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Ecosystem services valuation in China: A meta-analysis

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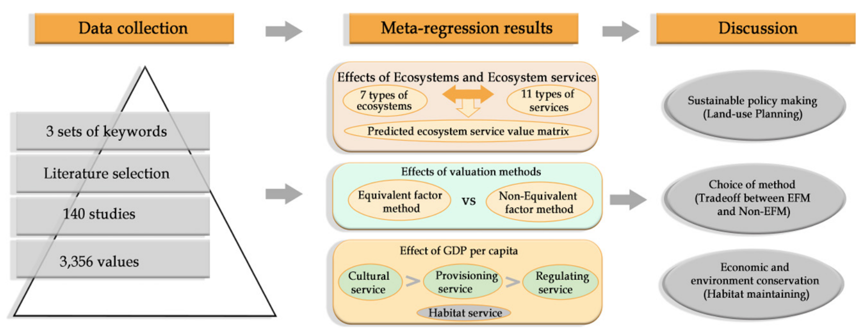
HIGHLIGHTS

- Large variations in the ecosystem services values in China are observed.
- A national database of ecosystem service value was constructed for meta-analysis.
- Ecosystem, services, and economic development have impacts on the values.
- The estimated values are sensitive to valuation methods.
- A value matrix is produced for rough prediction in land-use planning.

GRAPHICAL ABSTRACT



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ABSTRACT

Although the number of studies on ecosystem service value (ESV) has steadily increased, large variations and inconsistent patterns in the estimated results have motivated us to systematically explore the factors underlying such discrepancies. Therefore, this study aims to explore the role of different ecosystems, ESs, valuation methods, and economic development in the ESV by employing a meta-analysis of valuation research conducted on China's ES based on 3356 observations from 140 studies. The results show that wetlands ecosystem has the highest value among the seven major ecosystems, and regulation of water flows service is more valuable than the other services. We also provide a matrix of monetary values for different categories of ecosystems and their services, which can be used as a quick tool to predict ESVs in China and assess the value changes caused by land-use changes. We find that the ESVs estimated following the equivalent factor method are different from those estimated by the other methods, indicating that researchers should be very careful when selecting valuation methods for evaluating ESs. The economic development level has different impacts on different ESs, that is, gross domestic product (GDP) per capita has a high, positive correlation with the recreational service value, but has no correlation with the habitat service value.

1. Introduction

Estimating the monetary value of ES has received considerable attention from policymakers and scholars in recent decades. Such evaluation quantitatively measures the benefits that people obtain from ecosystems and can be used to estimate the economic losses due to ecosystem degradation caused by overexploitation (Keith et al., 2017). These estimates may then inspire policymakers to consider the ESV information when balancing competing land-use and making environmentally sustainable decisions.

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However, the estimated values in the existing literatures often show large variations and inconsistent patterns. Taking the valuation of recreational services as an example, as reported by the Ecosystem Service Valuation Database (ESVD), the global estimated recreational value ranges from approximately 0.1 USD/ha/yr for grassland ecosystems in Grampian, UK, to over 40 million USD/ha/yr for coastal ecosystems in Florida, USA (ESP, 2020). The values also vary greatly when studying one ecosystem in the same study area. For instance, Loyola et al. (2021) used a choice experiment method and calculated that the recreational services on Galapagos Island had a value of 38.37 USD/ha/yr, whereas Tanner et al. (2019) used the market price method and showed that this value was as high as 16,958 USD/ha/yr. Several studies suggest that the ecosystem types, ESs, valuation methods, and economic development level may have a significant influence on the estimated values (Costanza et al., 2014; He et al., 2014; Sutton and Costanza, 2002; Teoh et al., 2019).

Meta-analysis is commonly used to examine the influencing factors causing ESV variations between studies by synthesizing empirical findings reported in the literatures (Nelson and Kennedy, 2009). Several global databases, such as the ESVD and Environmental Valuation Reference Inventory (EVRI), have been used to conduct meta-analyses (Environment Canada, 2016; ESP, 2014). Although the global database provides a comprehensive understanding of the existing studies, one concern is that, without fully controlling for unobserved factors in the meta-analysis, the results may be biased. Specifically, if context-specific effects beyond socioeconomic and environmental variables, such as cultural and political institutions, are not explicitly considered in the analysis, the meta-analysis may not be suitable for benefit transfer applications, despite its superficially good performance on the statistical point of view (Johnston and Bauer, 2020). To some extent, national-scale meta-analysis may mitigate such bias, as a single country has relatively similar cultural and political backgrounds. To our best knowledge, only a few meta-analyses have used national-level databases (Alberto Lara-Pulido et al., 2018; Quintas-Soriano et al., 2016), and no national-level meta-analyses of ESs have yet been conducted in China.

China serves as a good example for conducting a meta-analysis on ESV, as almost all types of ecosystems are present in the country. With rapid economic development, China has suffered from severe resource overexploitation and environmental degradation problems (D'Amato et al., 2016). Therefore, the Chinese government has devoted more attention to ESs and their economic value. A large number of ESV studies in China have been published in recent decades (Fan et al., 2018; Sun et al., 2018; Wang et al., 2019). This provides an opportunity to gain a comprehensive understanding of ESVs by conducting a meta-analysis. Examples include Zhou et al. (2020), who focused on the national wetland ecosystem, and Kang et al. (2020), who focused on the grassland ecosystem in Qinghai Province. However, the two studies focused on a certain ecosystem and do not provide an overview of all the ESV in China. Although there are three other papers that reviewed the ESV status for all ecosystems at the national level in China, they did not conduct a quantitative analysis of the heterogeneity in the ESV (Bao et al., 2007; Jiang, 2017; Zhang et al., 2010).

The lack of quantitative research on the ESV nationwide has motivated us to explore existing ESV studies for more systematic analysis and address the following questions: (i) understanding the factors that explain the ESV variations, (ii) analyzing the preferred valuation methods of Chinese scholars to investigate the extent to which they determine the estimated values of ES, (iii) analyzing the relative contributions of economic development to different types of ESs, and (iv) predicting the value of each ES to provide a basis for integrating ESV information with land-use decision-making.

2. Methodology

The methodology of this study includes three progressive steps: (i) creating a database by systematically identifying the ESV articles conducted in China, (ii) defining all of the variables used in the meta-analysis, and (iii) conducting regression models to investigate the key factors driving the variations between ESV studies (Fig. 1).

2.1. Data collection

Fig. 2 shows the ESV literatures selection process used for this study. We first conducted a systematic search of existing studies using three commonly used search engines: the ISI Web of Science (Clarivate Analytics, 2020), Scopus (Elsevier, 2020b), and Engineering Village (Elsevier, 2020a). To construct a more comprehensive database, we supplemented the available studies using articles with China as the study area from The Economics of Ecosystems and Biodiversity (TEEB) valuation database. We also cross-checked the reference list at the end of each paper and included the relevant papers. Peer-reviewed articles published in English before the end of 2019 were included. We used three sets of keywords to search the title, abstract, and keywords of articles, including the study location, representation of value, and subject, which were linked by logical AND. The specific keywords for each set were as follows:

Study location: "*China*" or "*Chinese*".

Representation of value: "*valu**" or "*economic cost*" or "*economic loss*" or "*monetary*" or "*benefit*" or "*payment for**" or "*estimat**" or "*willingness to pay*" or "*WTP*" or "*assess**".

Subject: "*eco* service**" or "*eco* function*" or "*eco* goods*" or "*environmental service**" or "*environmental function*" or "*environmental goods*" or "*natural capital*".

The literature search process led us to identify 1838 peer-reviewed articles published in English. We then conducted a preliminary screening consisting of the following two steps: We first classified articles as "non-relevant" or "potentially relevant" based on their abstracts. The articles without any reference to one or several ecosystems in China, or review studies that did not report any monetary values, were grouped into the "non-relevant" group and directly excluded from our analysis. After further reading the articles' titles, abstracts, and keywords, we reclassified the "potentially relevant" articles as "most relevant" or "non-relevant". In both phases, all articles were reviewed by one postdoctor and one doctoral student from our team, and some conflicts were resolved by a third independent professor in this field. This selection process yielded 484 "most relevant" studies.

After browsing the 484 articles in more detail, 154 papers were finally included in the database for this study. The papers included in the final database must: (i) report a monetary value for a given ecosystem type or service during a specific period, (ii) use a valuation method to estimate the values, (iii) provide sufficient information to convert the

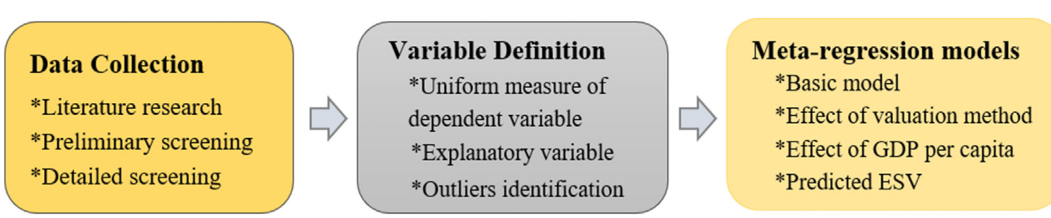

Fig. 1. Flow-chart of the meta-analysis in this study.

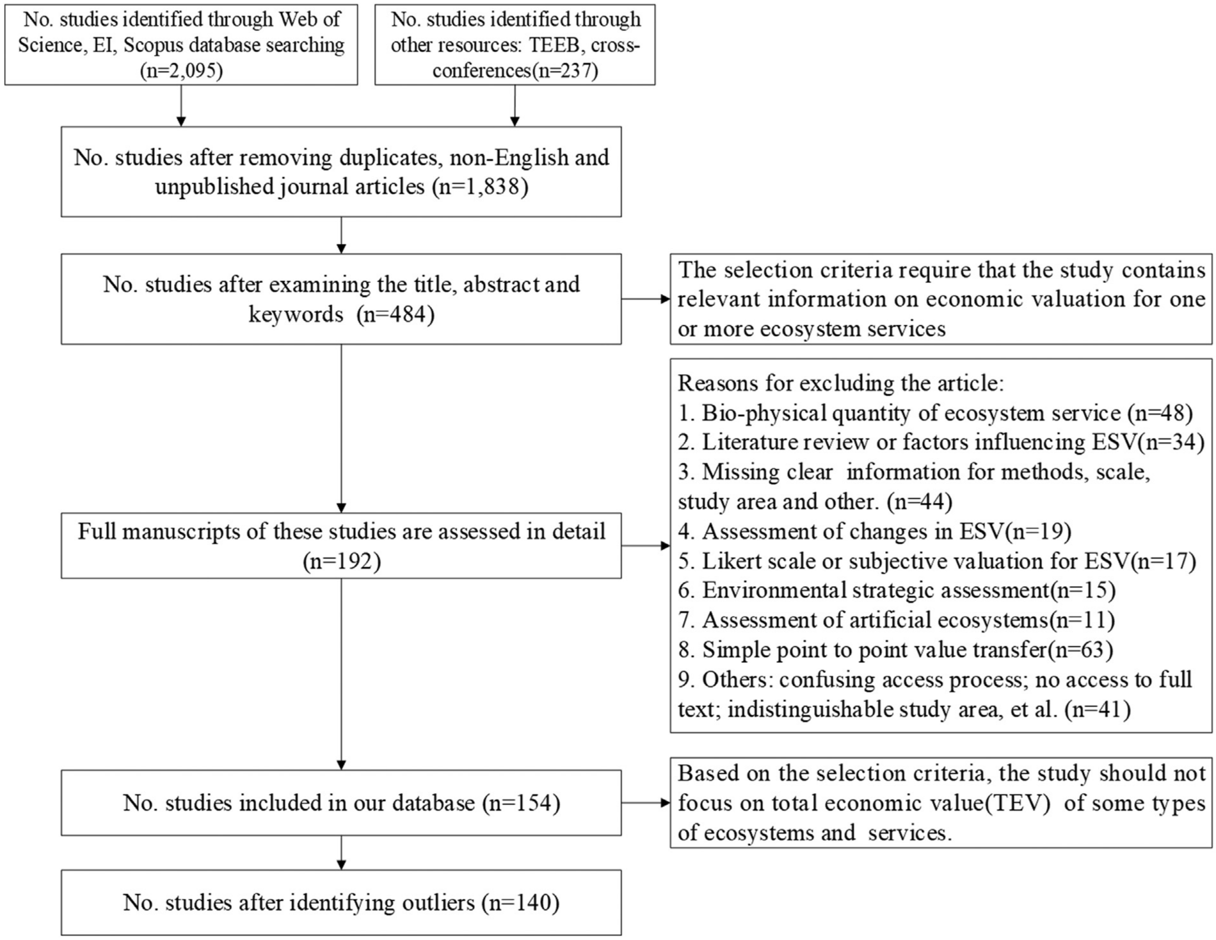

Fig. 2. Overview of the literature selection process.

monetary value to a standardized unit (i.e., yuan/ha/yr); and (iv) report the location of the study area and the year of research.

2.2. Variables used in meta-analysis

Meta-analysis is used to regress the dependent variable (i.e., estimated value) on a set of independent variables that represent the ecosystem, ESs, valuation methods, economic development, and other control variables. The names, definitions, and descriptive statistics of all variables are presented in Table A.1.

2.2.1. Dependent variable

We used the value of an ES provided by one hectare in 2015 (yuan/ha/yr) as the dependent variable. As a few studies have reported values in US dollars ($n = 19$) or Euros ($n = 1$), we first converted these monetary values reported in foreign currencies to Chinese yuan using the official exchange rate for the valid year of research. Furthermore, all values were adjusted to 2015 values using GDP deflators. The GDP deflator and official exchange rate values are obtained from National statistical database (National Bureau of Statistics of China, 2020).

Notably, existing studies often report ES values in different forms (e.g., mean value per hectare per year, total value of a certain ES, willingness to pay (WTP) per person per year, WTP per household per year). We need to convert the values into a uniform measure. For the studies reporting WTP by a single person or household, we calculated the value by dividing the total economic value by the area of the study site. Total economic value was calculated using the mean WTP multiplied by the number of stakeholders (e.g., tourists who come to travel, residents or households living around the ecosystem) in the research year. The number of stakeholders was either reported in the primary study or collected from an external source, such as government research and travel websites.

The database included 3636 values from 154 studies, which were uniformed through the process described above. We then identified outliers using a boxplot method (Schwertman et al., 2004). According to the interquartile range criterion, exceptionally small outliers were defined by Q_1-1.5*IQR, while exceptionally large outliers were defined by $Q_3 + 1.5$*IQR, where IQR = Q_3-Q_1, and Q_1 and Q_3 are the first and third quartiles of the value distribution, respectively. Finally, 3356 valid observations from 140 studies were included in the meta-analysis (see Table A.2 for the full reference list).

2.2.2. Explanatory variables

First, we grouped the ecosystems into seven types following the TEEB report (TEEB, 2010), i.e., cultivated ($n = 594$), desert ($n = 331$), forests ($n = 675$), grassland/rangeland ($n = 607$), lakes/rivers ($n = 433$), wetlands ($n = 562$), and other ecosystems ($n = 154$). The "other ecosystems" type includes systems with very few observations in our study, such as marine/open ocean ($n = 25$), coastal ecosystem ($n = 46$), urban ecosystem ($n = 63$), ice/rock/polar ecosystem ($n = 17$), and woodland/shrubland systems ($n = 3$).

Second, ESs were classified into 11 types according to the TEEB's classification method, which belong to 4 major categories (i.e. provisioning, regulating, habitat, and cultural services). Specifically, provisioning services include food provision, water supply, raw materials provision, and other provisioning services. Regulating services include gas regulation, climate regulation, maintaining soil fertility, regulation of water flows, waste treatment, and other regulating services. Habitat services have been identified as a separate category to highlight the importance of ecosystems to maintain biodiversity (e.g., gene pool protection). Cultural services are mainly associated with the recreational and tourism opportunities provided by the ecosystem. Some other provisioning services (e.g. genetic resource) and other regulating services (e.g. pollination, air purification) that have few observations are uniformly classified as "other".

Third, we divided all the valuation methods into eight groups (Table 1). All valuation methods could be classified into two types: the equivalent factor method and primary data-based approaches (Zhou et al., 2020). The former, which essentially belongs to the unit value transfer approach, was developed by Costanza et al. (1997). Xie et al. (2003) first used this method and set up a modified equivalent coefficients framework for China based on a survey of 500 ecological experts, which attracted a large number of followers in later ESV studies conducted in China (Jiang, 2017). Over half (52%) of the 140 studies used this method. Consistent with the nomenclature in most studies using this method, we renamed the former group "Equivalent factor method, EFM." For distinction, we referred to the primary data-based approaches as the non-EFM" group.

Fourth, we used the GDP per capita in the city where the study area is located to indicate the economic development level. The nominal GDP per capita, obtained from the local statistical yearbook, was converted to the 2015 value of the Chinese yuan. For the research covering multiple study cities, we used the permanent population of each city as the weights to calculate the weighted average GDP per capita.

Fifth, we also controlled for other variables representing the research time, publication, and location characteristics, including the year in which the research was conducted, journal type, and latitude and longitude of the study sites. Some studies have suggested different journals may have different preferences for the magnitude of the estimated values when reviewing articles for publication. Higher estimated values may be more likely to be appreciated by reviewers (Zhou et al., 2020). Therefore, we categorized all journals into the following four types through 'journal citation reports': Science Citation Index (SCI), Social Science Citation Index (SSCI), SSCI and SCI, and non-SCI/SSCI. Latitude and longitude coordinates were used to indicate the geographic location of the study site. We linked the address of a study site to latitudes and longitudes through the Geocoder service of the Baidu Map API, an online map and navigation system widely used in China. The coordinates are in the BD09 datum.

2.3. Empirical models

We built a basic model to identify the factors influencing the ESVs. The specification of the basic meta-regression model is as follows:

$$V_{ij} = \alpha + \beta_e EC_{ij} + \beta_s ES_{ij} + \beta_m M_{ij} + \beta_a E_{ij} + \beta_p C_{ij} + \varepsilon_{ij} \tag{1}$$

where V_{ij} is the ESV provided by one hectare for observation i from paper j;, and EC_{ij}, ES_{ij}, M_{ij}, E_{ij}, and C_{ij} represent the five sets of explanatory variables, that is, the ecosystem type, ESs, valuation method, economic development, and other control variables, respectively. The baselines of the ecosystem, ESs, valuation methods, and publication characteristic variables were defined as follows: cultivated ecosystem, food provision, market price method, and SCI journal, respectively. Coefficients β_e, β_s, β_m, β_a, and β_p represent the marginal effect of each explanatory variable on the value of ESs, α is a constant term, and ε_{ij} is the error term. We used the ordinary least-squares (OLS) method to estimate this equation and robust standard errors when estimating the model, accounting for the heterogeneity of ε_{ij} across different studies.

We then updated the basic model for the following three purposes:

First, we ran the above model separately to determine if the ESVs estimated by EFM differed from those estimated by non-EFM. This is rational that conducting the two sub-group analyses could separate the influence of EFM on the ESVs.

Second, we offer insight into the changes in the values of different types of ESs with changes in the GDP per capita to reflect the influence of economic conditions. Meta-analysis was then conducted for four subgroups: provisioning, regulating, cultural, and habitat services. A lot of valuable information was missing as some types of ESs had a small sample size. Therefore, we focused on the four major categories of ESs to obtain a more representative result.

Third, after investigating the isolated effects of independent variables on ESV, we predicted the monetary value of services for each ecosystem in China. As noted by Perosa et al. (2021), the quality of ESs depends greatly on the functionality of the ecosystem. Therefore, the possible cross-effects of services across ecosystems must be considered. We re-estimated the basic model by considering the interactions between the ecosystem type and its service variables. Additionally, it would be useful to ensure the robustness of the basic meta-regression result using an interactional model. Based on the results of this model, we generated a matrix of predicted values for each ES provided by each ecosystem when controlling for other variables at their means.

3. Results

3.1. Overview of ESV studies in China

The earliest paper on ESV in China was published in 2000. Since then, the number of related publications has steadily increased (Fig. 3). This topic has received considerable attention in recent years.

Table 1
Categories and definitions of valuation method.

Level 1	Level 2	Definition	Abbreviation
EFM	Equivalent factor method	The equivalent factor refers to the unit value of a specific type of ecosystem service, which can be calculated as the product of the corresponding equivalent coefficient (relative weight of a certain ecosystem service compared to the food provision of a cultivated ecosystem) and the standard equivalent factor (average net profit from 1 ha of cultivated land).[a]	EFM
Non-EFM	Market price method	Typically uses the price in a specific market to calculate the value of an ecosystem service.[b]	MPM
	Shadow price method	Establishes a surrogate market from which the prices of the nutrient content or net primary productivity of some ecosystem function can be derived.[c]	SPM
	Avoided cost method	Estimates monetary values based on the costs of avoided damages resulting from lost ecosystem services.[b]	ACM
	Replacement cost method	Calculates the costs of providing substitute ecosystem services.[b]	RCM
	Travel cost method	Estimates the usage value of expenses to visit a location for enjoying ecosystem services.[b]	TCM
	Contingent valuation and choice experiment methods	Ask people to directly state their WTP for a certain ecosystem service based on a hypothetical scenario.[b]	CVM/CEM
	Other	Some methods have few observations, such as the energy analysis, factor income, and expert estimation methods, and so on.	Other

Note: This classification was followed and modified from TEEB (2010).
[a] Xie et al. (2017).
[b] TEEB (2010).
[c] Zhang and Lu (2010).

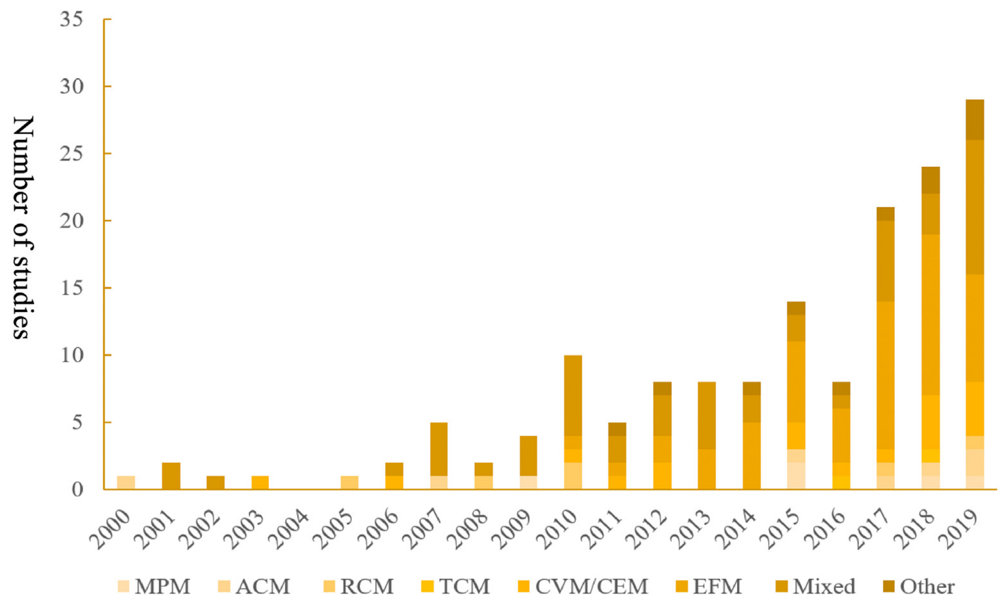

Fig. 3. Publication trend of ESV studies in China.

Approximately 63% of the studies were published from 2015 to 2019, which was 2.5 times higher than the number published in the previous five years (2010–2014). Fig. 4 provides an overview of the spatial distribution of the observations in our dataset. Over half of the observations (60.13%) were located in eastern and northeastern China, 21.3% were located in northern and northwestern China, 13.4% were located in southwestern and southern-central China, and the remaining 5.2% were at the national level. Eastern China is the most developed area, containing provinces such as Zhejiang and Jiangsu, which are also pioneers in protecting ecosystems. The northeastern areas of China, such as Heilongjiang Province, have rich ecological resources, such as forests, wetlands, and cultivated land, which have the interest of scholars in

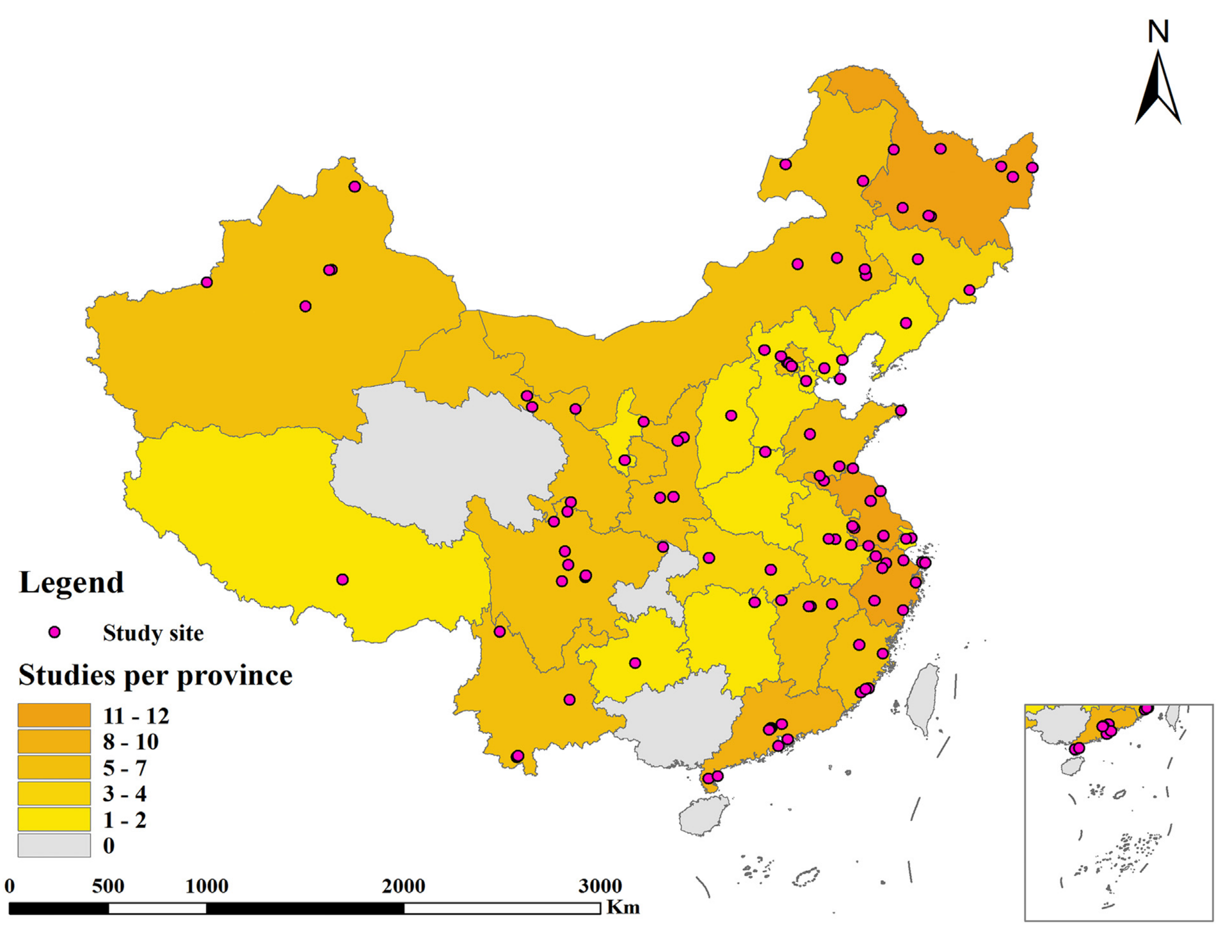

Fig. 4. Geographical distribution of the study area covered by the meta-analysis.

estimating the ESVs in this region. The unbalanced distribution of studies conducted across the country indicates that Chinese scholars have paid more attention to areas with richer ecological resources and higher economic development levels.

3.2. Meta-analysis results

The full regression results are presented in Table A.3 of the appendix, and they are graphically summarized in Fig. 5. Fig. 5.a summarizes the basic results of Eq. (1), while Fig. 5.b and c report the results of the separate meta-analysis for the EFM and non-EFM sub-groups. To check for multicollinearity, we analyzed the variance inflation factors (VIFs) for all independent variables. The maximum VIFs (3.01, 3.08, and 4.80, respectively) indicated that there was no collinearity for the three models. Fig. 6 presents the coefficients of the GDP per capita in the four meta-analysis models for different categories of ESs. The regression results of the interaction models across all ecosystem types and services are shown in Table A.4.

3.2.1. Ecosystem and ecosystem services

The results in Fig. 5.a indicate that different ecosystems are associated with different monetary values. The values of all ecosystems, excluding desert, exceeded that of cultivated ecosystems and decreased in the following descending order: wetlands, lakes/rivers, forests, and grass/rangeland. The desert ecosystem was the only ecosystem with a significantly lower value (1476 yuan/ha/yr lower) than the cultivated ecosystem, when other variables remained constant.

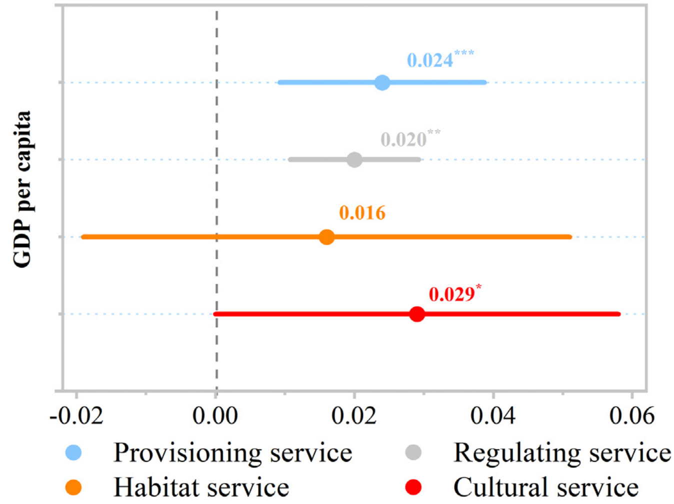

Fig. 6. Coefficients of GDP per capita in the four meta-regression models for different categories of ecosystem services. The bars present the 95% confidence interval.

The economic values of different types of ESs also vary greatly. All other ESs, excluding raw materials provision, had higher economic value than the baseline service, that is, the food provision service. Of the 11 types of ESs, the regulation of water flows had the highest value, which was 5887 yuan/ha/yr higher than that of food provision, when other variables

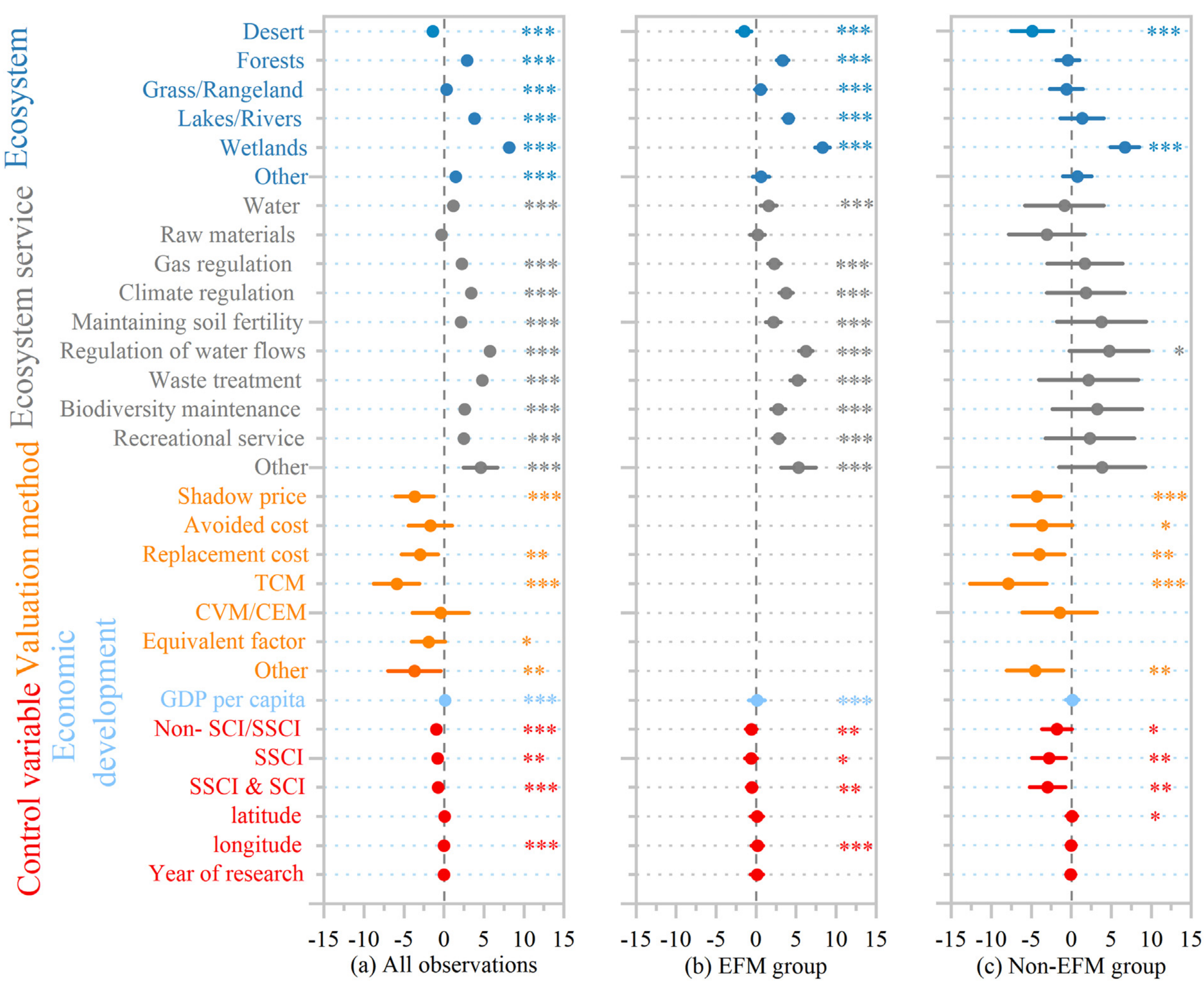

Fig. 5. Coefficients of each variable in the three meta-regression models. The bars present the 95% confidence interval.

remained constant. The other seven types of ESs also had higher values than food provision, which decreased in the following order: waste treatment, climate regulation, biodiversity maintenance, recreational service, maintaining soil fertility, gas regulation, and water supply.

3.2.2. Valuation methods

The results in Fig. 5.a show that, among the eight valuation methods, the market price methods, together with the avoided cost method and CVM/CEM, produced higher values than the other five methods. When the other variables were maintained, the valuation results obtained by EFM were 1854 yuan/ha/yr lower than those of the market price method. The replacement cost, shadow price, and TCM were over 3000 yuan/ha/yr lower than those of the market price method.

The full regression results for the EFM and non-EFM groups are presented in columns 2 and 3 of Table A.3 in the Appendix, and the results are summarized in Fig. 5.b and c. The non-EFM group included 455 observations collected from 88 studies, and the EFM group included 2901 observations collected from 73 studies. The average number of ESVs in EFM studies was relatively higher than those in the existing literatures. This is largely because the EFM uses land-use coverage/change (LUCC) in a certain region as a proxy for changes in ESs.

As shown in Fig. 5.b, the signs and statistical significance of coefficients of the EFM group were generally consistent with Model 1. Some variables are no longer significant in non-EFM studies (Fig. 5.c), but they were not qualitatively different from the other methods in terms of sign. For the non-EFM group, the wetland ecosystem also had higher values than the cultivated ecosystem, but the difference of 6455 yuan/ha/yr was lower than that for the full observations (8191 yuan/ha/yr). The difference in economic value between desert and cultivated ecosystems was 4885 yuan/ha/yr, which was much higher than the difference for the whole sample (1476 yuan/ha/yr). This requires further verification, as only five observations were available for desert ecosystems in the non-EFM group, resulting in insufficient sample representation. For ES, the results for the EFM and non-EFM groups exhibited a consistent trend with the whole sample, that is, the regulation of water flows was more valuable than food provision. However, the difference in the EFM group was higher than that in the non-EFM group (6108 vs. 4804 yuan/ha/yr, respectively).

3.2.3. Economic development

Consistent with previous research, the economic development of a region had a significant and positive impact on the estimated value (Fig. 5.a). On average, a 1000-yuan higher GDP per capita generated a 19 yuan/ha/yr higher value.

Another interesting question is whether the value of different ES categories responds differently to the level of economic development. Fig. 6 presents the coefficients of the GDP per capita in the four MRA models for different ES categories. Cultural services were most affected by the economic development level, followed by the provisioning and regulating services. An increase in the GDP per capita of 1000 yuan resulted in increases in value of the cultural, provisioning, and regulating services of 29, 24, and 20 yuan/ha/yr, respectively. Note that the interval estimation of the coefficients exhibited large variation, indicating that the differences between these categories were not big. The value of habitat services did not change with GDP level.

3.2.4. Control variables

Journal types were significant in explaining the ecosystem values. The studies published in SCI- or SSCI-indexed journals had relatively higher values than those published in non-SCI/SSCI-indexed journals. In addition, we found that the year when the research was conducted did not affect the value. In terms of the geographical location of the study sites, longitude had a significant positive impact on the valuation of ESs. In contrast, the latitude had no significant difference.

3.3. Predicted value matrix for ecosystems and ecosystem services

The full estimation results of the last model with the added interaction terms are presented in Table A.4 of the appendix. Diagnostic testing indicated that there was no multicollinearity between these explanatory variables, as VIF = 5.15, which was below 10. In this model, most of the interactional variables between ecosystems and their services exhibited the expected significance at the 95% confidence level. The value matrix is presented in Table 2. All values are expressed in 2015 Chinese yuan per hectare per year.

Our prediction shows that wetlands in China had the highest economic value (107,798 yuan/ha/yr), and the values for each service

Table 2
Predicted value matrix for ecosystems and ecosystem services.

							Unit: yuan/ha/yr
	Cultivated	Desert	Forests	Grass/rangeland	Lakes/rivers	Wetlands	Other
Water	445	−118	1218	724	7010	7607	3594
	(0, 1598)	(−0.758, 522)	(574, 1861)	(104, 1343)	(3746, 10,274)	(4602, 10,612)	(1719, 5468)
Raw materials	408	159	3424	627	262	1180	3106
	(148, 668)	(0, 584)	(2801, 4047)	(330, 924)	(−9, 532)	(495, 1865)	(−1993, 8205)
Food	1939	32	493	552	783	1955	1273
	(1556, 2322)	(0, 339)	(139, 846)	(338, 765)	(440, 1126)	(64, 3845)	(−2076, 4623)
Gas regulation	1652	113	6269	2203	1325	5371	5149
	(1197, 2107)	(220, 446)	(5570, 6968)	(1795, 2611)	(647, 2004)	(3651, 7091)	(2959, 7339)
Climate regulation	1832	214	6066	2532	3299	13,961	4198
	(1395, 2270)	(0, 566)	(5278, 6855)	(2058, 3007)	(2367, 4230)	(11,531, 16,392)	(2491, 5905)
Maintaining soil fertility	1990	65	5697	2913	604	7507	1908
	(1592, 2389)	(0, 299)	(4763, 6630)	(2533, 3293)	(260, 949)	(485, 10,170)	(137, 3679)
Regulation of water flows	1388	105	7044	2111	19,792	18,183	10,213
	(0.962, 1815)	(−161, 371)	(6100, 7987)	(1768, 2454)	(16, 433, 23,151)	(15,566, 20,800)	(5450, 14,975)
Waste treatment	1726	200	2885	2103	17,394	15,955	4071
	(1385, 2067)	(−0.066, 465)	(2395, 3376)	(1706, 2501)	(14,703, 20,084)	(13,205, 18,706)	(1044, 7099)
Biodiversity maintenance	926	324	5319	2104	4437	9983	2150
	(611, 1242)	(60, 587)	(4541, 6.098)	(1738, 2471)	(3403, 5472)	(7343, 12,624)	(453, 3846)
Recreational service	335	186	2718	957	7781	10,495	3622
	(0, 731)	(0, 460)	(2358, 3077)	(681, 1232)	(6121, 9.441)	(8421, 12,569)	(1966, 5278)
Other	3504	402	5038	4233	4588	15,601	2625
	(1410, 5598)	(574, 1378)	(2486, 7590)	(2452, 5925)	(975, 8202)	(10,992, 20,210)	(−133, 5383)
Total	16,145	1682	46,171	21,059	67,275	107,798	41,909

Note: 1 USD = 6.228 CNY in 2015. Values in brackets are the lower and upper boundaries of the predicted value, respectively. Water provisioning services are affected by precipitation and evapotranspiration; however, issues such as water resource shortages, climate drought, and soil erosion occur in the arid areas of China, resulting in poor soil water conservation capacity, which may have caused the negative value in desert ecosystems.

provided by wetlands were higher than those of other ecosystems. Not surprisingly, food provision had high value in the cultivated ecosystems, which was higher than that of food provision services in ecosystems other than wetlands. For instance, the food provision value of cultivated land was 1446 yuan/ha/yr higher than that of forests.

Recreational services were more valuable than provisioning and habitat services. Furthermore, wetlands, lakes, rivers, and forests ecosystems were found to have higher recreational value than grassland and cultivated land. Moreover, the values of some ecosystems or services were very low. For example, the total value of desert land was only 1682 yuan/ha/yr, which was just 1.56% of the value of wetlands.

4. Discussion

4.1. Factors determining ESVs in China

This study provides a comprehensive review of ESV studies conducted in China. The coefficient estimates of the models indicated that wetlands were the most valuable ecosystems. As the most productive ecosystems on Earth, wetlands provide humans with many uses and irreplaceable services (Bassia et al., 2014; Russi et al., 2012). In contrast, desert ecosystems had the lowest value. This result is consistent with the findings of Kang et al. (2020), who also reported that, regardless of the valuation method used, alpine desert had the lowest ESV per hectare. This low value could be due to the lower primary productivity of these ecosystems, which results in a lower amount and quality of services. Despite the low estimated values, the services provided by this ecosystem are vital for substance circulation and energy transformation in the Earth's ecosystems (Schild et al., 2018).

Regulation of water flows was the most valuable service, which is consistent with the findings of Chaikumbung et al. (2016) for developing countries. Overall, regulating services were more valuable than recreational and provisioning services, which differs from the findings on grassland ecosystems in Qinghai Province, China (Kang et al., 2020). We also found that recreational services were more valuable than provisioning and habitat services, which may be because recreational services are relatively easily perceived by users. As noted by Ghermandi et al. (2010), the value of ESs increases with the intensity of human use. Furthermore, the recreational service value from wetlands was found to exceed that of the other ecosystems, which may be because people prefer these areas for enjoyment, resulting in a higher response of the recreation value of the tourism industry to those preferences.

Our findings regarding the effects of valuation methods are consistent with those of previous studies (Balasubramanian, 2019; Chaikumbung et al., 2016), with the market price method producing the highest value when keeping the other conditions unchanged. The two non-market valuation methods (i.e. CVM and CEM) provided similar estimated values as the market price method. This result is consistent with that provided by Ghermandi et al. (2010). However, Chaikumbung et al. (2016) showed that non-market valuation methods generated lower values than market price method. More detailed discussion about the selection of valuation methods are presented in the following section.

Consistent with the findings of Ambrey and Fleming (2011), we found that ESs were normal goods. The annual value of an ecosystem per unit area is expected to increase as the level of economic development increases, especially in developing countries. However, the impact of economic development differs between different types of ESs. Nobel et al. (2020) conducted biodiversity value assessment and found a similar result. The mechanism influencing the impact of economic development on ESV is discussed below.

The model also revealed that the estimated values presented to readers were influenced by the characteristics of the journal. The year of research variable did not significantly impact the ESV, which may be because the values in our database cover multiple ecosystems and ESs in China. According to Zhou et al. (2020), among the 11 types of ESs provided by wetlands in China, only the recreational service value is significantly affected by research time. The diverse impacts of this variable on ecosystems and their services are not discussed in this study.

Regarding the geographical location of the study site, the ESs in the eastern regions of China were more valuable than those in the western regions. This could be because the ESs in eastern regions are more utilized as the population density in these areas is higher, resulting in higher values than those in the western regions. However, care should be taken when explaining these differences, as ESs in the western regions are not “valueless” or “worthless”. This difference could be because few studies have focused on western areas. Additionally, western China is mainly covered by arid and semi-arid regions with fragile ecological environments and sparse populations, thus lowering the ecosystem utilization rate. Therefore, the challenge is raising awareness of the valuation of ESs in western China in order to recognize the critical role of this region.

4.2. Challenges in valuation method selection

Our findings show that the estimated values differed between the EFM and non-EFM. By comparing the difference in value between the regulation of water flows and food provision services, we found that it was larger in the EFM group, which could be because Chinese ecological experts give higher weights to the regulation of water flows when developing EFMs (Xie et al., 2008). In Xie et al.'s (2003) study, which is most referred to by Chinese scholars, the equivalent coefficient of this service (i.e., relative weight of a certain ES compared to the food provision of cultivated ecosystem) reached 122.98.

These differences require further studies to verify the results from different methods. In our database, EFM was overrepresented, whereas the commonly used non-EFMs were underrepresented. Chinese scholars have placed more importance on EFM. Further research should consider that even the optimized EFM framework cannot change the irreplaceable position of the primary data-based approach in the field of ESV.

EFM provides a rapid, initial approximation of ESVs when the time and budget are limited as they typically do not require any input parameters or complex calculation procedures, resulting in the convenience of assessing multiple types of ecosystems and services at large spatial scales (Xie et al., 2017).

However, there are also some challenges when using this method. First, most EFM studies do not clearly define an ecosystem, resulting in confusing terminology usage for ecosystem types. For example, it is difficult to clearly classify land-use types in urban ecosystem into forest, grassland, urban, or artificial ecosystems. Second, although the EFM calculation process has been revised in some studies (Fu et al., 2016; Rao et al., 2018), further improvements for the adjustment of equivalent coefficients according to the local ecosystem structures, production functions, economic development, and demographic characteristics of the study site are still required.

The purpose of our comparison of estimated results between the EFM and non-EFM was not to suggest that one is superior to the other. For a given type of ecosystem or service, the most appropriate method should be selected depending on time and budget constraints, the purpose of the valuation results, and the ES characteristics (de Groot et al., 2012).

4.3. Economic development with ESV

As the GDP per capita significantly affects the ESV, considering the intrinsic influencing mechanisms may aid in further determining the economic development condition in future valuation studies. Some potential factors affected by economic development, such as the residents' income level, environmental demand, and individual environmental attitude, may greatly impact the ESV. First, people in more developed regions are more likely to have higher incomes and pro-environmental attitudes (Wang and Kang, 2019). Higher incomes and environmental awareness would result in a higher WTP for ESs (Carrasco et al., 2014; Santiago et al., 2015; Song et al., 2016). Additionally, the estimated value information indicates scarcity. In an area with a higher level of economic development, the demand for ESs is higher because the fraction of potential ecosystem values, particularly for tourism and provisioning services is larger (Latinopoulos, 2014; Teoh et al., 2019). The high demand of a large population in areas with higher income and the limited supply level will lead to a scarcity of ESs, which would then increase the ecosystem value. Moreover, economic growth is also a limiting factor in the maintenance of biodiversity in ecosystems (He et al., 2014). In less-disturbed habitats with lower economic development, ecosystems are expected to provide higher species richness and aggregated values.

Therefore, the development of evaluation strategies for ESs is an important issue, which are needed to properly capture the dependence of these factors on economic conditions. For instance, a lower WTP statement and environmental awareness of residents may lead to the underestimation of actual ESVs in low-income regions. Therefore, governments or other stakeholders may prioritize short-term benefits and compromise them with the target of ecosystem conservation. Given these results, we recommend that the evaluation models should be optimized by combining some control variables, such as environmental awareness, income level, and biophysical parameters.

4.4. Implications of the predicted value information in decision-making

As shown in the predicted matrix, the food provision service of cultivated land had a higher value than forests. Such value differences create strong incentives for farmers to change land-use from forests to cultivated land. However, from a social perspective, the total economic value should be considered, rather than the direct use value. Based on our prediction, converting forests to cultivated land causes a loss of 30,026 yuan/ha/yr, and converting grassland to cultivated land causes a loss of 4914 yuan/ha/yr.

As the first nationwide analysis examining the factors that affect ESVs in China, this predicted value matrix could work as a quick tool to make a more balanced decision regarding land-use options. In past decades, the degradation of forests and grasslands triggered by the continuously increasing demand for food production and tourism recreation has become one of the strongest drivers of soil erosion and biodiversity loss (Wang et al., 2019). Although the conversion of forests or grassland to cultivated land could bring greater market benefits on the short run, it substantially diminishes the aggregating values, especially the regulating values of natural ecosystems. This can be easily demonstrated by the results in the predicted value matrix.

In China, the government has implemented some national payment for ecosystem services (PES) projects, such as the “Grain for Green Program (GGP).” The differences in the values of food provision and regulating services observed here could aid in appraising the compensative standards of this program. For example, Table 2 shows that the difference in the food provision values of cultivated land and forests is 1446 yuan/ha/yr, i.e., 96.4 yuan/mu/yr. Mu is a Chinese unit of land measurement equal to 0.0667 ha. Following the GGP policy for 2015, if a farmer chooses to convert cultivated land into forest, they would receive a total subsidy of 1500 yuan/mu. This subsidy standard is higher than the economic loss of food production over 15 years ($96.4 \times 15 = 1446$). Additionally, farmers could adopt more sustainable tangible goods (such as mulberry) and intangible ecotourism resources from forests (Hou et al., 2004), thereby allowing the ecosystem functions of regulation, habitat provision, and tourism to be simultaneously realized. Our results not only aid in supporting the effectiveness of other similar programs in deterring the losses of the total ESV, but also provide a quantitative guideline for the government to trace changes in the ESV in the future.

4.5. Limitations of the study

Although this study has included most ESV studies in China and identified a direction for further research, several limitations should be mentioned. First, although the studies selected for our research are distributed across multiple ecosystems in the country, some ecosystems and regions are underrepresented. For instance, although the grassland areas of Qinghai, Tibet, and Inner Mongolia accounted for 50.21% of the total grassland area in China, only four studies have focused on grassland ecosystems in these three provinces. Additionally, only one study focused on Guizhou Province. The lack of studies in some regions may prevent our meta-analysis from adequately capturing the differences across study sites.

Second, some uncertainties that may cause errors in the meta-analysis have not been analyzed in this study. Most primary research selected in our database provides little information regarding the uncertainties of their values, such as the respondents' income and environmental attitude; thus, it is difficult for us to consider more independent variables in our meta-analysis. Additionally, this study did not consider other gray literatures. The uncertainty in the selection of prior research causes random errors, such as publication selection bias, which can affect the results. Several approaches to overcome these potential sources of uncertainties should be considered in the future, such as closer adherence to the research selection protocol, standardized application of the analysis model, and recording of potential uncertainties.

5. Conclusion

This study provides the first comprehensive review of empirical studies conducted on the ESV in China. We demonstrate that the ecosystem type, ESs, valuation methods, economic development, longitude of the study area, and journal types are significant factors in explaining the discrepancies in the ESV outcomes. We discuss the differences in ESV for each ecosystem and ESs, as it provides quantitative evidence for policymakers when making more balanced decisions regarding land-use options. Moreover, the estimated results are sensitive to valuation methods. Challenges also remain in the selection of valuation methods for Chinese scholars, particularly in the use of the EFM. The terminology of ecosystem types should be defined and equivalent coefficients should be modified according to local environmental and economic characteristics if an EFM is to be followed. Finally, the inconsistencies in the impact of economic development on different categories of services suggest that economic development is beneficial for the recreational service value. However, without strict conservation efforts, continuing economic growth will not be beneficial to the habitat functions of natural ecosystems.

CRediT authorship contribution statement

Nannan Kang: Conceptualization, Methodology, Formal analysis, Writing-Original Draft, Visualization.

Lingling Hou: Methodology, Formal analysis, Writing - Review & Editing, Visualization.

Jikun Huang: Formal analysis, Project administration, Funding acquisition, Supervision.

Huifang Liu: Resources, Methodology, Software, Investigation, Formal analysis.

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

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References

Alberto Lara-Pulido, J., Guevara-Sangines, A., Arias, Martelo C., 2018. A meta-analysis of economic valuation of ecosystem services in Mexico. Ecosyst. Serv. 31, 126–141. https://doi.org/10.1016/j.ecoser.2018.02.018.

Ambrey, C.L., Fleming, C.M., 2011. Valuing scenic amenity using life satisfaction data. Ecol. Econ. 72, 106–115. https://doi.org/10.1016/j.ecolecon.2011.09.011.

Balasubramanian, M., 2019. Economic value of regulating ecosystem services: a comprehensive at the global level review. Environ. Monit. Assess., 191 https://doi.org/10.1007/s10661-019-7758-8.

Bao, Y., Wu, W., Wang, M., Liu, W., 2007. Disadvantages and future research directions in valuation of ecosystem services in China. Int. J. Sustain. Dev. World 14, 372–381. https://doi.org/10.1080/13504500709469737.

Bassia, N., Kumarb, M.D., Sharmac, A., Saradhi, P.P., 2014. Status of wetlands in India: a review of extent, ecosystem benefits, threats and management strategies. J. Hydrol. Reg. Studi. 2, 1–19.

Carrasco, L.R., Nghiem, T.P.L., Sunderland, T., Koh, L.P., 2014. Economic valuation of ecosystem services fails to capture biodiversity value of tropical forests. Biol. Conserv. 178, 163–170. https://doi.org/10.1016/j.biocon.2014.08.007.

Chaikumbung, M., Doucouliagos, H., Scarborough, H., 2016. The economic value of wetlands in developing countries: a meta-regression analysis. Ecol. Econ. 124, 164–174. https://doi.org/10.1016/j.ecolecon.2016.01.022.

Clarivate Analytics, 2020. Web of Science [v.5.35]: Web of Science Core Collection Basic Search. 2020. https://apps.webofknowledge.com/WOS_GeneralSearch_input.do?product=WOS&search_mode=GeneralSearch&SID=C1lWbTfMzVwyeqnPlri&preferencesSaved.

Costanza, R., dArge, R., deGroot, R., Farber, S., Grasso, M., Hannon, B., et al., 1997. The value of the world's ecosystem services and natural capital. Nature 387, 253–260. https://doi.org/10.1038/387253a0.

Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S.J., Kubiszewski, I., et al., 2014. Changes in the global value of ecosystem services. Glob. Environ. Chang. Hum. Policy Dimens. 26, 152–158. https://doi.org/10.1016/j.gloenvcha.2014.04.002.

D'Amato, D., Rekola, M., Li, N., Toppinen, A., 2016. Monetary valuation of forest ecosystem services in China: a literature review and identification of future research needs. Ecol. Econ. 121, 75–84. https://doi.org/10.1016/j.ecolecon.2015.11.009.

de Groot, R., Brander, L., van der Ploeg, S., Costanza, R., Bernard, F., Braat, L., et al., 2012. Global estimates of the value of ecosystems and their services in monetary units. Ecosyst. Serv. 1, 50–61. https://doi.org/10.1016/j.ecoser.2012.07.005.

Elsevier, 2020a. Engineering Village. 2020. https://www.engineeringvillage.com/search/quick.url?usageZone=evlogo&usageOrigin=header.

Elsevier, 2020b. Scopus Preview - Scopus. 2020. https://www.scopus.com/home.uri?zone=header&origin=recordpage.

Environment Canada, 2016. Environmental Valuation Reference Inventory. https://www.evri.ca/.

ESP, 2014. Ecosystem Service Valuation Database (ESVD). http://espartnership.org/services/data-knowledge-sharing/ecosystem-servicevaluation-database/.

ESP, 2020. Ecosystem Service Valuation Database (ESVD). http://espartnership.org/services/data-knowledge-sharing/ecosystem-servicevaluation-database/.

Fan, X.C., Zhao, L.L., Hong, T., Lin, H., Hong, W., 2018. Prediction of land use change and ecosystem services value: a casestudy in Nanping,China. Appl. Ecol. Environ. Res. 16, 4935–4954. https://doi.org/10.15666/aeer/1604_49354954.

Fu, B., Li, Y., Wang, Y., Zhang, B., Yin, S., Zhu, H., et al., 2016. Evaluation of ecosystem service value of riparian zone using land use data from 1986 to 2012. Ecol. Indic. 69, 873–881. https://doi.org/10.1016/j.ecolind.2016.05.048.

Ghermandi, A., van den Bergh, J.C.J.M., Brander, L.M., de Groot, H.L.F., Pald, N., 2010. The economic value of wetland conservation and creation: a meta-analysis. Water Resour. Res. 46, 1–12.

He, Q., Bertness, M.D., Bruno, J.F., Li, B., Chen, G., Coverdale, T.C., et al., 2014. Economic development and coastal ecosystem change in China. Sci. Rep., 4 https://doi.org/10.1038/srep05995.

Hou, Y., Duan, S., Zhao, S., 2004. Main Tree Species of Conversion Farmland to Forest in China (Volume of the North). China Agriculture Press, Beijing, China.

Jiang, W., 2017. Ecosystem services research in China: a critical review. Ecosyst. Serv. 26, 10–16. https://doi.org/10.1016/j.ecoser.2017.05.012.

Johnston, R.J., Bauer, D.M., 2020. Using meta-analysis for large-scale ecosystem service valuation: progress, prospects, and challenges. Agric. Resour. Econ. Rev. 49, 23–63. https://doi.org/10.1017/age.2019.22.

Kang, B., Shao, Q., Xu, H., Jiang, F., Wei, X., Shao, X., 2020. Research on grassland ecosystem service value in China under climate change based on meta-analysis: a case study of Qinghai province. Int. J. Clim. Chang. Strat. Manag. https://doi.org/10.1108/ijccsm-06-2020-0073.

Keith, H., Vardon, M., Stein, J.A., Stein, J.L., Lindenmayer, D., 2017. Ecosystem accounts define explicit and spatial trade-offs for managing natural resources. Nat. Ecol. Evol. 1, 1683–1692. https://doi.org/10.1038/s41559-017-0309-1.

Latinopoulos, D., 2014. The impact of economic recession on outdoor recreation demand: an application of the travel cost method in Greece. J. Environ. Plan. Manag. 57, 254–272. https://doi.org/10.1080/09640568.2012.738602.

Loyola, R.P., Wang, E., Kang, N., 2021. Economic valuation of recreational attributes using a choice experiment approach: an application to the Galapagos Islands. Tour. Econ. 27, 86–104. https://doi.org/10.1177/1354816619885236.

National Bureau of Statistics of China, 2020. National Data. 2020. https://data.stats.gov.cn/.

Nelson, J.P., Kennedy, P.E., 2009. The use (and abuse) of meta-analysis in environmental and natural resource economics: an assessment. Environ. Resour. Econ. 42, 345–377. https://doi.org/10.1007/s10640-008-9253-5.

Nobel, A., Lizin, S., Brouwer, R., Bruns, S.B., Stern, D.I., Malina, R., 2020. Are biodiversity losses valued differently when they are caused by human activities? A meta-analysis of the non-use valuation literature. Environ. Res. Lett., 15. https://doi.org/10.1088/1748-9326/ab8ec2.

Perosa, F., Fanger, S., Zingraff-Hamed, A., Disse, M., 2021. A meta-analysis of the value of ecosystem services of floodplains for the Danube River Basin. Sci. Total Environ. 777, 146062.

Quintas-Soriano, C., Martin-Lopez, B., Santos-Martin, F., Loureiro, M., Montes, C., Benayas, J., et al., 2016. Ecosystem services values in Spain: a meta-analysis. Environ. Sci. Pol. 55, 186–195. https://doi.org/10.1016/j.envsci.2015.10.001.

Rao, Y., Zhou, M., Ou, G., Dai, D., Zhang, L., Zhang, Z., et al., 2018. Integrating ecosystem services value for sustainable land-use management in semi-arid region. J. Clean. Prod. 186, 662–672. https://doi.org/10.1016/j.jclepro.2018.03.119.

Russi, D., Brink, P.T., Farmer, A., Bandura, T., Coates, D., Dorster, J., et al., 2012. The economics of ecosystems and biodiversity for water and wetlands: a briefing note. CONFERENCE OF THE PARTIES TO THE CONVENTION ON BIOLOGICAL DIVERSITY, Hyderabad, India.

Santiago, L., Torres, A., A. O., 2015. Does Greater Environmental Awareness Translate Into Higher Valuation of Ecosystem Attributes? Visitor Attitudes in an Urban Tropical Watershed. The Second Asian Conference on the Social Sciences and Sustainability.

Schild, J.E.M., Vermaat, J.E., de Groot, R.S., Quatrini, S., van Bodegom, P.M., 2018. A global meta-analysis on the monetary valuation of dryland ecosystem services: the role of socio-economic, environmental and methodological indicators. Ecosyst.Serv. 32, 78–89. https://doi.org/10.1016/j.ecoser.2018.06.004.

Schwertman, N.C., Owens, M.A., Adnan, R., 2004. A simple more general boxplot method for identifying outliers. Comput. Stat. Data Anal. 47, 165–174. https://doi.org/10.1016/j.csda.2003.10.012.

Song, Q., Wang, Z., Li, J., 2016. Exploring residents' attitudes and willingness to pay for solid waste management in Macau. Environ. Sci. Pollut. Res. 23, 16456–16462. https://doi.org/10.1007/s11356-016-6590-8.

Sun, C., Wang, Y., Zou, W., 2018. The marine ecosystem services values for China based on the emergy analysis method. Ocean Coast.Manag. 161, 66–73. https://doi.org/10.1016/j.ocecoaman.2018.04.022.

Sutton, P.C., Costanza, R., 2002. Global estimates of market and non-market values derived from nighttime satellite imagery, land cover, and ecosystem service valuation. Ecol. Econ. 41, 509–527. https://doi.org/10.1016/s0921-8009(02)00097-6.

Tanner, M.K., Moity, N., Costa, M.T., Marin Jarrin, J.R., Aburto-Oropeza, O., Salinas-de-Leon, P., 2019. Mangroves in the Galapagos: ecosystem services and their valuation. Ecol. Econ. 160, 12–24. https://doi.org/10.1016/j.ecolecon.2019.01.024.

TEEB, 2010. The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. Earthscan, London, Washington.

Teoh, S.H.S., Symes, W.S., Sun, H., Pienkowski, T., Carrasco, L.R., 2019. A global meta-analysis of the economic values of provisioning and cultural ecosystem services. Sci. Total Environ. 649, 1293–1298. https://doi.org/10.1016/j.scitotenv.2018.08.422.

Wang, E., Kang, N., 2019. Does life satisfaction matter for pro-environmental behavior? Empirical evidence from China general social survey. Qual. Quant. 53, 449–469.

Wang, C., Li, X., Yu, H., Wang, Y., 2019. Tracing the spatial variation and value change of ecosystem services in Yellow River Delta, China. Ecol. Indic. 96, 270–277. https://doi.org/10.1016/j.ecolind.2018.09.015.

Xie, G., Lu, C., Leng, Y., Zheng, d., Li, S., 2003. Ecological assets valuation of the Tibetan Plateau. J. Nat. Resour. 18, 189–196.

Xie, G., Zhen, L., Lu, C., Xiao, Y., Chen, C., 2008. Expert knowledge based valuation method of ecosystem services in China. J. Nat. Resour. 23, 911–919.

Xie, G., Zhang, C., Zhen, L., Zhang, L., 2017. Dynamic changes in the value of China's ecosystem services. Ecosyst. Serv. 26, 146–154. https://doi.org/10.1016/j.ecoser.2017.06.010.

Zhang, X., Lu, X., 2010. Multiple criteria evaluation of ecosystem services for the ruoergai plateau marshes in southwest China. Ecol. Econ. 69 (7), 1463–1470. https://doi.org/10.1016/j.ecolecon.2009.05.017.

Zhang, B., Li, W., Xie, G., 2010. Ecosystem services research in China: Progress and perspective. Ecol. Econ. 69, 1389–1395. https://doi.org/10.1016/j.ecolecon.2010.03.009.

Zhou, J., Wu, J., Gong, Y., 2020. Valuing wetland ecosystem services based on benefit transfer: a meta-analysis of China wetland studies. J. Clean. Prod. 276, 122988. https://doi.org/10.1016/j.jclepro.2020.122988.