Company, 2017).

also previous or future cultural ESs. Even if the changes can be estimated, it is difficult to estimate what proportion of the changes is attributed to tourism development that improves human-nature interaction. This is because people's willingness to pay for cultural ESs can be affected by multiple factors, such as accessibility to natural areas, income, and distances (Ezebilo, 2016; Hirons et al., 2016; Mayer and Woltering, 2018). Sandstorm prevention overlaps with soil retention, so was not valued (if values of overlapping ESs are aggregated into the total value, there would be double counting). Waste management overlaps with purification of water and air, so was not valued either. Control of pests and diseases was not valued due to data limitation. Genetic resources belong to one of the most difficult ESs to value (Farber et al., 2006), and are beyond my knowledge and resource availability to value. The other ESs listed in Table 1 were valued.

In addition, I valued macaque monkeys impacted by tourism. While macaque monkeys are not an ecosystem type, they contribute to biodiversity which is a 'multilayered ES'. Biodiversity can be a supporting ES underpinning ecosystem health, a regulator of ecosystem processes, a service that provides a final good (e.g., a source of gene), and also a cultural ES (e.g., satisfaction gained from appreciating a species) (Mace et al., 2012).

2.2. Selection of existing conventional EIAs

I searched conventional EIAs in academic databases including Scopus, Google Scholar, and Baidu Scholar. As EIA reports in China can be published by governments, I also used general search engines, including Baidu (the largest search engine in Chinese language) and Google. The search was performed using specific terms ('environmental impact assessment' AND 'Wulingyuan' AND 'tourism') found in titles, keywords and abstracts.

Table 1
Main ESs from the Wulingyuan Scenic Area.

Categories:	Main services:
Provisioning services	Genetic resources Raw materials (e.g. timber, medicine resources) Food
Regulating services that regulate the integrated system	Air regulation (oxygen release, absorption of toxic and waste gas, dust control) Water regulation (water retention, water purification) Climate regulation (carbon sequestration, absorption of other greenhouse gases, local climate adjustment) Soil retention (fertility maintenance, reduction of land disuse, silt and sediment) Control of pests and diseases Sandstorm prevention Waste management
Cultural services (non-material physical and mental benefits gained from human-nature interaction)	Recreation Aesthetic appreciation Spiritual and religious experience Education and research Non-use and option value of ecosystems (existence of species, bequest)
Supporting services that support the other types of ESs by maintaining ecosystem functions and processes	Habitat biological interaction (e.g. pollination) ecosystem connectivity

Source: (Costanza et al., 2017; Li, 2004; Millennium Ecosystem Assessment, 2005; TEEB, 2019).

After reviewing the searching results, I found Wang (2009) and Guo (2010) were the most comprehensive EIAs assessing existing impacts. The fact that these two EIAs were published 10 years ago does not invalidate the existing impacts they assessed. Therefore, I selected them.

I found several predictive EIAs assessing potential impacts, but I only selected the EIA of a proposed tourism highway from Sangzhi County to Wulingyuan Scenic Area (Hunan Jingxi Environmental Protection and Scientific Technology Company, 2017). The others were not selected because they were either too brief for me to conduct ESV, or were not up-to-date at the time I started this research in 2019. For example, if a predictive EIA was published in 2006, the potential impact it assessed is not likely to be still potential today.

I acknowledge that the EIAs selected did not cover all the environmental impacts from tourism in the Wulingyuan Scenic Area, but still allowed me to achieve the research aim and objectives.

2.3. ESV method: benefit transfer

Primary monetary valuation methods include revealed preference methods (e.g., market price method) that infer preference from observed choices existing in real world, stated preference methods (e.g., contingent valuation) that infer preference from hypothetic questions, and cost-based methods that estimate value based on the costs of building alternatives or costs avoided by ESs (Chen, 2020; Costanza et al., 2017). However, these methods are often costly in terms of time, human resources, techniques, and funding. In comparison, benefit transfer is more timely and less constrained by resources (Liu et al., 2010b; Richardson et al., 2015; Wilson and Hoehn, 2006). Due to my time and resource limitation, I undertook benefit transfer.

This method estimates the value of an ES at a new site by transferring and adjusting existing original value estimates of the same ES from one or multiple sites where there are preferably similar ecological and socioeconomic contexts (Kubiszewski et al., 2013; Rosenberger and Phipps, 2007; Rosenberger and Loomis, 2003). Since this paper does not aim to improve the accuracy of benefit transfer, I conducted basis benefit transfer that assumes a constant unit value (e.g., value/ha/yr) of an ecosystem type and multiplies the unit value by the total units of each type to arrive at aggregate totals(Costanza et al., 2014). If there were multiple estimated values of the same ES in previous studies, median values were used. I did not use the mean value in order to avoid overestimation: the mean value of an ES is often larger than the median value, because of asymmetric distributions of willingness to pay (WTP) for an ES (Alberini and Cooper, 2000).

Despite that benefit transfer has lower accuracy than primary valuation methods (it ignores diminishing marginal benefits, and functional interdependency between different types of ecosystem) (Brondizio et al., 2009), it still allows to conduct ESV to assess environmental impacts more comprehensively. Moreover, Benefit transfer, if used to value ESs with high transferability, is capable of informing decision-makers of ES values at a relatively low cost (Costanza et al., 2014; Richardson et al., 2015).). ESs valued in this paper, including provisioning ESs, regulatory ESs, and macaque monkeys' contribution to biodiversity, in general have relatively high transferability (Farber et al., 2006; Richardson and Loomis, 2009). In addition, primary valuation methods may not work to assess existing changes in ESs' values. For example, I cannot primarily value ESs of a forest that was cleared already, unless data associated with the ESs was collected previously. Instead, I can use benefit transfer assuming that the cleared forest had similar ESs and values to forests at other sites. Accordingly, benefit transfer was suitable to this paper.

2.4. Valuation unit

ES values are expressed in US$ in order to communicate with a global audience. The monetary unit used in this paper is $US\$_{2010}$ unless otherwise noted, because an EIA report selected was published in 2010. Also, it is relatively easier to conduct calculation by using US GDP deflator_{2010}, which is 100. If the value was expressed in RMB (Renminbi, Chinese currency) in a previous study, it was converted to US$ of the same year by dividing it by the RMB's purchasing power parity (PPP) of that year (e.g. $US\$_{2000} = RMB_{2000}/RMB\text{'s } PPP_{2000}$). If the value was expressed in US$, it was converted into $US\$_{2010}$ by multiplying it by the ratio between US GDP deflator_{2010} and US GDP deflator of the year in which the value was estimated (e.g. $US\$_{2010} = US\$_{2000} * USGDPdeflator_{2010}/USGDPdeflator_{2000}$). Data of the PPP and US GDP deflator are from the OECD (2019) and World Bank (2019), respectively (Supplementary Materials).

3. Results

3.1. Unit value of ESs

The calculation of the unit value of macaque monkeys (WTP for protecting against the population decline of macaque monkey per visitor) and different types of ecosystems (value/ha/yr) was detailed in the Supplementary Materials. The WTP per visitor was estimated at $52

Table 2
Summary of ES values (US$/ha/yr).

ES Values			Forest	Unused lands	grasslands	Dry farmlands	Paddy fields	Ponds
Water regulation	Water retention	Flood control	1651	151	121	/	824	2388
		Water supply	98			−56	−121	3820
	Water purification		/	/	/	/	418	265
Gas regulation	Oxygen release		1027	10	2225	7602	1047	593
	Dust and toxic gas absorption		823	/	11	151	13	/
Climate regulation	CO_2 fixation		938	/	509	3245	−1166	493
	CH_4 absorption		/	/	0	36	−177	/
	N_2O absorption		/	/	1	−155	−62	/
	Local climate (e.g., humidity, temperature) regulation		7198	/	1597	937	8687	6348
Soil retention	Reduction of land disuse, silt and sediment		35	1337	340	/	/	2083
	Fertility maintenance		427			1331	2913	
Provision of resources			/	/	/	5880	3396	17368
Total value			12,197	1498	4804	18,971	15,772	33,358

Note: '/' in all tables of this paper means that no value estimate was found in previous studies.

in 2010. The unit values of different types of ecosystems are presented in Table 2.

3.2. Environmental impacts

Based on impacts sources (human behaviors leading to environmental impacts) and associated impacts on environmental components summarized from existing conventional EIAs, I inferred impacts on ESs and estimated impacts on ESs' values (Tables 3 and 4).

4. Discussion

4.1. Benefits from complementing conventional EIAs with ESV

The goal of EIAs is to assess the effects on human wellbeing and inform a non-technical audience of environment impacts (IUCN, 2016). However, merely assessing impacts on biophysical environmental components, such as the increased amounts of dissolved oxygen, total phosphors, total nitrogen, and ammonia nitrogen in the water (identified by the conventional EIAs in Table 3), does not illustrate how the changes would affect humans. In comparison, assessing impacts on ESs (e.g. provisioning and recreation) and their values helps to bridge the gap between biophysical environmental changes and human wellbeing. Doing so builds a common language between developers and environmentalists (Liu et al., 2010a), and translates scientific terms (e.g., ammonia nitrogen) into a language (e.g., value) more understandable to ordinary people with limited scientific knowledge. Using a common and understandable language in the process of undertaking EIAs reduces communication barriers, in turn promoting interdisciplinary collaboration and public engagement, and improving information for decision-making (Bingham et al., 1995; Coleby et al., 2012; Webler and Tuler, 2006).

Conventional EIAs may have implicit consideration of ESs, for instance, 'changes in the view of landscape' implies changes in aesthetic ES. However, a problem of implicit consideration of ESs is the risk of overlooking some ESs, especially indirect ESs, and hence underestimating environmental costs. As an example, in Table 4, while the conventional EIA indicated the tourism highway would encroach on some unused lands, it neglected to consider the environmental impacts from the loss of unused lands, because humans do not directly benefit from them. In fact, the unused lands are not useless, but provide various ESs that are worth at least $1498/ha/yr (Table 2). Moreover, when identifying the impacts from the loss of paddy fields, dry farmlands, ponds, and forests, the conventional EIA neglected to consider regulatory ESs that are more intangible and hidden compared to damage on vegetation, loss of agricultural products, changed landscapes, and ecosystem fragmentation, creating a lopsided view. Table 4 has shown that ESV helps to take into account a wider range of ESs, highlighting hidden values of ecosystems (CBD, 2004; Liquete et al., 2016).

When estimating the costs of the tourism highway, as an example, the conventional EIA only counted the market costs of construction (Hunan Jingxi Environmental Protection and Scientific Technology Company, 2017). Filling this gap can benefit from ESV, which can make non-marketable environmental costs visible in monetary units. Meanwhile, conventional EIAs may classify the significance of impact into different levels, such as 'major', 'medium', 'minor', and 'not significant' (IUCN, 2016). As an example, the temporary loss of vegetation resulting from constructing the tourism highway was 'not significant' according to the conventional EIA in Table 4, however ESV translated such impact into a temporary loss of $0.09 million/yr. This deems the level of significance of being "not significant" as questionable and variable. In comparison, ESV enables environmental impacts to be expressed in monetary units that are measurable, more objective, and less vague than some qualitative words, such as "significant".

4.2. General limitations of complementing conventional EIAs with ESV

It is not possible to fully assess impacts on ESs' values. Due to humans' incomplete knowledge of ecosystems, humans cannot anticipate all of the services provided by an ecosystem (Bingham et al., 1995), or all of the ESs impacted by human behaviors. Even if an ESs is anticipated, we may not be able to value it due to the lack of data or a resource-efficient valuation method.

Moreover, tourism impacts ESs by affecting different biophysical environmental components (e.g., nitrogen in water), so assessing changes in ESs is less straightforward than, and constrained by, assessing changes in environmental components. Researchers have developed quantifiable biophysical indicators of ESs (e.g. reduction of flood peak discharges), and discussed causal relationships between changes in environmental components and changes in ESs (Cardinale, 2011; Grizzetti et al., 2016; Harrison et al., 2014; Liquete et al., 2013). Nevertheless, there is a shortfall in knowledge regarding quantitative interaction between biodiversity, ecological process, ESs, and environmental components (de Groot et al., 2010a). For example, how do ESs (e.g., provisioning of fish) respond to changes in environmental components (e.g., increasing nitrogen in water by 5 mg per liter) quantitatively? And to what extent do changes in the population of some species (e.g., heliophilous vegetation replacing sciophilous vegetation) affect an ES (e.g., soil fertility maintenance)?

When considering cultural ESs, the interaction is more complex. Obtaining all ESs requires existence of relevant ecological functions, processes or characteristics, but obtaining cultural ESs also requires human-nature interaction and access to natural areas (de Groot et al., 2010a), and so may reduce biomass of ecosystems. Thus, unlike regulating or provisioning ESs, cultural ESs are not always positively correlated to biomass of ecosystems. Tourism development (e.g.,

Table 3
Existing environmental impacts from tourism in the Wulingyuan scenic area.

Impact sources	Impacts on environmental components	Impacts on ESs	Impacts on ESs' values
(Guo, 2010; Wang, 2009)			
Constructing tourism infrastructure, including 164.3 km of footpaths and 73.2 km of roads, cableways, parking lot, and other reception facilities	Damage on vegetation	Loss of provision, regulating and supporting ESs from forests	Loss of $0.9 million/yr in the worst situation (Note 1)
		Unclear changes in cultural ESs from forests (Note 2)	Unclear
	Ecosystem fragmentation	Non-quantified negative effects on supporting ESs	Unclear
	Changes in ecological conditions that favored heliophilous vegetation over sciophilous vegetation.	Non-quantified effects on biodiversity (a multilayered ES)	Unclear
	Changes in the view of landscapes	Non-quantified changes in aesthetic ES	Unclear
Waste water discharged into rivers	Increased contents of dissolved oxygen, permanganate, total phosphors, total nitrogen, and ammonia nitrogen in water	Non-quantified declines in aquatic provisioning (e.g., water supply, fish), regulatory (e.g., disease control), cultural (e.g., aesthetic and recreational) and supporting (e.g. habitat) ESs caused by increased total nitrogen (Note 3)	Unclear
		Negligible impacts from changes in the contents of the other substances (Note 3).	Negligible
Trampling on grasslands along both sides of the footpaths	Damage to vegetation	Loss of regulating, provisioning and supporting ESs from grasslands;	Loss of $0.3 million/yr in the worst situation (Note 4)
		Unclear changes in cultural ESs	Unclear
	Increased soil hardness;	Non-quantified damage on grasslands' supporting ESs	Unclear
Littering, engraving on trees or stones, and physically breaking vegetation	Damage to vegetation; Changes in the view of landscapes	Non-quantified changes in all ESs from forests and grasslands	Unclear
Reforesting 144.92 ha of deforested lands	Recovered natural landscapes;	Non-quantified changes in forests' cultural ES;	Unclear
	Increased forests' coverage	Increased regulatory, provisioning and supporting ESs from forests;	Generation of $1.8 million/yr
Closing 7165.3 ha of forests	As above	As above (but lack of information on the quantity of improved ESs)	Unclear
Waste gas and dusts generated by tourism facility	Increased SO_2 and dusts in air with negligible existing pollution	Negligible	Negligible
Noise from human activities	Disturbance to wild animals	Unclear (Note 5)	Unclear
All of the activities above	Less frequently observed rare species (e.g., clouded leopards, black bears)	Non-quantified changes in biodiversity (a multilayered ES)	Unclear
	Declined population of macaque monkey from 33 to 7 groups.	Declines in biodiversity (a multilayered ES)	Loss of $728 million in 2010 (Note 6)

Note 1: The authors did not specify the vegetation damaged, but the main ecosystem type in the area is forest. The average width of the roads is approximately 7 m (Zhangjiajie Wulingyuan Scenic Area and National Forest Park Administration, 2017), so the roads occupy 73.2 km × 7 m = 51.24 ha of land. The width of the footpaths varies, but is over 1 meter, so the area of the footpaths is over 164.3 km × 1 m = 16.43 ha. Parking areas for eco-sightseeing vehicles occupy 3.4 ha (Tian and Tian 20,11). There is no information on how much land area is occupied by cableways and reception facilities. In the worst situation whereby roads, footpaths and parking lots were completely established on previous forestry land, the area of destroyed forests would be over 51.24 + 16.43 + 3.4 = 71.07 ha.
Note 2: Why changes in cultural ESs were unclear was discussed later in Section 4.2.
Note 3: The contents of the substances were presented in the Table S6 in the Supplementary Materials. The contents of dissolved oxygen, permanganate, ammonia nitrogen and fluoride still met the first-level water quality standards specified by the Environmental Quality Standards for Surface Water (Ministry of Ecology and Environment, 2002). The content of total phosphors met the second-level standards, so had negligible impact, as water at second-level standards can still be a source of drinking water, meet living conditions of endangered aquatic, and be physically contactable to humans (Ministry of Ecology and Environment, 2002). The content of total nitrogen could not meet the fifth-level standards, so could not meet drinking conditions or guarantee health safety for direct human body contact (Ministry of Ecology and Environment, 2002). Increased nitrogen can also change fish yields and aquatic biodiversity, and also lead to harmful alga bloom, generating toxins, and changing color and transparency of water (Camargo and Alonso, 2006; Rabalais, 2002).
Note 4: Trampling mainly happened within 2 m from the footpaths. In the worst situation (if the whole area 2 m from both sides of the footpath was originally grasslands, and was destroyed), the area of destroyed grasslands would be 4 m × 164300 m = 65.72 ha.
Note 5: Noise's effects on the health of animals or ecosystems are not clear (Luo et al., 2019), neither are they on ESs.
Note 6: The number of visitors in 2010 was 13,998,300 (Zhangjiejie Wulingyuan Statistical Bureau, 2011).

building a hiking path) may improve accessibility to natural areas, and hence improve the use value of cultural ESs. The increasing tourism revenue in the Wulingyuan Scenic area reflects increasing use value of the area's cultural ESs for now, but it does not necessarily mean maintaining or enhancing tourism development in the area is desirable in the long-term. This is because use value of cultural ESs would decline if tourism development degrades culturally important ecological functions, processes or characteristics. Maximizing the use value of cultural ESs in the long-term requires tourism development to balance access to natural areas with the existence of ecosystems. Furthermore, unlike provisioning and regulatory ESs that only have use value, cultural ESs also have non-use value (value attributed to simple existence of an object) and option value between use and non-use value (an option to use an ES in the future) (de Groot et al., 2010a). Even if replacing existing natural lands with artificial tourism lands may improve use value of cultural ESs, it may simultaneously reduce non-use and option value. As presented in Tables 3 and 4, it was not clear if damage on ecosystems would improve or decline cultural ES. A gap remains in knowledge of quantitative interaction between use, non-use and option value.

In short, even if we can fully identify what ESs would decline or improve according to changes in environmental components, we may still be unable to understand to what extent those ESs would change. Quantifying impacts on ESs is particularly unfeasible when impacts on environmental components are simply described, rather than being quantified. Assessing changes in ESs' values is premised on quantifying impacts on ESs, so has more constraints. As presented in Tables 3 and 4,

Table 4
Potential environmental impacts of a proposed tourism highway from Sangzhi County to Wulingyuan Scenic Area.

Impact sources	Impacts on environmental components	Impacts on ESs	Impacts on ESs' values
(Hunan Jingxi Environmental Protection and Scientific Technology Company, 2017)			
Permanent land encroachment, including 8.577 ha of paddy fields, 10.297 ha of dry farmlands, 1.429 ha of ponds, 9.33 ha of forests, and 10.782 ha of unused lands	Loss of agricultural products and vegetation from the encroached lands	Loss of regulating, provisioning and supporting ESs from the encroached lands	Permanent loss of \$0.5 million/yr
		Unclear changes in cultural ESs	Unclear
	Permanent changes in the view of landscapes	Non-quantified changes in aesthetic ES	Unclear
	Ecosystem fragmentation	Non-quantified damage on supporting ESs	Unclear
Dump pits that temporarily encroach on 5 ha of unused lands; construction sites that temporarily encroach on 2.27 ha of forests, 1.69 ha of dry farmlands, and 0.6 ha of ponds	Temporary loss of vegetation (not significant)	Temporary loss of provisioning, regulating and supporting ESs from the encroached lands	Temporary loss of 0.09 million/yr
		Unclear changes in cultural ESs	Unclear
	Temporary changes in the view of landscapes	Non-quantified changes in aesthetic ES	Unclear
	Soil and underground water pollution caused by waste in dump pits	Non-quantified degradation of supporting ESs	Unclear
Waste gas and dusts discharged or dispersed by roadworks and vehicles	Negligible air pollution (Note 1)	Negligible	Negligible
	Hindered photosynthesis and growth of vegetation	Unclear negative effects on supporting ESs (Note 2)	Unclear
Wastewater and surface runoff that can carry pollutants into surface water and soil	Water and soil pollution	Non-quantified damage to supporting (e.g., habitat) and provisioning ESs (e.g., water supply, fish yields)	Unclear
Noise, lights and vibration from roadworks and vehicles	Changes to living conditions of animals along the highway	Unclear effects on supporting ESs	Unclear
Roadworks clearing 58,000 m^3 of surface soil; Artificial soil treatment, including planting 7 ha of grasslands and 17.29 ha of forests, and building soil conservation systems	Potential loss of 13,457 tons of soil (but this could be prevented by the artificial soil treatment)	Increased provisioning, regulating (excluding soil retention) and supporting ESs from the grasslands and forests	Generation of \$0.25 million/yr
		Unclear changes in cultural ESs	Unclear

Note 1: Although pollutants in air would increase, they could be diluted and self-purified.
Note 2: These changes can hardly be quantified because they depend on many factors, including the amounts of dust, and local weather events.

a number of inputs in the column "Impacts on ESs' values" are denoted as "Unclear" due to the lack of quantification of impacts on ESs.

4.3. Limitations of this study per se

This paper did not estimate the value of cultural ESs and other unanticipated regulatory ESs, but ignorance of these ESs may lead to a biased view of values of different types of ecosystems. As presented in Table 2, the estimated unit values of unprotected areas (e.g., paddy fields and dry farmlands) are higher than that of protected forests and grasslands, potentially leading to an incorrect perception that farmlands are more beneficial than protected areas. In fact, compared to single-purpose land use (e.g., merely farming), an increasing number of studies have shown that areas with more diverse species and functions provide more abundant ESs, and are ecologically more sustainable, socio-culturally preferable and economically more desirable (Balmford et al., 2002; de Groot et al., 2010a).

In theory, expressing environmental impacts in monetary terms assists with weighing-up environmental and financial benefits and costs in the same unit of measurement. For example, if the potential economic benefits generated by building a highway are lower than the potential environmental costs, building the tourism highway would not be cost-effective. However, since this paper did not fully value ESs impacted by tourism, it could not conclude whether tourism in the Wulingyuan Scenic Area generated greater benefits or costs.

The most efficient tourism development should maximize the sum of all values of different ESs. However, due to the difficulty in valuing cultural ESs and quantifying interaction between biodiversity, environmental components and ESs, especially cultural ESs, this paper could not estimate the potential maximum sum of ES values of the Wulingyuan Scenic Area in a dynamic development process, or to design a one-size-fits-all approach leading tourism development to reach the optimal efficiency.

In spite of the limitations, this study was still able to achieve the research aim and objectives.

5. Recommendations on addressing the general limitations

Quantification of changes in environmental components is the foundation to assess impacts on ESs' values in monetary units. Therefore, in order to further link changes in environmental components to changes in ESs, especially changes in ESs' values, future EIAs should provide more quantitative information on changes in environmental components. Further to this, there should be quantitative research regarding interactive relationships between biodiversity, environmental components, ecological processes and ESs, especially cultural ESs. However, if it is costly or unfeasible (e.g. lack of knowledge) to quantify changes in ESs and their values, assessing changes in ESs at relatively low costs can begin with describing changes in ESs qualitatively (e.g. an ES and its value would decline).

In order to reduce bias in understanding ESs' values, practitioners should clarify what ESs are valued or neglected. Moreover, environmental issues, including environmental impacts from tourism, are often connected with socioeconomic issues, and hence shaping a holistic understanding of environmental impacts should not merely rely on knowledge from a separate discipline. Instead, there should be enhanced interdisciplinary collaboration in the process of undertaking EIAs, especially integrated EIAs.

5.1. Recommendations on tourism development in protected areas

As demonstrated in the results, tourism development may reduce provisioning, regulating, and supporting ESs, as well as non-use and option value. The negative impacts on ecosystems should be minimized, as conserved ecosystems are the basis of developing tourism and providing other ESs. Repairing impacted ecosystems artificially can restore regulating, provisioning, and supporting ESs. For example, reforesting the Wulingyuan Scenic Area generates ESs at $1.8 million/yr, offsetting the infrastructure's environmental costs at $1.2 million/yr (Table 3).

Unlike regulating or provisioning ESs, biodiversity loss (e.g., extinction of a species) may not be repaired. Therefore, tourism should not decline biodiversity. Biodiversity loss is also financially undesirable. The largest environmental costs estimated in Tables 3 and 4 was the loss of macaque moneys' biodiversity value at $728 million in 2010. This example also evidences that generating tourism revenue is not always more economically cost-effective than conservation. Meanwhile, areas with richer biodiversity tend to provide richer ESs (Benayas et al., 2009; Costanza et al., 2007; Worm et al., 2006), and are often more resilient to environmental changes (e.g., global warming, invasion from alien species) (Oliver et al., 2015; Sakschewski et al., 2016; Steneck et al., 2002), so are more likely to maintain ESs and benefit humans in the long-term.

Developing tourism often inevitably replaces some natural areas with built areas, providing access to natural areas. However, doing so does not necessarily have positive but unclear impacts cultural ESs (Tables 3 and 4). Once cultural ESs degrade or disappear, it is difficult to replace or repair them (Millennium Ecosystem Assessment, 2005). Namely, the uniqueness and irreplaceability of cultural ESs are what make cultural ESs valuable. Accordingly, exploiting natural area should avoid deteriorating ecosystems with important cultural values (e.g., beauty, scientific value, spiritual significance). Although it is difficult to value changes in cultural ESs monetarily, EIA practitioners can identify what ecological functions, processes or characteristics are culturally important to people. This can be done during the process of public engagement, which is integral to undertaking primary EIAs (Coleby et al., 2012; Glucker et al., 2013; O'Faircheallaigh, 2010).

6. Conclusion

Based on a conservative estimation, some existing damage to vegetation reduces ES value by $1.2 million/yr in the worst situations. While reforestation that generates ES value at $1.8 million/yr can offset the damage, the cost of existing population decline of macaque monkeys was estimated at $728 million in 2010. Potential land encroachment of a tourism highway project would cause permanent and temporary loss of ES values at $0.5 million/yr and $0.09 million/yr, respectively. Nevertheless, potentially building artificial soil treatment system would increase ES values by $0.25 million/yr. Surface runoff and waste gas have negligible impacts on ESs and their values. However, it was unclear how impacts on landscape views and habitat conditions (e.g., ecosystem fragmentation, disturbance to animals) can change ES values. This paper did not fully assess impacts on ESs' values, and hence could not conclude if tourism in the Wulingyuan Scenic Area generated greater benefits or costs. Neither could this paper design a one-size-fits-all approach maximizing benefits from tourism. However, complementing conventional EIAs with ESV can link environmental impacts to human wellbeing, improve communication, and assess environmental impacts from tourism more comprehensively. Transdisciplinary knowledge and quantitative information are essential to integrated assessment. Recognizing the value of conservation, maintaining biodiversity, and protecting culturally important ecosystems, form three bottom lines of ensuring sustainable tourism development.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

None.

Acknowledgement

My sincere thanks go to Robert Costanza and Ida Kubiszewski for their supervision on writing this paper. I am also grateful for comments from Jennifer Dawes, the journal editor, and anonymous reviewers.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecoser.2020.101100.

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