

Systematic Review

The Synergy Between the Travel Cost Method and Other Valuation Techniques for Ecosystem Services: A Systematic Review

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Abstract

This systematic review examined how the Travel Cost Method (TCM) works together with other valuation methods, such as stated and declared preferences, to improve estimates of total economic value (TEV). Despite the widespread use of TCM, no systematic synthesis has examined how its integration with complementary methods enhances TEV estimation across different ecosystems and geographical contexts. Following PRISMA guidelines, we conducted searches in Scopus and Web of Science, identifying 245 records. After the screening process, 57 studies remained for analysis. Results show that 74% of the studies combined TCM with Contingent Valuation Method (CVM), and 12.3% with Choice Experiment (CEM). Three chronological phases were identified: early domination by the United States (1985–2000), international expansion and diversification (2001–2015), and recent methodological innovation led by China (2016–2024). Forest and recreational ecosystems accounted for 25% of applications, followed by marine-coastal (21%). Within cultural ecosystem services, the subcategory of physical and experiential interactions predominates with 63.1%. Comparative analysis indicates that TCM systematically produces higher and more variable monetary estimates than CVM, reflecting its sensitivity to travel behavior and spatial scale, while stated preference methods provide more stable estimates of non-use values. Persistent methodological limitations include non-probabilistic sampling and uneven ecosystem coverage. This review advances the literature by providing the first comprehensive synthesis of integrated TCM applications, demonstrating how methodological combinations strengthen TEV estimation beyond single-method approaches. The findings offer practical guidance for policymakers designing environmental impact assessments, environmental managers selecting valuation tools tailored to ecosystem and management objectives, and researchers seeking standardized and robust frameworks for integrated ecosystem service valuation.



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Keywords: total economic value; contingent valuation; choice experiment; market price; benefit transfer; cultural ecosystem services; recreation demand

1. Introduction

Economic valuation of the environment is used to assess the value of nature and its resources [1,2]. It has been applied in a variety of contexts, such as wildlife conservation [3], ecosystem services and public goods valuation [4]. It helps to set priorities, understand opportunity costs, and advocate for conservation efforts. It also contributes to the improvement of state regulation of natural resources management [5], as well as the environment and society [6]. Sustainable Development Goal 15 (ODS 15) “Life on land”, establishes the integration of ecosystem and biodiversity values into local and national planning [7] as one of its targets.

Total Economic Value (TEV) refers to the totality of values comprising environmental assets due to their multiple functions and benefits generated for society [8]. According to Pearce [9], the TEV is composed of Use Value (UV) and Non-Use Value (NUV). The UV includes Direct Use Value (DUV), linked to the direct consumption of goods and services; Indirect Use Value (IUV), related to ecological functions that support human welfare; and Option Value (OV), which reflects the value of maintaining the possibility of future use. The NUV includes Bequest Value (BV), associated with preserving resources for future generations, and Existence Value (EV), which captures the satisfaction derived merely from knowing that a natural resource or ecosystem exists, regardless of current or future use.

Ecosystems offer a diverse range of services, including provisioning, cultural, regulating, and supporting, which is a classification that stems from their material and immaterial value [10]. According to Haines-Young and Potschin [11], provisioning services are material outputs such as food, water, timber, and energy, while regulating and supporting services contribute indirectly through ecological functions. Cultural services encompass the non-material benefits associated with recreation, identity, and spiritual value. Overall, ecosystem services represent the direct and indirect benefits that humans obtain from natural ecosystems.

In the scientific literature on environmental economic valuation, we found several classifications of ecosystem services, such as those presented by the Millennium Ecosystem Assessment (MA) [12], the Economics of Ecosystems and Biodiversity (TEEB) [13], and Common International Classification of Ecosystem Services (CICES) [14]. These services connect nature with human well-being and are essential for people’s survival, economic development, and health [15].

According to Haines-Young [15], the CICES ecosystem services are defined as the contributions that nature makes to human well-being, as well as the goods and benefits that people subsequently derive from these contributions. The latest version of CICES classifies ecosystem services into three classes: provisioning, regulation and maintenance, and cultural. The methods Travel Cost (TCM) and Contingent Valuation (CVM) are more frequently employed in the context of cultural services [16]. The most frequent cultural services evaluated are related to recreation and ecotourism.

According to Cheng et al. [17], to value the cultural ecosystem services, the second method most used is the TCM, after the Market Price Method. The TCM was developed in the 1940s by Harold Hotelling [18]. This development was initiated at the request of the United States National Park Service, which sought a methodology to economically assess the esthetic, recreational, scientific, and social benefits provided by national parks. This method prioritizes the assessment of visitor contributions through the utilization of recreational services.

Cultural services refer to spiritual and religious values, esthetic values, recreation, and ecotourism [10]. According to Haines-Young [15] the updated classification of cultural ecosystem services comprises the following categories: physical and experiential interactions with natural environment, intellectual and representative interactions with natural

environment, and spiritual, symbolic and other cultural interactions with natural environment. An adaptation based on the Common International Classification of Ecosystem Services (CICES) 2023 is provided in Supplementary Material Table S1, outlining the types of cultural ecosystem services.

Several bibliographic review studies have addressed the economic valuation of environmental services, including reviews of the ecosystem services provided by estuaries, systematic reviews of methods applied to cultural ecosystem services [17], studies valuing ecosystem services at the urban scale [16], analyses of the valuation of environmental public goods and services across different spatial scales [19], and reviews of forest ecosystem services and their spatial value characteristics [20]. In addition, Wood et al. [21] conducted a global systematic review of the cultural ecosystem services provided by wetlands.

Cáñez-Cota [22] conducted a systematic review of the application of the Travel Cost Method (TCM) to the economic valuation of protected natural areas. In addition, Rolfe and Dyank, and Armbrrecht [23,24] conducted studies comparing the convergence between the Travel Cost Method (TCM) and the Contingent Valuation Method (CVM). However, while individual applications and pairwise comparisons of TCM and CVM are well-documented, systematic evidence on the methodological synergies, geographical patterns, and comparative monetary outcomes of integrated valuation approaches remains fragmented. To date, no study has comprehensively examined the combined application of the Travel Cost Method (TCM) with other environmental economic valuation methods.

This systematic review addresses this gap by providing the first comprehensive synthesis of studies that apply TCM in combination with other valuation approaches, examining their temporal evolution, geographic distribution, and the types of ecosystems in which they have been implemented. Accordingly, this study seeks to answer the following research questions:

- i. How has the integration of TCM with other valuation methods evolved geographically and temporally?
- ii. Which method combinations are most frequently applied and in which ecosystem types?
- iii. Which method combinations are most frequently applied and in which cultural ecosystem services
- iv. How do monetary estimates vary across methods and ecosystems?
- v. What are the main advantages and limitations of methodological integration?

This paper is organized as follows: Section 2 outlines the theoretical framework and valuation methods; Section 3 describes the systematic review methodology; Section 4 presents the main results on methodological integration, geographic and temporal patterns, and monetary outcomes across ecosystems; Section 5 discusses key findings and limitations; and Section 6 concludes with implications and future research directions.

2. Theoretical Framework

Environmental Economic Valuation Methods

The most common methods in environmental economic valuation are stated preferences and revealed preferences, along with others such as market-based methods and benefit transfer [25]. The most widely used method in the economic literature is CVM, which can estimate any value within the TEV. However, it has the weakness that the valued object cannot be disaggregated among its attributes [26]. Revealed preference methods, such as TCM, estimate the value that people assign to a natural resource from their observed behavior, such as the expenses incurred when visiting a recreational site; their strength lies in the use of real data, although they only allow for estimating direct use values [27,28].

In contrast, stated preference methods, such as the CVM or Choice Experiments (CEM), rely on surveys to pose hypothetical scenarios in which individuals are queried about their willingness to pay (WTP) for the conservation or enhancement of environmental goods. These methods allow for capturing both use and non-use values (existence, bequest, altruism). The combination of both approaches has been recommended to obtain more robust and complete estimates of the total value of ecosystems [29]. Table 1 presents the classification and core concepts of the main environmental economic valuation methods.

The economic valuation of ecosystem-related benefits is grounded in the distinction between revealed preferences and stated preferences, which capture different dimensions of economic value across multiple categories of ecosystem services [23]. In particular, the Contingent Valuation Method (CVM), which relies on stated preferences, elicits individuals' willingness to pay under hypothetical scenarios. As such, CVM is well-suited to capture a broad spectrum of values, including both use and non-use components associated with cultural, provisioning, and regulating services [23].

TCM as a revealed preference approach derives use values from observed behavior by linking visitation or participation rates to the travel and time costs incurred by users [23]. Indeed, a comprehensive review of the literature on TCM demonstrated that this method is specifically designed to estimate the use value of protected natural areas, rather than their market value per se [22]. Similarly, in the context of forest biodiversity valuation in a study in Mexico, Romo-Lozada et al. [30] found that almost all valuation studies in forest biodiversity undertaken in the country are restricted TCM and contingent valuation (CVM) methods. The integration of valuation methods is therefore theoretically and empirically justified as a response to the multidimensional nature of ecosystem services [24].

Table 1. Classification and core concepts of environmental economic valuation methods.

Valuation Method	Type Method	Core Concept
Methods of revealed preferences	Travel Cost	The TCM estimates recreational value of natural sites by analyzing the actual travel expenses incurred by visitors [31]. The Individual TCM, its most common variant, uses survey data on trip costs, visitation frequency, and socioeconomic characteristics to generate realistic use value estimates, supporting decisions on access fees, site management, and investment planning [22].
	Hedonic Pricing	The HPM estimates the value of environmental attributes by measuring how they influence the prices of market goods, such as housing [25,32]. It assumes that market prices embed multiple characteristics, including environmental factors like air quality and proximity to natural areas [25,32].
	Avoided Cost	The ACM is used to estimate the costs incurred to avoid or reduce undesired negative effects [24]. The necessary condition is that ecosystem services directly influence economic agents and that the application of strategies to avoid or reduce undesired impacts is feasible [33].
	Replacement Cost	The RCM estimates the monetary value of ecosystem services by calculating the cost of replacing lost ecological functions with artificial alternatives [34]. It does not rely on surveys but instead uses technical and economic data on feasible substitutes, making it suitable for valuing services like water regulation, erosion control, and air purification [35].
Methods of declared preferences	Contingent Valuation	The CVM estimates individuals' willingness to pay for environmental goods that lack market prices by presenting hypothetical scenarios through surveys. It captures both use and non-use values, making it especially useful in protected areas and settings where communities depend heavily on natural resources [25,35].
	Choice Experiment	The CEM uses structured choice scenarios to estimate the marginal willingness to pay for specific ecosystem attributes, allowing values to be decomposed into environmental, cultural, and recreational components [33]. By inferring preferences from repeated choices, it provides detailed insights into attribute-specific trade-offs and effectively captures non-tangible benefits in complex, multi-service ecosystems [35–37].
Value Market Method	Market Price	The MPM values ecosystem goods and services traded in formal markets by combining quantities with prevailing prices, assuming these reflect consumers' willingness to pay [38,39]. Widely applied in wetlands and lakes across diverse activities, MPM provides realistic economic values that support environmental management and policy decisions [38,40].
Benefit Transfer technique	Benefit Transfer	The BTM estimates ecosystem service values in areas lacking primary data by transferring results from previously studied sites [41,42], making it a cost-effective and time-efficient tool for policy and environmental management [43]. It can be applied through value transfer, function transfer, or meta-analytic approaches that account for contextual differences to improve accuracy [25,41].

3. Materials and Methods

3.1. Systematic Review Protocols

This systematic and critical review aims to provide a comprehensive analysis of the existing literature on the subject. In order to enhance the transparency, the PRISMA methodology will be employed [44]. I attach the PRISMA flow diagram in Figure 1, and the checklist in the Supplementary Material Table S2. I also attach the systematized information in the Supplementary Material Table S3.

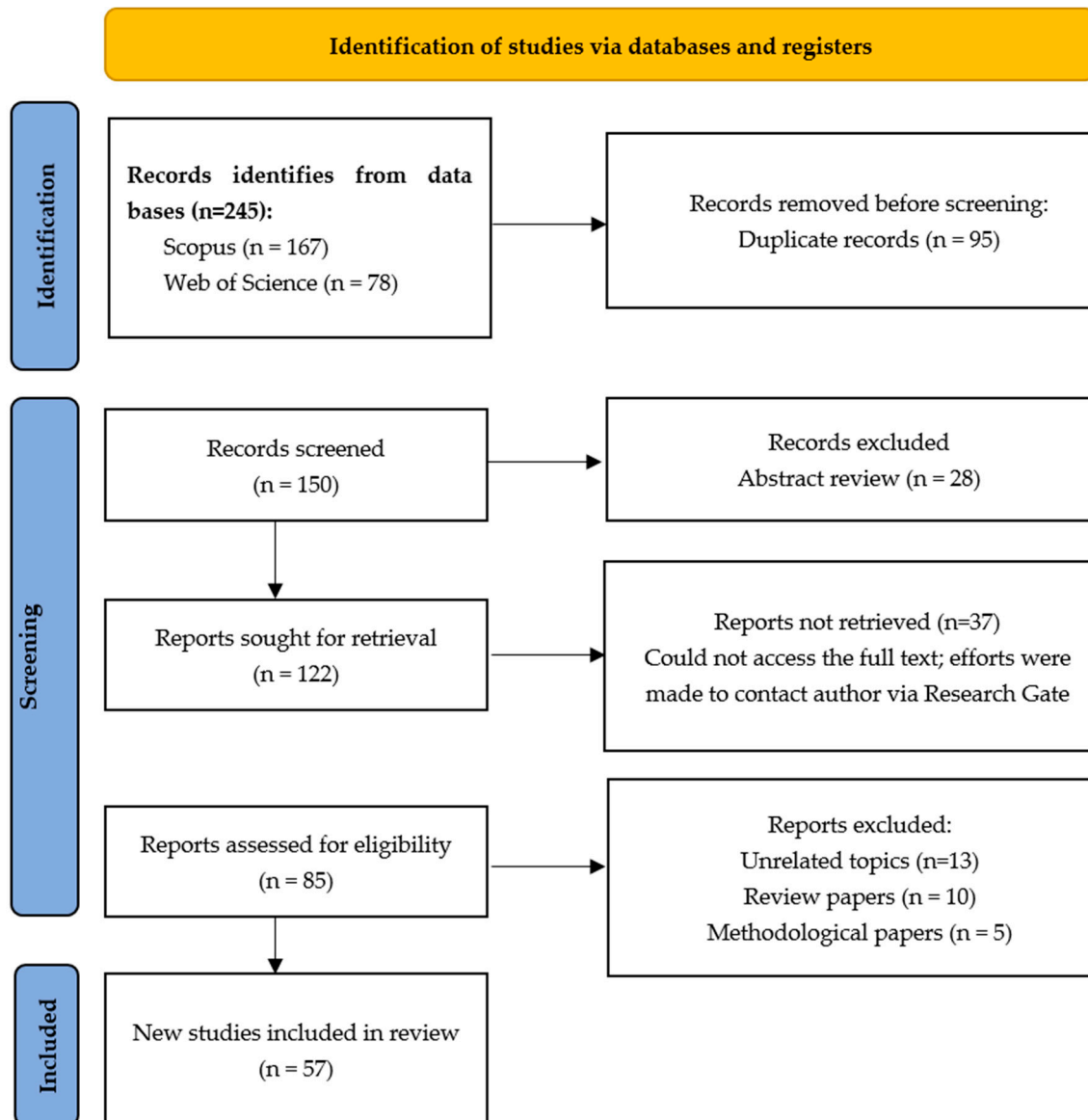


Figure 1. The PRISMA 2020 flow diagram for our papers.

3.2. Literature Search Protocol

This study analyzed original articles indexed in the bibliographic databases of the scientific literature Scopus (<https://www.scopus.com/>, accessed on 30 May 2025) and Web of Science (<https://clarivate.com/webofsciencegroup/solutions/web-of-science/>, accessed on 30 May 2025). These two databases are among the largest repositories of peer-reviewed scientific literature, characterized by a transparent public process. We only include articles that have been peer-reviewed and published in English and Spanish. No year filter was applied; all retrieved documents were included.

We excluded conference abstracts, conference proceedings, reports, book chapters, dissertations, and technical reports. Only peer-reviewed journal articles were included, as this study analyzes the scientific application of the methods in real cases. Reference to the term “travel costs” in the literal sense and not as a method of economic valuation is also excluded.

This study examines articles that employ the TCM in conjunction with other methods of economic environmental valuation. We searched studies that apply TCM with revealed preference (RP) and stated preference (SP), as well as hedonic pricing, avoided cost, contingent valuation, and choice experiments. We use the following keywords in the search fields: (“travel cost method” AND “contingent valuation method”), (“travel cost method” AND “choice experiment”); (“travel cost method” AND “hedonic pricing method”); and (“travel cost method” AND “avoided cost method”). During the comprehensive review of the articles, additional methods, namely the MPM, BTM, and RCM, were identified and included in the analysis of the results and the discussion. The search strings and corresponding results are provided in Supplementary Material Table S4.

The search was conducted in the title, abstract, and keyword fields of both databases on 30 May 2025. As shown in Figure 1, the queries retrieved 167 records from Scopus and 78 from Web of Science. After removing duplicate entries, 90 unique papers remained. During the screening phase, 28 records were excluded based on abstract review, and 37 could not be retrieved. A total of 85 full-text articles were assessed for eligibility; studies that were unrelated to the topic, review articles, and methodological papers were excluded at this stage. Ultimately, 57 articles were included in the final analysis.

3.3. Data Extraction Protocol

A comprehensive review of the 57 papers included in the study was conducted to ascertain the country or countries in which the research was conducted, the authors, the methods applied, the types of ecosystems and activities evaluated, the monetary results of the individual methods, the type of ecosystem services evaluated, the subtypes of cultural ecosystem services evaluated, the advantages of applying the methods, and the limitations of the studies. Zotero (Version 7) was used to manage all references during the analysis of the text, as well as to support the writing of the manuscript and the organization of citations and the bibliography.

Data extraction was performed independently by two reviewers using a standardized extraction form (see Supplementary Material Table S5). Extracted variables included: study location, year, ecosystem type, valuation methods applied, sample size, sampling method, monetary results (with units and reference year), advantages reported, and limitations. Discrepancies were resolved through consensus. Inter-rater reliability was assessed using Cohen’s kappa coefficient ($\kappa = 0.87$, indicating high agreement).

Descriptive statistics (mean, standard deviation, min, max) were calculated for monetary values after inflation adjustment. Given the non-normal distribution of economic values, we also report median values and consider the use of non-parametric tests where appropriate.

3.4. Quality Assessment

Each included study was assessed for methodological quality considering the following: (1) the application of the methods in real cases, (2) the sampling method and sample size adequacy, (3) the clarity of valuation methods description, (4) the potential sources of bias. Two independent reviewers conducted the assessment, with disagreements resolved through discussion.

3.5. Ecosystems Classification

The studies were applied to various natural and cultural assets. To enhance the analysis, the subjects were categorized into six classifications, with consideration given to the Updated Nomenclature Guide of the European Topic Centre on Urban, Land and Soil Systems [45], the Information Sheet on Ramsar Wetlands [46], and the International Union for Conservation of Nature [47].

- Marine-coastal. This category encompasses ecosystems associated with the open sea, coastline, beaches, mangroves, estuaries, coastal lagoons, reefs, and other related environments.
- Natural continental waters. This category encompasses rivers, lakes, and wetlands, among other water bodies.
- Artificial continental waters/infrastructure. This category encompasses reservoirs, dams, urban lakes, and other water-related infrastructure.
- Forest land and recreation. This classification encompassed forests of all types, mountains, and other related ecosystems.
- Agriculture/plantations. The category in question encompasses rice paddies, forest plantations, oil palm plantations, and other related ecosystems.
- Urban-cultural. The category in question encompassed a wide array of urban green spaces, including urban parks, green infrastructure, city parks, green areas in cities, museums, cultural institutions, mosques, sporting events, and other related ecosystems.

4. Results

4.1. Geographic Distribution of Studies According to the Combined Methods Applied

The findings indicate that the United States is responsible for the highest scientific output, with 10 publications employing the Travel Cost Method in conjunction with one or more other environmental economic valuation methods, accounting for 17.5%. This finding indicates both predominance and asymmetry in scientific output, as illustrated in Figure 2. The predominance of TCM combinations with CVM is also observed, in addition to more complex variants such as TCM, CVM, and HPM.

In China, five studies were identified, representing 8.8% of the total, primarily combining TCM with CVM (four studies) and one case of TCM with CE. Among these, the following stand out [48–50].

These studies integrated revealed preference approaches with stated preference approaches to capture both use values and specific attributes of recreational services. A similar trend was observed in Taiwan, with four publications representing 7%, focused on TCM with CVM, although some studies incorporated more complex variants such as TCM, CVM, and RCM, and TCM, CVM, and MPM. Examples include Huang et al. [50], Chet et al. [51], and Huang and Wang [52], whose analyses focused on coastal ecosystems such as artificial reefs, flower cultivation, and rice cultivation.

In countries such as India and Australia, the frequent application of TCM in conjunction with CVM was also observed, with the Indian study combining TCM, CVM, and MPM to estimate the value of wetlands. Research conducted by Chaundhry and Teware [53] serves as a prime example of these methodologies in the context of urban forestry. In Australia, the research of Herath [54], and Herat and Kennedy [55] applied these combinations to estimate the economic value of recreational activities associated with lakes and national parks. In Europe, countries such as the United Kingdom, Sweden, and Germany present studies with combinations of TCM with CVM or CE in the context of natural areas and cultural tourism [24,56,57].

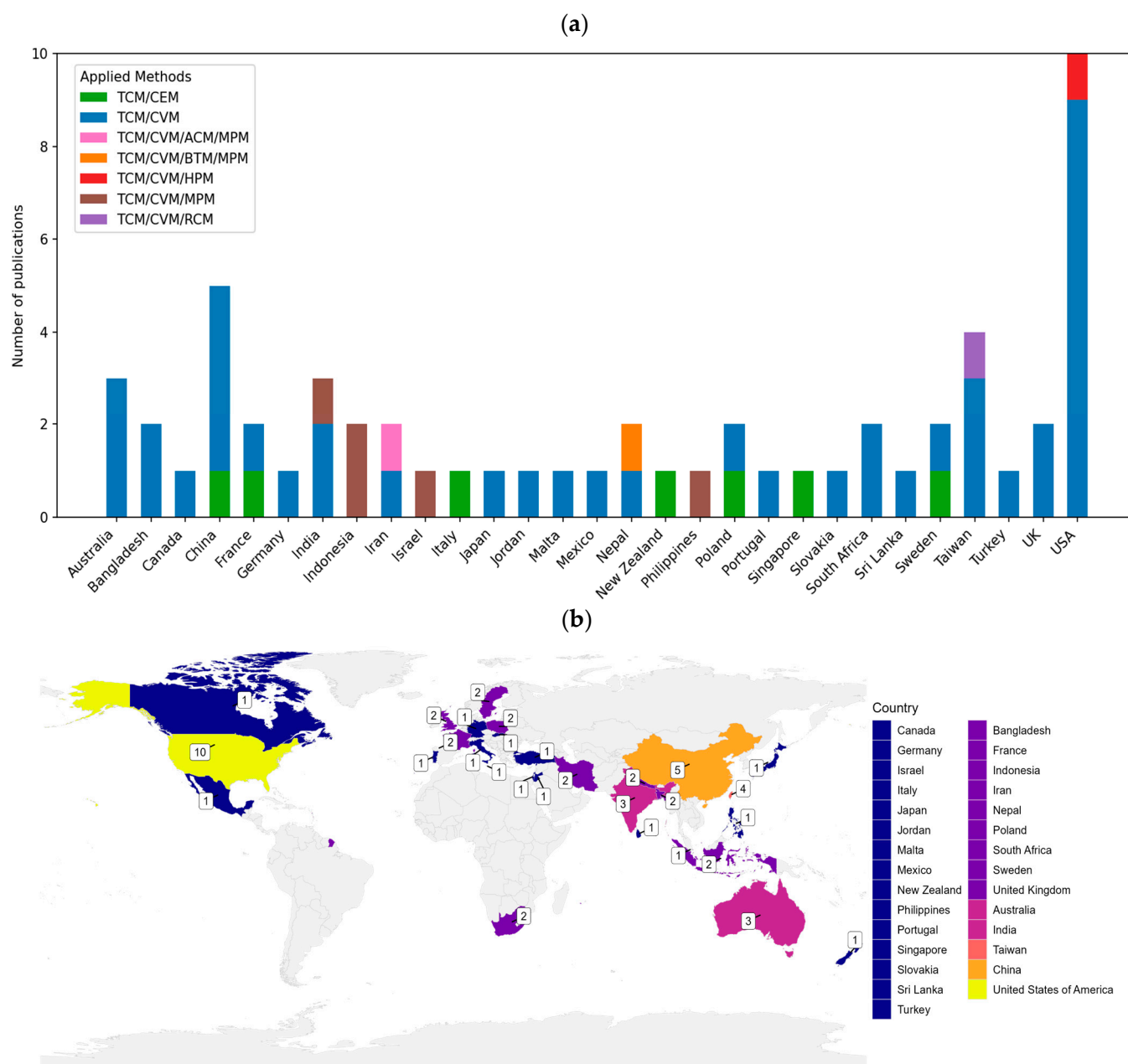


Figure 2. Frequency of publications by country and methods applied together. (a) Frequency of countries by methods. (b) Heat map of country frequencies by methods, the numbers indicate publications by country. Note: TCM/CEM indicates studies that applied these two methods together; the same applies to the other methods separated by a slash.

In developing countries, scientific production in the field of ecosystem service valuation remains at an early stage. In Bangladesh, two publications by Haider et al, [58], and Islam and Farjana [59] are particularly noteworthy for their application of CTM with CVM in eco-parks and mosques. In Iran, two publications by Madani et al [60], and Amirnejad and Jahanifar [29] integrated MPM with TCM. In South Africa, the work of Banda [61], and Digang and Hosking [62] also applied TCM with CVM in studies on water consumption and estuaries. Furthermore, isolated cases were identified in Nepal—Thapa and Lam-sal [63,64]—and in Mexico—Chavez and Fischer [65]—which also focused on combinations of TCM with CVM.

4.2. Evolution of Countries That Applied the Travel Cost Method Alongside Other Valuation Methods over the Years

For clearer visualization in Figure 3, only countries with two or more occurrences were included. As illustrated in this figure, the developmental process can be categorized into three distinct phases. In the initial phase, from 1985 to 2000, the majority of studies were concentrated in North America and primarily focused on water and forest resources. In the subsequent phase, spanning from 2000 to 2015, there was an augmentation in geographical diversification, with experiences in Asia, Europe, Oceania, and Latin America. An exemplar of this can be found in the study by Carandang et al. [66] in the Philippines, wherein mangroves were appraised through the integration of TCM, CVM, and MPM, underscoring the significance of these ecosystems with respect to both recreation and subsistence.

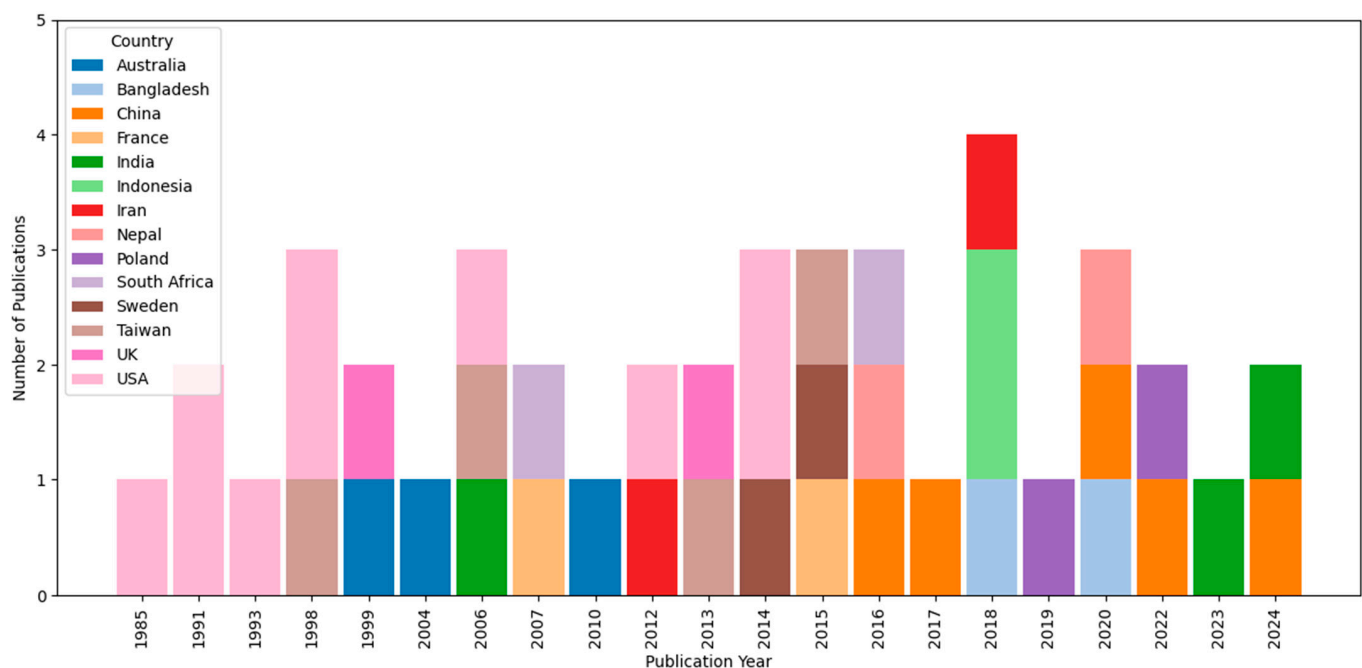


Figure 3. The evolution of publications per country per year, including only those countries with at least two studies. Note. The figure including the complete list of countries is provided in Supplementary Material Figure S1.

The third phase, from 2016 to 2024, is characterized by China's predominance in this type of study, with a greater distribution of countries such as India, Bangladesh, Poland, and Singapore. In addition to greater methodological sophistication, the incorporation of CEM and other methods has been demonstrated to enhance the estimation of ecosystem benefits in complex contexts [33,36]. Although the search was initially focused on TCM combined with the main environmental valuation methods, a thorough review of the articles identified additional methods that were used with some frequency, including MPM, BTM, and RCM.

4.3. The Evolution of Studies That Applied the Travel Cost Method Alongside Other Valuation Methods over the Years

The literature review identified seven combinations of TCM with another method for valuing environmental services, six of which involve TCM with CVM. As shown in Figure 4, there is a marked predominance of the combination of TCM with CVM, with 50 studies using them, equivalent to 88% of the total. Of these, only the two methods were used in 42 studies, equivalent to 74% of the total.

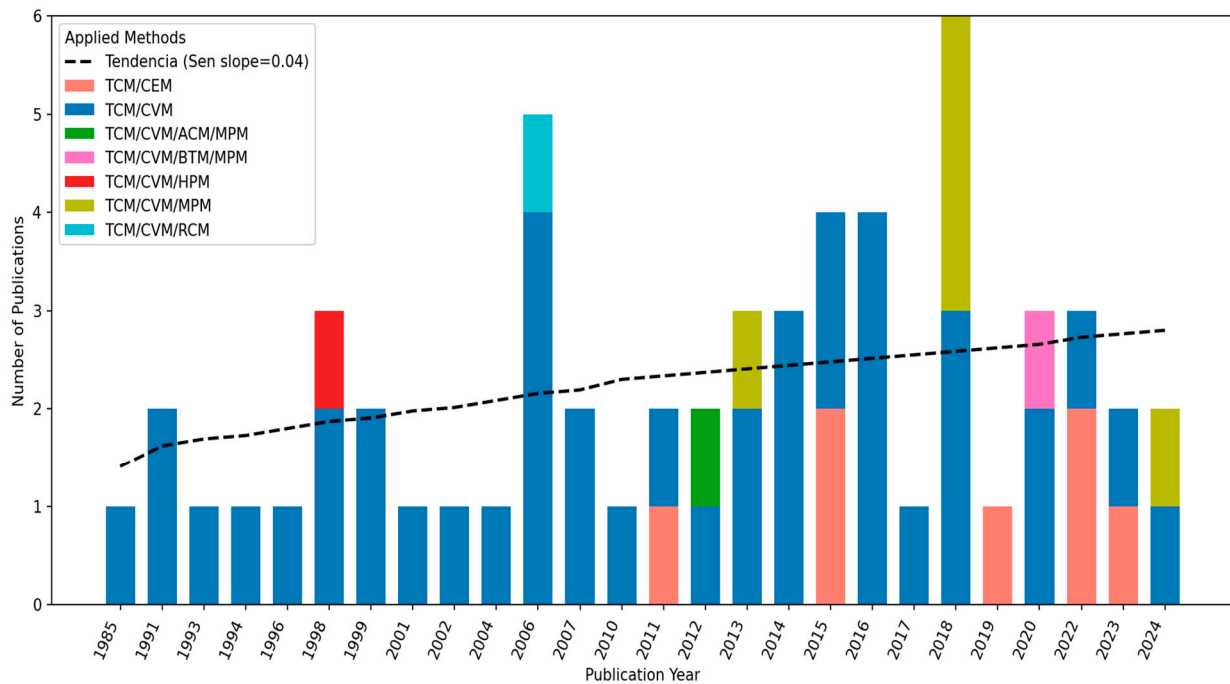


Figure 4. The evolution of publications per year using the Travel Cost Method with the other valuation methods. Note: Evaluated series: Total publications per year. n (years) = 26; statistic $S = 94$; $\text{Var}(S) = 1871.3333$; significance $Z = 2.1498$; two-tailed p -value = 0.031567; Kendall's tau = 0.2892; Sen's slope (publications/year) = 0.0357. Conclusion ($\alpha = 0.05$): a statistically significant increasing monotonic trend is detected.

The second most prevalent combination is TCM with CEM, which is present in seven studies, equivalent to 12.3%. This approach has been used to disaggregate recreational value into specific ecosystem attributes, thereby enabling the prioritization of management improvements for the environment. Xu and He [39], for instance, employed this approach in Haizhu National Park in China to ascertain environmental education and cultural heritage as pivotal attributes. In a similar vein, Bottero et al. [42] employed this approach in Italy to conceptualize an urban park, incorporating variables such as biodiversity, accessibility, and amenities.

To a lesser extent, four studies, equivalent to 7%, employ a combination of TCM, CVM, and MPM methods. This combination has been applied principally in coastal and wetland contexts to simultaneously assess recreational and productive services. Carandang et al. [66] estimated the economic value of the mangroves of Bohol and Palawan, including tourism, fishing, and coastal protection, while Singha et al. [44] applied this scheme to the Sone Beel wetland in India, incorporating agricultural and fishery production into the monetary estimates.

The Mann–Kendall test indicates a moderate, statistically significant upward trend in annual publications, with an estimated average increase of 0.036 publications per year, confirming sustained growth over the study period.

4.4. Cultural Ecosystem Services According to Combined Applied Economic Valuation Methods

According to the Common International Classification of Ecosystem Services (CICES) [14], cultural services are organized into three groups: physical and experiential (e.g., recreation, fitness, and stress relief); intellectual and representative (e.g., nature research and study, and esthetic appreciation and knowledge); and spiritual and symbolic (e.g., sacred or wild places, identity and heritage, and social cohesion).

The aggregate compositions of the studies indicate a distribution of 63.1% in the Physical and experiential cultural service subcategory, 15.5% in Intellectual and representative, and 21.4% in Spiritual and symbolic. This result reflects both methodological and structural patterns within the valuation literature. Most combined applications of TCM and CVM are inherently well-suited for quantifying recreation, visitation, and experience-based benefits, which rely on observable travel behavior and stated preferences regarding use.

As illustrated in Figure 5, when disaggregated by combined methodologies applied, the most prevalent category, TCM with CVM, accounts for 68% of research related to the subcategory of cultural ecosystem services, physical and experiential. The spiritual and symbolic subcategory encompasses 16%, while the intellectual and representative subcategory also comprises 16%.

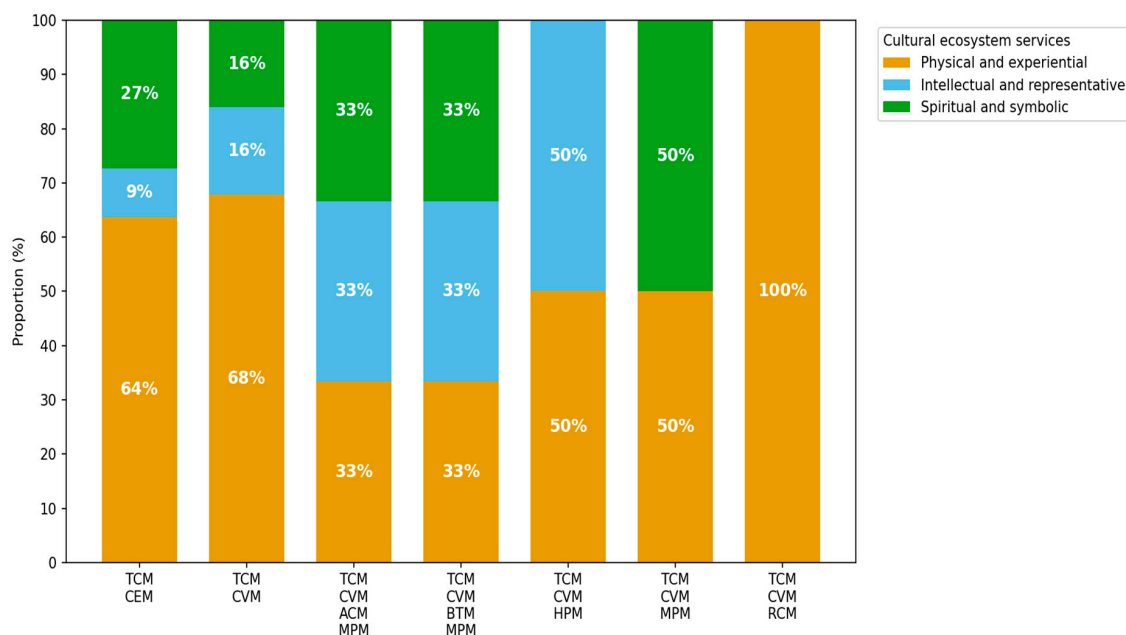


Figure 5. Distribution of cultural ecosystem services by applied economic valuation methods. Note: TCM/CEM indicates the distribution of the type of cultural service that was evaluated by applying these methods together. The same applies to the other methods separated by a slash.

The combination of TCM and CEM, which includes seven studies, shows a distribution of 64% physical and experiential, 27% spiritual and symbolic, and 9% intellectual and representative. The choice experiments demonstrated a prioritization of experiential (e.g., recreational opportunities) and symbolic (e.g., identity and heritage) attributes over intellectual ones. The TCM, CVM, and MPM approaches, with four studies, indicate a 50% Physical and experiential and 50% Spiritual and symbolic distribution.

In the case of the TCM, CVM, and RCM combination, the study only applies to the physical and experiential cultural ecosystem service. In the case of the TCM, CVM, and HPM combination, it addresses the physical and experiential, and intellectual and representative attributes. Finally, the TCM, CVM, BTM, MPM combination addresses the three subcategories of cultural services.

4.5. Statistical Comparisons of Monetary Results According to Ecosystems

To homogenize the monetary values reported in the studies, all the values were converted to USD according to the year of the study [67]. Then, to ensure intertemporal comparability, all the monetary values were updated to the 2025 base year. The conversion was performed using the Consumer Price Index for All Urban Consumers (CPI-U, All Items, U.S. city average) published by the U.S. Bureau of Labor Statistics and available

through the FRED database of the Federal Reserve Bank of St. Louis. The CPI value for July 2025 (323.048, not seasonally adjusted, series CPIAUCNS) was used as the reference. The adjustment was calculated applying the following formula:

$$\text{Adjusted value 2025} = \text{Historical value (CPI2025)} / (\text{CPI year})$$

where CPI2025 corresponds to the 2025 index and CPI year to the index of the study's publication year. This procedure corrects for the cumulative effect of inflation and allows expressing all results in constant 2025 USD, thus facilitating comparative analysis across different periods according to Bureau of Labor Statistics of the Federal Reserve Bank of St. Louis (2025).

Monetary Valuation Results by Ecosystem Type and Valuation Method

To facilitate the interpretation of monetary outcomes across studies, Table 2 summarizes key descriptive statistics (mean, median, minimum, maximum, standard deviation, and interquartile range) for valuation estimates grouped by ecosystem type and combined valuation methods. This structure allows both the central tendency and the internal dispersion of values to be assessed, which is particularly relevant given the well-documented heterogeneity of ecosystem service valuations.

This pattern reflects the strong sensitivity of TCM to market size, visitation intensity, and travel costs, whereas CVM tends to produce comparatively more stable and conservative estimates, as it is based on stated willingness to pay rather than observed expenditures. Extreme values span several orders of magnitude, ranging from a maximum TCM estimate of USD 28,048.69 million to a minimum CVM estimate of USD 0.02, highlighting the influence of spatial scale, aggregation level, and units of measurement on reported monetary values.

Across all ecosystems, monetary estimates derived from combined TCM + CVM applications exhibit pronounced right skewness, as evidenced by means that substantially exceed medians and by wide interquartile ranges. In most ecosystem categories, TCM produces systematically higher and more dispersed estimates than CVM, reflecting its strong sensitivity to visitation intensity, travel costs, and the spatial scale of the study area. In contrast, CVM tends to generate comparatively more conservative and stable estimates, as it captures respondents' stated willingness to pay under controlled hypothetical scenarios rather than observed market behavior. Extreme values span several orders of magnitude, from a maximum TCM estimate exceeding USD 28 billion to a minimum CVM estimate close to zero, underscoring the combined influence of methodological choice, spatial aggregation, and valuation units.

When comparing ecosystem types, forest land and recreation exhibits the widest valuation range, highlighting the high variability of recreational demand and use intensity across forest contexts. This pattern is closely followed by marine-coastal ecosystems, where tourism-driven visitation and large beneficiary populations lead to substantial dispersion in TCM + CVM estimates. In contrast, natural continental waters show comparatively moderate values, with CVM estimates exceeding those derived from TCM, suggesting that non-market and non-use considerations (e.g., water quality, ecological integrity) play a more prominent role in freshwater systems than direct recreational use alone.

For urban-cultural ecosystems, TCM again yields higher central values than CVM, although both remain lower than those observed in large natural ecosystems. This reflects the more localized nature of urban recreational demand and the typically smaller spatial scale of valuation. Notably, combinations involving choice-based methods (CEM) are associated with particularly modest TCM derived values, consistent with the marginal and attribute-based nature of these approaches.

Table 2. Descriptive statistics of monetary valuation estimates (USD) across ecosystems based on the most frequently applied combination of valuation methods.

Ecosystems	Frequency	Valuation Method	Mean	Median	Min	Max	Std	q25	q75	iqr
Forest land and recreation	12	Contingent Valuation	2.45×10^8	1.53×10^4	1.67×10^0	2.82×10^9	8.12×10^8	3.58×10^1	7.57×10^6	7.57×10^6
		Travel Cost	2.88×10^9	1.24×10^7	5.61×10^1	2.80×10^{10}	8.85×10^9	6.20×10^2	5.10×10^7	5.10×10^7
Marine-coastal	9	Contingent Valuation	2.69×10^9	1.72×10^2	1.64×10^{-2}	2.42×10^{10}	8.06×10^9	2.13×10^1	4.99×10^6	4.99×10^6
		Travel Cost	1.46×10^9	2.75×10^2	1.51×10^0	8.63×10^9	3.51×10^9	5.85×10^1	9.26×10^7	9.26×10^7
Natural continental waters	8	Contingent Valuation	9.48×10^7	3.55×10^4	5.78×10^1	7.05×10^8	2.47×10^8	1.21×10^2	1.33×10^7	1.33×10^7
		Travel Cost	3.46×10^6	2.17×10^4	5.55×10^1	2.74×10^7	9.69×10^6	1.15×10^2	8.44×10^4	8.42×10^4
Urban-cultural	8	Contingent Valuation	5.64×10^6	3.54×10^5	2.24×10^{-1}	2.33×10^7	8.74×10^6	6.52×10^2	8.86×10^6	8.86×10^6
		Travel Cost	4.30×10^7	3.30×10^6	1.03×10^1	2.42×10^8	9.74×10^7	1.57×10^5	8.70×10^6	8.54×10^6
	4	Choice Experiment	1.62×10^6	2.86×10^1	3.83×10^0	4.87×10^6	2.81×10^6	1.62×10^1	2.44×10^6	2.44×10^6
		Travel Cost	5.54×10^1	5.54×10^1	9.14×10^0	1.02×10^2	6.54×10^1	3.22×10^1	7.85×10^1	4.62×10^1
Artificial continental waters/infrastructure	4	Contingent Valuation	1.80×10^4	8.96×10^1	7.03×10^0	7.17×10^4	3.58×10^4	1.94×10^1	1.81×10^4	1.80×10^4
		Travel Cost	2.30×10^4	1.12×10^3	9.19×10^{-1}	8.99×10^4	4.46×10^4	1.34×10^2	2.40×10^4	2.39×10^4

Note. To ensure statistical robustness, only ecosystem method combinations with more than three observations were included in the statistical analysis. The complete list of studies and valuation details is provided in the Supplementary Material (Table S3).

Finally, artificial continental waters and infrastructure display the lowest overall valuations and the narrowest ranges, indicating more homogeneous valuation contexts and limited ecosystem service diversity. Agricultural or plantation landscapes, represented by a small number of studies, similarly exhibit low dispersion and comparatively modest monetary estimates.

Overall, these results demonstrate that monetary valuation outcomes are jointly shaped by ecosystem characteristics and methodological pairing. Natural ecosystems are associated with the highest variability and extreme values, while artificial or production-oriented systems exhibit more constrained valuation ranges. The recurring prominence of TCM + CVM combinations reinforces the complementarity of revealed and stated preference methods in capturing the multifaceted nature of cultural ecosystem services, while also highlighting the need for robust statistical treatment such as the use of medians, interquartile ranges, and log-transformed values when comparing monetary estimates across heterogeneous contexts.

A Wilcoxon signed-rank test comparing paired TCM and CVM estimates ($n = 35$) confirmed that TCM values are significantly higher than CVM values ($W = 494.0, p = 0.0013$). This result provides robust statistical support for the systematic differences observed between revealed preference and stated preference valuation approaches.

Consistent with the inferential results, the log-transformed boxplots presented in Figure 6 show that TCM estimates exceed CVM estimates across all ecosystem types. This pattern is particularly pronounced in forest land and recreation and marine-coastal ecosystems, where TCM exhibits higher medians, broader interquartile ranges, and more frequent extreme values. The explicitly marked outliers in these panels highlight the sensitivity of TCM to heterogeneity in travel behavior, including differences in travel distance, site accessibility, and tourism intensity.

In contrast, CVM distributions are generally more concentrated and display lower central tendencies across ecosystems. This reflects the nature of stated preference data, in which respondents' willingness to pay is constrained by hypothetical scenarios and cognitive anchoring, even when non-use values are conceptually included. The smaller dispersion and fewer extreme values observed in CVM boxplots further suggest that CVM yields more conservative and bounded estimates relative to TCM.

Taken together, the visual evidence from Figure 6 and the Wilcoxon test results indicate that TCM systematically produces higher monetary estimates than CVM. This divergence is primarily driven by TCM's reliance on observed travel expenditures, which capture actual use-related costs and spatial behavior, whereas CVM reflects stated willingness to pay that may underrepresent realized economic commitments. These findings reinforce the importance of method selection in ecosystem valuation and highlight how methodological choice can substantially influence estimated economic values.

Figure 7 illustrates the distribution of log-transformed monetary valuation estimates across ecosystem types derived from studies applying the Travel Cost Method in combination with other valuation approaches. To ensure statistical robustness, the Kruskal–Wallis test was conducted exclusively on ecosystem–method combinations involving TCM and the Contingent Valuation Method (TCM + CVM), as this was the only pairing with sufficient repetitions across ecosystems to support inferential analysis. Other method combinations were excluded from the test due to limited sample sizes at the ecosystem level.

The boxplots reveal substantial within-ecosystem dispersion, reflecting heterogeneity in valuation contexts, spatial scales, and study designs. However, the Kruskal–Wallis results indicate no statistically significant differences in median valuation estimates across ecosystems ($H = 6.27, p = 0.28$). This finding suggests that, once values are expressed on a logarithmic scale and restricted to the most frequent methodological combination, central

tendencies in monetary valuation are broadly comparable across ecosystem types. In the context of this review, the absence of significant inter-ecosystem differences highlights that methodological consistency and study design may exert a stronger influence on reported monetary values than ecosystem classification alone.

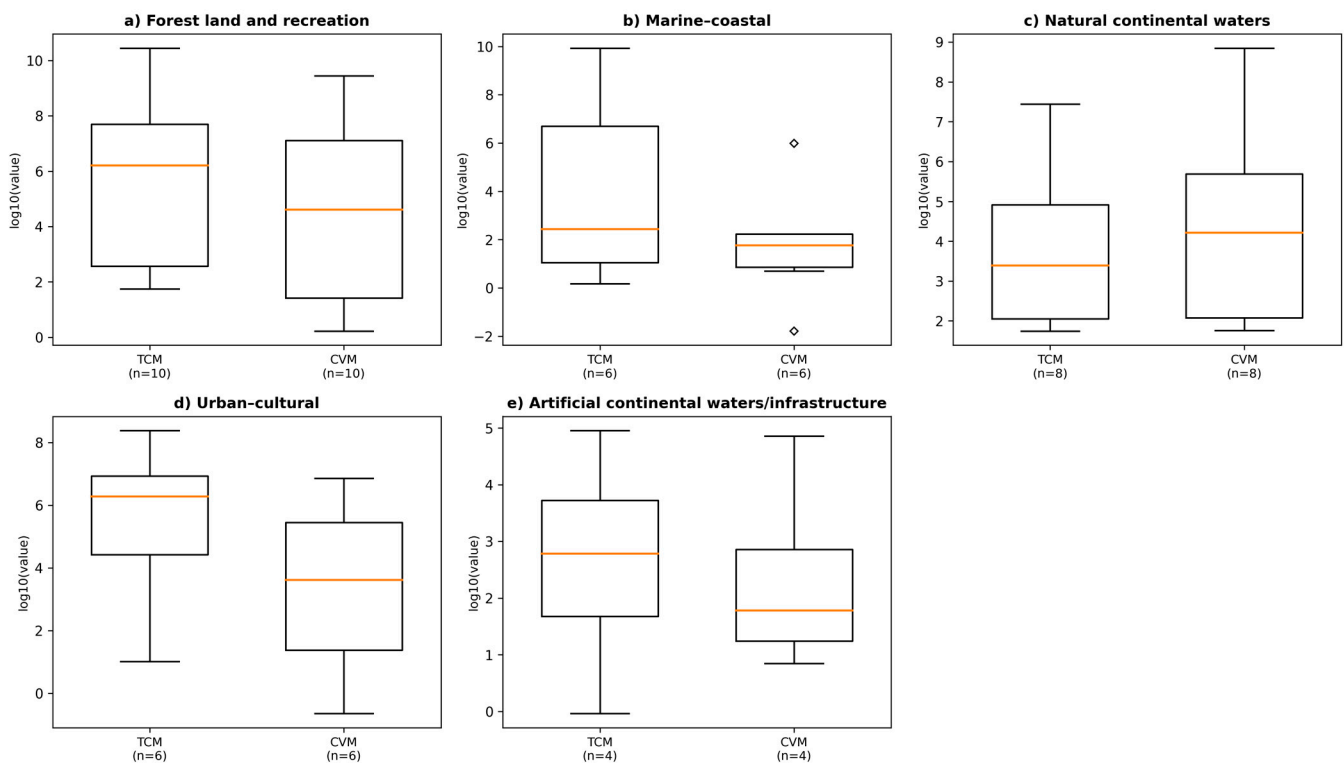


Figure 6. Comparison of log-transformed TCM and CVM values for each ecosystem type.

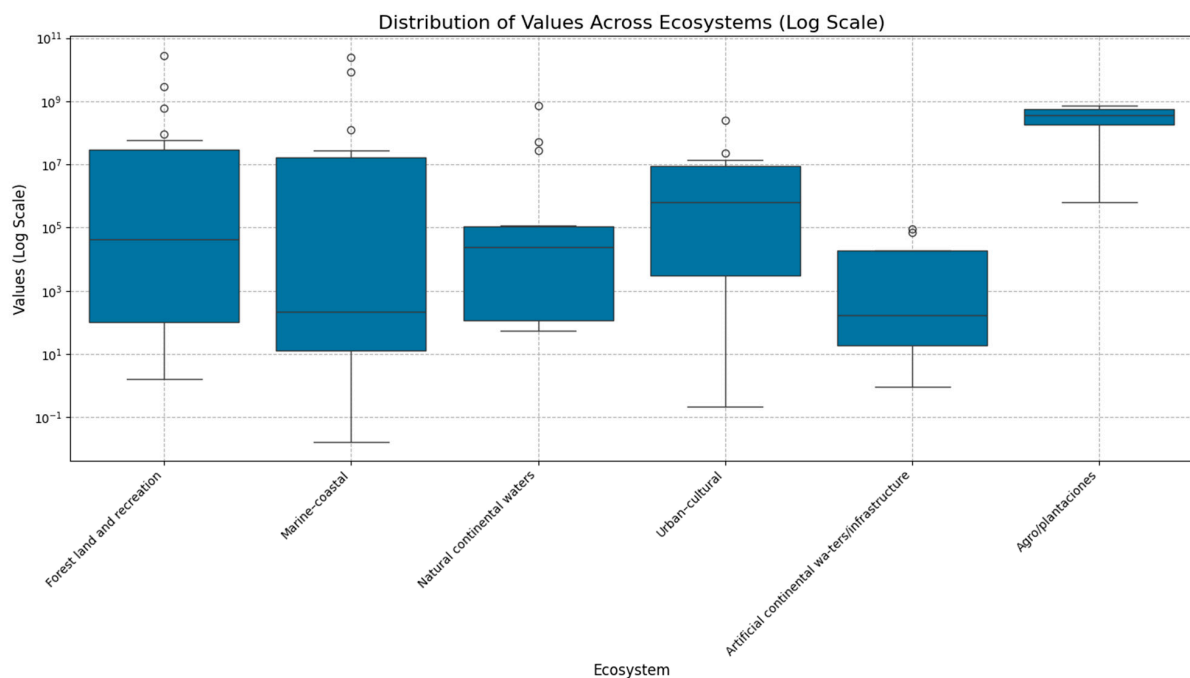


Figure 7. Comparative distribution of ecosystem service valuation estimates across ecosystems (log scale). Note: Kruskal–Wallis H test was applied to compare monetary valuation estimates across ecosystems. The test yielded $H = 6.27$ with $p = 0.28$, indicating no statistically significant differences in median values among ecosystem types at the 5% significance level.

5. Discussion

5.1. Geographic Distribution and Trends

The global evidence based on the combined application of TCM with other economic valuation methods remains geographically uneven, despite its chronological expansion. The concentration of studies in the United States reflects its historical leadership in the development and early empirical testing of TCM [18,68,69]. This tradition continued through the 1980s and 1990s, when foundational research compared TCM and CVM across multiple ecosystems, contributing to long-term methodological refinement [27,70]. These conditions generated a fertile academic environment that facilitated the adoption of RP–SP integration and strengthened the empirical basis for contrasting use and non-use values.

Beyond the United States, subsequent diversification toward Europe, Asia, Oceania became evident from 2000 onward. Studies in Turkey, Malta, Romania, Mexico, South Africa, India, Jordan, and Australia [53,61,65,71] expanded the range of ecosystems and valuation contexts, from inland and ocean waters to forests, estuaries, and urban recreation. These applications demonstrated the adaptability of TCM and its convergence with CVM and CE in heterogeneous socioeconomic settings.

However, this diversification masks persistent structural disparities. Regions with high biodiversity but limited technical capacity—such as much of South America and Africa—remain underrepresented, with South Africa [61] being the only African country identified. Several factors contribute to these gaps. First, unequal distribution of research funding and limited technical capacity restrict the adoption of multi-method valuation frameworks. Second, restricted access to biophysical and socioeconomic data complicates model specification, especially when integrating demand models or exploring RP–SP complementarities [72].

Third, many emerging economies have a weaker academic tradition in recreation-demand modeling, unlike the longstanding work in North America, Europe, and Australia. Fourth, language and publication barriers reduce the visibility of studies published in local journals. Finally, institutional priorities often emphasize Environmental Impact Assessment (EIA) processes or cost–benefit analyses over non-market valuation, reducing incentives to develop integrated methods [73].

The expansion of research in China illustrates how institutional investment can shift global patterns. China's first identified TCM combination study appeared in 2016 [74]. Since then, it has become the second most productive country, with applications in wetlands, nature reserves, and urban cultural landscapes [33,48,49,75]. These studies demonstrate how TCM combined with CVM or CE can support the valuation of heritage sites, ecological damage, and sociocultural attributes.

A recurring limitation across regions is the reliance on non-probabilistic sampling, especially in emerging economies and in multi-country studies. This pattern reflects financial and logistical constraints that limit statistical rigor and the comparability of valuations across sites.

Overall, these findings highlight the need to address persistent geographic disparities through greater investment in data infrastructure, training, and methodological standardization. Strengthening the research capacity in underrepresented regions would not only broaden the global evidence base but also enhance the relevance of integrated TCM applications for conservation planning and policy design.

5.2. Comparisons of Monetary Results According to Methods and Ecosystems

The higher variability observed in TCM estimates across ecosystems (Figure 6) is consistent with revealed preference theory as outlined in Environmental Economic Valuation Methods Section. Because TCM derives values from observed recreational behavior and

actual travel expenditures, valuation outcomes inherently reflect heterogeneity in travel distance, opportunity costs, site accessibility, and visitation patterns. As noted by [27,28], this behavioral basis implies sensitivity to spatial scale and user characteristics, which explains the wide interquartile ranges observed for TCM, particularly in forest and marine-coastal ecosystems.

In contrast, the more compact distributions and lower median values obtained through the CVM align with stated preference theory. CVM relies on hypothetical market scenarios to elicit willingness to pay within a structured survey setting, which tends to constrain responses and reduce variance relative to behavior-based methods [26]. This expectation is empirically confirmed in Figure 6, where CVM boxplots show narrower interquartile ranges across ecosystems, including forests and urban-cultural systems.

In Figure 7, where no statistically significant differences in median valuation estimates are observed across ecosystems after log transformation and restricting the analysis to the TCM + CVM combination (Kruskal–Wallis $H = 6.27$, $p = 0.28$), are consistent with the theoretical framework presented in Section 2. From a Total Economic Value perspective, valuation outcomes are strongly influenced by methodological design, as revealed and stated preference methods capture complementary and partially overlapping value components [9,26]. The convergence of central tendencies across ecosystems therefore suggests that heterogeneity in reported values is driven more by methodological differences than by ecosystem type, supporting the use of integrated RP–SP approaches to enhance comparability and reduce method-specific bias [23,24,76].

The comparative analysis of monetary valuations across ecosystems reveals clear methodological and ecological patterns that become evident when examining the log-transformed distributions and the boxplots of TCM and CVM. Across all ecosystems, TCM systematically produces higher and more variable values than CVM, a difference statistically confirmed by the Wilcoxon signed-rank test ($W = 494.0$, $p = 0.0013$). This consistent divergence reflects the intrinsic properties of each method: TCM captures actual travel expenditures that vary strongly with distance, transportation mode, opportunity costs, and visitor heterogeneity, while CVM elicits stated preferences that are more cognitively constrained and thus usually less variable. The boxplots illustrate this contrast, showing wider interquartile ranges and upper whiskers for TCM, particularly in ecosystems with high recreational mobility or large visitor catchments.

Forest and recreation ecosystems display the greatest dispersion in TCM values, reflecting a mix of highly localized studies with minimal travel costs [77] and large-scale assessments of national natural landscapes with substantial use values [74]. This heterogeneity aligns with previous work by Loomis et al. [78–81], who noted that forest recreation demand is strongly influenced by accessibility, population pressure, and multi-purpose visitation. In contrast, the CVM distributions for forests are more compact, suggesting that hypothetical willingness to pay for conservation or recreational improvements is less sensitive to geographical scale than travel cost-based estimates. This pattern reinforces the theoretical expectation that stated preference methods tend to produce stable valuations even in contexts where revealed preferences fluctuate widely.

Marine-coastal ecosystems also present large monetary values but exhibit slightly less TCM variability than forests. Boxplots show that local beach and lagoon studies, such as those in Mexico [65], South Africa [62], and the Mediterranean region, cluster around low log-TCM values, whereas studies focused on broader ecological restoration—such as sediment remediation in Japan [82]—produce markedly higher values. Interestingly, CVM boxplots for marine ecosystems often surpass TCM in the upper quartile, consistent with findings from Carandang et al. [66] and Haider et al. [58]. This indicates that non-use values including ecological protection, cultural heritage, and bequest motives, are

particularly relevant in coastal environments, where ecosystems carry both recreational and symbolic significance.

A contrasting pattern emerges in the case of natural continental waters, where CVM medians and upper whiskers exceed those of TCM. This inversion suggests that rivers, wetlands, and lakes are perceived by respondents primarily as ecological assets rather than recreational destinations. Studies such as Chen et al., Thapa et al., Lamsal et al., and Loomis et al. [27,44,52,64] have shown that freshwater systems evoke strong willingness to pay for water quality improvements, ecosystem integrity, and biodiversity protection far beyond what is captured through travel expenditures. The boxplots therefore reinforce that CVM is particularly effective in freshwater contexts where preservation and ecological health dominate public preferences. Meanwhile, TCM variability remains modest due to short-distance, low-cost recreational visits associated with these ecosystems.

Urban-cultural ecosystems exhibit the most compressed valuation ranges. In these settings, both TCM and CVM boxplots show narrow interquartile distributions and low median values. This is consistent with the predominantly local nature of cultural and recreational use in urban environments, as reported by Pak et al. and Bottero et al. [36,83]. Short travel distances reduce TCM variation, while repeated visitation and limited payment capacity temper CVM responses. The stability of these distributions also reflects the specificity of urban cultural services, where preferences relate more to attribute quality heritage, accessibility, environmental education, than to large-scale economic or ecological changes.

Artificial continental waters and hydraulic infrastructure exhibit the lowest overall values and the smallest variability, as shown in the boxplots. These systems, including reservoirs, dams, and urban lakes, are used primarily by local populations for daily activities, subsistence, or short-distance recreation. The narrow distributions of TCM and CVM values reported in studies such as Banda et al., Saravanakumar et al., and Loomis and Kawa [61,84,85] reflect the limited travel cost burden, lower recreational intensity, and smaller presence of symbolic or existence values. In these ecosystems, CVM tends to be slightly more stable than TCM, as perceptions of maintenance, water security, and public service functions are more homogeneous across users.

Although the agricultural and plantation category does not permit meaningful boxplot interpretation due to its small number of cases, the studies included, such as Huang and Wang, Huang et al., Turner et al., and Walyoto and Peranginangin [50,52,86,87], demonstrate that multifunctional rural landscapes often generate substantial non-market values, particularly when ecosystem services such as flood mitigation, cultural identity, scenic beauty, and recreation are accounted for. These findings indicate that agricultural landscapes behave more like hybrid socio ecological systems than purely productive ones and therefore benefit from integrated valuation approaches.

Taken together, these cross-ecosystem comparisons reveal that both ecosystem type and methodological pairing play decisive roles in shaping monetary outcomes. Forests and marine-coastal systems produce the highest use-related expenditures, while freshwater ecosystems elicit the strongest non-use valuations. Urban and artificial waters show the most stable and modest values. These gradients reflect underlying differences in accessibility, population density, cultural significance, and service multifunctionality. The results also highlight that the integration of TCM with CVM or CEM generates richer valuations by capturing complementary dimensions of total economic value, direct use activities through revealed preferences and non-use or attribute-specific values through stated preferences.

From a policy perspective, the patterns highlighted in the boxplots underscore the need for ecosystem-sensitive valuation strategies. High variability in forest and coastal

TCM indicates that management interventions such as infrastructure investment, fee-setting, and visitor regulation should consider heterogeneous user groups. The prominence of CVM in freshwater ecosystems signals the urgency of water quality restoration and ecological protection policies. The stability of urban and artificial water valuations suggests that targeted, low-cost improvements may yield substantial public benefits. Overall, the integrated interpretation of statistical evidence supports the argument that methodological complementarities are essential for developing robust, policy-relevant assessments of ecosystem services across diverse landscapes.

5.3. Methodological Quality and Limitations

Included studies and structural weaknesses in the existing evidence base are summarized. Identifying these constraints is essential for a balanced interpretation of the results and for guiding future research.

A pervasive limitation across the reviewed literature is the absence of probability-based sampling. None of the 57 studies employed probabilistic designs; instead, most relied on convenience. This pattern is consistent across all ecosystem types and systematically restricts statistical representativeness. While internal validity at the site level may be acceptable, external validity remains weak, particularly when estimates are extrapolated to broader policy contexts or used for benefit transfer.

Analysis of sample size distributions across representative ecosystems further highlights these concerns. Although the overall mean sample size is approximately 460 respondents, substantial heterogeneity exists. Marine-coastal ecosystems show the largest empirical scale (mean = 586 surveys), with values ranging from 93 to over 2000 observations, while forest land and recreation systems also present relatively large samples on average (mean = 48 surveys) but with minimum values close to 100 observations. In contrast, inland water and urban-cultural ecosystems exhibit lower mean sample sizes (40 to 393 surveys) combined with wide dispersion, including minima below 50 observations. Agro-ecosystems display moderate mean values (493 surveys) but are represented by few observations.

Importantly, larger sample sizes do not compensate for non-probabilistic sampling. Even studies with high respondent counts rely on non-random designs, while small samples face compounded limitations related to low statistical power and inflated variance. These issues are particularly relevant for TCM applications, which are sensitive to sample heterogeneity, and for CVM surveys, where limited samples amplify hypothetical and strategic biases. The predominance of on-site, face-to-face surveys further reinforces selection bias by excluding non-users.

Method-specific limitations also affect reliability. CVM studies frequently exhibit hypothetical, strategic, starting-point, and embedding biases, often with limited reporting on survey design and validation. TCM applications face challenges in isolating travel expenditures, handling multi-purpose trips, and valuing time costs, potentially leading to biased estimates. Additional concerns arise when revealed and stated preference methods are combined, particularly due to sub-sample inconsistencies and double-counting risks.

Overall, the combination of non-probabilistic sampling, highly variable sample sizes across ecosystems, and method-specific biases constrains the transferability and policy relevance of valuation results, underscoring the need for higher methodological standards in future ecosystem valuation research.

5.4. Limitations of This Review

This review is constrained by the scope of the search strategy, which focused exclusively on a predefined set of method combinations. Specifically, the literature search was

conducted using only four keyword pairings centered on the Travel Cost Method (TCM) combined with selected valuation approaches, namely TCM–CVM, TCM–CEM, TCM–HPM, and TCM–ACM. While this targeted strategy ensured conceptual coherence and methodological comparability, it may have excluded relevant studies that integrated TCM with other valuation methods and techniques, such as Replacement Cost, Benefit Transfer, and Market Price, without explicitly referencing these combinations in titles, abstracts, or keywords.

Consequently, some integrated valuation studies may not have been captured despite meeting the conceptual inclusion criteria. This limitation reflects a trade-off between search precision and completeness and suggests that future reviews could expand the range of keyword combinations or adopt citation-based snowballing techniques to capture a broader spectrum of hybrid valuation applications.

5.5. Policy Implications and Standardization Needs

The findings yield important implications for environmental policy and research practice. The results suggest that policymakers should require combined valuation approaches in comprehensive environmental impact assessments, particularly for large-scale projects affecting forest and marine-coastal ecosystems, where both use and non-use values are substantial and policy stakes are high. Reliance on a single valuation method risks systematically underestimating total economic value and misinforming decision-making.

At the same time, the high variability in monetary estimates across studies highlights the urgent need for standardized protocols for combined TCM–CVM applications. Future research would benefit from harmonized guidelines covering sampling strategies, survey instruments, econometric specifications, treatment of multi-purpose trips, and reporting formats. Such standardization would improve comparability across studies, facilitate evidence synthesis, and enhance the credibility of valuation results in policy contexts.

Addressing these methodological and structural limitations is essential for advancing the robustness, transparency, and policy relevance of integrated ecosystem service valuation research.

The decision framework groups method combinations by their observed frequency of use within each ecosystem type in the extracted dataset, prioritizing the most recurrent pairings as the most practical starting point for comparable management contexts. The most frequent pattern is the TCM + CVM core, illustrated across multiple ecosystems by foundational and widely used applications [68,78,80].

Table 3 is intended as a decision-support instrument for management and public policy, because it translates the evidence base into an explicit mapping linking ecosystem types, management objectives, and commonly applied method bundles, helping practitioners choose combinations that are empirically grounded and fit for purpose. Applications combine revealed and stated preference information to capture both use values and decision-relevant attributes, and that robust valuation is critical for evidence-based conservation decisions and for enabling policymakers to convert ecosystem service benefits into actionable monetary metrics for sustainable resource management.

Table 3. Decision framework for method selection by ecosystem type.

Ecosystem Type	Management Objective	Recommended Combination	Rationale
Forest land and recreation	Estimate recreation benefits and WTP for management (access, conservation, services)	TCM + CVM (add HPM when the objective includes capitalization in land/property values)	TCM anchors observed use values, CVM adds WTP for policy/quality scenarios; HPM is appropriate when ecosystem amenities are reflected in market prices [78,80,88].

Table 3. Cont.

Ecosystem Type	Management Objective	Recommended Combination	Rationale
Urban-cultural	Prioritize interventions based on attribute-level trade-offs (price, crowding, access, quality)	TCM + CEM	TCM provides behavior-based values; CEM identifies marginal WTP by attribute for operational decisions [36,37]. MPM captures marketed outputs, TCM recreation demand, and CVM WTP for
Marine-coastal	Support coastal management combining recreation with broader welfare and, when relevant, marketed services	TCM + CVM + MPM (expand with ACM/RCM for high-stakes TEV settings)	conservation/quality change; ACM/RCM can complement when avoided damage/replacement proxies are needed in complex TEV applications [60,66].
Agriculture/plantations	Value multifunctional production landscapes where some services are credibly proxied by engineered replacements	TCM + CVM + RCM	RCM approximates services via replacement/engineering costs, while TCM/CVM capture recreation-related use and stated WTP for multifunctionality [50].
Natural continental waters	Value multiple services when primary valuation is incomplete and data gaps exist	TCM + CVM + BTM + MPM	BTM fills information gaps via transfer, supported by local TCM/CVM anchors and MPM for traded outputs [63].
Artificial continental waters/infrastructure	Appraise recreation and management benefits in reservoirs, dams, and urban lakes	TCM + CVM	In artificial water infrastructures, TCM captures use values from observed visits while CVM elicits WTP for management/quality improvements; examples in the evidence base include urban lake ES valuation and reservoir-based recreation contexts [84,85].

6. Conclusions

This systematic review synthesized 57 peer-reviewed studies published between 1985 and 2024 to examine how TCM has been integrated with complementary valuation approaches. TCM combined with the CVM dominates the literature (74%), reflecting their complementarity in capturing use and non-use values. Applications are geographically concentrated in the United States and China, with persistent gaps in biodiversity rich regions of Africa and Latin America. Forest recreational and marine-coastal ecosystems account for nearly half of all studies, while agricultural and cultural landscapes remain undervalued. Among cultural ecosystem services, physical and experiential interactions clearly predominate. Across ecosystems, TCM yields higher and more variable monetary estimates than CVM, highlighting the importance of methodological integration for robust Total Economic Value (TEV) assessment.

This review contributes to environmental economics by providing the first comprehensive synthesis of integrated valuation approaches, revealing temporal and geographical patterns and demonstrating the added value of methodological combinations. Our findings have direct implications for environmental policy: comprehensive valuation of ecosystem services for impact assessments and conservation planning should prioritize TCM + CVM integration to balance revealed behavior with hypothetical scenarios, while TCM + CEM offers enhanced granularity for complex multi-attribute ecosystems such as urban parks and heritage sites.

Based on our synthesis, we propose the following practical recommendations. For forest and coastal recreational sites with high visitation, the integration of the Travel Cost Method with the Contingent Valuation Method (TCM + CVM) is recommended to jointly

capture consumer surplus and non-use values associated with conservation. In urban parks and other multifunctional ecosystems, TCM combined with CEM is particularly suitable for identifying priority ecosystem attributes and guiding management investments. In contexts characterized by budgetary or time constraints, TCM + CVM offers an optimal balance between feasibility and valuation completeness. Across all applications, the adoption of probabilistic sampling designs is strongly recommended to enhance external validity and generalizability, addressing a methodological gap consistently observed in the reviewed literature.

This review is subject to limitations. Restricting searches to Scopus and Web of Science may have excluded relevant studies indexed in regional databases, and language constraints likely limited coverage of work published in Chinese, Portuguese, and other languages. Future research should (1) develop standardized protocols for integrated TCM applications to improve cross-study comparability; (2) prioritize empirical studies in underrepresented regions such as the Amazon, Andes, and sub-Saharan Africa, as well as in agroforestry and cultural landscapes; (3) advance econometric techniques for combining revealed and stated preference data, addressing double-counting and consistency issues; and (4) conduct meta-analyses to identify key moderators driving valuation differences across methods and ecosystems.

As biodiversity loss accelerates and ecosystem degradation intensifies globally, robust economic valuation becomes critical for evidence-based conservation decisions. By demonstrating how methodological integration strengthens TEV estimation, this review provides guidance for researchers, practitioners, and policymakers seeking to translate ecosystem services into actionable monetary metrics that can inform sustainable resource management and contribute to achieving global conservation targets.

Supplementary Materials: The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/environments13010018/s1>, Figure S1. Number of publication by country and year; Table S1. Cultural ecosystems; Table S2. PRISMA checklist [44]; Table S3. Systematized information; Table S4. Search strings and results; Table S5. Extraction form.

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