Land use trade-offs in China's protected areas from the perspective of accounting values of ecosystem services

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Abstract

"Accounting values" (quantity * unit value), assessed with an assumption of a constant unit value, are often used in creating macroeconomic aggregates like Gross Domestic Product (GDP). This approach has also been used to estimate the total value of ecosystem services (ES) - the benefits humans receive from functioning ecosystems. Applications in China have called this Gross Ecosystem Product (GEP). While the concepts of value and ES may be understood from multiple perspectives, ESs' accounting values can contribute important information to the discussion of land use trade-offs in China's protected areas (PAs). These trade-offs include (1) whether more conserved lands should be converted into lands for tourism development, since tourism brings both positive and negative impacts; (2) whether PAs should be maintained and expanded, since PAs safeguard sustainable wellbeing but also require maintenance; and (3) how to undertake conservation on lands traditionally used for human livelihood, since conservation and livelihood may be conflicting. Previous studies have suggested that (1) joint evaluation based on both GDP and ESs' values may lead to more sustainable decision-making than GDP-oriented evaluation; (2) the benefits of maintaining terrestrial PAs in China would be $2.64 trillion/yr and over 14 times the costs; (3) integrating ES valuation into environmental impact assessment helps to link environmental impacts with human wellbeing and financial costs (e.g., land encroachment of a tourism highway in the Wulingyaun Scenic Area was estimated to cause permanent loss of ES values at $0.5 million/yr); and (4) integrating non-marketable cultural ESs into payment for ESs schemes can further balance conservation with livelihood development. Future research should consider (1) option and non-use values to present a more comprehensive picture of PAs' contributions to sustainable wellbeing and human interdependence with the rest of nature; (2) both PAs' quantity (e.g., optimal coverage of PAs) and quality (e.g., management effectiveness, connectivity); (3) more sophisticated and feasible valuation methods (e.g., more cost-effective and engaged deliberation) to improve the credibility of aggregate values over large spatial scales.

Key words: land use, protected areas, ecosystem services, accounting values, environmental impact assessment, payment for ecosystem services

1. Background of addressing land use trade-offs in China's protected areas

Since 1956, China has established over 11,800 protected areas (PAs) with different designations (e.g. national parks, nature reserves, geo-parks) that cover 18% (or 172.8 million hectares) of China's land area (Ministry of Ecology and Environment 2020a). This reflects increasing, broad recognition of PAs' role in conserving biodiversity, maintaining ecosystem services (ESs), and safeguarding sustainable wellbeing of people and the planet. This role is particularly crucial with population growth, increasing demands for sustainable wellbeing and hence for ESs, and growing recognition of the need to promote harmony between humans and the rest of nature to reduce the risk of zoonotic diseases and pandemics, such as Covid-19 (CBD 2020b; IPBES 2019; Millennium Ecosystem Assessment 2005). This crucial role has made PAs integral to the global Sustainable Development Goals (SDGs), the recent proposed Post-2020 Global Biodiversity Framework (CBD 2021), and China's 'ecological civilization' initiative (a vision of society with harmonious co-existence between humans and the rest of nature, environmentally conscious citizens, long-term persistence of biodiversity, sustainable prosperity, and integrated development) (Ministry of Ecology and Environment 2020a).

China is implementing unprecedented actions to improve management and conservation of ecosystems and biodiversity, ultimately contributing to the 'ecological civilization' initiative and global SDGs. Much of this response is associated with PAs, including, but not limited to: (1) creating a PA system mainly consisting of national parks. China has multiple designations of PAs, such as national parks, nature reserves, scenic areas, and forest parks, but plans to make national parks the main PA designation in the future; (2) planning an 'eco-redline' (geographic space with strict conservation) to protect 25% of China's terrestrial area; (3) making 'green mountains' into 'gold mountains' - a metaphor of making economic gains by taking advantage of well-preserved nature, such as by developing eco-tourism; and (4) making payments or compensation for conservation (General Office of the State Council 2017; Ministry of Ecology and Environment 2020a; National Development and Reform Commission 2017).

To maximise PAs' benefits and balance the wellbeing of a wide range of PA stakeholders, China needs to address PAs' land use trade-offs during their undertaking of the aforementioned actions. These trade-offs include (1) whether more conserved lands should be converted to lands for tourism development, as tourism may bring both positive and negative impacts (e.g., economic growth, decreased vegetation cover and ecosystem connectivity due to tourism facility construction) on PAs; (2) whether terrestrial PAs should be maintained and expanded, as PAs benefit humans and other species but also require direct management costs and opportunity costs over alternative land uses; and (3) how to undertake conservation on lands traditionally used for local human livelihood development (e.g., logging, grazing), as conservation and local livelihoods may be interdependent but also conflicting (Chen 2020b).

Here, we discuss how to address these trade-offs from the perspective of ESs and their accounting values (see more explanations in section 2.1). We focus on this perspective because a greater understanding of ESs' production and values can complement conventionally used Gross Domestic Product (GDP, which is measured merely based on market transaction without integrating non-marketable ESs) to assess benefits and costs of different land use options more thoroughly and promote more balanced decision- making than GDP-oriented evaluation (Chen 2020b; Costanza et al. 2014b; IPBES 2019; Millennium Ecosystem Assessment 2005). We acknowledge that PAs' land use trade-offs are too complex to be completely addressed by a limited set of approaches. Diverse perspectives, including biology, law, politics, and ethics are also required. Also, conservation-related debates on the concepts of ESs and ES valuation are ongoing (see Section 2.2). Hence, this paper intends to provide an additional important and increasingly influential perspective to address these trade-offs.

2. Key concept introduction

2.1. Overview of the concept of value

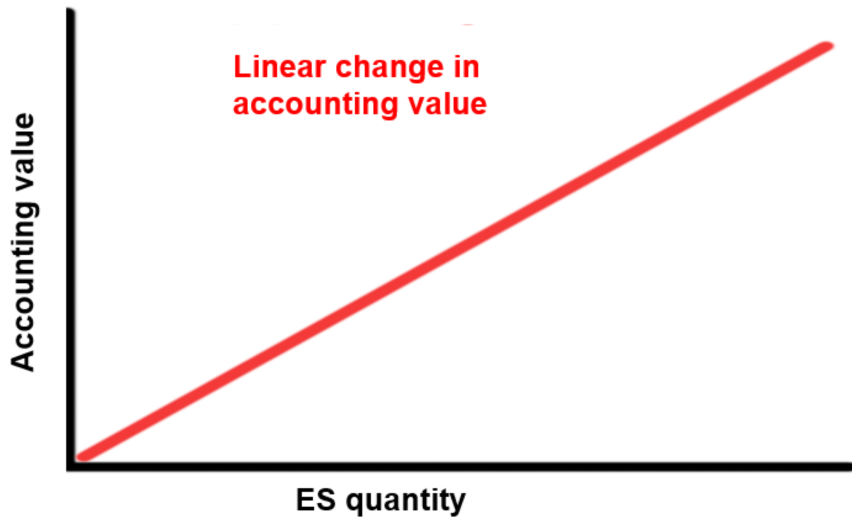
Valuation is the process of expressing the relative importance of a certain action or object, with the concept of value having a long history (Farber et al. 2002). In a general sense, if something has value, it means it has importance, worth, usefulness, or relative contributions to achieving goals, objectives or desired outcomes (Costanza 2020b). However, different disciplines and perspectives can consider and interpret the importance, worth, usefulness or relative contributions in various ways. Economists can consider the value of an object on the margin and on the whole, namely, the marginal value (value of an additional unit, such as the value of one additional tree) and the total value of the object (e.g., the value of all trees). With respect to whether an object is used by humans, value can be classified into (1) use value of utilisation of an object, (2) non-use value unrelated to current or future uses but attributed to existence of an object, bequest or altruistic purposes, and (3) option value (between use and non-use value) of maintaining an object for optional uses and possible benefits in the future (de Groot et al. 2010b; IPBES 2019; Marre et al. 2015). Based on use values, objects traded in the markets also have exchange values at which the objects can be exchanged for other market goods or services. Aristotle distinguished use and exchange values using the diamond–water paradox. Although the total use value of water, which is essential for life, is infinite, its exchange value is low, whereas unessential diamonds have a high exchange value. Many economists, including Menger, Gossen, Jevons and Walras, have argued that use value is based on utility, whereas exchange value is based on both utility and scarcity (Blaug 1997).

Classical economists attempted to seek a primary input to explain the production of exchange values. For example, Adam Smith and Karl Max regarded labour spent producing an object as the determinant of the object's exchange value. However, this labour theory is limited to societies when labour was the limiting factor and objects were exchanged based on the ratio of labour use. It has also been noted that labour is actually an intermediate input that requires other inputs, such as energy (Cleveland et al. 1984; Costanza 2004; Farber et al. 2002; Hall et al. 1992). In comparison, the current mainstream marginal value theory that emerged in the 20th century uses the value of marginal utility, which is reflected in market price, to explain exchange values (Costanza 2004, 2018; Farley 2012; Mazzucato 2018). Basically, price and marginal value of an object is determined by the object's supply and demand relationships in the market. Therefore, essential but abundant water has much lower exchange value than unessential but scarce diamonds. This demonstrates a key idea of the marginal value theory: diminishing marginal utility/benefit/value (e.g., the fist chocolate has larger marginal value than the one hundredth chocolate to a chocolate lover).

However, the diminishing marginal value theory may not be applicable to value ESs, because: (1) while diminishment of marginal value is applicable to assessment of exchange values of rival and excludable goods in the market, ESs' values are often more related to use values than exchange values, because most ESs are common (rival but non-excludable) or public (non-rival and non-excludable) goods, are not exchanged in the market, and do not have actual prices or exchange values (Costanza et al. 2014a). (2) Adopting diminishing marginal value may ignore the values of some abundant ESs (e.g., oxygen), underestimating ESs' values (Costanza 2018; Mazzucato 2018). (3) Diminishing marginal value implies that the more stocks of ecosystems are depleted, the greater the marginal value of ecosystems, potentially leading to an unsustainable and biased idea that it is not worth enhancing nature conservation since having less will increase their marginal value. (4) In complex economic systems and ecosystems characterised by non-linear dynamics, resilience, surprises, time lags in responses to changes, and especially existence of thresholds (Fisher et al. 2008; Liu et al. 2007), marginal value is not necessarily diminishing. A small change in economic activity or in environmental status, if crossing a threshold, may have enormous impacts (Farley 2012). Numerous studies have demonstrated existence of environmental or ecological thresholds, notably thresholds of biodiversity loss, ES degradation, and climate change, and many ESs (e.g., climate regulation and fish provision) are at critique state, hence small change in ESs' quantity may cause large changes in ESs' values (Asayama 2021; Farley 2012; IPBES 2019; IPCC 2018; Millennium Ecosystem Assessment 2005; Rockström et al. 2009). (5) Even if marginal value is always diminishing, it is challenging and even infeasible to measure diminishment of marginal value in complex, highly interdependent economic systems and ecosystems (Ouyang et al. 2020; Turner et al. 1998).

Instead, the total values of flows of a subset of ESs, including Gross Ecosystem Product (GEP, an emerging indicator in China), are often accounting values assessed using an assumption of a constant unit value, namely a linear relationship between ES quantity and value (Figure 1). Specifically, the unit value of an ES (e.g., value of sequestering a ton of carbon dioxide, purifying a ton of water, or preventing a ton of sand in air) is assumed to be independent from the increase or decrease in the ES's quantity without considering threshold of the ES's quantity, possible diminishment of marginal value, supply-demand relationship, or elasticities of the ES (Farley 2012; Howarth and Farber 2002; Ouyang et al. 2020). The assumption simplifies complex economic and ecological systems, but makes assessment of values, especially macroeconomic estimates, such as GDP, GEP and the global ESs' values in earlier studies (Costanza et al. 1997; Costanza et al. 2014a; Kubiszewski et al. 2017), practical and possible.

Figure 1: A linear relationship between ES quantity and value



Therefore, accounting values are calculated by multiplying unit value by quantity:

Accounting value = (1) unit value of an ES * total quantity of the ES; or (2) value/ha/yr of an ecosystem type (e.g., forest, grassland, wetland) * total land area of the ecosystem.

In Equation (1), an ES's unit value basically can be indicated by market price (e.g., of water provisioning), avoided damage costs (e.g., of a volume of potential flood prevented by ecosystems), replacement costs (e.g., of using artificial measures as an alternative of ecosystems to remove a ton of sand in air), or restoration costs (e.g., of artificially restoring a certain amount of a degraded ES) (Costanza et al. 2011; Pascual et al. 2010); whereas the quantity of an ES may be reflected in markets (e.g., how much water, timber or food is traded) or assessed by ecological models, examples of which can be found in the Supplementary Materials of Ouyang et al. (2016). Equation (2) corresponds to basic benefit transfer method that assumes the same type of ecosystem at different locations provide similar ESs with similar values and hence transfers the value/ha/yr of a type of ecosystem, estimated previously at one site or multiple sites, to a new site (Kubiszewski et al. 2013; Wilson and Hoehn 2006).

2.2. Conservation-related debates on ecosystem services and their valuation

The concept of ESs has been criticised as being anthropocentric, as the concept means that ESs do not exist without human presence. Being anthropocentric, in this critique, suggests that humans are the only species that matters, excludes the intrinsic value of ecosystem, and may promote an exploitative human-nature relationship (McCauley 2006; Raymond et al. 2013; Redford 2009). This critique is concerned about environmental ethics regarding whether human actions towards nature should be based on an anthropocentric or biocentric view (Jax et al. 2013; Schröter et al. 2014). The counter-arguments are that, (1) consideration of environmental ethics, including intrinsic values, is indivisible from anthropocentric values (Jax et al. 2013); and (2) the concept of ESs recognises the interdependence between humans and the rest of nature (Costanza et al. 2017) and provides an additional argument to conserve nature (Chen 2021; Schröter et al. 2014), rather than denying non-use value or intrinsic value of other species. Thus, as Costanza et al. (2017) explain: "…the concept of ESs makes it clear that the *whole system* matters, both to humans and to the other species we are interdependent with. If anything, the ES concept is a 'whole system aware' view of humans embedded in society and embedded in the rest of nature. 'Centric' with any prefix doesn't really describe this complex interdependence" (p. 3).

The ES concept is also criticised for the imprecision in the ES definitions and classifications (Schröter et al. 2014). For example, (1) ES may be used as a "catch-all" term to represent ecosystem functions, contributions to humans, and economic benefits from nature (Nahlik et al. 2012); (2) pollination may be classified as a regulating or supporting ES (Bartholomée and Lavorel 2019); (3) inconsistent terms, such as erosion regulation and erosion prevention, may describe the same ES; and (4) different ES subclasses, such water retention and flood control, may overlap (Chen 2021). However, imprecision allows flexibility for adjusting ES definitions and classifications to fit different research aims or perspectives (Costanza 2008).

Another critique is that basing conservation on ESs might not safeguard, but rather divert attention away from, biodiversity (McCauley 2006), as areas with abundant ESs may not necessarily have rich biodiversity. However, there is growing evidence that biodiversity underpins ecosystem functions, characteristics and processes that produce ESs, and areas with richer biodiversity tend to have more diverse, resilient, and valuable ESs than areas with poorer biodiversity (Oliver et al. 2015; Sakschewski et al. 2016). Meanwhile, the ES concept can support biodiversity conservation by highlighting biodiversity's contributions to human wellbeing (CBD 2020b; Schröter et al. 2014).

In addition, it is not meaningful to argue whether humans should value ESs, if valuation is regarded as trading off benefits towards a goal or a desired outcome (Costanza et al. 2014a; Farber et al. 2002). This is because any action trading off ESs with other benefits involves at least implicit ES valuation. Instead, what should be considered is whether ESs are valued implicitly or explicitly in some units (e.g., money, time, labour, energy) comparable with other benefits (Costanza 2020b). Monetary units are the most frequently used because they are the most well-known.

The main critiques against monetary valuation of ESs include the misconception that valuation implies privatising or commodifying ESs ("selling out" ecosystems), implying that money can be a substitute for ESs, and favouring richer people with higher purchasing power for ESs than poorer people (Hirons et al. 2016; McCauley 2006; Schröter et al. 2021). However, monetary valuation complements assessment in other units or criteria, and illustrates that ESs are valuable and should not be sacrificed for money or commercial benefits (Chen 2020b). Moreover, privatisation and commodification are not applicable to most ESs, as most ESs are common or public goods and services that cannot (or should not) be traded in markets (Costanza et al. 2014a). ES valuation can also lead to more informed conservation decisions by raising awareness about the relative importance of ESs (especially non-marketable ESs) to human wellbeing, highlighting the undervaluation of externalities, and allowing for comparison of ESs and financial benefits of human-made services using the same unit (CBD 2020b; Costanza et al. 2017; de Groot et al. 2012). Finally, ES valuation embraces economic, social, cultural and ecological knowledge and connects science with policies, fostering multifaceted perspectives and transdisciplinary approaches (Schröter et al. 2014). Multifaceted perspectives and transdisciplinary approaches are essential to address land use trade-offs in PAs, as these trade-offs are associated with environmental, socioeconomic and cultural issues, and cross disciplinary boundaries (Chen 2020b; Costanza 2020a).

3. Land use trade-offs and policy implications

3.1. Should more conserved lands be converted to lands for tourism development?

Since PAs are primarily established to achieve long-term nature conservation, economic activities are usually restricted in PAs (UNEP-WCMC and IUCN 2021). However, tourism is an exception and popular in many PAs. Because tourism has both negative and positive impacts (Table 1), decisions about whether more conserved lands should be converted to lands for tourism development is controversial. The key to address this question is to assess tourism impacts comprehensively. Environmental impact assessments (EIA) have been undertaken to support decision-making on tourism in PAs in China and the rest of the world (Chang et al. 2018; Kumar et al. 2013). However, conventional EIAs tend to assess direct impacts on separate environmental components (e.g., soil, water, animals), hence may (1) underestimate environmental costs due to ignorance of potential indirect impacts, and (2) poorly link environmental impacts with human wellbeing and financial costs, due to lack of explicit explanations of why environmental impacts matter to humans and a common measure between environmental and financial benefits and costs (Baker et al. 2013; Chen 2020a; Honrado et al. 2013; Karjalainen et al. 2013).

Table 1: Examples of tourism impacts in PAs

Tourism impacts	**Stage of tourism development**	
	Facility construction	**Operation**
Positive		
Tourism revenue that can fund maintenance of PAs and boost local economic growth		X
Increased employment opportunities	X	X
Improved access to and experience in nature areas due to infrastructure availability		X
Replacement of more disruptive land uses (e.g., mining, mass grazing) with lands for tourism use		X
Negative		
Vegetation clearance and damages on spatial integrity of ecosystems and natural landscapes due to construction of tourism infrastructure (e.g., roads)	X	
Disturbance to wild animals and local communities due to infrastructure construction and tourism activities (e.g., hiking, camping)	X	X
Pollution in water, soil, or air due to waste gas or water discharged from tourism land uses (e.g., roadworks, restaurants, restaurants)	X	X

Sources: (Chen 2020b; Donázar et al. 2018; Tolvanen and Kangas 2016; Wang et al. 2012)
Note: "X” indicates at which stage of tourism development the impacts may occur.

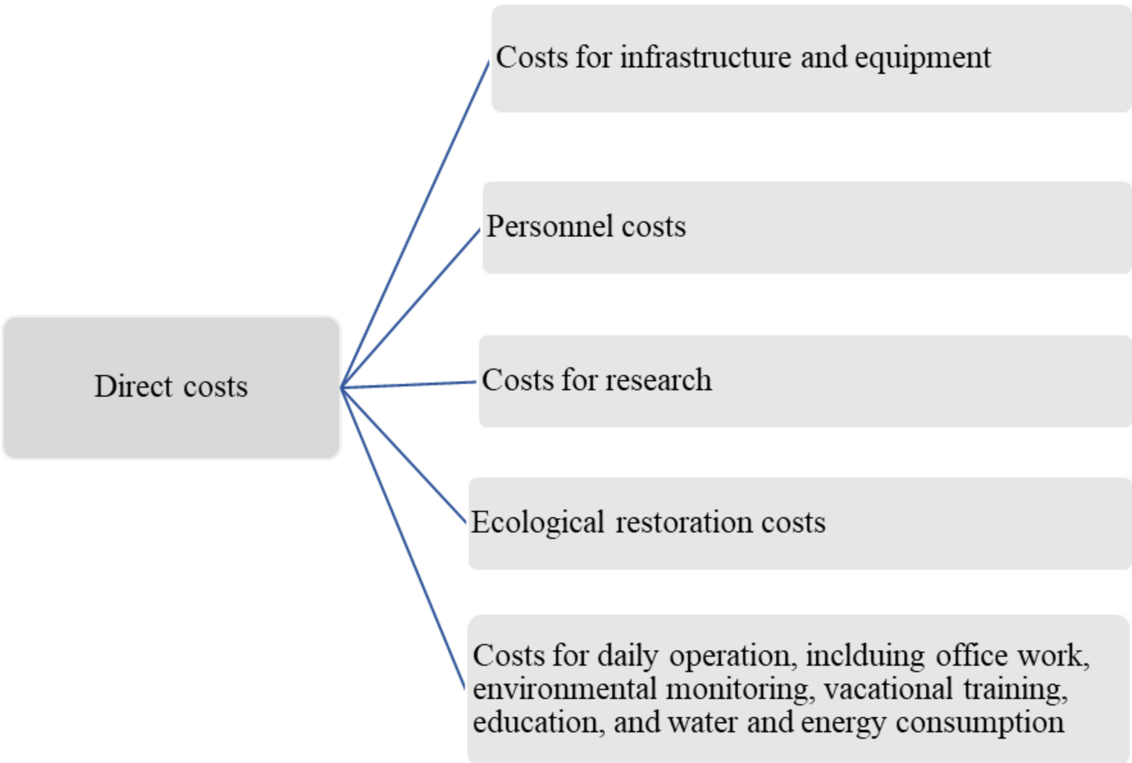
Improving conventional EIAs and assessing tourism impacts more comprehensively can benefit from integration of ES valuation, because ES valuation (1) identifies and assesses the impacts on indirect and non-marketable ESs; (2) links environmental impacts to human wellbeing; (3) improves EIAs’ communication with general readers; and (4) enables comparison of environmental costs with financial gains in the same unit of measurement (Costanza et al. 2014a; Geneletti 2011; Kumar et al. 2013; Wang et al. 2010). For example, in the case of the Wulingyuan Scenic Area, China, Chen (2020a) assessed tourism's impacts on ESs' and their values based on changes in environmental components assessed by conventional EIAs and provided evidence of the four advantages of integration of ES valuation: (1) loss of 'unused lands' not conserved or directly used by humans were considered as negligible in conventional EIAs, but was estimated to be loss of $1,500/ha/yr; (2) tourism facility's existing damage to vegetation was estimated to be the loss of nature's contributions to humans at $1.2 million/yr; (3) increased content of nitrogen in a river was translated into reduction of water provisioning, and degradation of recreational and aesthetic enjoyment); and (4) permanent land encroachment of a tourism highway would cause loss of ES values at $0.5 million/yr.

We call for integration of ES valuation into PAs' EIAs because of the advantages of doing the above. In accordance with the *Environmental Impact Assessment Law of People's Republic of China* (National People's Congress 2018), decision makers need to conduct EIAs prior to approving or rejecting proposals for development, unless the potential environmental impacts are negligible. The Chinese government also requires PA managers to monitor existing environmental impacts in PAs (Ministry of Ecology and Environment 2020b). Integration of ES valuation means that EIAs should not only assess impacts on separate environmental components in a conventional way, but also the quantity and the values of ESs. Even if changes in ESs' quantity and values cannot be fully quantified, integration of qualitative descriptions of changes in ESs into conventional EIAs still improve EIAs' credibility, comprehensiveness, and communication (Chen 2020a; Geneletti 2011; Helming et al. 2013). EIAs particularly need improvement during the process of fulfilling China's ecological civilisation initiative, because this initiative requires unprecedented efforts to identify, analyse, monitor, avoid, mitigate or eliminate negative environmental impacts from human activities (Antwi et al. 2021; Wu et al. 2019). Note that, tourism in PAs is based on cultural ESs, which are more irreplaceable and unlikely to be recovered than provisioning and regulating ESs (Chen 2020a; Millennium Ecosystem Assessment 2005). Sustainable tourism requires conservation of biodiversity and ecosystems especially those with cultural importance.

3.2. Should terrestrial PAs in China be maintained and expanded?

China requires PAs to conserve the country's biodiversity and enhance the wellbeing of the Chinese people, by improving air quality, safeguarding water security, and beautifying landscapes. However, it was unclear if PAs' generate more benefits than costs, unless PAs' benefits, which include various ESs, could be assessed and compared with conservation costs. Balmford et al. (2002) first estimated that the benefits of maintaining and expanding global PAs to cover around 15% of global terrestrial area to be US$4400 – US$5200 billion/yr, approximately 100 times the costs. There are also studies valuing individual PAs at the local level. As an example, Liu et al. (2017) estimated the ES value of the Wanglang Nature Reserve, China, to be $30 million/yr, corresponding to 40 times the costs. Wei et al. (2018) estimated that the ES value of the Giant Panda Reserves in China to be up to $6.9 billion/yr and 27 times the costs. However, Balmford et al. (2002), Liu et al. (2017) and Wei et al. (2018) might overestimate the benefit-cost ratios of maintaining the PAs, because they only assessed direct costs but ignored opportunity costs of forgoing alternative land uses over conservation. The average direct costs/ha/yr may vary, depending on calculation methods, data availability, and socioeconomic conditions of the PAs. However, the direct costs normally include the components in Figure 2.

Figure 2: Components of direct costs for maintaining PAs



Source: (Balmford et al. 2002; Bruner et al. 2004; Liu et al. 2017; Wei et al. 2018; Yang and Wu 2019)

A recent study integrating opportunity costs was Chen (2021) that conservatively estimated the value of a subset of ESs in China's existing nationwide terrestrial PAs to be $2.64 trillion/yr and over 14 times the conservation costs (including both opportunity and direct costs). The actual percentage of China's terrestrial ESs conserved by the 'eco-redline' covering 25% of China's land is unknown. However, if the 'eco-redline' was to conserve 25% of China's terrestrial water retention, soil fertility maintenance, sandstorm prevention, carbon sequestration and oxygen release, the value of those conserved regulating ESs would be $4.83trillion/yr, corresponding to over 18 times the conservation costs (Chen 2021). While existing studies could not consider all potential ESs or opportunity costs of all potential alternative land uses over conservation, they still provided indicative information on conservatively expected economic return from maintaining terrestrial PAs and establishing the 'eco-redline', as well as financial incentives to undertake conservation.

We strongly support maintaining existing terrestrial PAs and establishing the 'eco-redline' in China. Establishing PAs can address severe environmental challenges met by China and the rest of the world, including climate change, biodiversity loss, ecosystem degradation, natural disasters (e.g., flood, sandstorms, and costal storm surges), and growing concerns about food and water security. The Covid-19 pandemic has highlighted that these environmental challenges not only threaten ecosystem health, but also the health of humans, the economy and society, generating new momentum to realise PAs' benefits to their full potential (UNEP-WCMC and IUCN 2021). This pandemic has also emphasised that humans are a part of, rather than apart from, the rest of nature, and economic and social systems are in essence embedded in the rest of nature, namely the ecological life support systems (Costanza 2020a).

3.3. How can payment for ecosystem services be improved to promote conservation on lands traditionally used for local livelihood development?

China has widely conducted payment for ecosystem services (PES, this is also known as eco-compensation) to compensate livelihoods impacted by conservation (e.g., restricted economic activities and access to natural areas) in PAs (National Development and Reform Commission 2017). Valuing ESs can provide an economic baseline to the compensation amount (He et al. 2018b; Zou et al. 2020), but non-marketable cultural ESs have been rarely valued in China and the rest of world (Chen 2020b; Hernández-Morcillo et al. 2013; Milcu et al. 2013). Ignorance of PAs' non-marketable cultural ESs may lead to an underestimate of PAs' benefits, incorrect perception that marketable cultural ES represents PAs' cultural importance as a whole, and ignorance of the fact that non-marketable cultural ESs are often important reasons for people to protected nature (Chen 2020b; Hirons et al. 2016; Milcu et al. 2013).

We suggest that the Chinese government integrate non-marketable cultural ESs into PES schemes. Namely, if people lose non-marketable cultural ESs of PAs due to conservation, they deserve compensation because the ESs are valuable to them and to others. Although financial or other material compensations (e.g., food) do not substitute cultural ESs, providing them with compensation is better than ignoring compensation, in terms of improving PES's capacity in balancing conservation with livelihood development (Chen 2020b). In China, PES is also aimed at reducing poverty, enhancing social stability (e.g., less resistance against conservation) and alleviating income inequality (Le and Leshan 2020; Liu et al. 2021; National Development and Reform Commission 2017). These objectives are more likely to be achieved if PES schemes integrate compensation for loss of non-marketable cultural ESs. Note that, when determining the compensation amount, decision makers should consider the uncertainties in value estimates of non-marketable cultural ESs, as values of non-marketable ESs are typically stated from hypothetical scenarios and can be affected by scenario design and reshaped by deliberation (Costanza et al. 2017; Fifer et al. 2014; Kenter et al. 2016c).

Moreover, we suggest integration of deliberation into the process of designing PES schemes. Existing studies have demonstrated that deliberative valuation may infer more rational, more realistic, more converged, and more socially just values of cultural ESs, compared to conventional stated-preference valuation that assesses individual preferences separately (Mavrommati et al. 2017; Orchard-Webb et al. 2016). This is because deliberation provides opportunities to account for more diverse knowledge and issues, allows participants to reconsider and explain preferences, allows researchers to clarify research actively and address misunderstanding and concerns of participants, promotes mutual learning, trust, and consensus building (Kenter et al. 2016b; Lliso et al. 2020; Vargas et al. 2016). In addition to promotion of legitimacy and credibility of valuation elicitation, deliberation also provides opportunities to recognise diverse voices in decisions and bridge potentially conflicting interests and perspectives (Kenter et al. 2016a; Saarikoski and Mustajoki 2021).

3.4. Additional comments

While China has started to incorporate Gross Ecosystem Product (GEP) into official policy making since 2013, GEP accounting is still at an early stage in China (Zou et al. 2020), and has only been applied in some pilot administrative regions, such as Guizhou Province, Shenzhen City and Zhejiang Province (Ouyang et al. 2013; Shenzhen Scientific and Technilogical Innovation Committee 2021; State Council Information Office 2020). This study suggests the Chinese governemnt popularise GEP accounting in PAs to enhance assessment of effectivenss and performance of PAs' management, including land use management. Decisions dealing with the three land use trade-offs discussed earlier, if made without integration of GEP, can be biased and often compromise conservation to alternative GDP-enhancing land uses (Chen 2020b, 2021). This is because many benefits of conservation are not traded in the market or counted in GDP, which is calculated by measuring only market transactions (Costanza et al. 2014b). To pursue GDP growth, some PA decision makers in China previously overdeveloped tourism (e.g., artificially re-routing rivers to attract tourists in the Potatso National Park, regardless of negative environmental impacts), trimmed the boundaries of PAs (e.g., the Karamori Nature Reserve) to increase land area for economic activities, and gave permission for unsustainable resource-exploiting activities (e.g., illegal mining in the Qilian Mountain National Park) (Kram et al. 2012; Li et al. 2021; Zhang et al. 2017).

Therefore, we emphasise that joint evaluation based on both GDP and GEP benefit more sustainable and balanced decision making in PAs, compared to biased evaluation based on GDP alone. We also acknowledge GEP shares limitations (e.g., imprecision in valuation, ignorance of non-linearity, insufficient ES data, knowledge gaps in some ESs) with other accounting measures. This calls for decision makers and researchers to work together for more credible and informative GEP accounting.

4. Implications for further research on addressing land use trade-offs

Non-use and option values of PAs are crucial to nature conservation. For example, Marre et al. (2015) estimated the non-use value to comprise 25 - 40% of their respondents' mean willingness to pay for conserving coral reefs in New Caledonia. Jin et al. (2016) estimated the option value of the Hongxing Nature Reserve, China, to be 65 million Chinese yuan in 2013. However, existing studies valuing PAs usually only consider use values (Chen 2020a; Chen 2020b, 2021; Milcu et al. 2013), potentially producing an underestimate of PAs' values and constraining incentives to conserve nature. Ignorance of nature's non-use and option values is also explicitly linked with biodiversity loss (Faith 2021; IPBES 2019). Stronger recognition of non-use and option values of ESs and biodiversity presents a more comprehensive picture of the multiple contributions nature makes to sustainable wellbeing, integrates diverse worldviews on human-nature relationships and interdependence, considers environmental ethics, and promote a vision of living in harmony with nature (CBD 2020b; IPBES 2019; Schröter et al. 2021; Schröter et al. 2014).

Option and non-use values should also be integrated into future EIAs of PAs to understand benefits and costs from land use changes more holistically and improve consideration of non-human species (Chen 2020a; Helming et al. 2013). In terms of tourism's impact on use values of PAs' ESs, it is unlikely to fully measure changes in quantity and value of ESs based on changes in environmental components. This is due to the knowledge gap of quantifying interactions between environmental components, biodiversity, ecological process, and ESs, even though some studies exist that discuss the causal relationships between changes in environmental components and changes in ESs (de Groot et al. 2010a; Grizzetti et al. 2019; Harrison et al. 2014). It is particularly challenging to measure how changes in environmental components affect cultural ESs, compared to provisioning and regulating ESs. The quantity of provisioning and regulating ESs is positively correlated with biomass and productivity of ecosystems (Ren et al. 2016; Xie et al. 2017). However, producing cultural ESs requires existence of ecosystems as well as positive physical and mental human-nature interaction and access (e.g., a road) which may reduce the area of ecosystems (Chen 2020a; de Groot et al. 2010a). Further integration of ES valuation into EIAs in the long-term requires transdisciplinary collaboration and more research on the knowledge gaps of quantifying how environmental components interact with ESs, especially cultural ESs. If this gap cannot be addressed soon, a short-term solution for EIAs can include qualitative descriptions of changes in ESs.

Further research is required on the optimal coverage rate of PAs. The larger the land area being protected do not necessarily mean an increase in human wellbeing (e.g., it makes no sense to protect 100% of global land). China met the CBD's Achi Target, stating that at least 17% of its terrestrial area should be protected (CBD 2020a). Some ambitious targets regarding global terrestrial PAs' coverage, such as 30%, 43%, and 50%, have been proposed by the first draft of the Post-2020 Global Biodiversity Framework (CBD 2021), Yang et al. (2020), and Dinerstein et al. (2019), respectively. However, the scientific legitimacy, practical feasibility, as well as suitability of these targets in China's context require further research. Moreover, to maximise PAs' benefits to people and the planet, researchers and policymakers should also consider PAs' effectiveness and connectivity (UNEP 2021). Effectiveness means the need for, effect of, and cost-effectiveness (the relative costs of achieving per unit of outcomes) of an approach in terms of achieving goals and desired outcomes (UNEP 2019). Lower PA connectivity means more fragmentation of protected habitats, smaller space for species to migrate, lower possibility of gene flow, lower adaptivity to climate change, and higher risk of biodiversity degradation (Saura and Rubio 2010; Zhang et al. 2017). Therefore, further research needs to consider which areas should remain in, and be added to, the existing terrestrial PA system in China, so as to ensure the PAs produce the maximum possible benefits with a certain coverage; measure the PAs' effects on maintaining and improving biodiversity and ES; evaluate whether management policies and activities in PAs have achieved their goals; and assess which areas should be demarcated as corridors to connect the PAs as well as the corridors' values.

While we have explained why accounting measures were acceptable and the best available to assess the values of multiple ESs especially at large spatial scales, we still acknowledge that accounting measures simplify the interplay between different ESs and non-linear relationships between ESs' quantities and values (Brondizio et al. 2009; Farley 2012; Liu et al. 2007). ES valuation is often conducted, and more likely to be improved, at a specific site for a specific service, but aggregate values of multiple ESs over larger spatial scales are often needed, for example, to raise awareness of nature's importance and inform environmental policy making at national and global levels (Chen 2021; Costanza et al. 2014a). We anticipate that more sophisticated valuation methods may become practical in the future to improve the credibility of aggregate values over large spatial scales.

While deliberation can complement conventional stated-preference approaches by promoting more legitimate, rational, credible, and considered valuation elicitation, deliberation still needs improvement. Further research should address how to undertake deliberations in a more time-efficient and financially affordable manner for researchers and participants, how to convene a greater representational and inclusive group of target participants, and how to promote more participant interaction and engagement. A key limitation of face-to-face deliberation is the difficulty in convening participants (Costanza 2020b). When deliberation only has a limited number of participants, results after deliberation may be subject to randomness (Saarikoski and Mustajoki 2021; Turner et al. 2010). Although online deliberation has lower costs and better flexibility, it potentially excludes IT-illiterate participants, lowers engagement and in-depth communication of participants with insufficient abilities (e.g., poor IT skills) or willingness to deliberate online, and attracts fewer participants than simply filling in questionnaires (Kenter et al. 2016c; Smith et al. 2009; Strandberg and Grönlund 2018). Moreover, the effects of different deliberation medias (e.g., video meeting, typing, in-person meeting) on deliberation outcomes also require further research.

5. Conclusion

A key approach to better management of land use trade-offs around PAs is to thoroughly assess coexisting benefits and costs of land uses and make decisions or policies that maximise PAs' net benefits. PA decision makers should ensure the wellbeing of the widest possible range of stakeholders. PAs' benefits include various ESs, many of which are external to the market, invisible from commonly used development indicators (e.g., GDP), indirect in terms of contributing to human wellbeing, difficult to compare to human, social and built capital with a common measurement unit, and may be hard for the general population to understand. Without accounting ESs' values, decision making ignores some ESs, underestimates ESs' values, has difficulty weighing up natural and other capital, or lacks a common language between scientists, government servants, and the public. ES valuation can internalise ESs into cost-benefit analysis, visualise ESs' contributions to true development (improvement of human wellbeing, rather than merely economic growth), consider both direct and indirect ESs, build a common measurement unit (e.g., money) between natural and other capital, and translate scientific terms into plain language. Accordingly, valuing ESs' is essential to better management of land use trade-offs associated with PAs in China.

Joint evaluation based on both GDP and ESs' values leads to more balanced and sustainable decision making than biased evaluation based on GDP only. However, existing studies valuing PAs' ESs usually ignore option and non-use values, which we recommend be integrated into future ES valuation to present a more encompassing picture or PAs' contributions to sustainable wellbeing and shape a greater recognition of human interdependence with the rest of nature. We also recommend integration of ES valuation into EIAs and integration of compensation for non-marketable cultural ESs into PES schemes to better address land-use trade-offs in PAs. Moreover, future research and policy making associated with PAs' land management should consider PAs' quantity (e.g., optimal coverage of PAs in China) and their quality (e.g., management effectiveness, connectivity). Although accounting measures that assume a constant unit value are acceptable to estimate the aggregate value of ESs, we anticipate that more sophisticated valuation methods may become practical in the future to improve the quality and credibility of aggregate values over large spatial scales. In addition, further research is needed on how to conduct deliberation in a more time-efficient, financially affordable, and engaged manner.

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