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Research Article

Sustainable management of Urban river ecosystem services: A systematic literature review on community engagement and environmental behavior in Indonesia

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Abstract
Rivers play a pivotal role in providing essential ecosystem services and natural resources that are crucial for both human and ecological well-being. However, inappropriate exploitation of river ecosystems can jeopardize their ability to deliver these services, posing significant risks to human welfare and environmental sustainability in the future. Therefore, restoring degraded river ecosystems is crucial to ensuring the sustainability of environmental provisions to meet current and future demands. In urban settings, rivers hold particular significance in maintaining the sustainability of water resources. Batang Arau, a major river flowing through the heart of Padang City, Indonesia. serves as a critical resource supporting various community needs and activities. The river provides essential ecosystem services, including raw water for the municipal water supply (PDAM), as well as support for bathing, washing, sanitation, agriculture, and livestock. Additionally, its estuary supports vital transportation services, functioning as an inter-island shipping port on the West Coast of West Sumatra. This study employs a Systematic Literature Review (SLR) methodology, reviewing scholarly articles from Google Scholar, Elsevier, and ScienceDirect. The TCCM (Theory, Context, Characteristics, and Methodology) framework was used to classify research and identify knowledge gaps, thereby paving the way for future research directions. Sustainable management of the river's ecosystem services can be achieved through a sociocultural assessment approach, emphasizing environmental behavior via the New Ecological Paradigm (NEP), and an economic approach through Payment for Ecosystem Services (PES). These strategies can inform policies and programs that mitigate environmental degradation by actively involving community participation.

Keywords: Environmental services, New ecological paradigm, Payment for ecosystem services, Social-cultural, Willingness to pay

INTRODUCTION

One of the ecosystems that provides essential environmental services, natural resources, and supports human livelihoods is the river ecosystem. Globally, nearly one billion people rely on water resources, that face growing challenges in terms of access and reliability, particularly for drinking water and other essential uses (Fraccascia *et al.*, 2021) Furthermore, nearly half of the global population lacks access to proper sanitation facilities. This issue is particularly prevalent in urban areas within developing countries, where approximately 95% of untreated wastewater is discharged directly into surface water sources. As a result, communities living downstream of urban rivers, who rely on these waterways for essential daily activities such as drinking, bathing, and washing, are exposed to significant health risks. The direct use of polluted river water often leads to waterborne diseases and other serious health complications, highlighting the urgent need for improved sanitation infrastructure and wastewater treatment systems ((Sumarga *et al.,* 2024; Yang and Deng, 2020).

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The city of Padang, the capital of West Sumatra Province, is an urban area undergoing significant development as a hub for education, commerce, and tourism. According to the Regional Medium-Term Development Plan (RPJMD) of Padang City for 2019–2024, the city's population has increased to 919,145, with a population density of 1,323 people per square kilometer. This high population density is primarily attributed to urbanization, driven by the expansion of residential areas and commercial developments, which have attracted many residents to settle along riverbanks (Kim *et al*., 2022)

Several major rivers flow through the heart of Padang, serving as critical resources for the community's daily needs. Among them, the Batang Arau River holds particular importance, providing a wide range of environmental services. These include serving as a raw water source for PDAM (municipal water supply, and supporting activities such as bathing, washing, sanitation (MCK), agriculture, and livestock. Additionally, the river's estuary facilitates inter-island shipping on the West Coast of Sumatra, underscoring its economic significance.

Historically, Batang Arau has played a pivotal role in the formation of Padang City. In 1606, the Dutch began to establish their presence at Muaro Port. Over time, their influence grew with the establishment of a VOC trading office, the introduction of currency systems, and the construction of a lodge that symbolized their dominance. The first lodge, built at the mouth of Batang Arau, became the largest in the West Sumatra region. On August 7, 1669, this lodge was attacked and burned by local fighters from Pauh and Koto Tangah, marking an event commemorated as Padang City's anniversary. Later, on May 20, 1784, the Dutch officially designated Padang as the central trade hub of West Sumatra. By 1837, it had become the administrative centre for the West Coast of Sumatra. Until the 18th century, the Batang Arau area, along with its surrounding regions, including Kampung Cina, Kampung Keling, Pasar Hilir, Pasar Mudik, Pulau Aia, Ranah Binuang, Alang Lawas, and Seberang Padang, played a crucial role as centres of trade, settlement, and military defence.

The role of rivers in urban areas is essential, particularly in ensuring the sustainability of water resources. Efforts to prevent the degradation of water quality and safeguard the environment have become focal points of the Sustainable Development Goals (SDGs), which were launched on September 25, 2015. . which focuses on clean water and sanitation, aims to improve water quality by 2030 through measures such as reducing pollution, eliminating untreated wastewater discharge, minimizing hazardous waste disposal, and significantly increasing the safe reuse and recycling of water globally.In the context of urban river management, environmental services can be categori flood prevention, stormwater runoff mitigation, sediment control, and water quality preservation. Beyond these technical functions, urban rivers also provide cultural services, including recreation, tourism, education, knowledge, and aesthetic value. However, the interaction between natural resources and human activities in urban rivers is a complex phenomenon. Human activities significantly impact water quality, and excessive waste discharge can surpass the river's natural self-cleaning capacity, leading to pollution. This negatively impacts aquatic ecosystems and poses health risks to communities that depend on river water (Hasibuan *et al.,* 2025).

The ecological environment is deeply intertwined with economic and cultural services, both of which are critical components of urban ecosystem services (Granstrand and Holgersson, 2020). Therefore, it is imperative to implement control measures to ensure the sustainability of river-based environmental services, addressing current and future demands in terms of time, quantity, spatial distribution, and quality.Despite various studies on water resource management, achieving optimal planning and sustainable solutions remains a significant challenge. Water resources, as essential ecosystem services, are influenced by non-linear objectives, complex models, extensive control requirements, and uncertainties in hydrological systems due to climate change (Georgiou *et al*., 2020). The complexity of water resource and sanitation issues cannot be resolved solely through technical approaches. Environmental values play a key role in shaping pro-environmental behaviors, as ecological problems often stem from societal attitudes, values, and beliefs. A cultural environmental service approach, which considers community behavior toward the environment, is essential for developing sustainable solutions. Currently, limited efforts to control water pollution are further compounded by low public environmental awareness and weak enforcement of environmental laws. Therefore, it is crucial to assess the cultural environmental services provided by urban rivers as part of a comprehensive and sustainable management strategy. This approach can be effectively developed through a Systematic Literature Review (SLR).

METHODOLOGY

Systematic literature review

Information about this research was obtained using the Systematic literature review (SLR) method. This method was carried out systematically, based on the provisions outlined in the literature review flow, to minimize errors in subjective understanding by researchers. The SLR method aimed to summarise the

existing literature on urban river cultural and environmental services. The article search strategy utilized national and international scientific publication databases, including Google Scholar, Elsevier, and Scopus. This method consisted of five steps. First, determine the topic, questions, and objectives of the study. Second, identify relevant keywords and sources for publication search. Third, search and filter the literature based on inclusion criteria. Fourth, read and analyze the publications to filter out the relevant findings. The final step is to summarize and present the findings.

Literature identification

The study was conducted to support the research process by conducting a literature review to obtain references and comparisons for the implementation of the research. The literature review was conducted by collecting references from several previous studies, which were then compiled to draw conclusions (Granstrand and Holgersson, 2020) . The article selection stage began by identifying documents through a comprehensive database search, resulting in the retrieval of 1,438 papers. Furthermore, documents were excluded if they included non-journal articles with a publication date range of 2013 to 2023 and full text was not available. This resulted in 468 papers being obtained. The papers were then filtered based on their titles and abstracts, which were relevant to the subject matter, resulting in 384 pieces. Documents were filtered based on their title, abstract, and suitability of content, considering their relationship to river cultural and environmental services, resulting in 101 articles. After going through a literature feasibility assessment, 62 articles remained that were relevant to this review. The following is an article search scheme, illustrated in a flowchart diagram in Fig. 1.

Data extraction and analysis

The study conducted a comprehensive search through national and international scientific journal publication databases, obtaining 62 relevant article data points after extraction and analysis. At this stage, data analysis was conducted using bibliometric techniques, a method that examines relevant literature over time (Zaidi, 2024). Include source analysis, country and continent research analysis, methodology analysis, theory analysis, and network analysis. Currently, numerous software tools are available to analyze networks. The main tool used in this study is VosViewer software (version 1.6.20) (Zaidi, 2024). The present study utilized the TCCM (Theory, Context, Characteristics, and Methodology) model in analyzing future research developments. In addition, the TCCM model provides a stronger understanding, rigour, and relevance of the article review (Padmadewi *et al.*, 2023).

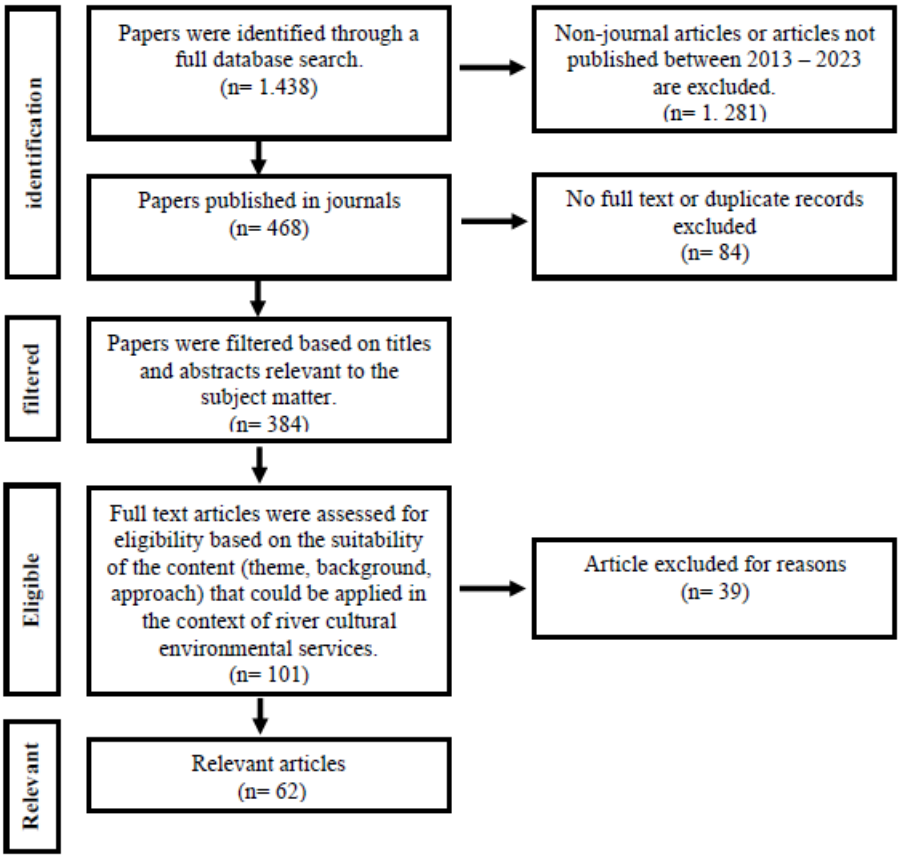

Fig. 1. *Relevant literature selection and screening process (SLR) shown in the flow chart*

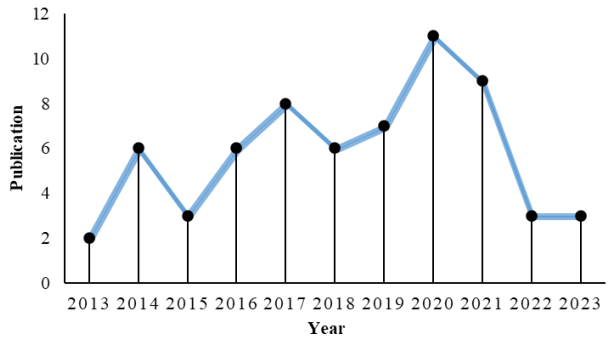

Fig. 2. *Distribution of Journal Publications 2013-2023*

Description analysis

Publications on cultural, environmental services in rivers experience spikes and declines in frequency each year. The following *Fig.* shows the publication volume from 2013 to 2023 (Fig. 2). The distribution of relevant journal sources comprised six categories: Environmental Journals (44), Economic Journals (9), Urban Studies Journals (4), Marine Science Journals (3), Energy Journals (2), and Social Science Journals (1) (Table 1).

The distribution of studies by country is spread across twenty-six countries (Fig. 3a). The majority of case studies were conducted in China (15), the United States (7), and Brazil (6). The distribution by Continent was most extensive in Asia (22), followed by Europe (16), and the least in Australia (2) (Fig. 3b).

Mixed, qualitative, and quantitative methodologies were employed across all scales, with a general preference for 62 relevant studies that used mixed methods (54), qualitative methods (4), and quantitative methods (4) (Table 2). Mixed methods consisted of a combination of qualitative and quantitative approaches, such as factor analysis, interviews, surveys, and observations. Qualitative Methods, such as Interviews, Case Studies, Literature Reviews, and Q Methodology. Quantitative meth-

Table 1. Distribution of Journal sources

Journal Source	Amount	%
Environmental (43)		
Journal of Environmental Management	6	9.68
Science of the Total Environment	5	8,06
Ecohydrology and Hydrobiology	1	1,61
Ecosystem Services	14	22,58
Environmental Challenges	1	1,61
Biological Conservation	1	1,61
Journal of Cleaner Production	2	3,23
Sustainability	1	1,61
Ecological Indicators	4	6,45
Environmental development	1	1,61
Journal of Environmental Psychology	1	1,61
Journal for Nature Conservation	1	1,61
Marine Pollution Bulletin	1	1,61
Environmental Science and Policy	1	1,61
Heliyon	1	1,61
International Journal of Environmental Research and Public Health	1	1,61
Geography and Sustainability	1	1,61
Economy (9)		
Water Resources and Economics	2	3,17
Journal of Behavioral and Experimental Economics	2	3,17
Journal of Environmental Economics and Management	2	3,17
Ecological Economics	3	4,76
Urban Studies (4)		
landscape and urban planning	2	3,23
Land Use Policy	1	1,59
Journal of Urban and Regional Development	1	1,59
Ocean Science (3)		
Ocean and coastal management	2	3,17
Estuarine, Coastal and Shelf Science	1	1.59
Energy (2)		
Renewable and Sustainable Energy Reviews	1	1.59
Biomass and Bioenergy	1	1.59
Social Science (1)		
Social and Behavioural Sciences	1	1.59

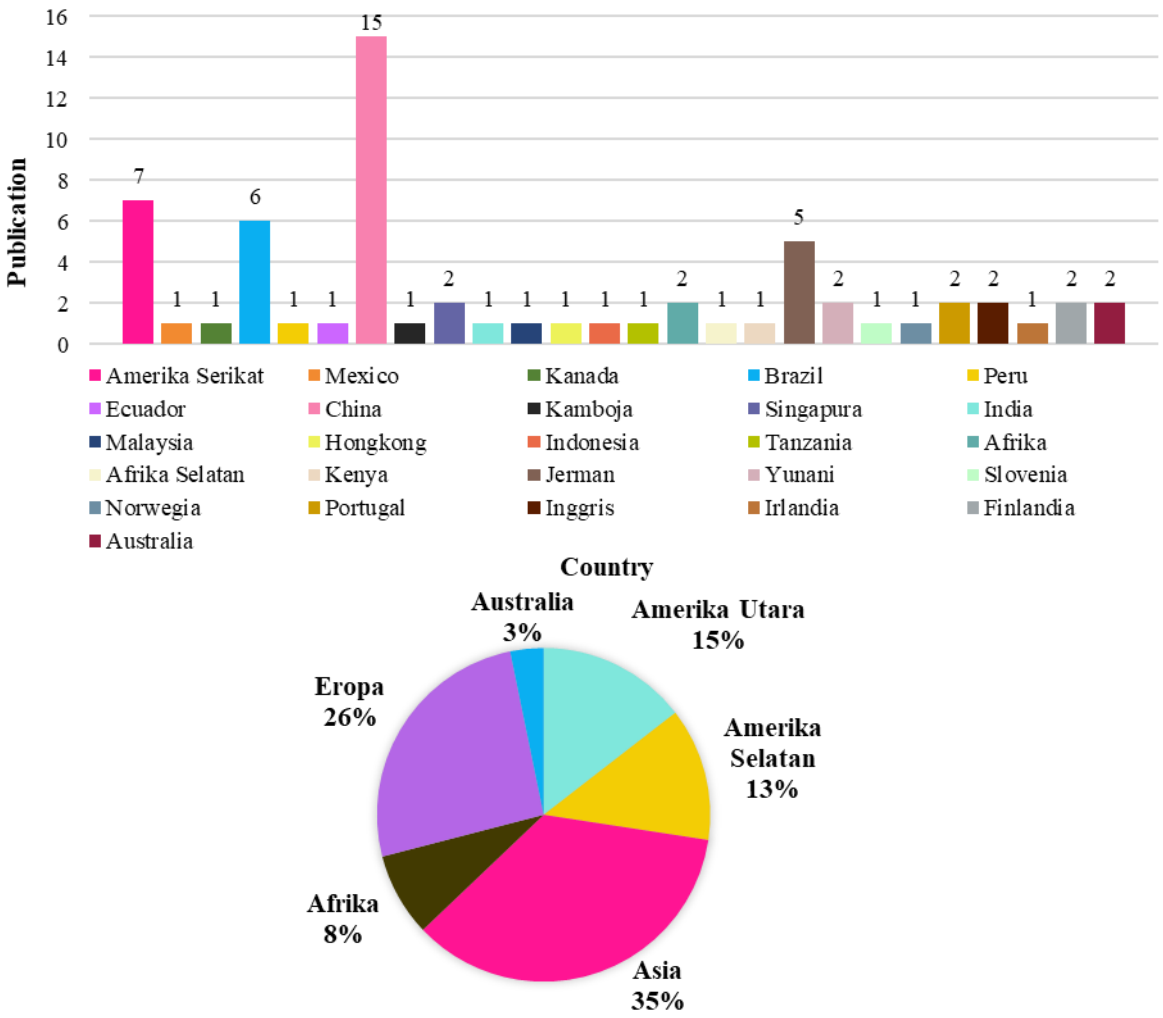

Fig. 3. *Distribution of research by Country (a) and Continent (b)*

ods included Surveys and Factor Analysis (Regression, Descriptive, and Correlation).

Overall, the research obtained uses certain theories, models, and approaches. As many as 45 out of 62 studies employed several theories, including Sustainable Development, Economics, and Social Assessment, among others (*Fig.* 4a). Furthermore, 32 out of 62 studies employed several models, including econometric modelling, Mathematical Modelling, and Hedonic Pricing (HPM), among others (*Fig.* 4b). Following the approach used, as many as 55 out of 62 studies employed approaches such as Payments for Ecosystem Services (PES), Contingent Valuation Method (CVM), New Ecological Paradigm (NEP), and others (*Fig.* 4c).

Overall, the research focuses on three main impacts, including environmental impacts (as discussed in 50 studies) that cover river restoration, environmental damage, water quality, nature conservation, and other related topics. Furthermore, the economic impacts (as reported in 52 studies) are discussed, including environmental service payments, cultural environmental services, environmental products, and economic development, among others. Finally, the social impacts (32 studies) are discussed, including environmental ethics, public perception, welfare, and other related aspects (Table 3).

Network analysis

Network analysis is a significant method in the field of bibliometrics. Its purpose is to display the structure and development of scientific research fields related to urban river cultural environmental services, utilizing networks and research landscape visualizations based on effective clustering capabilities, dynamic visualization, and keyword mapping, with customization options available. The Fig. 5 illustrates the network analysis of keywords determined in the study. The present study created the network and landscape visualization using VosViewer software that presents (a) Network Visualization (NV), (b) Overlay Visualization (OV), and (c) Density Visualization (DV) of keywords with 52 occurrences in the search and analysis. A total of 52 keywords out of 251 keywords met the search requirements, resulting in 10 clusters with 3-7 keywords, 98 links, and a Total Link Strength

Table 2. Distribution of research methods

No.	Methodology	Amount	%
Mixed Methods (54)			
1	Factor Analysis and Thematic Analysis	1	0.62
2	Factor Analysis and Questionnaire	15	9.32
3	Factor analysis and experimental methods	1	0.62
4	Qualitative Factor Analysis and Area Mapping	1	0.62
5	Factor Analysis and Case Study	17	10.56
6	Factor Analysis and Literature Review	5	3.11
7	Factor Analysis and Interviews	5	3.11
8	Environmental perception analysis	1	0.62
9	Hotspot analysis	1	0.62
10	Geographic Information System Methods	1	0.62
11	Observation and Psychological Factors	1	0.62
12	Revealed Preference Method	1	0.62
13	Assessment and Questionnaire Study	1	0.62
14	Survey and Observation	13	8.07
15	Online Surveys and Panels	1	0.62
16	Survey and Case Study	1	0.62
17	Literature Survey and Review	2	1.24
18	Survey and Interview	25	15.53
19	Travel Cost Method	1	0.62
Qualitative (4)			
1	Content Analysis	1	0.62
2	Questionnaire	4	2.48
3	Focus Group Discussion (FGD)	1	0.62
4	Documentation	1	0.62
5	Impact Evaluation	1	0.62
6	CES class identification	1	0.62
7	In-depth Interview	1	0.62
8	Media Coverage	1	0.62
9	Observation	2	1.24
10	Q Methodology	1	0.62
11	Case study	5	3.11
12	Literature review	11	6.83
13	Interview	3	1.86
Quantitative (4)			
1	Survey	7	4.35
	Factor Analysis	24	14.91
	Variable Bias Analysis	1	0.62
	Practice Efficiency Analysis	1	0.62
	Econometric Analysis (Logit)	2	1.24
	Empirical Analysis	1	0.62
	Topographic Factor Analysis	1	0.62
	Probability Analysis	1	0.62
	Sensitivity Analysis	1	0.62
	Spatial Analysis Mapping	1	0.62
	Descriptive Statistical Analysis	3	1.86
2	Multivariate Statistical Analysis	1	0.62
	Univariate Statistical Analysis	1	0.62
	Exploration	1	0.62
	Water Safety Assessment Index	1	0.62
	Model calibration	1	0.62
	Correlation	2	1.24
	Load Duration Curve (LDC)	1	0.62
	Mean	1	0.62
	Median	1	0.62
	Regression	1	0.62
	Mann-Kendall Test	1	0.62

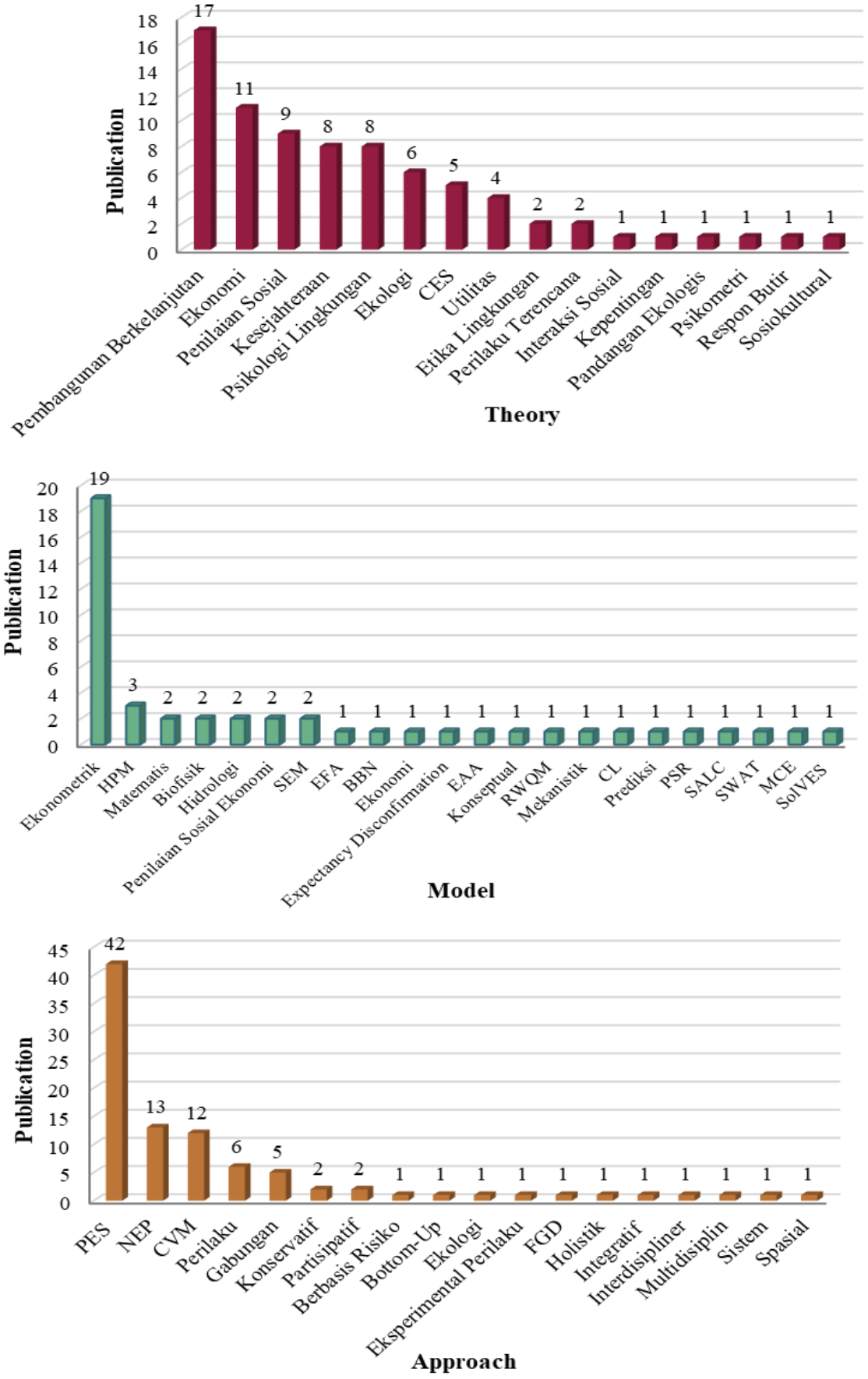

Fig. 4. *Distribution of research based on theory (a), Model (b), and Approach (c)*

Table 3. Distribution of research based on environmental, economic, and social impacts

No.	Impact	Amount	%
Environment (50)			
1	Environmental Education	3	1.69
2	Ecology	3	1.69
3	Ecosystem	6	3.39
4	Biodiversity	2	1.13
5	Environmental damage	11	6.21
6	Nature Conservation	10	5.65
7	Water Quality	11	6.21
8	Environmental Protection	3	1.69
9	Climate Change	1	0.56
10	River Restoration	19	10.73
Economy (52)			
1	Behavioral Economics	1	0.56
2	Education Investment	1	0.56
3	Cultural Environmental Services	27	15.25
4	Economic Development	4	2.26
5	Payment for Environmental Services (PES)	29	16.38
6	Economic Problems	3	1.69
7	Economic growth	3	1.69
8	Environmental Products	5	2.82
Social (32)			
1	Environmental Ethics	21	11.86
2	Environmental Policy	1	0.56
3	Welfare	2	1.13
4	Social conflict	2	1.13
5	Public Perception	9	5.08

(TLS) of 105. The keywords that appeared most frequently were Ecosystem Services (12), Willingness To Pay (9), Cultural Ecosystem Services (6), Contingent Valuation (6), New Ecological Paradigm (5), and Payment for Ecosystem Services (5).

DISCUSSION

The TCCM (Theory, Context, Characteristics, and Methodology) framework is used to classify and categorize literature based on various aspects of research, and to identify knowledge gaps and future research directions. Guided by the TCCM framework, relevant information about theoretical foundations, contexts that shape research settings, characteristics, and methodological approaches can be identified and compiled. TCCM is one of the most widely used frameworks due to its ability to present a comprehensive view of research in a versatile manner (Paul *et al*., 2023).

Development of theory

The theoretical development flow in this study included theories from several disciplines (*Fig.* 4.a). Studies on the cultural environmental services of the Batang Arau River draw upon various theories, including those of sustainable development, economics, social assessment, and ecology. Sustainable development is a development concept that prioritizes environmentally friendly practices and respects the culture and interests of local communities. To achieve sustainable development, it is essential to recognize the importance of ecological economics. The primary target of sustainable development is the significant dependence of humans on environmental ecosystems. Therefore, to assess the success and achievement of sustainable development, it can be observed from the ecological impact of development in a given area.

A river basin or a particular area, based on the social development situation, the principle of sustainable development is related to the situation that water resources and the water environment can support economic development and maintain the health of the ecosystem (Dou *et al*., 2021).

Environmental aspects are prerequisites for the development and sustainability of life. Environmental aspects will ensure the sustainability of the ecosystem. Environmentally aware development management is essential for the sustainability of the ecosystem. This can be achieved through the prevention of environmental pollution, the rehabilitation and restoration of ecosystems, and the enhancement of both natural and human-built ecosystems' production capacity. Damage to river environmental services can eliminate the opportunity for future generations to enjoy the same services. Economic activities should not be directed solely at the utilization of natural resources

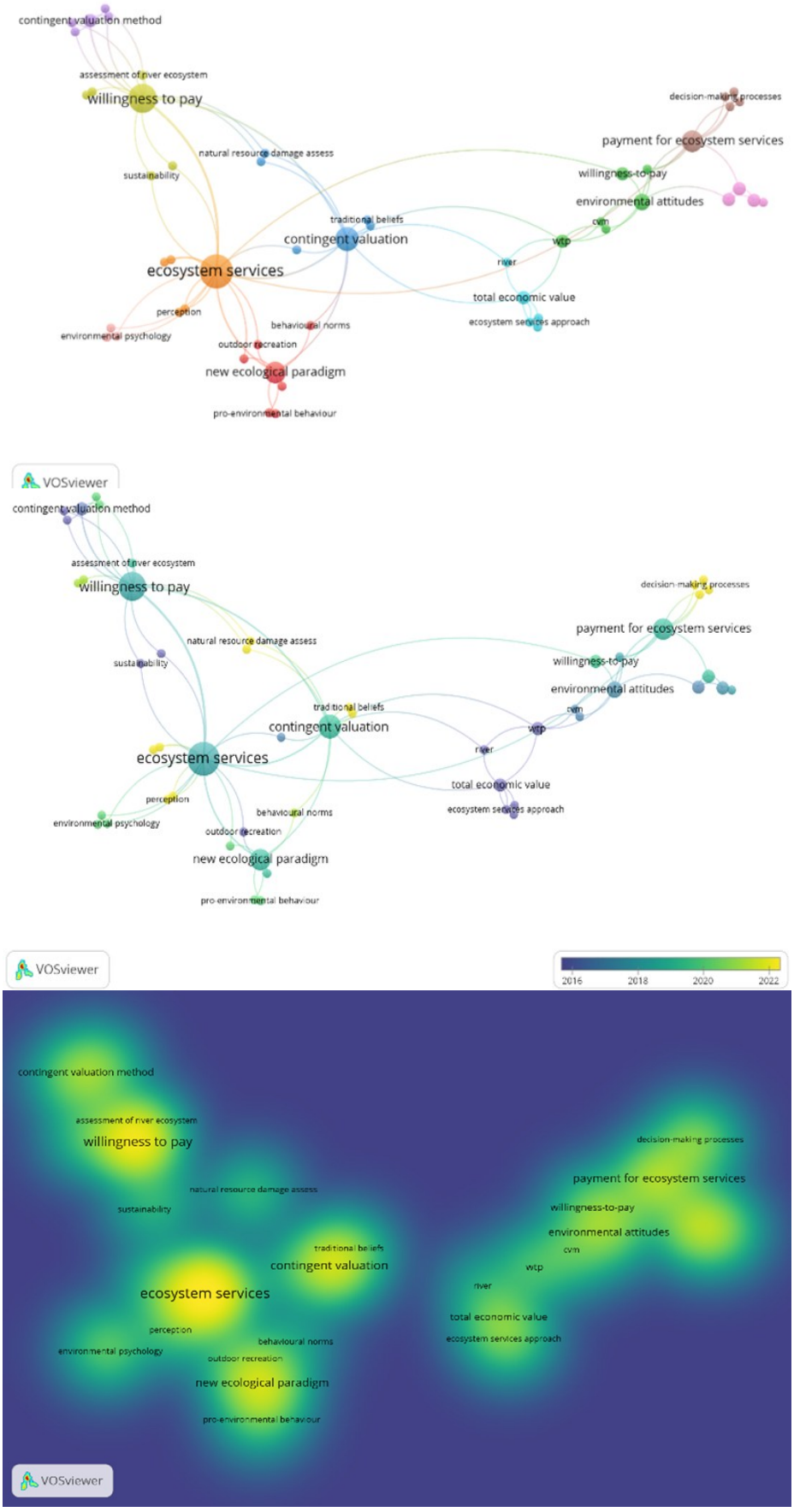

Fig. 5. *Analysis of keyword occurrence in the research landscape (a) Network visualization (b) Overlay visualization (c) Density visualization*

Table 4. Environmental services based on their value to humans

No.	Environmental Services Typology	Product	River Management
1.	Provision Services (commodities)	Food, clean water, wood and fiber, fuel	Clean Water for household and industrial purposes. Water for power generation (energy). Agricultural irrigation. Fisheries and livestock.
2.	Management/Regulation Services (ecosystem)	Microclimate regulation, flood prevention, pest and disease prevention, carbon reserve storage, provision of flora and fauna habitat	Prevent floods and droughts. Mitigation of rainwater runoff. Prevent dam sedimentation. Maintaining the supply and quality of natural resources.
3.	Support Services	Nutrient cycles, soil formation, pollination and seed dispersal, hydrological functions	The river's ability to support water management problems (geological conditions and soil structure)
4.	Cultural Services	Education, ecotourism, recreation, spiritual, beauty.	Waterfalls, rivers, lakes as possible places; recreation, tourism and cognitive development. Education, education and knowledge. Aesthetic value

Source : (Petersen *et al*., 2022)

and the environment, which can ultimately threaten ecological functions. Sustainable development cannot be achieved if there is a gap in the distribution of prosperity or the existence of social classes. Priority must be given to social spending and programs directed towards shared benefits, and investment in resource development. Development that considers environmental, economic, and sociocultural aspects has a positive impact on sustainable development. Sustainable development strategies implemented in the region can create the welfare of the current community and future generations.

The concept of ecosystem services refers to the biophysical components of ecosystems that humans use, either actively or passively, to enhance their well-being. To characterize the benefits associated with ecosystem services (ES), the assessment framework highlights various aspects of human well-being, including the need for safety, health, living conditions, social relationships, and economic needs (Mendoza *et al*., 2020). Socio-culturally, the environmental conditions of riverbank areas determine the quality of river water, which in turn affects human life. Therefore, efforts Mendoza are needed to change the behaviour of people living in riverbank areas (Maryani and Probowati, 2020).

A specific challenge for cultural ecosystem services research is developing a coherent approach to stay connected to the broader ecosystem services research community (Xie and Wang, 2020a). *Cultural ecosystem* services (CES) found in urban rivers offer benefits in the form of aesthetics, relaxation, spirituality, recreation, and education, providing non-material benefits. However, the limited empirical data and complexity of interactions between natural capital and human activities make it challenging to measure the value of cultural ecosystem services. Ecosystem services in urban agglomeration also include *Cultural Ecosystem Services* (CES). CES is defined as non-material benefits obtained through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences (Findasari *et al*., 2022) Sociocultural ecosystem assessment is increasingly being incorporated into ecosystem service assessments. The sociocultural assessment approach can be used to evaluate environmental services that lack a monetary reference or market value, as sociocultural value differs from the value of cultural ecosystem services. Sociocultural value reflects the benefits obtained in material and non-material welfare. While cultural ecosystem services reflect non-material welfare related to ecosystems, such as spirituality and aesthetic value.

Context development

The research theme focuses on river cultural ecosystem services and the assessment of these services using behavioural and economic approaches. The topics discussed in the research are generally related to the environment, economics, and urban studies. Threats associated with degraded watershed ecosystems are influenced by individuals' general awareness of the consequences of future ecosystem conditions, their perceptions of their ability to mitigate

these threats, and their sense of individual responsibility to act (Ackerman *et al*., 2019)According to the Total Economic Value of Ecosystems and Biodiversity initiative (TEEB), ecosystem services can be divided into four main categories: (i) provisioning services, namely products obtained from ecosystems, (ii) regulating services, namely benefits arising from regulating ecosystem processes and functions, (iii) habitat services, namely services that support the production of all other ecosystem services, (iv) cultural services, namely benefits for humans such as spiritual enrichment, cognitive development, recreation and education (Koundouri, 2016). Ecosystems provide an environmental service that has four important benefits, namely: i) providing services, ii) regulating services, iii) supporting services, and iv) cultural services.

Based on the country analysis in the Table 4, the literature review reveals that most studies focus on Asia and Europe. Research on the Asian Continent is mostly conducted in China, the United States, and Brazil. Future research should focus more on studying how cultural environmental services, especially those provided by urban rivers, influence them and how to effectively assess these services. This will help highlight the role of rivers in the urban context as being very important, especially in efforts to maintain sustainable water resources. Therefore, efforts to prevent the decline in water resource quality and ensure environmental restoration have become a special concern in the sustainable development program, specifically the SDGs (Sustainable Development Goals).

Characteristics development

The primary function of cultural environmental services is to assess the impacts of ecosystem changes on human well-being and establish a scientific basis for actions required to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being. There are specific criteria for urban drainage, including (1) linkage to land use; (2) linkage to the city drainage *masterplan*; and (3) linkage to sociocultural issues. This means that the complexity of urban drainage criteria is not only a technical problem. Therefore, it is necessary to adopt a sociocultural, environmental awareness, and behavioural approach that is influenced by education and income, as well as limited costs, availability of facilities, and accessible places. Factors that influence environmental perception and behaviour include education, income, limited costs, and the availability of facilities and places (Hussain *et al.,* 2024). Overall, the study focuses on three main impacts, including environmental impacts on river restoration, environmental damage, water quality, and nature conservation, among others. Furthermore, the economic impact extends to payments for environmental services, cultural environmental services, environmental products, economic development, and other related areas (Sieber *et al*., 2021). Finally, the social impact on environmental ethics, public perception, welfare and others.

Table 5. River Environmental services assessment methods

No	Researchers and years	Classification	Assessment Method
1.	(Chen and Vardon, 2024))	Water-related ecosystem services and policy accounting	SEEA-EA framework Key issues: water security, quality, soil erosion Services: water supply, sediment retention, purification Models: SWAT, InVEST, ARIES, AWRA-L, OzWALD Policy linkage: catchment restoration and IWRM - Global applicability for water governance
2.	(Sumarga et al., 2024)	Grouping and classifying methodologies for mapping and assessing ecosystem services	Water use: household, agriculture, recreation Spatial analysis: provisioning vs benefiting areas Infiltration test: double ring infiltrometer Findings: mining reduces infiltration capacity
3.	(Qu et al., 2025)	Climate change and ecosystem respiration	Climate Control Ecosystem control Economic approach.

Ecosystem services include *Cultural Ecosystem Services* (CES). CES is defined as non-material benefits obtained through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences. There are 2 types of CES stakeholders, namely:
Direct beneficiaries of CES are stakeholders who benefit from and demand ecosystem services. Examples include tourists and urban development decision makers.
Stakeholders negatively impacted by the impaired supply of ecosystem services.
Given that environmental damage in urban rivers continues to occur, a sociocultural assessment approach is necessary to evaluate environmental services that lack a monetary value or market reference. In addition to the sociocultural assessment approach, an economic value approach also needs to be taken to assess the community's ability to contribute to reducing environmental damage. These two approaches must be employed to mitigate environmental damage, enabling the development of policies and programs that incorporate community contributions.

Methodology development

A particular challenge for cultural environmental services research is to develop a coherent approach that stays connected to broader environmental services research. Several previous studies have employed an economic approach, enabling a review of urban areas with multi-ethnic conditions. Several related studies reviewed contain methods for assessing cultural environmental services using a combination of survey and interview approaches, as well as social media

Table 6. Sociocultural methods for environmental services assessment

No	Researchers and years	Classification	Assessment Method
1	(Radicic *et al.,* 2020)	Sociocultural values are the benefits obtained in material and non-material welfare.	Measurement of sociocultural values; Observational approach, Document research, Expert-based approach, In-depth interviews, Focus group discussion Questionnaire.
2	(Fraccascia *et al.,* 2021)	Ecosystem Services in urban agglomerations include Cultural Ecosystem Services (CES), namely non-material benefits obtained through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences.	Urban Agglomerations Ecosystem (UAE) method ; Interviews and questionnaires, The development of information technology, Online surveys and social media data analysis. Data analysis: Hierarchical cluster method Q Method GIS based mapping
3	(Souliotis and Voulvoulis, 2021)	Ecosystem Services were assessed by focus group discussions consisting of; Local experts, Environmental officer, Resident, Policy makers.	Discrete Choice Experiment (DCE) method is a questionnaire to identify important attributes of urban residents of Shaoguan: Water quality, River view, Biodiversity, and Recreational facilities.
4.	(Qu *et al.,* 2025)	New Ecological Paradigm (NEP) Scale, with basic Socio-Economic Characteristics of respondents, including gender, age, education level, occupation, income, and ecological awareness.	NEP scale assessment method 1. Questionnaires and interviews 2. Respondent satisfaction and interest scores with a Linkert scale with a 5-point scale; very dissatisfied, dissatisfied, neutral, satisfied, very satisfied.

analysis. The results obtained from these studies are focused on assessing a specific area. Very few cultural environmental services studies are related to the economy, most cultural environmental services studies are oriented towards research on biodiversity conservation and ecology (Petersen *et al*., 2022)

Several researchers have developed various methods for assessing environmental services, including the explanation that there has been an increase in the need to combine methods and tools for the interdisciplinary evaluation of water ecosystem services. The study proposed a framework for assessing water supply ecosystem services that includes three dimensions: 1] environmental, 2] social, and 3] economic. The same thing was also conveyed by (Ruskule *et al*, 2018)those who grouped and classified methodologies for mapping and assessing ecosystem services, namely; 1] Biophysical methods, 2] Sociocultural methods, 3] Economic methods and 4] Expert-based quantification. Furthermore, (Xie and Wang, 2020b)mapping a comprehensive integration of methods for measuring and assessing ecosystem services consisting of; 1] biophysical models, 2] international mapping models, 3] land change scores, 4] participatory mapping, 5] Sociocultural methods, 6] monetary methods and 7] integrative approaches. (Teo *et al*., 2019) in his journal explained that the Environmental Services Assessment Method can be carried out through three approaches, namely the ecological approach, the sociocultural approach, and the economic approach. The summary of environmental service assessment methods from several previous researchers can be seen in Table 5.

Several previous studies have also tried to analyze CES with various approaches, such as those conducted by (Sieber *et al*., 2021) those who conducted cultural environmental service analysis with the *Mixed method approach* in the USA; (Thiele, Hareen, and Albert, 2019)those who conducted CES analysis with the RLAQ (*Role of landscape aesthetic*) approach and spatial analysis using GIS in Germany; (Glavan *et al*., 2020) conducted cultural environmental service analysis with the social media and interview approach in the Colorado River, USA; (Alvarez-Codoceo *et al*., 2021)conducted cultural environmental service analysis with the Geographic Information System (GIS) approach in Chile and (Blake *et al*., 2021)conducted cultural environmental service analysis with the *stepwise fashion and quitioner approach* in the Falkland Islands, UK. They obtained different analysis results, but with the same focus: cultural environmental services. Social and participatory research will develop in the future. Different approaches to analysing cultural environmental services, including those that involve ambiguity and intangibility, can contribute to solving problems in managing interactions between humans and the natural environment.

Based on Table 6, Human environmental behaviour can be shaped by an economic approach. A concept that has been widely used is the Payment for Ecosystem Services (PES) (Harahap, Yonariza, and Yuerlita, 2021). The PES concept is based on the principle that environmental service beneficiaries make payments to environmental service providers regulated in a contract to manage natural resources and communities. This scheme involves direct payments or compensation from users of downstream services to upstream providers, conditional upon their adoption of more sustainable management practices (Cordoves-Sánchez and Vallejos-Romero, 2019). In contrast to the polluter pay principal (PPP) concept, where this principle is a polluter that requires polluters to bear the costs required in the context of efforts taken by public officials to maintain environmental conditions in acceptable conditions or in other words that the costs required to carry out these efforts must reflect the price of goods and services that have caused pollution during the production and consumption process (Souliotis and Voulvoulis, 2021) . The use of PPP is more widely used by companies or industries that produce waste and dispose of it into the environment. The amount of waste disposed of into the environment will be converted into an economic value that must be paid to environmental management, in this case, the Indonesian government, as an environmental tax.

Through the PES economic approach, the willingness to pay for *environmental* services reflects the community's perception of the existence and importance of environmental services, specifically water resources, to the community. PES has been popularized over the past decades as a promising and innovative tool to shape the use and management of natural resources and achieve sustainable development goals (Zafar *et al*., 2019). PES aims to translate non-market environmental values into financial incentives for local actors to provide more environmental services. The successful implementation of PES depends on several general prerequisites being met, such as well-defined and secure property rights, and adequate administrative, monitoring, and enforcement capacity. In addition, a comprehensive PES management approach implements local participation in the decision-making process and the facilitation of intermediary institutions.

Socioculturally, the environmental conditions of the riverbank area determine the quality of river water, which in turn affects human life. Therefore, it is essential to make efforts to regulate the behaviour of of people living in the riverbank area (Maryani and Probowati, 2020). The quality of river water in an area

is significantly influenced by human activities, particularly those surrounding the river (Ozkeser, 2019; Radicic *et al*., 2020). If these activities are balanced by high public awareness in preserving the river environment, then the quality of river water will be relatively good. However, on the contrary, without awareness and active participation from the community, the quality of river water will be bad.

Sociocultural analysis of ecosystem services has been further developed with the introduction of the NEP Scale (New Ecological Paradigm) (Krishnan *et al*., (2021). The New Ecological Paradigm (NEP) is a new perspective that emerged to protect the environment, which was previously still adhering to the Dominance Social Paradigm (DSP) or anti-ecology. Different from NEP, which assumes that humans are a unity of nature whose sustainability must be maintained. NEP is a concept that includes the perspective of individuals or communities towards the environment and their relationship with humans. NEP is a framework that tries to understand the attitudes, values, and wealth that underlie behavior towards the environment (Putrawan, 2017). *New Ecological Paradigm* (NEP) was developed as a way to measure a person's environmental views. This concept measures the conceptual paradigm or a set of general beliefs that represent a person's concern for the environment. NEP is considered an appropriate solution to address the declining quality of environmental services in the lower Batang Arau River. The NEP approach can be combined with the economic approach of assessing and paying for cultural environmental services. The economic value that emerges from the PES economic analysis will be capital in improving the environmental behavior of the community in the lower Batang Arau River.

Conclusion

Urban rivers play a dual role as both ecological systems and cultural landscapes, enriching community life. The Batang Arau River exemplifies this relationship by providing not only regulatory services, such as flood control, runoff reduction, and water quality maintenance, but also cultural services tied to identity, recreation, education, and heritage. These benefits reveal the inseparable link between ecosystems and sociocultural well-being, making rivers critical assets in urban sustainability.This study shows that sociocultural assessment is a valuable tool for capturing the non-material dimensions of river services that are often overlooked from market-based evaluation. It highlights a clear distinction between sociocultural values and cultural ecosystem services, emphasizing the importance of recognizing intangible benefits like inspiration, spirituality, and aesthetic appreciation. Such recognition is particularly significant in urban areas where community connections to rivers are deeply symbolic and culturally embedded. The novelty of this work lies in demonstrating how Payment for Ecosystem Services (PES), when integrated with the Natural Environment Program (NEP), can effectively translate cultural environmental values into economic and behavioral incentives. By fostering community willingness to pay, PES not only affirms the worth of environmental services but also strengthens collective responsibility for conservation. The revenues generated can be reinvested into ecological and cultural initiatives, ensuring that urban rivers continue to function as both ecological regulators and cultural assets.

This integrated approach offers a replicable framework for sustainable urban river management, bridging ecological, cultural, and economic perspectives. Future work should focus on testing this model across diverse urban contexts to refine its applicability, identify barriers to community participation, and ensure that rivers remain vital sources of cultural meaning and ecological resilience.

Conflict of interest

The authors declare that they have no conflict of interest.

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