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Systematic Review

Assessing Cultural Ecosystem Services in Sponge City Infrastructure: A Systematic Review and Framework Proposal

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Abstract: Urbanization has significantly transformed ecological landscapes and created challenges in sustaining both environmental functionality and cultural values. In response, China's Sponge City Infrastructure (SPI) aims to enhance urban water resilience by integrating green and blue infrastructure. While the ecological benefits of SPI have been widely studied, the cultural ecosystem services (CES) it provides remain underexplored. This study systematically reviews 61 empirical articles to evaluate how CES has been addressed in SPI-related research. Bibliometric analysis was conducted to identify CES research trends and to systematically categorize CES types, assessment methods, and evaluation indicators in SPI-related studies. The findings reveal a dominant use of non-monetary assessment methods, led by questionnaire surveys (47.5%), while monetary approaches were rarely applied. However, several limitations were identified, including the geographic concentration of studies in a few major cities, the scarcity of research on abstract CES categories (e.g., inspiration and sense of place), and the lack of measurable indicators in nearly half of the reviewed studies. To address these issues, this study proposes a context-specific CES assessment framework aligned with China's socio-cultural conditions and planning priorities in sponge city development. The framework, based on the reviewed literature, provides a preliminary tool for evaluating CES in sponge city contexts. This work contributes to the integration of cultural ecosystem services into urban ecological planning and offers insights for sustainable development in rapidly urbanizing regions.

Keywords: sponge cities infrastructure; cultural ecosystem services; urban sustainability; green infrastructure; CES assessment; urban planning

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1. Introduction

Intensifying climate change has triggered a global surge in extreme rainfall events, significantly exacerbating the risk of urban flooding—a major threat to ecological sustainability and human well-being worldwide [1–3]. In response, the United Nations' 2030 Agenda for Sustainable Development—particularly SDG 11 (Sustainable Cities and Communities) and SDG 6 (Clean Water and Sanitation)—highlights the importance of inclusive, resilient, and water-sensitive urban development. National-level strategies have emerged accordingly, including the European Union's Green Infrastructure Strategy, the United States' Low Impact Development (LID), Australia's Water Sensitive Urban Design (WSUD), and the Netherlands' Room for the River program, all of which integrate hydrological functions with urban spatial planning [4,5].

China, facing distinct socio-ecological challenges due to its rapid urbanization and population density, introduced the SPI in 2013 as a novel approach to urban water management [6,7]. By mimicking natural hydrological processes, SPI incorporates green and

blue infrastructure into urban planning, aiming to mitigate urban flooding, improve water quality, and enhance urban resilience [8,9]. It has since been embedded into the national "Ecological Civilization" agenda, which emphasizes the synergistic advancement of ecological and cultural values in urban development [10,11]. This policy alignment is reflected in key documents such as the Sponge City Construction Technical Guide [12] and the 14th Five-Year Ecological and Environmental Protection Plan [13].

Despite SPI's multifunctional design and its potential to provide CES—such as recreation, aesthetics, identity, and spiritual well-being—current research and evaluation frameworks primarily focus on ecological outcomes, including runoff reduction, habitat restoration, and pollution control [14,15]. CES, defined as the non-material benefits people obtain from nature, remains underexplored in the context of SPI, especially within China [16,17].

Although SPI like rain gardens, wetlands, and permeable pavements inherently offer cultural value, empirical studies addressing CES in this context remain limited both domestically and internationally [18,19]. Existing CES evaluation frameworks, largely developed in Western contexts, often lack cultural relevance for China's socio-ecological realities [20,21]. Furthermore, abstract CES categories—such as cultural diversity, traditional knowledge systems, or inspiration—are rarely operationalized, due to conceptual ambiguity and a lack of context-sensitive indicators [21–23]. Figure 1 illustrates how SPI components—such as wetlands, rain gardens, and permeable pavements—can potentially support various CES. A single type of infrastructure may provide multiple CES at the same time, and the specific services it supports can vary depending on the design and surrounding environment.

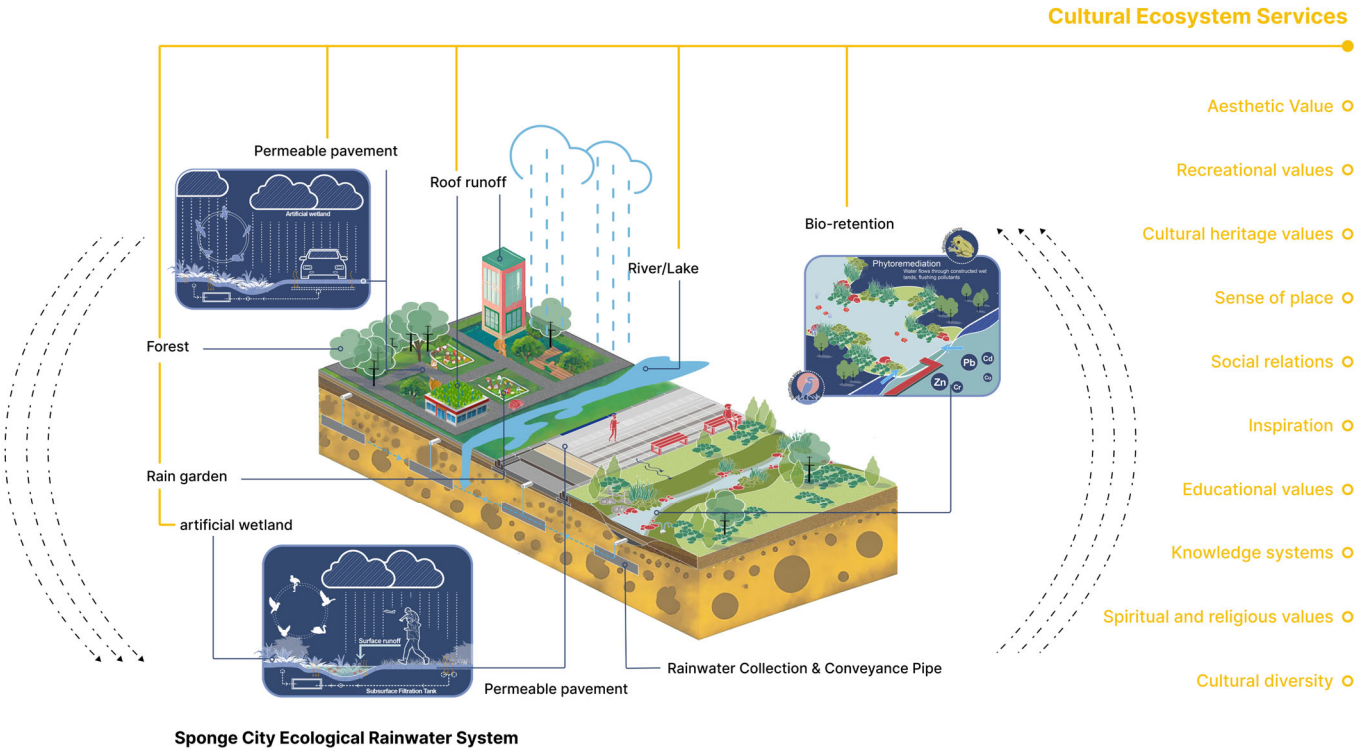

Figure 1. The relationship between sponge cities and CES.

To address these gaps, this study conducts a systematic review of empirical research on CES within the context of sponge city development. Specifically, it analyzes the geographic distribution, research themes, assessment methods, CES categories, and indicator usage in the selected studies. Drawing on these findings, a CES evaluation framework is developed for application in SPI planning. This framework is specifically developed for the assessment

of cultural ecosystem services within sponge city infrastructure. It serves as a practical instrument to support governments and urban planners in effectively incorporating cultural services into ecological planning and promoting public well-being.

2. Methods

2.1. Data Collection

This study performed a systematic literature search with reference to PRISMA 2020 guidelines. Protocol registration: https://osf.io/fge5r. The search focused on identifying empirical studies related to CES in the context of SPI within China.

Searches were conducted in the Web of Science Core Collection and Scopus. The search strategy combined multiple related terms across four conceptual dimensions: (1) core CES concepts (e.g., "cultural ecosystem services", "cultural services", "social values"); (2) urban infrastructure terms (e.g., "sponge cities", "green infrastructure", "stormwater management", "urban green space"); (3) specific CES types (e.g., "recreation", "aesthetic value", "sense of place", "cultural heritage"); and (4) landscape features (e.g., "urban park", "blue-green infrastructure", "wetland", "urban nature"). Boolean operators (AND/OR) were used to structure the queries, and search terms were applied to the titles, abstracts, and keywords of the records. Although the primary search strategy was based on English-language sources, two high-relevance Chinese-language studies retrieved from CNKI were also included due to their empirical relevance and methodological contributions to CES assessment in sponge city contexts.

The search was restricted to English-language, peer-reviewed journal articles published between 2013 and April 2025. This time frame was selected to capture the literature surrounding the development and implementation of China's sponge city policy, which was formally initiated in 2015. Grey literature, conference papers, and non-peer-reviewed materials were excluded.

All search results were imported into Zotero, and duplicates were removed manually using its built-in deduplication function. Subsequent title and abstract screening, full-text review, and inclusion decisions were made based on predefined eligibility criteria (see Section 2.2). This systematic review was conducted in accordance with the PRISMA 2020 guidelines. Although the protocol was not registered in a public database, all study selection and reporting procedures followed PRISMA recommendations.

2.2. Study Selection Criteria

A set of inclusion and exclusion criteria was developed to ensure the relevance, quality, and comparability of the studies included in this systematic review.

The selection criteria were established based on the research objectives, focusing on empirical assessments of CES in the context of SPI within China.

Inclusion Criteria:

Studies were included if they met the following requirements:

- Published between 2013 and April 2025 to capture the emergence and development of CES research in relation to China's sponge city initiative, formally launched in 2015;
- Written in English;
- Published as peer-reviewed journal articles reporting original empirical research;
- Focused on the evaluation of CES;
- Conducted in China and specifically focused on green or blue infrastructure associated with sponge city initiatives (e.g., urban parks, wetlands, blue–green corridors);
- Provided empirical data through case studies, surveys, participatory mapping, or other forms of primary data collection.

Exclusion Criteria:

Studies were excluded if they:

- Were conducted in regions other than China;
- Were conceptual or theoretical papers, editorials, or policy commentaries lacking empirical analysis;
- Focused exclusively on provisioning services (e.g., food, water supply) or regulating services (e.g., flood control) without incorporating any CES components;
- Were limited to hydrological or engineering aspects without discussing cultural values;
- Were non-peer-reviewed materials, including conference abstracts, dissertations, technical reports, and other non-peer-reviewed publications.

The study selection was conducted in two stages: initial screening based on titles and abstracts, followed by a full-text review for eligible studies. Any ambiguity regarding eligibility was resolved through detailed reading and manual cross-validation by the authors. Zotero was used for reference management and deduplication, while Microsoft Excel was employed to track inclusion decisions and document key screening criteria.

2.3. Identification of Paper Categorization

The following attributes were used to provide a comprehensive description of each publication: (1) the geographic distribution and research type; (2) CES categories examined; (3) the assessment methods applied; and (4) the CES indicator usage.

2.3.1. Geographic Location and Type of the Study

This study first classified the geographic distribution and thematic focus of the 61 reviewed publications to uncover spatial patterns and research emphasis. Specifically, for each study, the city or region where the data were collected was recorded. For studies involving multiple locations, each study site was recorded separately to enable disaggregated geographic analysis. The reviewed publications reflect diverse disciplinary orientations and research objectives, which influence their specific positioning within the sponge city research agenda.

For instance:

(1) Blue and Green Areas: Dou et al. [24], focused on blue areas (e.g., water and wetlands) and green areas (e.g., forests, street trees, cropland, and grasslands), which are among the measures employed by sponge cities in addressing stormwater management.
(2) Urban Green Spaces: Mao et al. [25] studied roadside parks, residential green areas, and natural woodlands, highlighting their dual role in both stormwater regulation and cultural ecosystem services, particularly in providing recreational opportunities.
(3) Typologies of Green Spaces: Panduro and Veie [26], and Bell et al. [27], proposed detailed classifications of urban green spaces—such as parks, gardens, and green corridors—which offer a structured framework for understanding the spatial characteristics of CES in sponge city contexts.

In this study, geographic distribution was categorized to include all relevant spatial levels discussed above, such as individual parks, neighborhoods, and entire cities, to ensure comprehensive representation of green and blue spaces related to CES in sponge cities.

2.3.2. CES Categories

The Millennium Ecosystem Assessment (MEA) framework has been increasingly recognized as a robust and comprehensive structure for categorizing ecosystem services. To ensure terminological consistency and analytical comparability, this study adopted the MEA classification system as the primary theoretical basis for identifying and interpreting CES categories (see Table 1).

Table 1. Categories of CES. Classification and definitions quoted from the Millennium Ecosystem Assessment (MEA, 2005).

Category	Concept
Cultural diversity	Cultural diversity reflects how the variety of ecosystems contributes to the development of diverse cultures.
Spiritual and religious values	Many religions attach spiritual and religious values to ecosystems or their components.
Knowledge systems	Ecosystems influence the types of knowledge systems developed by different cultures.
Educational values	Ecosystems and their components and processes provide the basis for both formal and informal education in many societies.
Inspiration	Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising.
Aesthetic values	Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, 'scenic drives,' and the selection of housing locations.
Social relations	Ecosystems influence the types of social relations that are established in cultures. Fishing societies, for example, differ in many respects in their social relations from nomadic herding or agricultural societies.
Sense of place	Many people value the 'sense of place' that is associated with recognized features of their environment, including aspects of the ecosystem.
Cultural heritage values	Many societies place high value on the maintenance of either historically important landscapes ('cultural landscapes') or culturally significant species.
Recreational values	People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.

A systematic review of the selected literature was conducted to identify the CES categories employed across empirical studies. A set of ten categories was identified for analysis, drawing from the MEA, 2005 and its subsequent extensions as commonly adopted in the reviewed literature. These categories include Cultural Diversity; Recreational Values; Aesthetic Values; Spiritual and Religious Values; Knowledge Systems; Educational Values; Inspiration; Social Relationships; Sense of Place; and Cultural Heritage Values. Categories that lacked conceptual clarity, consistent definitions, or measurable indicators were excluded from the comparative analysis. This approach ensured greater consistency, clarity, and cross-study comparability in the evaluation of CES representation in sponge city research.

2.3.3. CES Indicators

To support robust evaluation of CES, this study systematically identified 186 distinct indicators from the reviewed empirical literature. These indicators were assigned to ten CES categories based on their primary measurement intent and thematic alignment. For instance, Recreation and Ecotourism were commonly assessed using visitor frequency, activity participation rates, and satisfaction surveys, whereas Aesthetic Values were measured through landscape quality ratings, visual preference surveys, and the frequency of landscape photography. To reduce redundancy and enhance categorical clarity, each indicator was reviewed for thematic coherence and grouped under the CES category that best reflected its primary evaluative purpose. Indicators that lacked clear definitions, measurable dimensions, or contextual relevance were excluded to maintain consistency and analytical rigor. A detailed list of all indicators, definitions, and classification references is provided in Table S2. In this study, information such as authors, publication year, study region, CES categories, evaluation methods, and evaluation indicators was systematically

extracted for analysis. As all data were obtained from published sources, no imputation or supplementary data handling procedures were necessary.

2.3.4. Classification of CES Assessment Methods

To classify the empirical methods used for evaluating CES, this study adapted the typology proposed by Scholte et al., which provides a structured overview of data collection techniques [28]. Based on this framework and refined according to the methods observed in the reviewed literature—CES evaluation methods were classified into the following categories:

(1) Market-based (e.g., market prices);
(2) Observation-based (e.g., direct observation, document analysis, social media data);
(3) Stated preferences (e.g., interviews and questionnaires);
(4) Expert-based methods (e.g., Delphi technique); and
(5) Participatory and technology-assisted approaches (e.g., PGIS, PPGIS, VEP, and Virtual Reality).

A summary of these methods and their descriptions is provided in Table 2.

Table 2. Classification of CES evaluation methods and descriptions.

Category	Method	Method Description
Method Description	Market Prices	Estimates the economic value of CES based on the prices of marketable goods. For example, the entrance fee to a park can be used to approximate the value of recreation and ecotourism.
	Observation	Directly observes human behaviors and actions to infer the social value of CES. For instance, counting visits to a park can help deduce the importance of recreation in that area.
	Document Analysis	Examines texts, images, or other forms of documentation to glean information about human preferences for CES. For example, analyzing the number of photographs taken by the public or featured in advertisements can indicate aesthetic value.
	Social Media-Based	Utilizes social media data from various platforms to assess CES. For example, the number of wildlife photographs posted on photo-sharing sites (e.g., Flickr) can serve as a proxy for recreation and ecotourism values.
Stated Preferences	Interviews	Gathers in-depth insights into how and why people value CES through direct, often face-to-face, discussions. Respondents freely express their feelings and thoughts, facilitating a deeper understanding of services such as a sense of place or inspiration.
	Questionnaires	Uses a series of questions to collect information on CES from respondents. For example, researchers may employ Likert scales, asking participants to select from a given set of CES to reveal their perceived benefits.
	Expert-Based	Leverages the specialized knowledge and extensive experience of experts who are familiar with technical terminology and concepts. Experts identify key factors they deem relevant to CES issues.
	Participatory GIS (PGIS)	Integrates participatory mapping methods with Geographic Information Systems (GIS), involving stakeholders in spatial data collection and analysis.
	Public Participation GIS (PPGIS)	Emphasizes local-level engagement, encouraging knowledge production by communities and non-governmental groups.
	Visitor-Employed Photography (VEP)	Involves participants using location-enabled applications to freely photograph specific sites. Participants then evaluate various CES value types depicted in the photographs, enabling the quantification of perceived values [27].
	Virtual Reality (VR)	Employs panoramic VR or immersive virtual environments to create realistic, interactive scenes, allowing participants or subjects to virtually "enter" and experience specific natural or urban settings.

To reflect evolving practices in CES research, the framework was further expanded by incorporating emerging approaches such as participatory mapping, participatory geo-

graphic information systems (PGIS), public participation GIS (PPGIS), social media data analysis, building on the work of Márquez et al. and Yang and Cao [21,29]. These additions highlight the increasing adoption of digital and participatory tools in urban ecosystem service assessments.

Following the typology proposed by Hirons et al. and Christie et al. [30,31], a distinction was also made between monetary and non-monetary assessment approaches. For monetary methods, revealed preference methods assess value by observing market behavior related to CES, while stated preference methods construct a hypothetical market and ask respondents about their willingness to pay for, accept, or obtain services. For non-monetary methods, revealed preference methods typically involve indirect measurements of human preferences through behavioral observations or document analysis, whereas stated preference methods directly inquire about individuals' values related to CES.

This classification was iteratively refined during the literature review to accommodate methodological heterogeneity across the 61 studies. All evaluation methods used in the selected studies were recorded. For studies employing multiple methods, each method was documented and categorized separately to ensure an accurate representation of methodological diversity.

3. Results

3.1. Study Selection and Publication Trends

The study selection process is illustrated in the PRISMA 2020 flow diagram (Figure 2). A total of 341 records were retrieved from Web of Science and 745 from Scopus, yielding 1086 total records. After removing 77 duplicates using Zotero, 1009 unique records remained. An initial screening based on titles and abstracts excluded 814 records, resulting in 195 studies eligible for full-text screening.

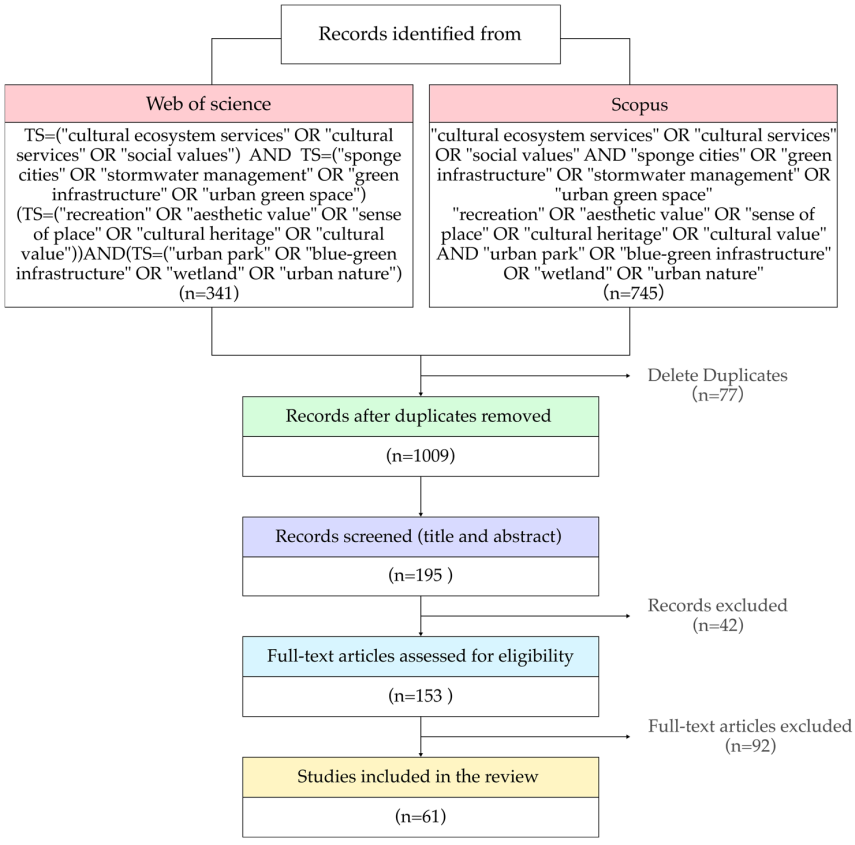

Figure 2. PRISMA 2020 flow diagram for study selection.

Following full-text assessment, 42 articles were excluded due to a lack of empirical data, irrelevance to CES, or not being conducted within the Chinese SPI context. Consequently, 153 full-text articles were assessed for eligibility, and 61 studies met the inclusion criteria and were included in the final review.

From 2013 to 2025, a total of 61 empirical studies on CES in the context of SPI were identified. As shown in Figure 3, the number of publications remained relatively low between 2013 and 2019, with fewer than five studies published per year. A noticeable increase began in 2020, reaching a peak in 2024 with 15 studies. As of April 2025, only three relevant studies have been identified. Therefore, the analysis of publication trends in this study is limited to the period up to 2024. From 2019 to 2024, the number of studies shows a consistent upward trajectory.

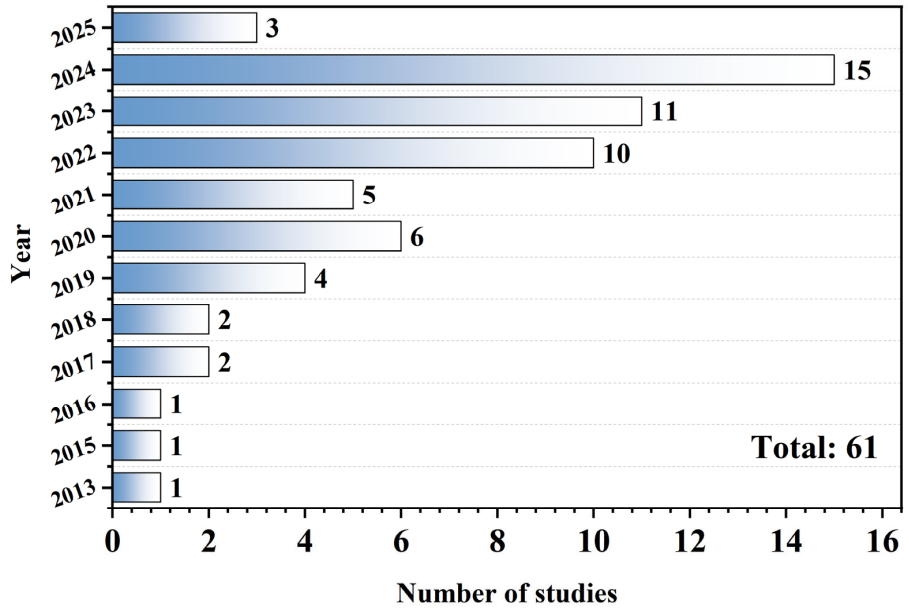

Figure 3. Number of published studies on CES between 2013 to April 2025.

3.2. Geographic Distribution and Thematic Focus of CES Studies

The included studies were analyzed based on key characteristics such as study location, thematic focus, CES categories addressed, and assessment methodologies. A structured summary of these attributes—covering authorship, publication year, study location, CES classification, and evaluation methods—is presented in Table S1 and served as the basis for subsequent analysis.

The spatial distribution of the reviewed literature reveals a clear concentration of CES studies in economically developed and research-intensive Chinese cities. As illustrated in Figure 4, Beijing has the highest number of studies (10), followed by Shanghai (8), Chengdu (6), and both Guangzhou and Hangzhou (3 each). Several other cities—such as Wuhan, Nanjing, and Shenzhen—were represented by only one or two studies. Only five papers included multi-city comparative designs, indicating limited geographic diversification in current CES research that explicitly addresses Cultural Ecosystem Services in the context of Sponge City development.

This distribution indicates that researchers tend to favor tangible, accessible, and clearly defined green public spaces, especially parks [32]. In contrast, few CES studies adopt a city-scale or infrastructure-oriented perspective on sponge city development, or investigate underrepresented spatial types such as rooftops, drainage corridors, and permeable surfaces [29,33]. This imbalance may constrain the ability to assess CES within the full complexity of SPI spatial configurations.

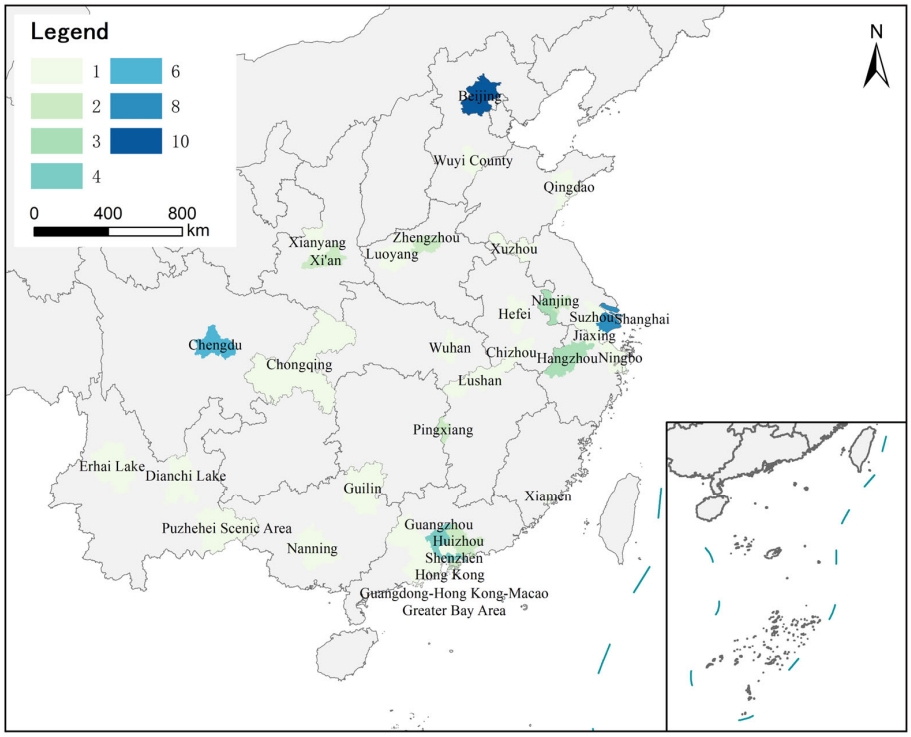

Figure 4. Geographic distribution of the reviewed studies (N = 61).

Figure 5 illustrates the thematic focus of the 61 CES-related empirical studies based on their primary research area. Parks are the most frequently studied spaces, accounting for nearly half of the studies (48.5%), followed by urban/town-level areas (27.3%). Studies explicitly focused on sponge cities, green infrastructure, and urban green spaces are much less common (each ≤8%). Blue areas such as rivers or wetlands are rarely addressed (only 3%). This indicates that CES studies under the SPI context are still predominantly park-centered, with broader urban water-related infrastructure largely underexplored.

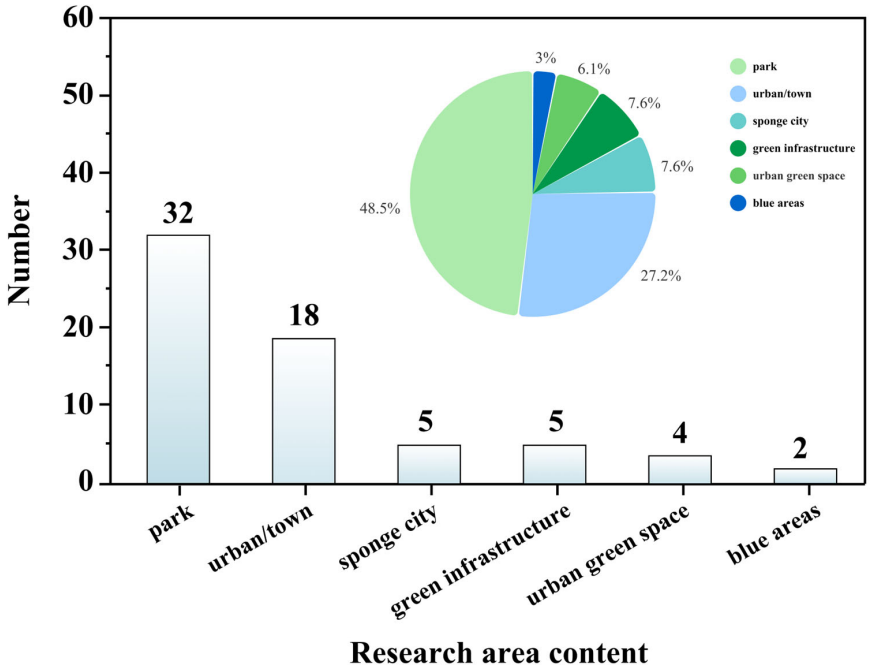

Figure 5. Thematic focus of CES studies.

3.3. CES Category

As illustrated in Figure 6, the reviewed literature shows a significant imbalance in the frequency of CES categories assessed. Recreational services were by far the most evaluated, with 58 times, followed by aesthetic value (48), educational services (33), and cultural heritage (29). These categories are often more tangible, directly observable, and relatively easy to quantify in urban environments.

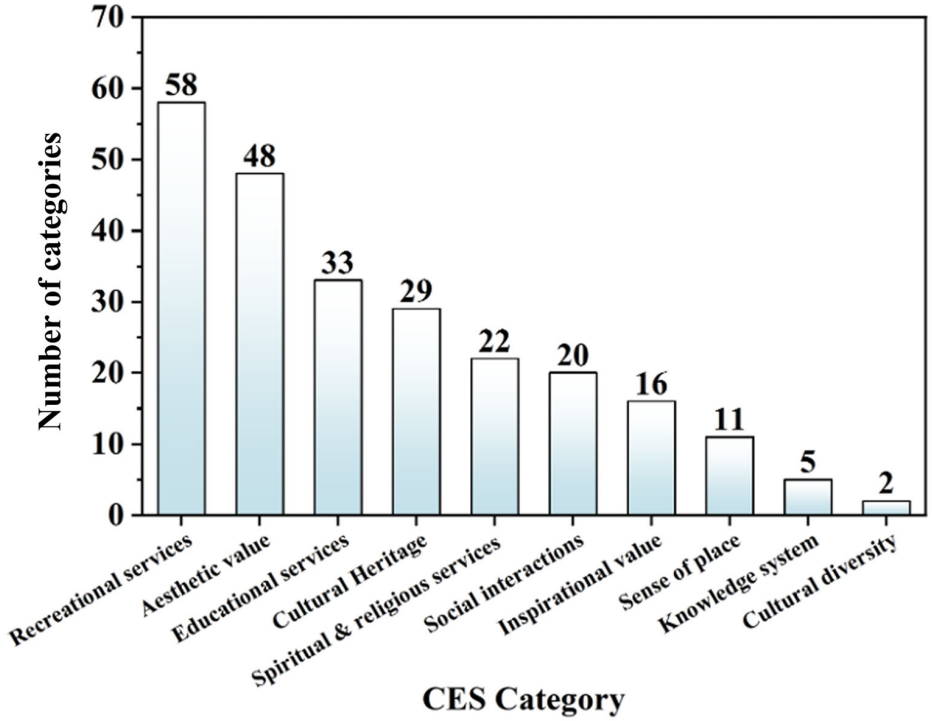

Figure 6. CES category.

In contrast, less emphasis was placed on more abstract CES dimensions. Categories such as spiritual and religious services (22 studies), social interactions (20), inspirational value (16), and sense of place (11) appeared to be underrepresented, especially when compared with frequently assessed categories such as recreation (45) and aesthetic value (41). This indicates a research bias toward more tangible and directly perceived cultural benefits. The least addressed categories were knowledge systems (5) and cultural diversity (2), which may be due to the conceptual complexity and cultural specificity of these values, making them difficult to operationalize through standard indicators.

These results demonstrate that tangible CES categories, such as recreation (45 studies) and aesthetic value (41), dominate current research in SPI contexts. In contrast, more abstract or culturally sensitive categories—such as knowledge systems (5) and cultural diversity (2)—remain significantly underrepresented. Full definitions of all CES categories are provided in Table S2.

3.4. CES Assessment Methodology

As illustrated in Figure 7, non-monetary methods represent the predominant approach for assessing CES in sponge city studies. Questionnaire-based surveys are the most frequently employed tool, used in 36 out of 61 studies, reflecting their ease of implementation and suitability for capturing public perceptions at scale. Social media-based analysis ranks second, featuring in 15 studies, with platforms such as Weibo, Ctrip, and Mafengwo providing real-time, user-generated data for sentiment and behavior analysis.

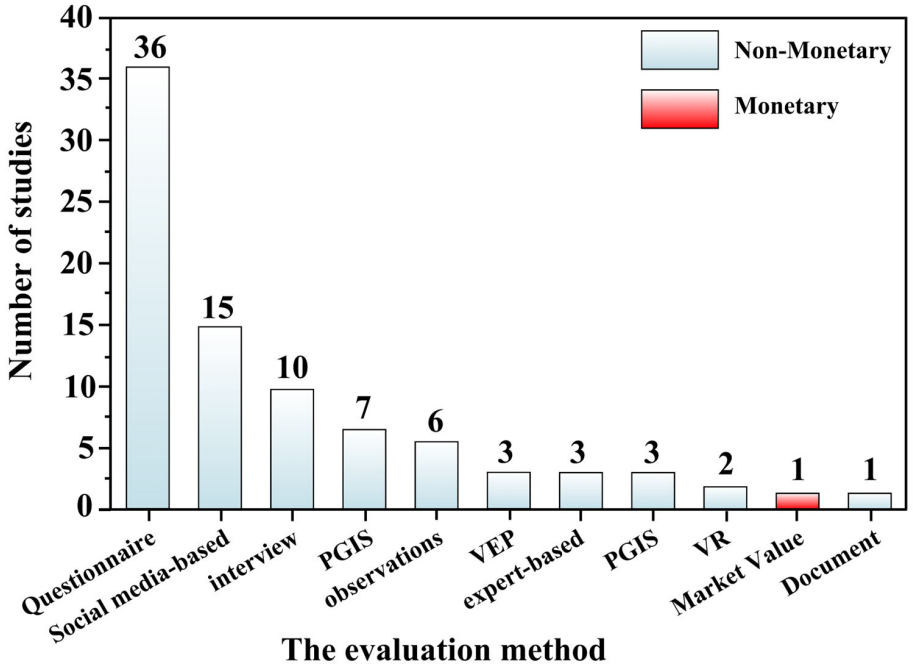

Figure 7. Assessment methods applied in CES.

Other commonly used non-monetary approaches include in-depth interviews (10 studies), participatory GIS (PGIS) (7 studies), and field observations (6 studies). Less commonly applied methods—such as visitor-employed photography (VEP), expert-based evaluation, and participatory public GIS (PPGIS)—were each used in three studies. Two studies employed VR-based participatory mapping to visualize user preferences in spatial planning contexts.

By contrast, monetary valuation methods remain extremely limited. Only one study employed economic techniques to quantify CES, highlighting the challenges of monetizing intangible cultural benefits in urban green infrastructure. One additional study relied on document-based analysis.

These findings highlight the prevalence of qualitative and spatially explicit non-monetary methods—such as surveys, interviews, and participatory GIS—in CES assessments under the SPI framework. However, they also reveal a methodological gap in integrating economic valuation with cultural perception, suggesting the need for mixed-method approaches that combine qualitative depth with quantitative rigor.

3.5. CES Assessment Indicators

A total of 187 CES indicators were extracted from the reviewed literature and categorized based on the Millennium Ecosystem Assessment (MA) framework as presented in Table S2. However, as shown in Figure 8, only 54.1% of the studies provided clearly defined and measurable indicators for the respective CES categories, highlighting the persistent inconsistency in indicator reporting.

As shown in Figure 8, the studies were classified based on whether they explicitly reported indicators that were both clearly defined and quantitatively or qualitatively measurable for the CES categories under investigation. "Yes" refers to studies that provided at least one such indicator per CES category, while "No" includes studies that discussed CES conceptually or descriptively without specifying measurable indicators. The nearly even split between the two (54.1% vs. 45.9%) indicates a lack of standardization in how CES indicators are defined and reported across the literature.

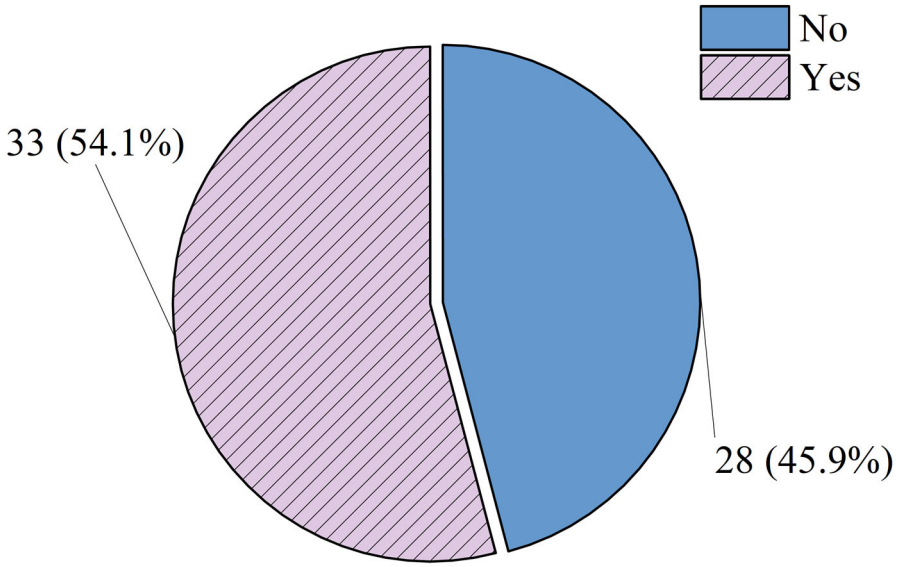

Figure 8. The proportion of indicators in the reviewed research.

As shown in Figure 9, recreational services were the most frequently represented category, with 46 indicators, followed by aesthetic value (32 indicators), cultural heritage (28), educational services (25), and spiritual and religious services (21). In contrast, more intangible or abstract categories, such as social interactions (14), inspiration (10), and sense of place (9), were much less commonly assessed. Notably, knowledge systems were represented by only two indicators, and cultural diversity was entirely absent from the reviewed studies.

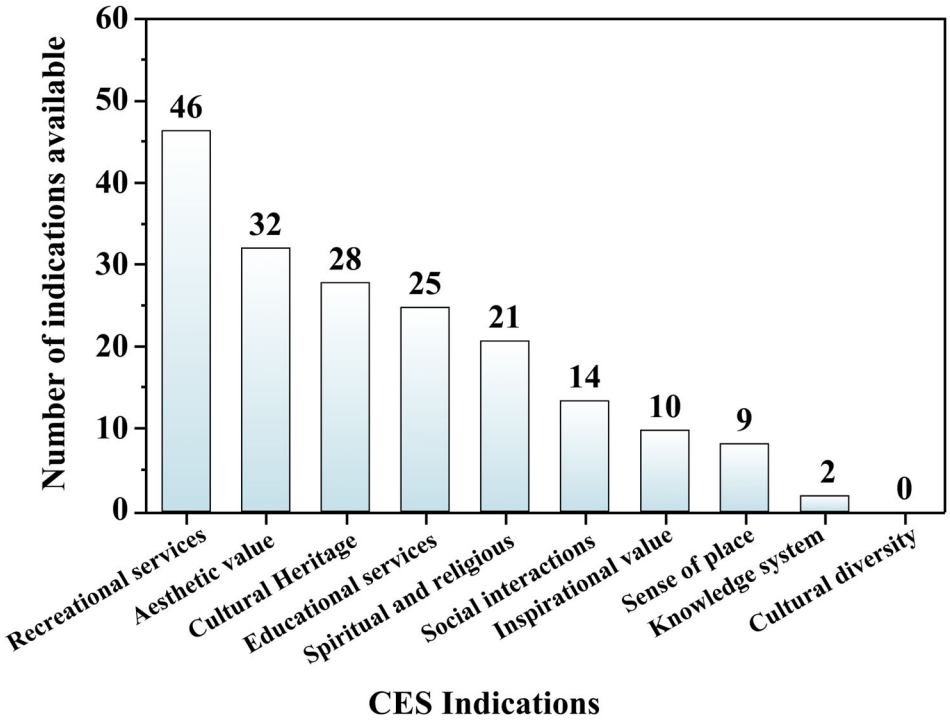

Figure 9. The number of indicators used for each CES category in the reviewed study.

This highly uneven distribution suggests a strong emphasis on tangible, easily quantifiable services, while symbolic and culturally embedded values remain underrepresented. For a complete list of indicator definitions and applications, please refer to Table S2.

4. Discussion

This discussion section synthesizes the key findings from the systematic review and critically analyzes the current state of CES research under the SPI framework. It focuses on five main dimensions: publication trends, geographic and thematic distributions, CES category coverage, assessment methods, and indicator use. Based on the identified gaps and contextual challenges, the section concludes by proposing a localized CES evaluation framework tailored to China's SPI context.

4.1. The Number of Articles Related to This Topic

The steady growth in CES-related publications within sponge city research since 2013 reflects a broader shift in academic and policy interest. Early stages of SPI implementation were dominated by engineering-led approaches, focusing on hydrological control and ecological restoration [5,6]. However, after the gradual completion and initial evaluation of pilot projects around 2017, scholars began to pay attention to the broader socio-cultural aspects of urban ecological infrastructure.

This shift is particularly evident in the notable rise in publications between 2020 and 2024. During this period, China's ecological civilization policies began to emphasize cultural values alongside ecological performance [34–37]. The resulting regulatory and funding support helped foster empirical research beyond traditional ecological indicators [37]. In addition, the growing recognition of CES—particularly recreational and aesthetic values—as integral to public acceptance and urban livability has encouraged interdisciplinary collaboration among planners, designers, and environmental scientists [19,38].

Despite the growing interest in CES, its incorporation into SPI research frameworks has been relatively recent, with most studies emerging after 2017 when pilot projects began to be evaluated [39]. This highlights the importance of integrating cultural ecosystem services more systematically during the early stages of sponge city planning and evaluation [40,41]. Moving forward, CES is likely to become a central component of sponge city evaluation as the discourse around urban sustainability continues to evolve.

4.2. Geographic Location and Research Focus

The reviewed studies demonstrate a strong geographic concentration in Tier 1 and New Tier 1 cities in China, particularly in metropolitan areas such as Beijing, Shanghai, Chengdu, and Guangzhou (see Figure 4). Tier 1 cities refer to the most developed and internationally recognized metropolitan areas (e.g., Beijing, Shanghai), while New Tier 1 cities are emerging urban centers with rapid economic growth, such as Chengdu and Hangzhou. Due to their advanced infrastructure and the concentration of academic and research institutions [42], these cities have become leading centers for CES research in the context of SPI. In contrast, small and medium-sized cities—many of which serve as designated sponge city pilot zones [9,43]—are significantly underrepresented in CES-related empirical studies, with only a limited number of publications focusing on these urban contexts. Moreover, the lack of cross-departmental accountability mechanisms makes it difficult to implement cultural functions across less conventional spatial types [25,44] This creates a spatial mismatch between where SPI is most comprehensively implemented and where academic research is primarily conducted.

A similar pattern of thematic bias is evident in the spatial types studied (Figure 5). Nearly half of the reviewed studies (48.5%) concentrate on park, whereas other forms of green and blue infrastructure—such as green corridors, community wetlands, and blue spaces—are comparatively underrepresented [45,46]. This narrow focus may be attributed to both practical and institutional constraints: urban parks are readily accessible, widely recognized, and conducive to short-term evaluations [47]. However, this preference may obscure the

multifunctional cultural benefits provided by less visible or integrated elements of sponge city infrastructure, such as green corridors, community wetlands, and blue spaces [19,48,49].

To address these limitations, future research and policy implementation should emphasize adaptive governance approaches, integrate CES metrics into early-stage planning, and establish clearer inter-agency coordination pathways. Future research could broaden its spatial scope to include small and medium-sized cities and consider a more integrated, system-level perspective on SPI to better reflect the cultural ecosystem service functions embedded in its infrastructure. Such an approach would help reveal the layered and spatially distributed cultural values within sponge city landscapes.

4.3. Categories Assessment of CES

The analysis of CES categories within the context of sponge city infrastructure reveals a pronounced imbalance in the current research focus. As shown in Figure 6, recreational services and aesthetic value dominate the literature, with a substantial number of studies concentrating on these easily observable and quantifiable categories. In contrast, more abstract cultural categories—such as spiritual values, sense of place, cultural diversity, and knowledge systems—remain significantly underrepresented.

In the context of China's SPI research, abstract categories such as "cultural diversity", "knowledge systems", "inspiration", and "sense of place" are often underrepresented. This imbalance may be attributed to several interrelated factors: first, the difficulty of incorporating these categories into performance-oriented evaluation systems; second, the dominance of natural and engineering sciences in the research paradigm; and third, the diminishing visibility of local cultures amid rapid urbanization [50–52]. Additionally, topics related to religion, ethnicity, and intangible cultural heritage are often considered institutionally sensitive, which further constrains exploration of these categories [53]. Even when the MA framework is formally referenced, some Chinese studies restructure or consolidate complex categories for practical purposes—for instance, merging "inspiration" with aesthetics, or treating "knowledge systems" as part of environmental education or cultural heritage [54–56]. Such adjustments result in surface-level alignment with international classification systems while differing substantially in practical interpretation and application [57].

Notably, the conceptual treatment of CES also diverges between Chinese and Western scholarship. In contrast, Chinese CES research has generally emphasized planning-related or aesthetic–cultural perspectives, focusing more on landscape use, user satisfaction, and heritage preservation [58,59]. This tendency may reflect the influence of national planning priorities and the practical orientation of environmental governance, which differs from the interpretive and theory-driven approaches more common in Western contexts [60].

On the other hand, emerging categories such as "infrastructure appreciation" and "future services" have begun to appear in the SPI-related literature, reflecting a growing interest in the diverse values of CES. However, these categories have yet to be supported by consistent theoretical or operational frameworks [61]. Overall, the imbalances in CES category assessment are evident in both Chinese SPI studies and international CES research, though the contexts and emphases vary.

In summary, CES research under the SPI framework in China exhibits common biases toward tangible and measurable categories [62]. However, their underlying analytical traditions and policy environments differ significantly. Moving forward, there is a pressing need to develop CES classification systems that are both globally comparable and locally adaptive. Such frameworks should integrate abstract cultural values through participatory, context-sensitive methods, and align with both international standards (e.g., MA) and the socio-political realities of Chinese urban governance [63,64].

4.4. Assessment Methods

In the context of SPI, CES is predominantly assessed through non-monetary approaches, reflecting the intangible and value-laden nature of cultural benefits in urban ecological planning. Among the 10 non-monetary methods analyzed in this study, questionnaires are most frequently employed, appearing in 36 instances—a finding that underscores their simplicity and practicality [65]. Recent global reviews have shown that questionnaire-based assessments remain the primary tool in CES research, reflecting a broader trend toward structured, quantifiable methods.

However, despite their popularity, questionnaires face well-documented limitations. These include restricted ability to capture context-specific meanings, challenges in expressing symbolic or emotional dimensions, and limited sensitivity to intergroup differences [64,66]. As a result, scholars increasingly emphasize the need to integrate multisensory perspectives, long-term behavioral observation, and socio-cultural variables into future CES assessment frameworks.

In recent years, technology-driven non-monetary methods, such as social media data analysis and participatory GIS, have garnered increasing attention [67]. These methods enable researchers to access real-time behavioral data and spatial preferences from diverse user groups [68]. However, their application requires significant technical capacity and often lacks standardized analytical protocols, which may limit cross-context comparability and local adaptability [61].

Other common non-monetary methods—such as field observation, expert scoring, and semi-structured interviews—can offer richer cultural insights, particularly in uncovering subjective perceptions and community narratives. However, their use is often constrained by small sample sizes and difficulties in integration with spatial planning instruments [69,70].

Although monetary valuation methods—such as contingent valuation and hedonic pricing—are widely used in broader ecosystem service research [71,72], their application in CES remains limited, particularly within the context of SPI. This is largely due to the intangible and symbolic nature of cultural values, ethical concerns, and the methodological difficulty of translating non-material benefits into economic terms [73].

To address the above challenges, CES assessment in the context of SPI may benefit from adopting integrated and mixed-method approaches to balance quantitative scope and qualitative depth [28,74]. Such as participatory GIS, virtual reality simulations, qualitative interviews, or observational approaches. These methods are better suited to capturing intangible cultural values that are difficult to quantify—such as sense of place, spiritual experience, and cultural identity—and can complement Likert-scale surveys to enhance the depth and legitimacy of CES assessments in the context of sponge city planning.

4.5. CES Evaluation Indicators Challenges in the Application

Despite the increasing attention to CES in sponge city research, the development and application of robust and standardized indicators remain limited [27,31]. As highlighted in the results (Section 3.5), although 187 CES indicators were identified across 61 studies, only 54.1% of the publications provided specific and measurable indicators, while the rest referred to general CES categories without defining how they were operationalized [75].

Even among those studies that did utilize indicators, inconsistencies in definitions and classification were common [76,77]. For example, the same activity—such as urban cycling—was categorized as both recreation and social interaction in different studies, resulting in ambiguity and potential data overlap [67]. This reflects the broader challenge of aligning indicator use with clearly defined CES typologies.

Assessing CES in sponge city contexts remains difficult due to the lack of clear, consistent, and practical indicators [28,78]. While CES categories such as recreation, aesthetics,

and education are widely used, many studies fail to define how these categories are measured in practice [15,75]. In nearly half of the reviewed papers, only general categories were listed without any corresponding indicators, making results hard to compare or apply (See Figure 8).

Abstract CES categories, such as inspiration, sense of place, and cultural identity, remain particularly underrepresented [79]. These categories are difficult to quantify and often lack clear measurement tools or baseline data [23,78]. Even more marginal are knowledge systems and cultural diversity, which were represented in only two indicators—or were entirely absent—in the reviewed literature (see Figure 9). Such gaps are not exclusive to Chinese cases but are also observed in international research, where symbolic and non-material CES dimensions remain poorly captured [80].

In the context of SPI, which seeks to integrate ecological and cultural functions, the lack of context-specific CES indicators may contribute to the underrepresentation of certain cultural values in planning and evaluation processes [81]. This may result in limiting the potential for infrastructure design to reflect and support local cultural needs and identities.

To address these challenges, future studies could focus on developing CES indicators that are simple, context-sensitive, and culturally grounded. International frameworks such as MA and IPBES provide valuable reference points [82,83], but local adaptation and participatory validation are essential to ensure relevance. Involving community stakeholders, urban planners, and interdisciplinary experts in indicator design can help improve both the scientific robustness and the cultural legitimacy of CES assessments in sponge cities [84]. Thus, the current body of evidence remains fragmented and uneven, limiting the generalizability of CES evaluation findings across diverse SPI contexts.

4.6. Toward a Localized CES Evaluation Framework for SPI: Structure and Implications

This study identifies several key challenges in existing research on CES within the context of sponge cities, as summarized in Sections 4.1–4.5. These challenges include the spatial and thematic concentration of research areas, imbalanced use of CES categories, limited methodological diversity, and inconsistencies in indicator systems—as demonstrated in the empirical results presented in Sections 3.2–3.5. Collectively, these issues underscore the limitations of existing CES evaluation frameworks in addressing cultural services in sponge city development. Therefore, it is necessary to propose a localized and practice oriented CES classification and assessment framework to reflect the characteristics of cultural services accurately in the context of SPI.

The proposed framework adopts a structured and standardized approach to address the widespread inconsistency in CES indicator usage identified in previous studies. Each CES category is clearly defined and linked to a set of representatives, perception-based indicators, enhancing conceptual clarity, comparability, and replicability. To support practical implementation, all indicators are designed to be evaluated through 5-point Likert-scale surveys, enabling consistent data collection across different sponge city contexts.

The design of this framework is informed by three main sources of input. First, it is informed by a systematic review of 61 empirical studies, which helped identify the definitions, frequency of use, and indicator types associated with various CES categories. Second, it references key national planning and environmental policy documents such as the Ecological Civilization Strategy, the Technical Guide for Sponge City Construction [12] and the National Territorial Spatial Planning Outline (2020–2035), all of which emphasize the integration of ecological and cultural values in urban development. Although this study does not include a detailed policy analysis section, these documents serve as guiding references that inform the framework's alignment with national planning priorities and practical applicability. Third, the framework incorporates insights from pilot project prac-

tices, especially observed cultural and educational design interventions such as wetland education zones, landscape art installations, and interactive community spaces. These sources collectively support the framework's structural logic and categorization strategy.

The proposed framework organizes CES into eight context-relevant categories, specifically tailored for application within the SPI context. These eight services include aesthetic value, recreational value, educational value, cultural heritage, spiritual and religious value, social relations, sense of place, and inspiration. Each category was selected based on its empirical prevalence, contextual relevance, and alignment with the objectives of SPI planning.

Compared with the Millennium Ecosystem Assessment (MA) framework, this localized version deliberately excludes the categories of "cultural diversity" and "knowledge systems", due to their limited operational feasibility, data scarcity, and heightened cultural sensitivity within China's urban governance system. In both the international and domestic CES literature, these two categories lack mature, context-specific indicators that can be reliably used in quantitative evaluation—particularly in urban infrastructure settings like sponge city parks [69,77]. Moreover, the intangible and often overlapping nature of these dimensions—especially in relation to "cultural heritage" and "educational value"—makes them difficult to delineate clearly within the perception-based questionnaire format adopted in this study [78]. In the Chinese context, elements such as local dialects, traditional crafts, and indigenous knowledge are typically incorporated under heritage protection or community education programs, further reinforcing their conceptual integration with existing categories [85,86].

While maintaining conceptual clarity and international comparability, the framework places greater emphasis on cultural adaptability and practical applicability. By ensuring that each included CES category contains at least three measurable sub-indicators, the structure of the evaluation tool is optimized for statistical reliability and ease of public understanding during field surveys. Over-fragmentation at this stage may reduce respondent clarity and compromise data quality [77,86]. However, future iterations of the framework may consider disaggregating these two dimensions—once reliable indicators emerge from empirical observation or policy development—to enhance global alignment [69,77].

Each category is accompanied by SPI-specific definitions and recommended example indicators, aiming to provide both theoretical grounding and actionable tools for CES evaluation in real-world sponge city contexts. The structure and contents of this framework are summarized in Table 3, which presents each CES category along with its SPI-relevant definition and selected example indicators.

Table 3. Proposed cultural ecosystem services evaluation framework for sponge city planning in China. Each CES category is defined in the context of SPI, with illustrative indicators suggested for practical assessment.

Category	Definition	Example Indicators
Educational values	Sponge cities provide essential material for formal and informal education.	Science education facilities: the presence of educational infrastructure (labs, field classrooms, informational signage); on-site educational activities: organized ecological tours, environmental education programs, and outdoor classrooms; informal learning: casual nature observation by individuals or families.
Leisure and entertainment	Sponge cities support opportunities for leisure and recreation.	Sports activities: walking, jogging, playing sports (e.g., football, basketball), swimming, kite flying, square dancing; passive leisure: dog walking, sitting/relaxing, reading, meditation; water-based recreation: crab fishing, boating, angling, feeding fish.

Table 3. *Cont.*

Category	Definition	Example Indicators
Social relations	SPI promotes public social interaction and cohesion.	Social spaces: availability of gathering spots for family and friends; community participation: events or design features encouraging community involvement and cohesion; community activities: frequency of outdoor events (movies, concerts, group camping, etc.).
Cultural heritage	Sponge cities help preserve and showcase historical and cultural heritage.	Conservation of relics: protection of historical monuments, buildings, and cultural sites; maintenance of heritage sites: regular upkeep (inspections, restoration) of cultural landmarks; intangible heritage: support for traditional crafts, oral histories, and performing arts.
Sense of place	Emotional attachment and identity derived from the uniqueness of SPI sites.	Attachment: residents' emotional attachment to local SPI features; belonging: the sense of belonging or pride in the sponge city neighborhood; memorability: the degree to which the SPI landscape offers unforgettable experiences or lasting impressions.
Aesthetic value	Enjoyment of natural beauty and pleasant surroundings in sponge cities.	Natural scenery: visual appeal of landscapes (water bodies, wetlands, greenery); natural sounds: presence of pleasing sounds (birdsong, flowing water, insect calls); natural scents: occurrence of pleasant natural aromas (flowers, wood, fresh grass).
Spiritual and religious	Spiritual fulfillment and religious expression supported by SPI environments.	Physical relaxation: sponge city spaces facilitating stress relief and physical well-being; psychological restoration: opportunities for mental relaxation and recovery; spiritual activities: spaces or elements enabling religious practices or personal contemplation.
Inspiration	Stimulus for artistic creation and intellectual inspiration from SPI.	Artistic inspiration: settings inspiring art, photography, music, or design; cultural narratives: inspiration for folklore or local cultural stories; intellectual stimulation: new ideas or learning prompted by the sponge city environment (innovative thinking in daily life).

To operationalize this framework, all indicators have been translated into perception-based survey items for practical use in public satisfaction assessments. A sample questionnaire is provided in Table S3, demonstrating how the framework supports planning feedback and policy decision-making in sponge city design.

This framework aims to bridge the gap between global CES classifications and the operational needs of SPI, offering a practical approach tailored to China's socio-cultural and planning context. By incorporating China's unique socio-cultural characteristics, the framework enhances the local adaptability of CES classification systems and helps to address the disconnect between internationally adopted CES frameworks and local planning practices. Moreover, it provides methodological guidance for aligning global CES evaluation systems—such as MA and IPBES—with the practical needs of sponge city development in China, while offering relevant experience for other rapidly urbanizing countries. Through SPI-specific examples and operational definitions, the framework also facilitates the translation of abstract concepts—such as "sense of place" and "inspiration"—into planning-oriented tools via perception-based indicators, thereby improving the integration of cultural services into infrastructure decision-making. Additionally, the localized approach demonstrated in this framework offers a practical pathway for grounding global CES frameworks within specific cultural contexts and exhibits strong potential for scalability and international applicability.

Despite its advantages, several limitations should be acknowledged regarding the practical application of this CES framework. First, the framework is developed based on empirical studies that are predominantly concentrated in China's Tier 1 and New Tier 1 cities, such as Beijing, Shanghai, and Chengdu (see Section 3.4). This geographic concentration may limit the generalizability of the findings, as cultural perceptions, institutional structures, and public values can vary significantly across smaller or less-developed urban areas. Additionally, it is inherently shaped by China's policy-driven planning system and centralized governance structure. These institutional factors often create practical implementation barriers such as fragmented responsibilities, limited cross-sectoral coordination, and bureaucratic inertia, potentially hindering effective integration of intangible CES dimensions into operational planning processes [6,69].

Nevertheless, the underlying structure of the proposed framework remains transferable and aligns conceptually with internationally recognized CES frameworks such as the Millennium Ecosystem Assessment (MA) and IPBES. Like these global frameworks, the proposed model emphasizes the multidimensional and context-sensitive nature of CES, advocating for place-based, culturally specific adaptations rather than universal categories [77,87]. Through localized modifications—such as adjusting indicator definitions, incorporating traditional knowledge, or customizing participatory evaluation approaches—this framework may effectively be adapted to diverse socio-cultural and governance contexts.

To support integration into China's planning systems, the framework is suitable for incorporation into post-construction evaluations of sponge city parks, community satisfaction surveys, and pilot assessments conducted jointly with planning and environmental agencies.

Future research should explicitly explore the framework's applicability through comparative studies involving diverse international contexts, particularly within rapidly urbanizing regions such as Southeast Asia, Latin America, and Africa. Such studies should focus on identifying and validating culturally relevant indicators, engaging local communities through participatory methodologies, and addressing governance variations. Additionally, empirical studies are encouraged to investigate practical localization strategies, aiming to develop operational protocols for adapting global CES typologies into specific cultural and institutional settings, thus enhancing the framework's international scalability and comparative analytical value.

This review was limited by the exclusive use of Web of Science and Scopus databases, English-language restrictions, and the absence of protocol registration, which may have led to the omission of relevant studies published in other languages or in the grey literature.

5. Conclusions

This review has synthesized the current state of research on CES in the context of SPI and identified key challenges across spatial scope, category representation, methodological diversity, and indicator standardization. To address these gaps, the study proposes a localized CES evaluation framework that integrates China's socio-cultural specificities while maintaining conceptual alignment with global standards such as MA and IPBES.

By offering SPI-oriented definitions and perception-based indicators, the framework enables the practical integration of abstract CES dimensions—such as sense of place and inspiration—into planning processes. It provides not only a theoretical reference but also a pragmatic tool for policymakers and urban designers seeking to embed cultural values in ecological infrastructure.

The proposed framework exemplifies how global CES typologies can be meaningfully localized in rapidly urbanizing contexts, serving as a transferable model for other countries facing similar sustainability transitions. Future research should build on this foundation

through empirical validation, multi-city comparisons, and participatory approaches that deepen cultural relevance and policy impact.

Future studies should explore the applicability of the proposed framework across different cultural and administrative settings to enhance its scalability and transferability.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su17115130/s1, Table S1: Study Metadata of Empirical Research on Cultural Ecosystem Services; Table S2: CES Indicators Categorized by Service Type in the Reviewed Studies; Table S3: Operationalization of the CES Evaluation Framework via Questionnaire Items.

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