Environment and Ecology Research 13(1): 151-164, 2025 http://www.hrpub.org
DOI: 10.13189/eer.2025.130114

Valuating Wetland Ecosystem Services Based on the Discrete Choice Experiments: A Systematic Review and Meta-analysis

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Received November 11, 2024; Revised February 6, 2025; Accepted February 24, 2025

Cite This Paper in the Following Citation Styles

(a): *[1] Senquan Kong, Wan Norhidayah W Mohamad, Anitha Rosland, Yuanyuan Lee , "Valuating Wetland Ecosystem Services Based on the Discrete Choice Experiments: A Systematic Review and Meta-analysis," Environment and Ecology Research, Vol. 13, No. 1, pp. 151 - 164, 2025. DOI: 10.13189/eer.2025.130114.*

(b): *Senquan Kong, Wan Norhidayah W Mohamad, Anitha Rosland, Yuanyuan Lee (2025). Valuating Wetland Ecosystem Services Based on the Discrete Choice Experiments: A Systematic Review and Meta-analysis. Environment and Ecology Research, 13(1), 151 - 164. DOI: 10.13189/eer.2025.130114.*

Abstract This study conducts a systematic review and meta-analysis of wetland ecosystem service values based on discrete choice experiments across 49 studies from 22 countries. It finds that the expansion of wetland areas negatively impacts public willingness to pay (WTP) for conservation, with a 1% increase in wetland areas leading to a 0.66% decrease in WTP, particularly in developed countries. However, larger wetland areas positively affect the total value of ecosystem services, with a 1% increase in the area contributing to a 0.337% rise in service value. The study also reveals that higher GDP, cultural values, and biodiversity significantly enhance WTP, with wealthier nations and wetlands offering cultural or biodiversity benefits seeing higher public support for conservation. The research suggests that policies should prioritize improving the quality and functionality of existing wetlands rather than solely expanding their area. Additionally, integrating cultural and biodiversity values into conservation plans can increase public participation and willingness to pay. For developed countries, improving existing wetland services is key, while developing countries should focus on both expanding and enhancing wetland quality. These findings emphasize the need for balanced, quality-focused wetland conservation strategies that maximize ecological and socio-economic benefits.

Keywords Wetland Ecosystem Service, Discrete Choice Experiments, Systematic Review, Meta-analysis

1. Introduction

Research on wetland ecosystem services, including wetland ecosystem service evaluation, determination of drivers, management, and policymaking, has been growing rapidly over the last decade. Wetlands play such significant roles in ecosystem functions, including water purification and carbon storage, so that they are highly valued as inland wetlands [1]. Otherwise, the global wetland share has been reduced by approximately 70% compared with that in the early 20th century, which in turn has caused many ecosystem service losses. Standalone studies have made meta-regression model applications possible for an estimation of provisioning and regulatory wetland ecosystem service values [2].

Wetland environments offer communities a wide range of advantages, such as flood control, weather modification, water cleansing, and biodiversity assistance [3][4]. These contributions are rarely exchanged in standard markets and are often undervalued, despite their substantial contributions to human welfare. Numerous ecosystem services have been reduced owing to this lack of financial acknowledgement, specifically those holding traits that are useful for the public. The overuse of resources from the shared pool and incentives that back the transformation of natural wealth into vendible commodities are the root triggers of the "misfortune of ecosystem services" [5][6]. For the protection and sustainable administration of wetland ecosystem services, it is essential to acknowledge their real value and incorporate them into decision-making processes. As such, the monetary significance of numerous wetland ecosystem services that could be used in land-use planning, trade-offs and cost-benefit examinations is important, and the development of wetland conservation strategies is regularly problematic. To address this issue, several strategies have been attempted and refined to determine the monetary esteem of the ecosystem administrations given by wetlands, an idea known as "wetland values" [7].

Discrete choice experiments have been applied to assess the public demands and economic value of services related to wetland ecosystems. Previous research in places such as the Severn Estuary, United Kingdom [8], Cheimaditida Wetland, Greece [9], and Lake Tana, Ethiopia [10], has demonstrated that wetlands provide significant positive externality value for public consumption, where they could be more valuable than costs to users. Studies such as these highlight how such experiments reveal the trade-offs concerning what is being fixed with higher biodiversity, water quality improvements and even ecotourism. The overall findings additionally highlight how respondents are averse to reference pricing for various reasons, thereby demonstrating the necessity for policymakers to consider multiple stakeholder perspectives in policy design. These economic benefits can be estimated and then incorporated into priority setting via cost-benefit analyses, which may act as a foundation for the public policies necessary for socially optimal wetland conservation and management, hence successful and sustainable preservation strategies [9][11].

Benefit transfer, which applies existing value estimates to new locations or policies, is one method for assessing how much ecosystem services are worth [12]. This approach is particularly suitable when site-specific studies are not possible due to time and resource constraints. Transfer validity, however, depends on how close the original site is to the target. Errors are most likely for land cover or habitat type transfers [13]. The factors influencing wetland valuation include wetland size, economic development level, wetland type, and valuation method. Wetland ecosystems provide various services. The landowner or manager benefits from these services depending on stakeholder preferences and who holds title to the land. When estimating the value of ecosystem services, it is also important to distinguish between ecosystem stocks and service flows. While benefit transfer can provide valuable information for policymakers, proper caution is needed to ensure reliable results [14][15].

There are two main methods of benefit transfer used in environmental evaluation. The first is known as unit value transfer, and the second is called benefit function transfer [16][17]. Unit value transfer applies average values or single-point estimates from previous research; benefit function transfer involves demand functions, benefit functions, or meta-analyses. These methods present a practical alternative to primary research: they use previous empirical benefit estimates in ongoing policy implementation [17]. According to empirical studies, benefit function transfer is generally more reliable than direct transfer of average site benefits [18], but errors may also be significant, even for amenities that appear to be equivalent.

In recent years, a series of studies in wetlands have carried out meta-regression analyses. Eric et al. [2] created models so that one can implement and control the ecosystem services provided by wetlands and reported that variables such as population density, land productivity, and income level highly influence wetland values. As a result, Zhou et al. [15] conducted a meta-analysis of Chinese wetland studies and discovered that the size of the wetland is by far the most important factor influencing reporting outcomes. Furthermore, Chen et al. [19] emphasized the need to include wetland quality in meta-analyses if value estimates are to be more precise. Through meta-regression models, case studies demonstrate the value of benefit transfer with reduced transfer errors compared with unit value transfers [2].

Discrete choice experiments (DCEs), survey-based stated preference approaches, have been increasingly used for examining preferences and guiding policy in both developed and developing countries. Studies in wetland management that use DCEs to determine what features people want for long-term conservation have shown that people usually want activities that help them make a living along with protection [20]. In the context of developing countries, DCEs have been used to test the willingness to pay for improved environmental quality which supports conservation strategies [21]. Although DCEs work well in resource-starved areas, they require effective implementation expertise [22].

This extensive analysis examines four discrete choice experiment models: the multinomial logit model (MNLM), the conditional logit model (CLM), the mixed logit model (MXLM), and the random parameter logit model (RPLM). The MNLM is deemed the most elementary design, yet it has restrictions, such as the independence of irrelevant options assumption. The CLM expands the MNLM in terms of party standing in issue spaces, permitting more intriguing political questions [23][24]. Both the MXLM and RPLM models, which are similar, loosen the IIA assumption and allow respondents to have different preferences. While MXLM/RPLM designs offer more flexibility and can achieve superior performance, they are more computationally exhaustive. Discrete mixtures, a less widespread alternative to continuous random coefficient models such as the MXLM, have displayed equal or greater performance with computational benefits [25][26]. The selection of the framework is dependent on the exact research context and data quality.

To investigate existing research that has used the discrete choice experiment method to estimate wetland ecosystem service values, a systematic literature review and meta-analysis were conducted. The authors first reviewed the literature to categorize and codify those studies via the discrete choice experiment method to value wetland ecosystem services; then representative samples were selected from them. A further normalization method is used to verify these chosen studies. These studies are then subjected to quantitative analysis to look at how current research arrives at the value of wetland ecosystem services. This paper aims to provide a useful reference point for subsequent research by identifying both significant findings in general, the main research trends, and any gaps in the discrete choice experiment method.

2. Methodology

The following three electronic databases were searched to achieve comprehensive coverage of the valuing of wetland ecosystem services based on discrete choice experiments: Scopus, Web of Science and Engineering Village. The initial search was conducted in June 2024. The search was conducted separately for each database, and database-specific search strings were used.

2.1. Systematic Review

According to Table 1, the search strategy combines keywords and titles, with an abstract generally describing four main groups, including discrete choice experiments, wetland types, and representations of value and subject [27][28][29].

Discrete choice experiments: ("choice model*" OR "choice experiment" OR "choice behav*" OR "part-worth utilities" OR "discrete choice" OR "best*worst scaling" OR "functional measurement" OR "paired comparisons" OR "pairwise choice*" OR "stated preference").

Wetland types: ("wetland" OR "flooded vegetation" OR "Peatland" OR "bog" OR "fen" OR "marsh" OR "swamp" OR "mangrove" OR "estuarine" OR " riverine" OR "lacustrine " OR "palustrine").

Representations 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*").

Subjects: ("eco* service*" OR "eco* function" OR "eco* goods" OR "environmental service*" OR "environmental function" OR "environmental goods" OR "natural capital").

The final search was defined as combinations of groups of terms: discrete choice experiments AND wetland types AND representations of value AND subjects. Only studies published in English were included.

Log-log and log-linear are two functional formations that we used to perform the meta-regression model estimation. The log-log model involves the transformation of dependent variables and continuous explanatory variables by logarithm. This transformation was intended to enhance model fitness and reduce heteroscedasticity, which occurs far too often in meta-regression analyses that contain economic valuation data [32]. We used ordinary least squares (OLS) to estimate equation (1) to account for heterogeneity ε_i across studies. We use robust standard errors when estimating equation (1).

Table 1. The search string

Scopus	TITLE-ABS-KEY ("choice model*" OR "choice experiment" OR "choice behav*" OR "part-worth utilities" OR "discrete choice" OR "best*worst scaling" OR "functional measurement" OR "paired comparisons" OR "pairwise choice*" OR "stated preference") AND TITLE-ABS-KEY ("wetland" OR "flooded vegetation" OR "Peatland" OR "bog" OR "fen" OR "marsh" OR "swamp " OR "mangrove" OR "estuarine" OR " riverine" OR "lacustrine " OR "palustrine") AND TITLE-ABS-KEY (valu* OR "economic cost" OR "economic loss" OR "monetary" OR "benefit" OR "payment for*" OR "estimat*" OR "willingness to pay" OR "WTP" OR "assess*") AND TITLE-ABS-KEY ("eco* service*" OR "eco* function" OR "eco* goods" OR "environmental service*" OR "environmental function" OR "environmental goods" OR "natural capital")
Web of science	TS= ("choice model*" OR "choice experiment" OR "choice behav*" OR "part-worth utilities" OR "discrete choice" OR "best*worst scaling" OR "functional measurement" OR "paired comparisons" OR "pairwise choice*" OR "stated preference") AND TS= ("wetland" OR "flooded vegetation" OR "Peatland" OR "bog" OR "fen" OR "marsh" OR "swamp " OR "mangrove" OR "estuarine" OR " riverine" OR "lacustrine " OR "palustrine") AND TS=(valu* OR "economic cost" OR "economic loss" OR "monetary" OR "benefit" OR "payment for*" OR "estimat*" OR "willingness to pay" OR "WTP" OR "assess*") AND TS=("eco* service*" OR "eco* function" OR "eco* goods" OR "environmental service*" OR "environmental function" OR "environmental goods" OR "natural capital")
Engineering Index	("choice model*" OR "choice experiment" OR "choice behav*" OR "part-worth utilities" OR "discrete choice" OR "best*worst scaling" OR "functional measurement" OR "paired comparisons" OR "pairwise choice*" OR "stated preference") AND ("wetland" OR "flooded vegetation" OR "Peatland" OR "bog" OR "fen" OR "marsh" OR "swamp " OR "mangrove" OR "estuarine" OR " riverine" OR "lacustrine " OR "palustrine") AND ("ecosystem service*" OR "eco* function" OR "eco* goods" OR "environmental service*" OR "environmental function" OR "environmental goods" OR "natural capital") AND ("valu*" OR "economic cost" OR "economic loss" OR "monetary" OR "benefit" OR "payment for*" OR "estimat*" OR "willingness to pay" OR "WTP" OR "assess*")

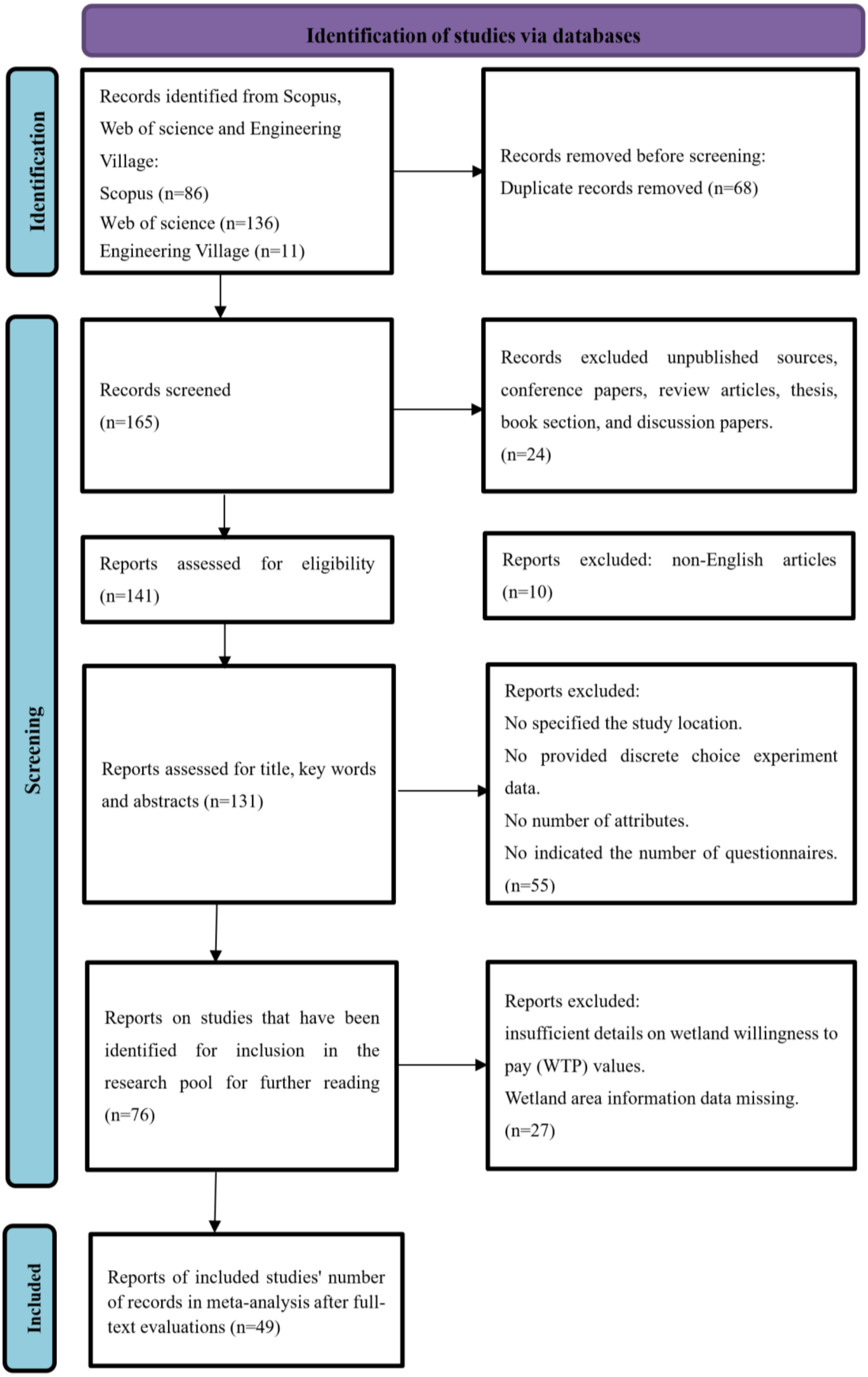

Figure 1. The flow diagram (adapted from Page et al, 2021) [30]

Table 2. Definition of variables

Variable type	Variable	Variable Description
Dependent Variable	WTP value (WTPV)	Willingness to pay value for wetland (USD/ha/year)
	Wetland ecosystem service value (WESV)	Wetland ecosystem service value (USD/year)
Independent Variable	Wetland area (WA)	Wetland area(ha)
	Survey number (SN)	Survey number
	Survey year (SY)	Research year
	Publication year (PY)	The publication year of the article
	Number of attributes (NOA)	The number of attributes when using discrete choice experiments
	PGDP	GDP per capita
	CUL (Culture)	If the attribute contains a culture variable, culture = 1, otherwise culture =0
	BIO (Biodiversity)	If the attribute contains a biodiversity variable, Biodiversity = 1, otherwise Biodiversity=0

According to Figure 1, among the 233 papers, duplicates from the Scopus, Web of Science, and Engineering Village databases were first removed, resulting in 165 articles. All unpublished sources, conference papers, review articles, theses, book chapters, and discussion papers were subsequently excluded, leaving 141 articles. They are typically not peer-reviewed and may lack rigorous quality control and validation processes. In contrast, the peer-review mechanism helps ensure the quality and data reliability of research. Therefore, excluding gray literature helps reduce the impact of low-quality or unverified data on the results of meta-analysis. Next, non-English articles were removed, resulting in 131 papers. We then examined the titles, keywords, and abstracts of each paper to determine whether they met the criteria for inclusion in the meta-analysis: (i) specified the study location, (ii) provided discrete choice experiment data, (iii) included the number of attributes, and (iv) indicated the number of questionnaires. This screening process identified 76 papers, which were then thoroughly reviewed to assess whether they contained relevant and usable data on wetlands. From this subset, papers that did not provide (i) sufficient details on wetland willingness to pay (WTP) values or (ii) information on wetland areas or data that could be used to estimate wetland areas were excluded. Ultimately, 49 papers met the eligibility criteria (Figure 1).

2.2. Meta-regression Analysis

As a tool of synthesis and comparison that employs meta-regression, regression analysis is used to synthesize and analyze estimation data from various studies that are comparable [31]. In this research, data extracted from a systematic literature review were used to perform a meta-regression on the economic value of wetlands, measured in US dollars per hectare per year (US$/ha/year). The wetland value was the dependent variable of our model. In contrast, wetland area, GDP per capita, survey number, survey year, publication year, and the number of attributes considered—all predictors in different studies—were independent variables (Table 2).

2.3. Meta-regression

We constructed a meta-regression model as follows:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \varepsilon_i \qquad (1)$$

where i represents the number of individual studies; Y represents the value of wetland ecological services; X_1 represents the wetland area, which is a numerical variable in logarithmic form; X_2 represents the survey number; X_3 represents the survey year; X_4 represents the publication year; X_5 represents the number of attributes; X_6 represents GDP per capita; X_7 represents cultural attributes; X_8 represents biodiversity attributes, and ε represents the random error term.

3. Results and Discussion

According to Table 3, there are 49 observations in this study. We observed significant diversity and heterogeneity among wetland ecosystem service satisfaction valuation studies based on descriptive statistics. For instance, the willingness to pay (WTPV) and wetland ecosystem service value (WESV) exhibit large variations, indicating that the public valuation of wetland services varies widely and there are regional differences in the value of these ecological services. The wetland area (WA) encompasses a wide range of small to large wetlands, potentially affecting the value of the ecosystem services they deliver. Differences in sample sizes (SN) and survey years (SY) are likely related to differences in study designs, including the selection of study participants and the study periods considered. This diversity in per capita GDP (PGDP) indicates divergence in regional economies all over the world. Moreover, cultural (CUL) and biodiversity (BIO) country integrations occured in half of the articles, highlighting the significance of the effects of these variables on wetland service values. Ultimately, these statistics indicate that the wetland value is affected by a combination of factors, thus, policies must account for local economic conditions, cultural contexts, and ecological significance in discussions of wetland conservation.

According to Table 4, in the model where the WTP value is taken as a dependent variable, the wetland area has a significant negative effect on the WTP value at the 1% significance level. In that case, the analysis reveals that for every 1% increase in wetland area, the WTP value decreases by 0.663%. There are several reasons, including when the wetland area increases (marginal benefit per unit of wetland), and so on. The greater the monetary value of water purification, flood mitigation, and biodiversity conservation is, the more expensive it may be to carry out on a small scale; wetlands provide all these important ecosystem services. Nonetheless, as we scale up concerning area, the branching increase in wetlands' marginal contribution toward producing a whole ecosystem implies a diminished WTP (because of prediction) from a larger public. This negative effect of wetland areas on WTP has been evidenced by previous studies [15]. A greater wetland area also means a greater supply. Additionally, this finding is also in line with the principle of economics that when more resources become available, their scarcity decreases, so does the reduction in marginal value per unit [33]. The value per unit area decreases because the wetlands that are already present may be considered sufficient, and a risk then arises when people consider buying more land to protect or expand on existing ones that are less valuable. Moreover, as the wetland area increases, so do the opportunity costs of choosing to use land for agriculture or industry rather than residential development. This finding is consistent with a previous study by Eric et al. [2], who reported that people in developing countries are relatively poor and might need to sacrifice wetlands to meet their daily needs. In these cases, a loss of wetland value per unit area may be reinforced when the public prefers other uses for land rather than further extension of their coverage by marshes. However, this finding needs to be validated by more extensive literature from developing countries.

Moreover, according to the analysis, SY has a negative effect on lnWTPV and passes the 5% significance test. The reason is that recent studies often give lower valuation results [15]. PY positively affects lnWTPV and passes the 1% significance test. However, since the paper was published, more people have realized the importance of wetlands, which has a positive impact on valuation. This indicates that as time progresses, there is a growing recognition of the value of wetlands among the public.

lnPGDP positively affects lnWTPV and passes the 10% significance test. In highly developed economic societies, people are generally better able to pay and more willing to do so [34][35]. As per capita GDP increases, the standard of society's living income increases, which can prompt residents and tourists to afford more collective goods such as ecological protection. With increased income levels and economic forces, people are usually more willing to pay. They have more money to become involved in or support projects for the conservation of wetlands.

Table 3. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
WTPV	49	48828.709	181467.19	0.012	1103831.8
WESV	49	1.265e+10	7.383e+10	11560	5.085e+11
WA	49	1628270.1	4791597	400	22200000
SN	49	675.816	669.252	60	3464
SY	49	2014.918	4.577	1998	2022
PY	49	2018.041	4.42	2001	2024
NOA	49	5.102	1.262	3	9
PGDP	49	25904.534	23669.519	755.753	77246.672
CUL	49	0.49	0.505	0	1
BIO	49	0.531	0.504	0	1

Table 4. The meta-regression results

	(1)
VARIABLES	lnWTPV
lnWA	-0.663***
	(-4.165)
lnSN	0.301
	(0.403)
SY	-0.832**
	(-2.630)
PY	1.087***
	(3.475)
NOA	-0.400
	(-0.816)
lnPGDP	0.668*
	(1.814)
CUL	1.753*
	(1.829)
BIO	2.009*
	(1.937)
Constant	-511.3**
	(-2.434)
Observations	49
R-squared	0.521

Robust t-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

CUL positively affects lnWTPV and passes the 10% significance test. As the service is provided, cultural aspects (e.g., attributes related to local culture, traditional practices, or heritage conservation in the context of wetland services) increase as do people ́s willingness to pay for wetland conservation. This suggests that when cultural values are built into wetland conservation programs, the public will probably think that it is worth great pains to see these places as being protected [36].

BIO has a positive effect on lnWTPV and passes the 10% significance test. The significant positive effect of biodiversity attributes on lnWTPV indicates that the greater the importance of biodiversity (e.g., species richness, habitat diversity and endangered species conservation), the greater the public's willingness to pay for wetland conservation. This means that people consider biodiversity conservation very important, and when wetland ecosystems are seen to sustain rich and varied forms of life, people are willing to pay more money to protect wetlands [34][35].

According to Table 5, when comparing developed and developing countries, the analysis revealed that for every 1% increase in wetland area, the lnWTPV in developed countries decreased by 0.966%, and the lnWTPV in developing countries decreased by 0.688% and passed the 5% and 1% significance tests, respectively. In both developed and developing countries, the marginal utility of increasing wetland area is usually a declining function of the total area. Naturally, wetlands give rise to essential ecosystem services: purifying water, mitigating floods, and conserving biodiversity. For these reasons, they are highly valued. However, increasing the area of wetlands will mean that each additional unit of new wetland does less for these ecological services; therefore, fewer people are prepared to pay any more than this amount towards their future expansion.

Table 5. Comparative analysis between developed and developing countries

	(1)	(2)
	Developed Countries	Developing Countries
VARIABLES	lnWTPV	lnWTPV
lnWA	-0.966**	-0.688***
	(-2.466)	(-3.580)
lnSN	0.925	0.637
	(0.707)	(0.766)
SY	1.903	-1.070***
	(1.278)	(-4.086)
PY	-1.585	1.307***
	(-1.061)	(5.469)
NOA	0.465	-1.177***
	(0.738)	(-3.518)
lnPGDP	-1.604	1.149
	(-0.507)	(1.332)
CUL	-0.799	3.439**
	(-0.468)	(2.860)
BIO	2.442	2.292*
	(0.972)	(1.802)
Constant	-612.0	-479.9
	(-1.715)	(-1.252)
Observations	21	28
R-squared	0.482	0.786

Robust t-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

According to economic theory, an increase in the supply of an ecological resource such as a wetland area will reduce scarcity and, in turn, lower prices for each unit of it. In developed countries, existing wetlands may already adequately meet ecological requirements, in which case the perceived value of more wetlands is low. Moreover, wetlands are less abundant in developing countries. However, the costs of alternative land use, such as agriculture or infrastructure development, may destroy further wetlands. Moreover, in both instances, as the wetland area increases, opportunity costs decrease. The maintenance or expansion of wetlands may be more expensive in developed countries because of higher land values or stricter environmental regulations. However, in contrast, in developing countries where expanding wetlands may conflict with other economic priorities, such as agricultural expansion and urban development, the value of further investment in them will decrease. However, this study narrowed the valuation method to the choice experiment. These findings need to be evidenced by rich data from different developed and developing countries and other valuation methods in the future [37][38].

An analysis of the data in Table 6 demonstrated that, whether the conditional logit model was applied or not, a 1% increase in wetland area consistently led to a decrease in WTP. With the conditional logit model, a 1% increase in wetland space results in a 1.112% decrease in the payment value. In contrast, without using the conditional logit approach, a 1% growth in the wetland regions results in an approximately 0.597% reduction in willingness to pay. Both outcomes passed the stringent 1% significance evaluation. The conditional logit model is particularly adept at dissecting choice behavior since it captures how specific options, such as the wetland areas in this scenario, influence decision-makers' preferences. A core strength of the conditional logit model is its ability to account for diversity among different options. Specifically, it considers how various wetland qualities, such as area, impact individuals' selections and how much they are prepared to offer.

If the CLM is used, it can control the wetland area better. As a result, the wetland area now has an even stronger influence on WTP: owing to the use of the CLM, a 1% increase in wetland areas now decreases that percentage by an even greater 1.305%. The CL can record people's various responses to such changes in wetland areas. This tells us that the wetland area has a direct and significant effect on WTP as one attribute of choice options. When the CLM is not used, the model may not completely control the wetland area as a choice option consequence and may underestimate its impact on WTP (a decrease of only 0.674%). Without the CLM, a model may wrongly assume that differences between choice options are small and fail to distinguish how wetland area influences WTP. Thus, the negative effects on wetland areas are underestimated.

Table 6. Comparative analysis between the use of CLM (Conditional Logit Model) and Nonuse of CLM (Conditional Logit Model)

	(1)	(2)
	CLM=1	CLM=0
VARIABLES	lnWTPV	lnWTPV
lnWA	-1.112**	-0.597***
	(-2.748)	(-3.311)
lnSN	3.417**	-0.404
	(2.367)	(-0.783)
SY	2.951	-1.003***
	(1.095)	(-2.853)
PY	-2.708	1.275***
	(-1.022)	(3.670)
NOA	0.0958	-0.360
	(0.0859)	(-0.702)
lnPGDP	1.572*	0.787*
	(2.046)	(2.007)
CUL	2.564	1.965
	(1.047)	(1.661)
BIO	1.953	1.063
	(0.964)	(0.818)
Constant	-503.1	-547.1*
	(-1.229)	(-2.022)
Observations	18	31
R-squared	0.617	0.691

Robust t-statistics in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

According to Table 7, a study in wetlands revealed that with the RPLM, as the wetland area increased by 1%, the value of the WTP decreased by 0.833% and passed the 1% significance test. Without it, an increase in the same proportion of wetland areas resulted in a 0.396% decrease in WTP, which was not significant at the 10% level. The RPLM reflects people's different attitudes toward wetland area change. Therefore, the marginal effect of wetland area on WTP (decrease of 0.833%) is greater, which is just the model's advantage. The parameters in the model can also vary randomly among people, providing a better reflection of the spread of opinions concerning how much wetlands should be paid among all different members of the society. Regardless of whether the model uses RPLM or not, the results are unambiguous: willingness to pay decreases as wetland area increases. This might be because larger wetland areas incur higher economic costs or decrease the marginal utility of wetlands for people. When RPLM is applied, the negative effect of the wetland area on people's willingness to pay is significant and passes the 1% significance test.

Table 7. Comparative analysis between the use of RPLM (random parameter logit mode) and nonuse of RPLM (random parameter logit mode)

	(1)	(2)
	RPLM=1	RPLM=0
VARIABLES	lnWTPV	lnWTPV
lnWA	-0.833***	-0.396
	(-4.491)	(-1.610)
lnSN	0.169	0.109
	(0.191)	(0.0966)
SY	-0.966	-0.618*
	(-1.319)	(-1.827)
PY	1.296*	0.797**
	(1.868)	(2.433)
NOA	-0.134	-0.387
	(-0.164)	(-0.687)
lnPGDP	1.582**	0.480
	(2.779)	(0.879)
CUL	0.534	2.102
	(0.464)	(1.667)
BIO	0.0917	2.511
	(0.0516)	(1.540)
Constant	-671.1	-358.7
	(-1.537)	(-1.417)
Observations	22	27
R-squared	0.790	0.318

Robust t-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

When applying the RPLM, the complex model adeptly captures nuances between individuals, enabling a more precise portrait of how wetland areas shape one's readiness to pay. Therefore, in wetland research, which accounts for the diversity in what people value for wetland protection, the RPLM offers a preferable selection. This intricate model provides a more thorough and dependable economic evaluation of wetland conservation policies, which remained consistent with several previous studies [39][40][41]. The findings reveal that the RPLM estimated reduction in WTP is more sizable. Such heterogeneity in viewpoints yields models that are more sensitive than standardized approaches are, particularly where preferences diverge substantially between people.

According to Table 8, the meta-analysis explored how the wetland area impacts WTP via different valuation models. When the mixed logit model was assessed, the study revealed that a 1% increase in wetland acreage led to a 0.107% decrease in WTP, although this outcome lacked statistical significance. In comparison, without applying the mixed logit approach, a 1% increase in wetland extent resulted in a 0.882% reduction in what people were willing to pay, confirming significance at the 1% level. This divergence in findings suggests that the mixed logit model captures more diversity in how individuals respond, leading to a broader spread in the estimated impacts. The systematic review therefore demonstrated that accounting for preference heterogeneity strengthened the validity of assessing the economic value of ecosystem services such as wetlands.

Table 8. Comparative analysis between the use of MXLM (mixed logit model) and the nonuse of MXLM (mixed logit model)

	(1)	(2)
	MXLM=1	MXLM=0
VARIABLES	lnWTPV	lnWTPV
lnWA	0.107	-0.882***
	(0.714)	(-4.554)
lnSN	-0.501	0.813
	(-0.676)	(0.812)
SY	-1.016***	-0.669*
	(-7.407)	(-1.921)
PY	1.220***	0.928***
	(6.376)	(2.886)
NOA	-0.305	-0.616
	(-1.031)	(-0.990)
lnPGDP	0.288	0.882
	(0.701)	(1.538)
CUL	2.544*	1.419
	(2.199)	(1.326)
BIO	-2.068*	2.461*
	(-2.500)	(1.910)
Constant	-408.6	-522.2*
	(-1.230)	(-1.877)
Observations	14	35
R-squared	0.846	0.588

Robust t-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

The MXLM considers individual variations in reaction to changes in wetland size, resulting in a more widespread prediction. This heterogeneity signifies that for some individuals, the impact of wetland areas is minimal, or perhaps even growth in wetland areas could lead to a greater WTP for certain people. As a result, the overall alteration in willingness to pay is smaller, and it is challenging to achieve statistical importance. In contrast, if the MXLM is not used, the model presumes that all individuals reply to changes in wetland areas uniformly, resulting in more concentrated estimates. This makes the impact of wetland areas look stronger, leading to higher levels of statistical importance.

According to Table 9, the statistical analysis revealed a notable reduction in willingness to pay for every 1% increase in wetland terrain when the multinomial logit model approach was used. As denoted in Table 9 of the systematic review and meta-analysis of wetland studies, a single percentage rise in an area was correlated with a 1.107% decrease in monetary value at the 5% significance level. In stark contrast, overlooking the multinomial logit model technique showed that an equivalent 1% expansion triggered a 0.507% drop in willingness to spend, achieving a heightened statistical significance of 1%. Additional studies are warranted to test whether more nuanced models can provide enhanced insight into the monetary assessment of various types of wetland preservation.

While the MNLM assumes that people react similarly to changes in wetland areas, ignoring the fact that people react differently, this assumption averages the effects of wetland areas across people, leading to a greater expected decrease in the WTP of 1.107%. In contrast, without the MNLM, the display considers heterogeneity among people's inclinations and permits shifting reactions to shifts in swamplands. Consequently, the anticipated impact of the wetland region on WTP is more limited, at a decrease of only 0.507%, which more precisely mirrors the assorted qualities and preferences of singular people.

According to Table 10, when lnWESV is used as the dependent variable, the analysis reveals that for every 1% increase in lnWA, lnWESV increases by 0.337%, and the 5% significance test reveals that for every 1% increase in the wetland area, the ecological service value of the wetland increases by 0.337% [15]. The greater the area of wetlands is, the more effective these services can be provided. For this reason, their overall value is enhanced. While the marginal increase in value per unit area may diminish, the sum of the ecosystem services continues to increase because wetlands can provide these benefits more widely and with greater capacity. In areas where wetlands are somewhat scarce, a small increase in wetland area can greatly enhance the ability of an ecosystem to serve crucial services. As a result, it contributes to the overall value.

In addition, wetlands benefit the balance of many species and maintain ecological stability. As the size of wetland areas increases, they can support more species and thus increase the resilience and stability of ecosystems. This increased ecological resilience increases the capacity of ecosystems to withstand environmental changes or shocks such as floods, droughts, and climate change. This, in return, further increases their perceived value. More extensive wetland areas will offer opportunities for better recreational facilities, tourism, and educational purposes, which adds to the social and economic value of those ecosystems. In regions where wetlands are an integral part of people's lives, even a slight expansion will produce significant economic benefits to local people. This underscores the importance of maintaining and expanding such locales.

Table 9. Comparative analysis between the use of MNLM (multinomial logit model) and nonuse of MNLM (multinomial logit model)

	(1)	(2)
	MNLM=1	MNLM=0
VARIABLES	lnWTPV	lnWTPV
lnWA	-1.107**	-0.507**
	(-3.294)	(-2.658)
lnSN	2.461**	-0.807
	(3.105)	(-1.632)
SY	-0.942**	-0.812**
	(-2.588)	(-2.106)
PY	0.879	1.205***
	(1.787)	(3.171)
NOA	-2.199**	0.0243
	(-3.300)	(0.0362)
lnPGDP	0.481	0.183
	(0.901)	(0.504)
CUL	3.905**	0.911
	(3.120)	(0.740)
BIO	3.698**	1.621
	(2.616)	(0.970)
Constant	129.4	-782.2**
	(0.262)	(-2.500)
Observations	17	32
R-squared	0.868	0.610

Robust t-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 10. lnWESV is the dependent variable

	(1)
VARIABLES	lnWESV
lnWA	0.337**
	(2.121)
lnSN	0.301
	(0.403)
SY	-0.832**
	(-2.630)
PY	1.087***
	(3.475)
NOA	-0.400
	(-0.816)
lnPGDP	0.668*
	(1.814)
CUL	1.753*
	(1.829)
BIO	2.009*
	(1.937)
Constant	-511.3**
	(-2.434)
Observations	49
R-squared	0.328

Robust t-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

4. Conclusions

This paper conducts systematic literature review and meta-analysis of wetland ecosystem service valuations based on discrete choice experiments. This study uses the discrete choice experiment method to conduct a meta-analysis of wetland valuation, which is based on 49 independent studies from 22 countries published in Scopus, Web of Science, and Engineering Village before June 2024. The main findings are as follows: the wetland area has a negative impact on WTP values, with an elasticity coefficient of -0.663, indicating that as the wetland area increases, the WTP value decreases. In contrast, the wetland area has a positive impact on the valuation of wetland services, with an elasticity coefficient of 0.337, indicating that as the wetland area expands, the value of all ecosystem services will increase.

The GDP per capita, culture, and biodiversity all have positive effects on the WTP for wetland protection, each passing the 10% significance test. With GDP per capita rising, local people and tourists in highly developed societies are typically more able and willing to pay for collective goods such as ecological protection. This implies that higher levels of living income correlate with higher support for wetland conservation. Cultural elements, such as local practices and heritage conservation, also have an appreciated influence on WTP as well. As cultural attributes associated with wetland services increase, people’s willingness to pay to protect them increases, suggesting the need to integrate cultural value into conservation plans. The WTP is strongly enhanced by the importance of biodiversity (species richness, habitat diversity, and endangered species protection). Most importantly, people are willing to pay more for wetland protection when these ecosystems provide a home for a broad variety of life forms, highlighting the high value of the conservation of biodiversity.

When the impact of wetland areas on willingness to pay in developed and developing countries is compared, it is found that for every 1% increase in wetland area in developed countries, WTP decreases by 0.966%. However, for every 1% increase in wetland area in developing countries, the willingness to pay decreases by 0.688%. The negative effect of wetland areas on the willingness to pay in developed countries is greater than that in developing countries.

When comparing the impact of the wetland area on the willingness to pay across different models—CLM, RPLM, MXLM, and MNLM, it was found that the negative effect of wetland area on willingness to pay was more pronounced when certain models were used. Specifically, when the Conditional Logit Model (CLM) was applied, the willingness to pay decreased by 1.112% for every 1% increase in wetland area. In contrast, when CLM was not used, the decrease in willingness to pay was 0.597%. Similarly, using the Random Parameter Logit Model (RPLM) resulted in a 0.833% decrease in willingness to pay for every 1% increase in wetland area, whereas without the RPLM, the decrease was only 0.396%. The Multinomial Logit Model (MNLM) also showed a greater reduction in willingness to pay, with a 1.107% decrease for each 1% increase in the wetland area, compared to 0.507% when MNLM was not used. This indicates that the negative effect of the wetland area on willingness to pay was stronger when CLM, RPLM, and MNLM were applied, and these effects were statistically significant. On the other hand, when the Mixed Logit Model (MXLM) was not used, willingness to pay increased by 0.882% for every 1% increase in wetland area, a result that passed the significance test. However, when the MXLM was used, the increase was only 0.193%, which did not pass the significance test. This suggests that the negative effect of wetland area on willingness to pay is more significant when the MXLM is not included. Based on these findings, this study provides key policy recommendations for effectively considering wetland areas in conservation strategies.

These results suggest that larger wetlands may carry more economic worth per unit area basis than smaller wetlands do because they bear in mind a greater average return for the large ecosystem services supplied by highperforming sites. Some possible reasons for the opposite relationship are lower returns per hectare, meaning that adding more hectares of wetland does not add much to the overall value of the ecosystem service, or there are more differences between sites regarding in-stream subsidies. For example, larger wetlands might offer greater recreation yields or water filtration services per unit area, and flood defense values could be positive but decrease as soon as nearby flooding has been prevented. These results are important for policy and practice. Although the use of resources to protect wetlands may provide significant total social benefits, any such efforts must consider decreasing marginal values per hectare if they are cost effective. Additionally, the negative elasticity for unit value underscores that we should dimension and manage wetland areas according to ecological, economic, and social objectives.

The findings also offer a reminder to practitioners, such as environmental managers and conservationists, that it is important to evaluate both the total value of wetlands and their per-unit value while planning interventions. This suggests that restoration projects should aim at increasing both the wetland area and the quality of ecosystem services per unit of the restored area. This could require area-specific management practices to protect key habitats, improve water quality, or increase biodiversity, helping to ensure that the gains from wetland conservation can be realized locally as well as regionally. Future research is needed to investigate why per-unit wetland value elasticity varies negatively, but possible explanations for this result may be examined among different types of wetlands or geographical areas because ecosystem services are valuable. Significant improvement in the accuracy of wetland value estimates that are intended to inform policy decisions should be possible by standardizing these factors. Therefore, policymakers should think about improving the quality and function of existing wetlands rather than expanding them indefinitely. Another way is to increase public support and secure the sustainability of wetland preservation efforts by integrating cultural and biodiversity values into conservation strategies.

To our knowledge, this is the first study to conduct a comparative analysis of different models in the valuation of wetlands through discrete choice experiments. It reveals significant differences regarding the economic estimates. However, it has some limitations, such as the limited richness of the data and sample. The more detailed the attributes, the smaller the sample size we can use. At the same time, the study's focus on discrete choice experiments and its reliance on specific valuation models leave room for further exploration into how other methods, such as contingent valuation or benefit transfer, might provide additional insights. Future research could explore the differences in wetland service valuation across different wetland types or geographical regions to refine conservation strategies further.

5. Policy Recommendations

Based on the above research findings, this paper suggests the following policy recommendations:

Wetlands provide a wide range of ecosystem services. Decision-makers should integrate wetland appraisals into land-use planning, conservation strategies, and cost-benefit analyses. Given the findings from meta-analyses, which reveal that an expansion in wetland areas results in a lower marginal willingness to pay (WTP), policies should prioritize enhancing the quality and functionality of existing wetlands rather than focusing solely on area expansion. This approach can ensure better returns on ecosystem services.

Recognizing that wetlands deliver a variety of high-value ecosystem services, conservation efforts should be designed to maximize these benefits. Policies could include targeted interventions in areas where services such as flood control, water purification, and carbon sequestration have been undervalued or overlooked. Additionally, in regions where wetlands contribute significantly to livelihoods, governments and international donors could implement economic incentives to encourage local communities and stakeholders to actively participate in wetland conservation.

Additionally, the study highlights distinct differences in response to wetland area changes between developed and developing countries. In developed countries, policies should focus on improving the quality and provision of specific ecological services within existing wetlands. In contrast, in developing countries, both expanding wetland areas and enhancing their quality should be pursued simultaneously to address ecological and socio-economic needs.

According to the review of related studies, most studies have focused on public valuation and paid insufficient attention to getting stakeholders involved in the valuation. Stakeholder involvement is critical to ensure practical applicability. Therefore, collaborating with policymakers, local communities, and conservation organizations in future research designs can help ensure that findings address real-world challenges and needs, and foster broader acceptance and support for conservation policies.

Future research should focus on understanding mechanisms to make wetland ecosystems more robust and resilient to global environmental changes, such as climate change. This could include examining how wetland quality interacts with species richness and ecosystem functionality across various wetland sizes. Additionally, there is a pressing need for expanded valuation studies to capture the ecosystem services of underrepresented wetland types, particularly in developing regions. These efforts can provide a fuller picture of the global value of wetlands and guide investment priorities effectively.

Appendix

Table 11. List of developed countries and developing countries list

Developed countries	Developing countries
Australia	Bangladesh
Belgium	Belarus
Canada	China
France	Colombia
Netherlands	Ecuador
Korea	Ethiopia
Spain	India
United Kingdom	Indonesia
United States	Islamic Republic of Iran
	Kenya
	Poland
	Thailand
	Vietnam

Arranged according to IMF classification

According to the classification by the International Monetary Fund (IMF), the developed countries in the research sample include Australia, Belgium, Canada, France, Netherlands, Korea, Spain, the United Kingdom, and the United States. The developing countries in the research sample include Bangladesh, Belarus, China, Colombia, Ecuador, Ethiopia, India, Indonesia, the Islamic Republic of Iran, Kenya, Poland, Thailand, and Vietnam.

Table 12. Estimation methods when using discrete choice experiments are used

Variable	Full variable name
CLM	Conditional Logit Model
RPLM	Random Parameter Logit Model
MXLM	Mixed Logit Model
MNLM	Multinomial Logit Model

The estimation methods for discrete choice experiments include Conditional Logit Model (CLM), Random Parameter Logit Model (RPLM), Mixed Logit Model (MXLM), and Multinomial Logit Model (MNLM). The estimation methods commonly used in discrete choice experiments include the Conditional Logit Model (CLM), Random Parameter Logit Model (RPLM), Mixed Logit Model (MXLM), and Multinomial Logit Model (MNLM). These models differ in their assumptions and flexibility in modeling choice behavior. CLM assumes independence between choices, while RPLM and MXLM introduce randomness to capture heterogeneity among individuals, with MXLM allowing both individual and choice parameters to vary randomly. MNLM is suited for multi-category choices but assumes independence between choices, which may lead to biases. The specific application of regression methods is discussed in detail in the main text.

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