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Review

A Review of Urban Ecosystem Services Research in Southeast Asia

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Abstract: Urban blue-green spaces hold immense potential for supporting the sustainability and liveability of cities through the provision of urban ecosystem services (UES). However, research on UES in the Global South has not been reviewed as systematically as in the Global North. In Southeast Asia, the nature and extent of the biases, imbalances and gaps in UES research are unclear. We address this issue by conducting a systematic review of UES research in Southeast Asia over the last twenty years. Our findings draw attention to the unequal distribution of UES research within the region, and highlight common services, scales and features studied, as well as methods undertaken in UES research. We found that while studies tend to assess regulating and cultural UES at a landscape scale, few studies examined interactions between services by assessing synergies and tradeoffs. Moreover, the bias in research towards megacities in the region may overlook less-developed nations, rural areas, and peri-urban regions and their unique perspectives and preferences towards UES management. We discuss the challenges and considerations for integrating and conducting research on UES in Southeast Asia based on its unique and diverse socio-cultural characteristics. We conclude our review by highlighting aspects of UES research that need more attention in order to support land use planning and decision-making in Southeast Asia.

Keywords: natural capital; blue-green infrastructure; urban environmental challenges; Global South; tropical cities

1. Introduction

The global urban population has grown rapidly in the last few decades, with over 70% of the population in the Global North now residing in urban areas [1]. Similar trends are evident in the Global South and while developed regions may be better equipped to manage urban transformations [2], cities in developing regions such as Southeast Asia face increasing environmental pressures. In 2018, an estimated 320 million people lived in the urban areas of Southeast Asia (49% of the region's total population), and this figure is expected to increase to 66% of the total population by 2050 [1,3]. This rapid urbanisation has been accompanied by a range of environmental problems, including

the urban heat island effect, floods, poor air quality and noise pollution, all of which directly impact the health of urban residents [4–11]. These issues are expected to be further exacerbated by the general vulnerability of the region to climate change impacts [12–14]. Moreover, countries within Southeast Asia have extremely diverse biophysical, cultural, socio-economic and political characteristics (Table 1). Levels of urbanisation range from 23% (Cambodia) to 100% (Singapore) and gross national incomes range from the 11th (Singapore) to the 162nd (Myanmar) rank globally. Efforts to mitigate urban environmental challenges should take into consideration these characteristics, in so doing provide context-specific solutions [15–17].

Table 1. Basic statistics that characterise the diverse biophysical, socio-economic and political backgrounds of Southeast Asian countries for the year 2019.

Country	Land Area (km²) [18]	Population Size (mil) [19]	Percentage of Urban Population (%) [20]	Average Annual Population Growth Rate (%) * [19]	Per Capita Gross National Income Ranking [21]	CO₂ Emissions (Million Metric Tons) † [20]	Governance (−2.5 TO +2.5)	
							Government Effectiveness [22]	Voice and Accountability [22]
Singapore	720	5.80	100.0	0.90	11	37.5	2.22	−0.18
Brunei Darussalam	5765	0.433	77.1	1.06	31	7.6	1.32	−0.95
Malaysia	331,388	31.94	76.2	1.33	69	248.2	1.0	−0.04
Indonesia	1,916,862	270.62	56.0	1.14	118	512.7	0.18	0.16
Thailand	513,140	69.62	53.6	0.31	86	283.7	0.36	−0.83
Philippines	300,000	108.11	47.1	1.41	123	122.2	0.05	0.03
Lao PDR	236,800	7.16	35.6	1.52	139	17.7	−0.78	−1.80
Vietnam	331,230	96.46	35.0	0.98	141	192.6	0.04	−1.38
Timor Leste	14,870	1.29	30.9	1.94	151	0.49	−0.88	0.38
Myanmar	676,576	54.04	30.0	0.64	162	25.2	−1.15	−0.84
Cambodia	181,035	16.48	23.8	1.48	158	9.9	−0.58	−1.20

Notes: * from 2015 to 2020; † for the year 2016.

Planning and designing cities to incorporate blue-green spaces is vital for mitigating socio-environmental problems affecting health and well-being [23–25]. Urban blue-green spaces promote greater resilience, sustainability and liveability in cities through the provision of services such as shading and cooling, carbon sequestration, stormwater management, noise attenuation, habitat for biodiversity and recreational opportunities [26–30]. These services, termed 'urban ecosystem services' (UES), capture the role of water (blue) (i.e., lakes and wetlands) and vegetation (green) (i.e., parks and urban forests) in or near the built environment at different spatial scales (streets, buildings, cities, regions) [31–33]. Generated through the functions and processes of blue-green structures, UES can alleviate the environmental pressures of urbanisation and enhance the wellbeing of urban residents [34–39].

The complex pathways through which UES are delivered can be analysed by the relationships between (i) structures (e.g., mangrove forests), (ii) their biophysical processes and functions (e.g., wave attenuation), and (iii) the derived services that deliver goods and benefits to humans (e.g., coastal flood protection) [40]. The interactions between these different components can be illustrated through frameworks such as the cascade model, which acts as a communication tool between experts and local stakeholders to help support UES assessments for urban planning [41]. Moreover, incorporating UES into urban planning requires an understanding of the various interactions between services, which are linked to one another as they stem from the same structures and functions of a particular ecosystem [42,43]. These interactions include synergies and tradeoffs, described respectively as positive-positive or positive-negative relationships between two or more services [44,45].

Research on UES can also be undertaken from various perspectives, given the interdisciplinary nature of the concept. The field has gained prominence for its ability to integrate natural and social sciences, communicating the dependence of society on ecological structures [43]. A wide range of methods have been used to characterise UES and assess their value to humans. These methods range from biophysical modelling to social surveys applied at various scales (e.g., landscape scale, site-based scale), with benefits valued biophysically (e.g., tonnes of carbon sequestered per year), economically (e.g., $500 per hectare per year) and socio-culturally (e.g., sense of place) [46–48]. UES hold diverse values to various communities and the valuation of UES is necessary to understand local demands or benefits [30,49]. Valuations should be supported by the involvement of stakeholders to further deepen the understanding of local UES needs, while promoting the consideration of alternative management options [50,51].

Previous reviews of global UES research by Haase [28] and Luederitz [41] highlight that research has mostly been undertaken in Europe and North America, with research in Asia dominated by China. Although these reviews have explored the scope and nature of research on a global scale, they lack the finer resolution needed to understand patterns and traits of research in any one region. Despite the rapid economic growth and urbanisation in Southeast Asian countries, UES research across this region has not been reviewed. Hence, a systematic review of UES is timely, to assess the nature and extent of research on UES in Southeast Asia.

This review covers the last 20 years, the period within which the global UES literature has burgeoned. Inspired by Luederitz [41], we address four specific research questions: (1) How is UES research distributed across Southeast Asia and at what scale(s) are UES analysed? (2) Does UES research focus on single or multiple services and what type of blue-green structure are assessed? (3) Which components of the 'cascade' are assessed, and how are the interactions between UES conceptualised and stakeholders involved? (4) What research perspectives, and data collection and analytical methods are used to assess UES? Upon reviewing the current state of research in the region, we discuss the challenges and considerations for integrating UES research given the unique context of Southeast Asia. We conclude our review with recommendations for UES research in order to support planning in the region.

2. Methods

The search string composed terms that expressed the geographical area of interest ('Southeast Asia' and all the countries within the region), the topic of interest ('ecosystem service', its alternative term 'natural capital' and, to capture studies that did not explicitly refer to these two phrases, we included the keywords 'human', 'environment' and 'benefit') as well as terms that further specified the subtopic of interest (i.e., the urban environment). The search was applied to publication Titles, Abstracts and Keywords in the Scopus and Web of Science database as shown below:

(TITLE-ABS-KEY (("Southeast Asia" OR "South East Asia" OR "Indonesia" OR "Vietnam" OR "Thailand" OR "Malaysia" OR "Singapore" OR "Philippines" OR "Cambodia" OR "Laos" OR "Myanmar" OR "Brunei" OR "Timor-Leste"))) AND (TITLE-ABS-KEY (("ecosystem service*" OR "natural capital" OR ("human" AND "environment" AND "benefit*")))) AND (TITLE-ABS-KEY ("urban" OR "city" OR "cities"))

The initial search return was refined to include only journal articles, book chapters and conference papers (see Supplementary Material for complete search string). This search returned a total of 255 unique articles published in the English language. The abstracts of the returned articles were screened manually to include publications within the scope of this review based on the following guiding criteria:

- Studies conducted in urban or peri-urban areas in Southeast Asian countries.
- Focuses on ecosystem services or benefits provided to an urban population.
- Explicitly includes the phrase 'ecosystem services' or 'natural capital', otherwise describes the link between the environment and the benefits provided to urban populations.

The final list comprised 149 empirical articles, assessing one or more ecosystem services in urban Southeast Asia (see Table S1 in Supplementary Material). Studies that investigated multiple urban areas within and outside of Southeast Asia were included in the review, if at least one study site was located within Southeast Asia. Each article was classified to identify information relevant to the four research questions, as described in the sections which follow. Refer to Table S2 in Supplementary Material for further details on definitions and classification protocol.

(1) How is UES research distributed across Southeast Asia and at what scale(s) have they been analysed?

Following the TEEB classification for ecosystem services [52], we classified the ecosystem services studied into four main categories: (i) provisioning, (ii) regulating, (iii) supporting and (iv) cultural. These four categories will be hereafter referred to as 'ecosystem service domains'. We chose the TEEB classification of ecosystem services over the two other common approaches to classifying ecosystem services—the Millennium Ecosystem Assessment (MEA) and Common International Classification of Ecosystem Services (CICES). TEEB is well-known in the context of environmental economics and provides a robust framework for applications in urban planning and policies [53]. Moreover, the TEEB framework emphasises the need for valuing ecosystem services such that the wide range of benefits of ecosystems and biodiversity is recognised by decision-makers [54]. We also recorded the location (e.g., city and country) of studies and quantified the number of times ecosystem service domains were assessed for each country. To analyse the scale of UES assessment, we recorded the population size and area of study sites, scale of assessment as well as distinguished between 'urban' and/or 'peri-urban' areas.

(2) Does UES research focus on single or multiple services and what type of blue-green structure have been assessed?

We recorded the ecosystem services assessed as one of the 17 ecosystem services defined by the TEEB framework [52]. As studies can mention more ecosystem services than those that were empirically assessed, we only classified ecosystem services that were explicitly investigated. We evaluated the number of services assessed in each study and

whether the services belonged to the same ecosystem service domain. The ecological structures that provide the investigated ecosystem service(s) were classified as either vegetative (green) or water (blue) structures. We identified 12 categories of blue-green structures, comprising four blue structures (coastal lands, wetlands, rivers, lakes) and eight green structures (urban forests, parks, street greenery, gardens, rooftops, green walls, cultivated lands and grasslands; refer to Table S3 in Supplementary Material for detailed definitions of blue-green structures).

(3)   Which components of the 'cascade' have been assessed, how are the interactions between UES conceptualised and stakeholders involved?

The components of ecosystem service 'cascade' were assessed according to structure, function, services, and each linkage between structure-function-services (Figure 1). We described studies as either reviewing one of these six components, all of the six components or none, if studies did not assess any of the components in depth. We recorded the explicit assessment of synergies and tradeoffs in studies as well as the involvement of stakeholders in supporting UES assessments. The latter was defined as the feedback or involvement of external parties, aside from the researcher, in assessing UES. Studies involving surveys and interviews were considered to have involved stakeholders.
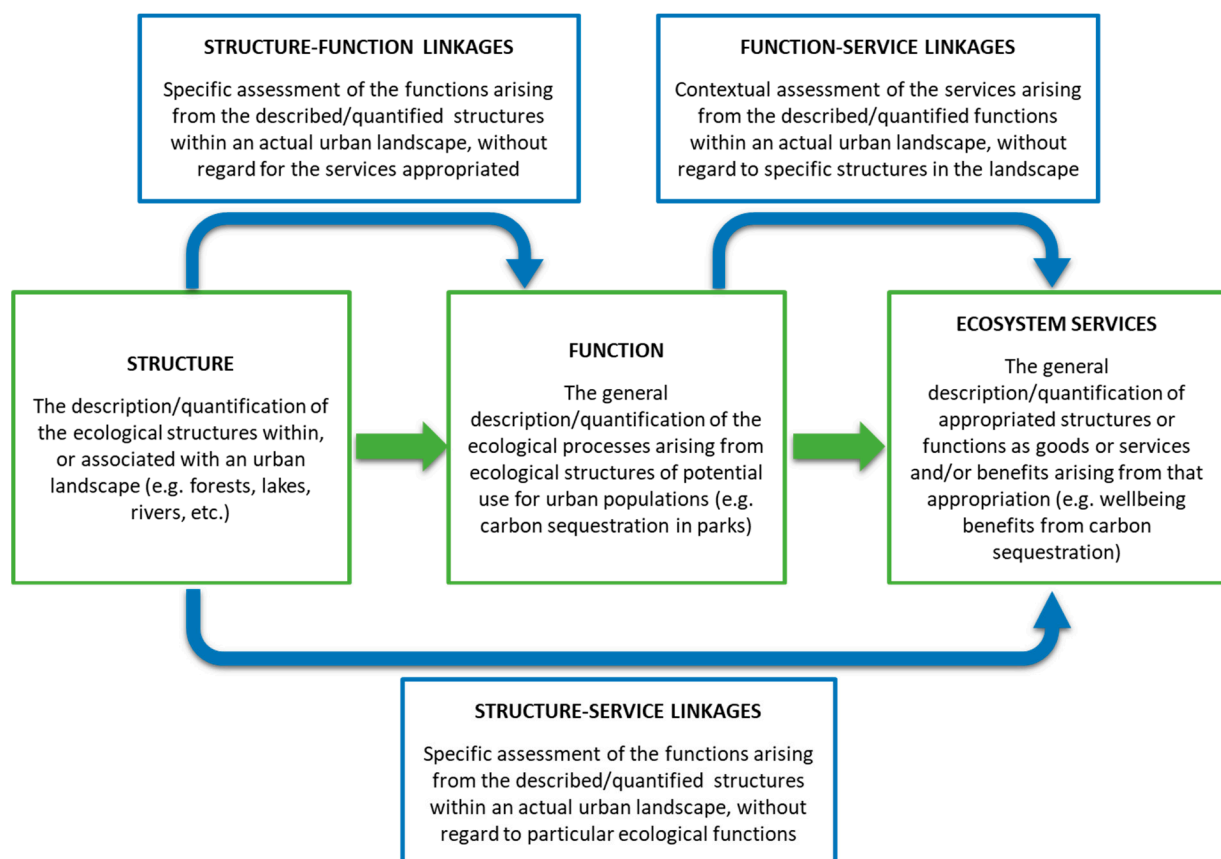

Figure 1. The components and definitions of the cascade model used to classify UES studies [41].

(4)   What research perspectives, and data collection and analytical methods are used to assess UES?

We assigned each study one of the following six research perspectives: (i) ecology, (ii) social, (iii) planning, (iv) governance, (v) economic and (vi) methods [41]. The definitions for this classification are available in Table S2 in Supplementary Material. Although a single study can be undertaken with more than one perspective, we classified each study by its most dominant research perspective.

Data collection methods were classified into four categories: (i) 'field-based empirical', (ii) 'biophysical modelling' which is sub-divided into 'process/mechanistic modelling' and 'land cover proxy' (e.g., remote sensing of land cover), and (iii) 'social surveys' and (iv) case studies. We also recorded the type of data collected (i.e., 'quantitative', 'qualitative', or 'both') and the temporal focus of the study. Studies were also reviewed for the valuation of UES and where valuations were conducted, we distinguished between 'monetary valuation' (i.e., economic) and/or 'non-monetary valuation' (i.e., social or biophysical).

3. Results

3.1. Distribution and Scale of UES Assessment across Southeast Asia

Of the 149 studies reviewed in Southeast Asia, 29% were conducted in Singapore (n = 44), followed by 22% in Indonesia (n = 33). Myanmar (n = 4) and Timor Leste (n = 1) had very few studies, while no published studies from Brunei were returned in the search (Figure 2). About 64% of studies had authors with their primary research institution in Southeast Asia (n = 95), with 59% of studies conducted in the country where their primary research institution was located. As for studies with authors' primary research institutions located outside of Southeast Asia, 16% of authors were based in Europe (n = 24), 11% in other parts of Asia (n = 17) (mainly East Asia), 5% in North America (n = 8) and 3% in Australia (n = 5). Note the possibility of some bias in this analysis due to the inclusion of only studies published in English.
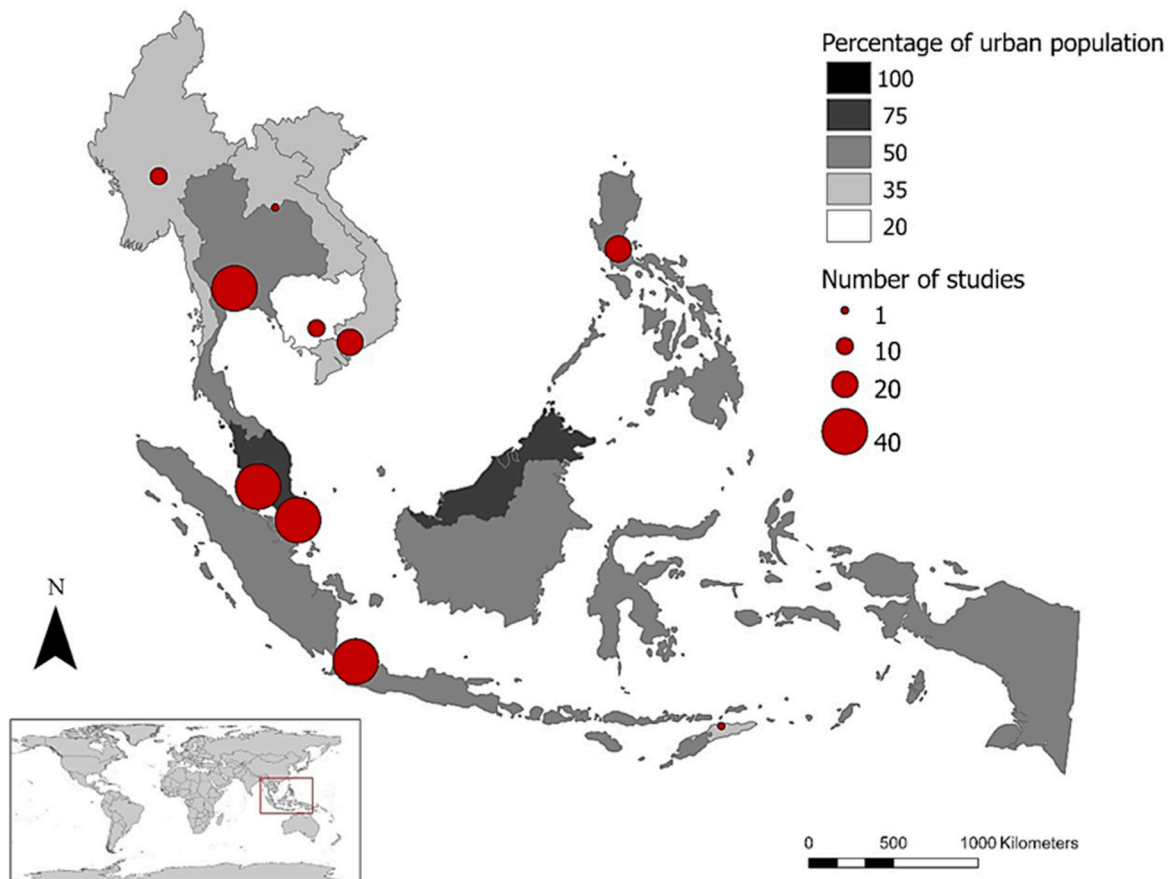

Figure 2. Number of UES studies in Southeast Asia and percentage of urban population in each country. Not visible in the map is the percentage of urban population in Singapore, which is 100%. No studies from Brunei were reviewed.

77% of studies are concentrated in four cities; the city-state of Singapore was most frequently studied (n = 44), followed by the metropolitan capital cities of Bangkok in Thailand (n = 13), Jakarta in Indonesia (n = 12) and Kuala Lumpur in Malaysia (n = 8).

In terms of the type of urban area assessed, 76% of studies were conducted in fully urban areas (n = 113), 15% in peri-urban areas (n = 23) and 8% of studies spanned both urban and peri-urban areas (n = 13). Around 43% of studies were conducted at a 'single-city scale' (n = 64), followed by 32% at the 'sites within cities' scale (n = 48) (Figure 3). Only 17% of studies assessed multiple cities (n = 26) and 7% of studies were conducted at scales larger than cities (i.e., regional or continental scales) (n = 11). Study area sizes varied markedly, extending from a few square kilometres to tens of millions of square kilometres. Similarly, population sizes within the study areas differed greatly, from 750 (Botoc village, Philippines) to 9.6 million (Jakarta metropolitan).

Figure 3. The general characteristics of UES research. (**A**) The various scales at which UES were assessed; (**B**) The percentage of studies conducted by authors based in and outside of Southeast Asia (denoted by the country in which the primary institution of the first author is located); (**C**) The assessment of UES within and/or across domains; (**D**) The types blue-green structures assessed; (**E**) The temporal focus of the study where 'single temporal focus' represents studies that examined UES at one point/period in time and 'multitemporal' represents studies that compared UES across time; (**F**) The methods of data collection and analysis of UES; and (**G**) The types of UES valuations conducted by studies.

3.2. Services and Blue-Green Structures Assessed

Of the four domains, regulating (36%) and cultural (26%) services were most assessed. Most countries had studies encompassing services across all four domains; exceptions were Laos and Timor Leste (Figure 4a). Studies comprised all 17 ecosystem services across all domains, with the 'recreation and mental and physical health' as the most frequently studied service (n = 54), followed by the 'moderation of extreme events' service (n = 51). The 'medicinal resources' and 'biological control' services were least assessed, with only 5 and 4 studies respectively (Table 2). Most studies took a multi-domain approach (n = 67) by investigating ecosystem services across multiple domains. Around 42% of studies assessed a single ecosystem service (n = 63), while 13% studied multiple services from a single domain (n = 19).

60% of studies assessed a single blue-green structure (n = 90) while the remaining studies assessed two or more structures; the maximum was seven structures (n = 2) (Figure 4b). Of the 12 blue-green structures, parks were most frequently studied (n = 57), followed by wetlands (n = 45) and urban forests (n = 44) (note: values differ from the number of times each structure was studied under ecosystem service domains, see Figure 4b). All 12 structures were studied across the four ecosystem services domains except for green walls, which were not studied for provisioning services. Rivers, urban forests and cultivated lands were most commonly studied for provisioning services, while street greenery and wetlands were commonly studied for regulating services. Parks were almost equally studied for regulating (n = 39) and cultural services (n = 36), although studies of cultural services pre-dominantly assessed parks in comparison to all other structures (23%).
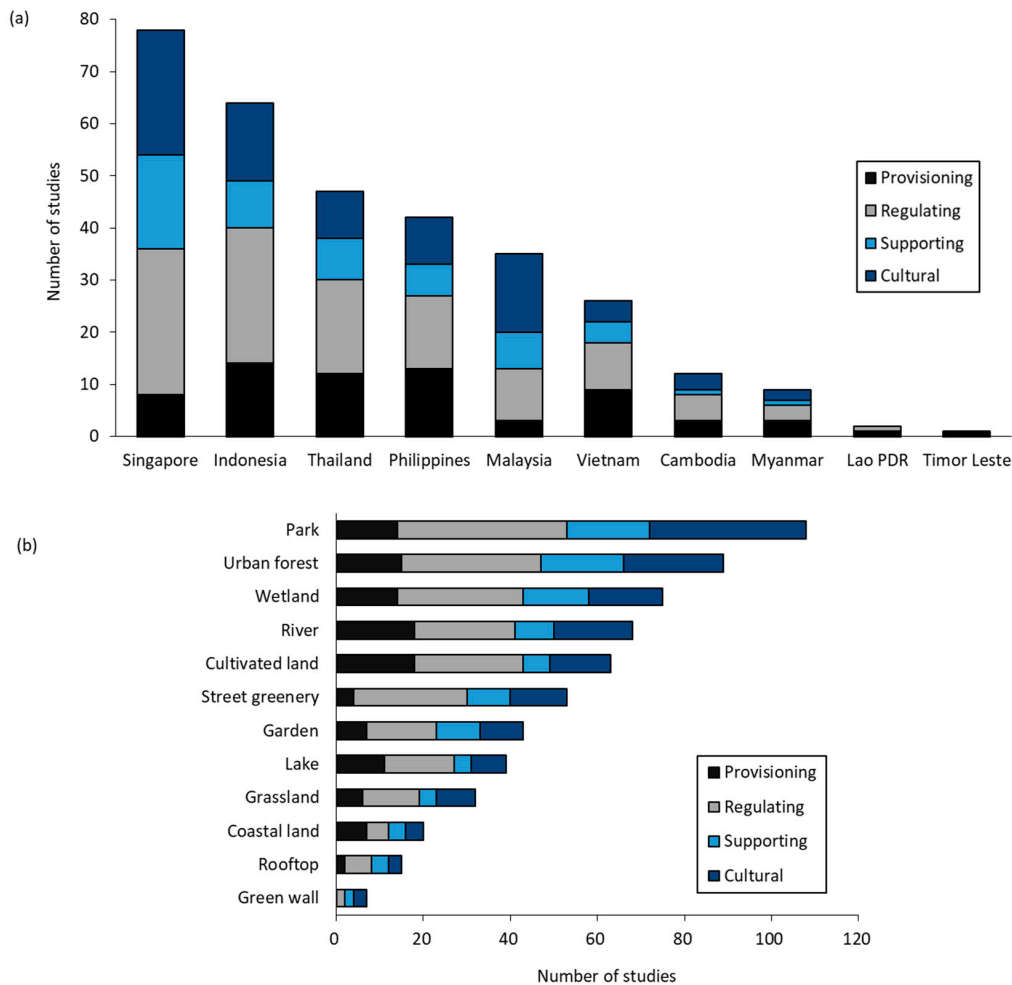

Figure 4. Ecosystem service domains assessed according to (**a**) countries and, (**b**) blue-green structures.

Table 2. The number of studies that assessed each ecosystem service according to the TEEB classification system [52]. Note that some studies assessed multiple ecosystem services; thus, the total number of ecosystem services assessed is greater than the 149 publications reviewed.

Domain	Ecosystem Service	Number of Studies
Provisioning	Food	40
	Raw materials	29
	Fresh water	18
	Medicinal resources	4
Regulating	Local climate and air quality	44
	Carbon sequestration and storage	27
	Moderation of extreme events	51
	Wastewater treatment	11
	Erosion prevention and maintenance of soil fertility	15
	Pollination	9
	Biological control	5
Supporting	Habitats for species	43
	Maintenance of genetic diversity	8
Cultural	Recreation and mental and physical health	54
	Tourism	19
	Aesthetic appreciation and inspiration for culture, art and design	44
	Spiritual experience and sense of place	25

3.3. Components of the 'Cascade' and Stakeholder Involvement

Only 2% of studies (n = 3) did not assess any component of the cascade in depth. These studies were mainly on the management of ecosystem services using frameworks that did not focus on any specific component of the cascade (e.g., [55,56]). Conversely, 16% of studies (n = 24) assessed all three components (Table 3). For instance, Remondi [57] simulated changes to land use surrounding rivers in Jakarta under different urbanisation scenarios. The study modelled the capacity of the river (structure) to retain water (function), in providing fresh water and flood protection services to the local population (services and benefits). The most studied component was the structure-function linkage (26% of studies; n = 38), while the function component was least assessed, with only 4% of studies (n = 6). Only 4% (n = 6) of the 149 studies had explicitly investigated ecosystem service interactions such as synergies and tradeoffs. The majority of the studies (56%) did not involve stakeholders either through surveys, interviews or expert input. Of those that did, most assessed cultural services (n = 46). Links between UES and climate change were only assessed by 3% of studies (n = 5).

Table 3. Distribution of the number of studies assessing various components of the ecosystem services cascade.

Cascade Component	Number of Studies
Structure	11
Structure-function	38
Function	6
Function-benefit	14
Benefit	29
Structure-benefit	24
All	24
None	3

3.4. Research Perspectives and Methods of UES Assessment

The number of studies in the region has increased across all ecosystem service domains (Figure 5a), particularly over the last decade; the review only yielded three studies prior to 2011 (Figure 5b), with more than 89% being published post-2014 (n = 133). The highest annual number of studies was in the year 2018, although bearing mind that for 2020 the review only included studies published between January and August, this year also saw a relatively high number of papers published.
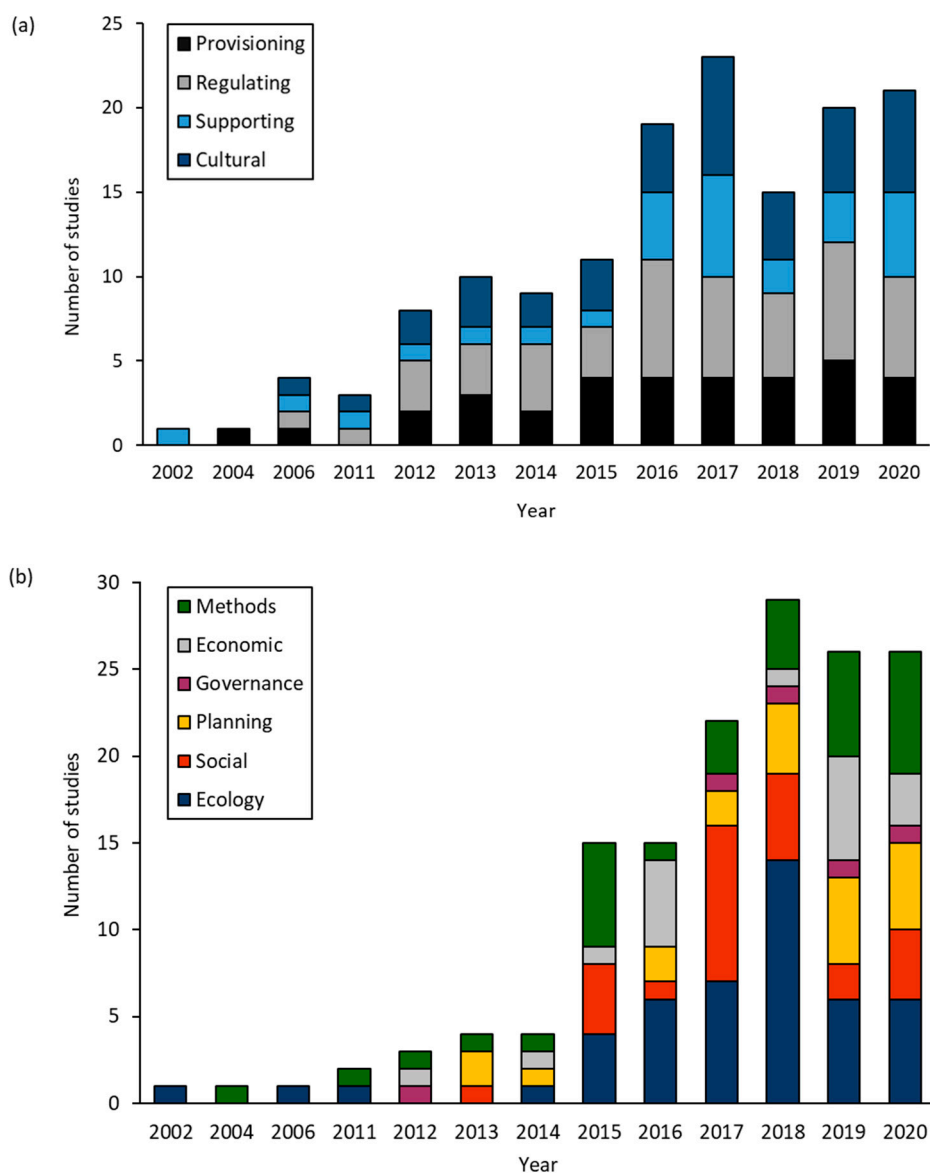

Figure 5. The (**a**) ecosystem service domains and (**b**) research perspectives, undertaken by studies over time. Note: A study may have assessed more than one ecosystem service domain but only one research perspective. Hence, **b** represents the actual number of studies reviewed over time.

Only papers published between 2018 and 2020 encompass all six research perspectives. Of the 149 studies, 32% were dominated by an ecological perspective (n = 47), while studies undertaken with a governance perspective were least common (3%; n = 5). Since 2013, more studies have been undertaken with social and planning perspectives, while governance-based research has received more attention since 2017. Studies with an ecological perspective were conducted in all countries except Timor Leste, which had the least

number of studies in the region (Figure 6a). Singapore, Indonesia, Thailand and Vietnam had studies comprising all six perspectives. About 34% (n = 15) of the 44 studies conducted in Singapore had an ecological perspective, while only 5% (n = 2) had an economic perspective and one study had a governance perspective. There were no studies with an economic or governance perspective in Malaysia, although the social perspective comprised 43% (n = 10) of studies in this country.
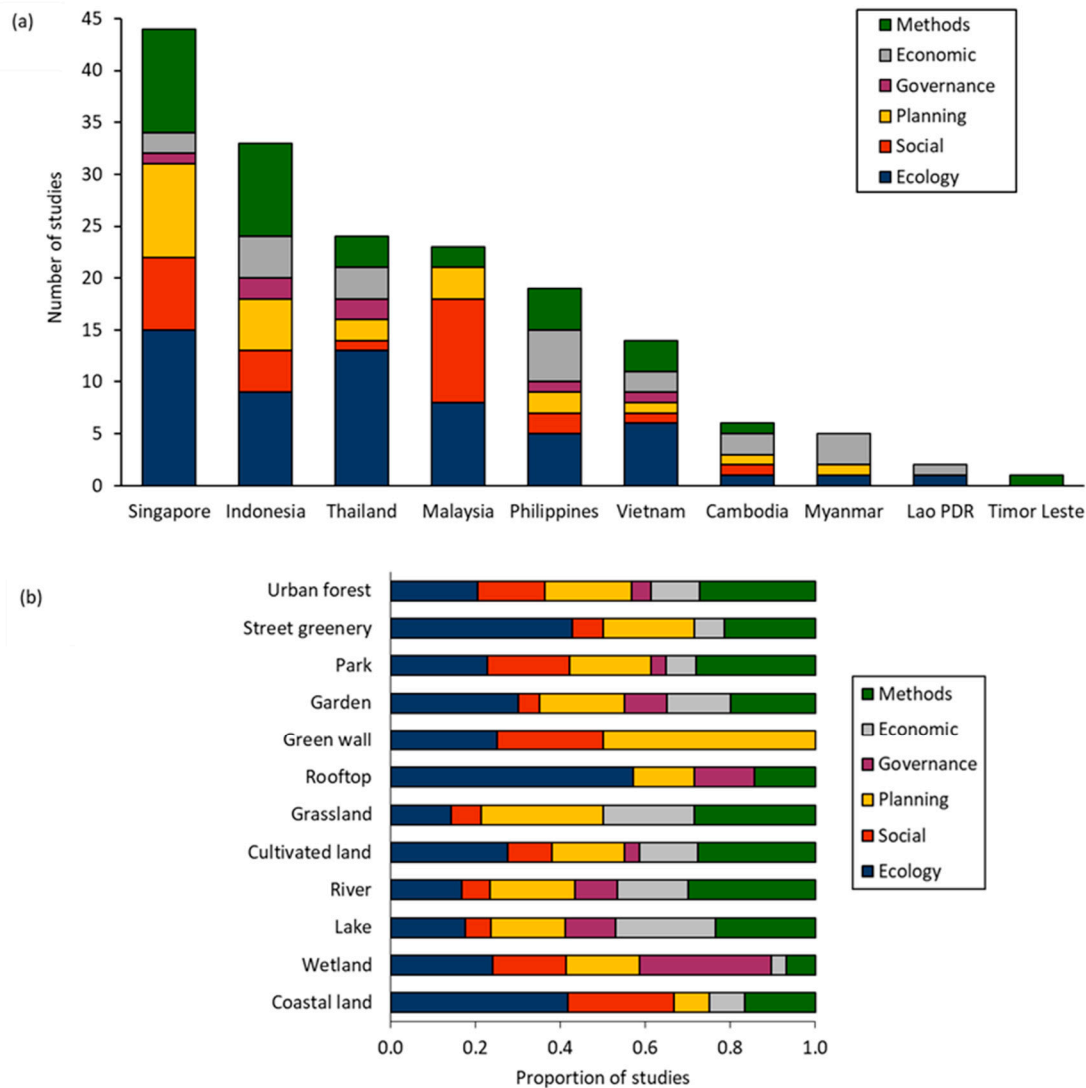

Figure 6. Research perspectives undertaken by studies across (**a**) countries and (**b**) blue-green structures.

Street greenery, gardens and rooftops were mainly studied from an ecological perspective, while parks, urban forests and rivers were predominantly assessed from a methods perspective (Figure 6b). Wetlands were most studied under the governance perspective (n = 9) and two of four studies of green walls had a planning perspective. Cultivated lands were equally studied using methods and ecological perspectives.

Over 89% of studies (n = 133) examined UES in a single time period or duration, with only 16 studies comparing services over two or more points in time. With respect to the type of data collected, 65% of studies (n = 97) collected only quantitative data, while only 5% of studies (n = 8) examined qualitative data. The remaining 44 studies examined both qualitative and quantitative data. Process and/or mechanistic models were the most utilised method of data collection and analysis in the region, comprising 88 studies (note: studies can utilise more than one method). Social surveys were the next most common

method (n = 43), followed by field sampling (n = 33). 13 studies used case studies to assess UES and 8 studies used landcover proxies. Only 23% (n = 34) of studies conducted valuations, of which over half were monetary (n = 19). Two studies conducted both monetary and non-monetary valuations, while the remaining studies (n = 12) conducted non-monetary valuations.

4. Discussion

4.1. Current State of Research

Our review found that the there was a growing body of research on UES in the Southeast Asia, particularly in the last five years. The research was biased towards more developed countries, in particular the city-state of Singapore, where about one third (29%) of published research was conducted. Previous reviews have also found that UES research tends to focus on highly developed and urbanised countries [28,41]. It is also apparent that little research has been conducted in less developed countries such as Myanmar, Cambodia and Laos. While most papers were authored by researchers based in Southeast Asia, there were no clear differences between the research foci of authors based in Southeast Asia and those based outside of the region.

Studies in Southeast Asia provided sufficient contextual information in their assessment, contrary to the findings of Luederitz [41] in their global review. Studies provided detailed descriptions of the boundary of respective the study areas, population size, location of ecological structures and type of structures studied. Of the four ecosystem service domains, in Southeast Asia, regulating and cultural services were predominantly assessed (62% of all studies). The two most commonly assessed services were recreation, mental and physical health (n = 54) and moderation of extreme events services (n = 51). Parks were the most assessed blue-green structure, while there were few studies focused on coastal areas (n = 12), rooftops (n = 7) and green walls (n = 4).

Over half the studies examined multiple ecosystem services, within and across domains, and mostly at a landscape scale (i.e., city scale or larger). Studies also assessed multiple components of the cascade, although there is room for a more holistic research approach, as interactions, such as synergies and tradeoffs between services were rarely examined (4%). There was also a lack of studies with a multitemporal focus (11%). Process/mechanistic modelling was the dominant method of UES assessment [58–60], although valuations of services were lacking.

Stakeholder involvement was higher in studies that examined regulating and cultural services. Many studies that involved stakeholders also had social or planning research perspectives suggesting a strong applied focus on managing UES. There were few studies with a dominant governance perspective and this finding is not unique to Southeast Asia, as global reviews by Haase [28] and Luederitz [41] also report the lack of governance discourse on UES research. While the nature of UES research within the region may have some commonalities with its global counterpart, we highlight aspects of research that are specific to Southeast Asia, discussing considerations and opportunities for integrating UES in the region below.

4.2. Specificity of Research in Southeast Asia

The transferability of research may be limited due to the diverse characteristics of Southeast Asian countries—in particular economic power and government effectiveness (see Table 1 and Figure 2) [17]. Furthermore, even within countries there can be diversity in values. There is diversity in environmental conditions as well as the nature of urbanisation and cultural perspectives and values. For example, Hassan [61] highlighted substantial differences in wetland management preferences between urban and rural areas in Malaysia. While, in Singapore, contrary to popular assumptions around the desire for natural green spaces, some urban residents do not favour high conservation value vegetation and unmanaged secondary forests due to perceived wildlife threats and poor aesthetics [62,63].

If regional uniformity is assumed in how services are perceived and valued, the specific preferences and/or needs of minority groups may be overlooked when managing UES.

Considering that countries in Southeast Asia are renowned agro-industrial producers and exporters [64], provisioning services and services from agricultural landscapes (e.g., oil palm) were fairly understudied in the region. Although it is generally expected that highly urbanised areas are less likely to include productive areas, agricultural landscapes can be commonly found within the urban matrix of Southeast Asia [65,66]. While this adds to the uniqueness of urban-scapes in the region, the interactions between provisioning services and other service types, as well as implications for different stakeholders is yet to be fully understood.

Much remains to be learnt about biodiversity and UES in Southeast Asia. As Mammides [67] reported, despite most of the world's biodiversity being concentrated in the tropics and the imminent threats it faces, research on tropical conservation is largely underrepresented. In our review, the initial search string, which contained only UES related terms, returned only 48 relevant publications. It was only through expanding our search string with more general keywords that we were able to increase the number of publications. Like most other Global South regions, the underrepresentation of research could be attributed to Southeast Asia being data poor [68,69], which was noted in a number of studies [62,70,71].

Limitations in the quality, availability and access to data pose major challenges to UES research in the region. Databases and organisations that collect and provide open-access regional environmental data are few to none, compared to those in North America or Europe (e.g., United States Geological Survey, European Soil Data Centre, National Biodiversity Network, Biodiversity Information System for Europe, European Environment Agency). This was reported in several studies such as Balmford [72] who used global environmental data in their assessment of road networks in the Greater Mekong subregion, as finer scale, regional data was not available. Estoque [70] also utilised global ecosystem service values reported by Costanza [73] due to the limited availability of local data in Baguio, Philippines. Estoque [74] highlighted the need for available and accessible city-scale data across Philippines for conducting heat vulnerability assessments, while Belcher and Chisholm [62] reported that in Singapore LULC data is not publicly available. This limitation significantly affects research outputs as collection and generation of high-resolution regional data requires important human and time resources.

5. Conclusions: Research Needs to Move Forward

As Southeast Asian cities grow and the population density in urban areas rise, demand for ecosystem services will become increasing important [75]. The recognised importance of UES is also seen with the increased number of UES assessments in the region over the last decade (Figure 5b). Increasing urbanisation and urban sprawls in Southeast Asia often result in the loss of natural ecosystems due to the infrastructure demands of growing urban populations [17]. Conserving nature and supporting the provision of UES is often more cost effective and practical than restoring degraded ecosystems [76,77], so a worthwhile objective for cities in the region is avoiding the loss of natural ecosystems through the consideration of UES in planning.

The prevalence of certain services within UES research suggests some UES are considered to be more important than others, from a research perspective, in the Southeast Asian context. For instance, the preservation of cultural services such as recreation services (n = 54) and aesthetic appreciation (n = 44), which are strongly associated with green spaces [33,78], may be of high interest to urban residents, as these areas are being rapidly lost to high density development patterns, characteristic of urbanisation in Southeast Asian cities [79,80]. Similarly, climate regulating services (n = 44) appear to be valued for their role in reducing urban heat island effects, which is a common issue in the region's densely urbanised tropical cities, with high average temperatures [81–84]. These UES, which have

been the focus of research, may be valued for their direct contribution to the wellbeing of urban populations and liveability of cities [33,85,86].

Recent research on the nexus between urban challenges, UES and Nature-based Solutions [17,87,88], highlights the role of UES in improving the liveability, resilience and sustainability of cities [15,89]. However, the future availability of UES is determined by land use decisions made in urban planning [90], which need to be supported by exhaustive assessments of UES. Thus, we highlight the following research areas, based on our review, that need further attention in order for UES research to wholly support land use planning and decision-making in the region (Figure 7).
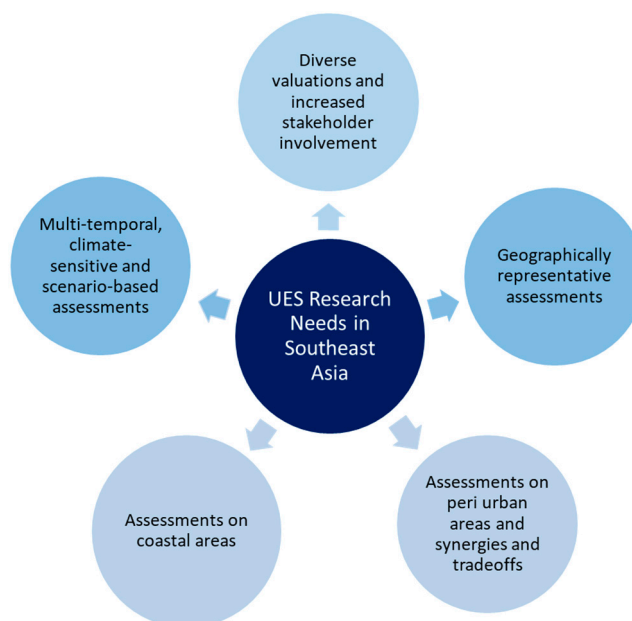
Figure 7. A diagram summarising the needs of UES research in Southeast Asia to support planning.

(i)   Geographically representative assessments

UES research is biased towards specific countries, regions and cities (Figure 2; Figure 4a). Aside from socioeconomic characteristics (Table 1), there are major biophysical differences between locations with maritime, continental and island climates in the region. This means that research conducted in Singapore may not necessarily be applicable in Cambodia or Myanmar. UES research needs to be context specific in order to purposefully address local needs. We therefore stress the need for a diverse range of UES assessments in countries that have very low representation of research such as Myanmar (n = 9), Laos (n = 1), Timor-Leste (n = 1) and Brunei (n = 0). The focus of assessments should also expand from megacities to secondary cities that are underrepresented (77% of studies concentrated on only four megacities—Singapore, Bangkok, Jakarta and Kuala Lumpur).

(ii)   Assessments on peri-urban areas and synergies and tradeoffs

As cities expand, peri-urban areas experience rapid land use change. However, only 15% of assessments examined peri-urban areas, consistent with Richards [91] and Wangai [75] that highlight peri-urban areas as being understudied globally. We encourage UES research in peri-urban areas, as these areas are where the intensity of development is the greatest and UES are being lost or degraded, and therefore where planning is mostly urgently needed.

It is especially important to investigate the synergies and tradeoffs of UES in urban and peri-urban areas so the consequence of planning decisions can be considered systematically [92,93]. Although 58% of studies in the region assessed multiple ecosystem services, only 4% dealt with synergies and tradeoffs. A clear understanding of the complex interac-

tions between UES, as well as UES and land use management, is particularly important in rapidly developing peri-urban areas.

We also highlight the need for synergy and tradeoffs assessments between urbanisation and provisioning services. The spatial expansion of cities has negative impacts on urban/peri-urban agriculture [94], which is commonplace in Southeast Asia [66,95]. Given the importance of agricultural production to local livelihood in the region [96], the sustainability and multifunctional capacity of urban agricultural landscapes needs to be better understood [97,98]. Careful management of land use as peri-urban areas develop can yield more sustainable UES provision, than attempts to retrofit restoration efforts in the future.

(iii) Assessments on coastal areas

Many of Southeast Asia's densely populated cities are located along the coastlines (e.g., Greater Jakarta, Singapore, Ho Chi Minh, Bangkok, Manila), yet few studies examined UES in coastal areas. Coastal cities are particularly vulnerable to coastal and riverine floods, coastal erosion, storm surges, monsoons and tsunamis [99,100], all of which bring adverse health risks to the urban population [101,102]. Moreover, many of these extreme events are expected to increase in frequency in Southeast Asia because of climate change effects [14,99]. Thus, we bring to attention the exigency of assessments of coastal structures as a Nature-based Solution in coastal cities. Research should also focus on opportunities to support the resilience of urban communities through the sustainable provision of UES [103].

(iv) Multi-temporal, climate-sensitive and scenario-based assessments

Few studies (11%) have conducted temporal assessments of UES, which are key to understanding changes in service provision and demand [104]. This is challenging in practice as there is limited information on how UES change over time and/or under different future scenarios [57,105]. Moreover, Southeast Asian cities are seen to be highly vulnerable to climate change effects [17,106,107], yet few studies have examined the link between UES and climate resilience (n = 5). Assessments of changes in UES can be used to identify areas vulnerable to weather-related disaster risks and/or support decisions on appropriate land use management strategies [14]. Our review highlights a pressing need for multitemporal and/or scenario-based research on the resilience of UES provision. Research should also address the increased risk of diseases in tropical ecosystems due to the effects of climate change [108,109], as well as the consequent impacts to UES, particularly provisioning services [110,111].

(v) Diverse valuations and increased stakeholder involvement

Literature supporting the valuation of ecosystem services is abundant [30,112–114], with recent research emphasising diverse perspectives in valuations through value pluralism [49]. However, our review found that only 23% of studies in the region conducted valuations. Valuations support decision-making by providing explicit quantification of UES demand, which can be in monetary or non-monetary terms [46]. The involvement of stakeholders (44%) in UES assessments can support valuations by identifying context-specific demands and preferences of the people appropriating the services [41,49].

In line with TEEB and the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) [49,115,116], we urge research to incorporate diverse valuations, monetary and non-monetary, as well as increase stakeholder involvement in UES assessments. Although contentious [117], the comprehensive representation of UES through valuations has been proven to be effective in influencing decision-makers towards planning agendas [118]. This is because valuations can be used as a tool to demonstrate the cost of restoring ecosystems or the critical importance of alternative land use options objectively to decision-makers [119–121]. As the invisibility of nature in economic choices often drives its depletion [53], valuation of UES can encourage more transparent assessments of tradeoffs to support the planning of sustainable cities.

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