International Journal of Scientific Advances
ISSN: 2708-7972
Volume: 4 | Issue: 3 | May – Jun 2023 Available Online: www.ijscia.com
DOI: 10.51542/ijscia.v4i3.2

Ecosystem Service Concept as a Rationale for Urban Green Space Conservation- A Systematic Review Report

Saubhagya SILWAL[1]*, Rebecca THOMAS[2], and Smriti SHRESTHA[3]

[1]Department of Biology, Salem College, NC, USA
[2]Associate Professor of Parks and Resource Management, Slippery Rock University, PA, USA
[3]Senior Lecturer of Statistics, North Carolina Agriculture and Technical University, NC, USA

*Corresponding author details: Saubhagya SILWAL; sausilwal@gmail.com

ABSTRACT

Urban Green Space (UGS) is recognized as vital to modern infrastructure development worldwide. While the conventional method of urban planning has long prioritized built structures over UGS, an increasing number of scientific studies have demonstrated that UGS not only supports biodiversity but also provides numerous essential benefits for humans, such as clean air, water, weather regulation, food, and a place for respite for urban residents. This points to a need for an interdisciplinary synthesis of recently published research to document the ecological and social benefits and present comprehensive recommendations. We conducted an in-depth review of existing scientific literature to explore supporting, regulating, cultural, and provisioning ecosystem services benefits, major factors enhancing them, and management recommendations to optimize those benefits. The results indicate that optimizing heterogeneous UGS coverage as an essential part of urban design benefits natural as well as human communities in the form of enhanced wildlife habitat, clean air and water, weather regulation, and livability. Findings highlight the multifaceted contributions of UGS in maintaining natural ecosystems to provide essential benefits for human wellbeing and environmental health, which are integral components of sustainable development. We discuss evidence-based recommendations for policy and planning for optimum UGS suitable for different environmental, geographic, ecoclimatic, and socioeconomic statuses worldwide. The availability of comprehensive information on the enhanced benefits of UGS renders new directions and impetus for UGS conservation in the era of expanding urbanization and climate change.

Keywords: ecosystem services; urban green space; conservation rationale; urban conservation; biodiversity conservation; research synthesis.

INTRODUCTION

Urban landscapes have been managed to incorporate green spaces to fulfill aesthetic, cultural and natural values for millennia [1, 2]. However, rapid urbanization driven by rising demand and underlying economic pursuit have caused a staggering loss of urban natural areas in recent decades, drastically transforming how people interact with their environment [3, 4]. Such a decline globally is detrimental to wildlife, threatening biodiversity [5, 6], accelerating the impact of climate change [7] and degrading the quality of human and nature interactions [8]. One significant impact is enormous pressure on already constrained sociocultural and socioecological benefits and ecological functions of an urban environment, especially compared to rural areas [8]. As urbanization is projected to expand to accommodate as much as 70% of the world population by 2050 [10], the loss of natural and semi-natural landscapes is likely to intensify unless socio-ecologically sound measures are taken to facilitate evidence-based sustainable development.

Ecosystem services (ES)-driven landscape-scale configuration, allocation and management of urban green space (UGS) to enhance urban sustainability and resiliency represents one critical and strategic measure to mitigate these challenges [11].

In a broad sense, the ES concept in as complex a landscape as UGS [12] includes socioeconomic and ecological components [13-15] that signify not only economic, aesthetic and cultural values for people [16] but also structurally intricate places conducive to landscape-scale biodiversity conservation. Thus, rather than promoting a strictly utilitarian view, the UGS ES approach employs a long-term and evolving vision by combining the multifaceted integrality of natural and human components [17].

With this integrated focus on humanity's dependence on ecosystems and biodiversity [18], ES-driven UGS functions have received increasing scientific attention in recent decades, positively influencing human wellbeing [19] in terms of four categories of ecosystem services [20, 21]. The four categories include supporting, regulating, cultural, and provisioning services that promote biodiversity and species richness; regulate weather and climate; facilitate mental and physical wellbeing; and provide natural resources such as freshwater, food supply, and energy [22-24]. However, due to UGS ES functional synergies and tradeoffs complexities [25, 26], ES contributions to human wellbeing are intricate and sometimes poorly understood [27], especially when ES functions' multifaceted interconnectedness is not considered during planning and development.

This complexity further intensifies along with socioeconomic vulnerability, instability, and interdependence when one considers the impact of suburban communities and the quality of adjacent or peripheral natural environments [28]. For instance, while heterogeneous and native habitat enhances supporting and regulating services, a disproportionate focus on cultural services may be detrimental to these functions [29]. Moreover, mismanaged provisioning services such as over-extraction and exploitation of natural resources on top of overdevelopment within or around cities may cause resource depletion, deteriorating regulating functions such as soil and water contamination [30, 31] and ultimately hampering overall socioecological resiliency.

One potential approach to achieving socioecological resiliency surrounding the interaction of UGS ES systems could be to explore the integrality of social and biophysical features from various aspects to achieve ecologically sensible management actions. These aspects include but are not limited to physical drivers such as scale (spatial and temporal) and ecological reversibility potential assessed using multi-scale complexity dynamics of the system's thresholds and nonlinear responses [32-34], as well as essential sociocultural and natural drivers [4]. Further, management actions calibrated based on spatial and temporal dynamic environmental heterogeneity enhance biological diversity, ecosystem services, and ecological resilience [29]. Such wholistic actions may better facilitate the possibility of long-term conservation and land management practices that integrate a well-balanced approach to the natural and built environment [35]. In other words, emphasizing ecological processes in development in terms of the immense benefits of nature through "greening" the overall landscape could enhance ES by improving the living conditions of urban residents and enhancing biodiversity. Yet urban planners and policymakers do not always have the luxury and resources to adopt the most up-to-date advancements in UGS planning because it is convenient to maintain the status quo, and such scientific data are often inaccessible to a global audience due to paywalls, language barriers, and limited technical capacity [36].

Moreover, adaptable decision support tools for multiple ecosystem services using complex and heterogeneous data are still in the early developmental stage [37]. Even where the efforts to restore and integrate UGS exist, management recommendations are complicated due to variable conditions in urban natural areas, leading to a need to document the spatiotemporal dynamics of urban ecosystem services [38]. Meanwhile, as urban planners and policymakers are demanding the evidence and rationale of nature conservation, ES-based management practices could become a significant paradigm for natural resource management [39] along with the efforts to establish a scientifically robust analytical framework to corroborate those benefits both in terms of quality and monetary value. Although there have been systematic reviews of individual ES functions such as urban agriculture and biodiversity [40], cultural ES and human wellbeing [41], climate and social conditions [42], non-spatial urban park dimensions [43], nature-based stormwater mitigation [44], and edible green infrastructure [45], to our knowledge, the scientific scope has been lacking to consider multiple ES concept as a rationale for UGS conservation. Thus contrary to the wider trend, we determined that collectively analyzing and synthesizing the current state of UGS ecosystem services is the first step in this direction. We undertook a comprehensive systematic review of UGS's multiple ES benefits to build a rationale for optimal UGS conservation and propose evidence-based management recommendations adaptable to varying global socioeconomic, geographic, and eco-region situations.

In response to these time-appropriate demands, we conducted a thorough and transparent examination of peer-reviewed literature published between 2010 and 2019 from around the world to better understand the key drivers of UGS in enhancing ecosystem services and ultimately determining its conservation approach. Specifically, we addressed the following key research questions regarding the ES provided by UGS:

(1) What are the publication trends, geographical study location characteristics and dominating UGS ES category?
(2) Do economic and climatic conditions impact the state of UGS conservation around the world?
(3) What are the ecological and social predictors of UGS that determine the extent of positive and negative outcomes in each ES category, and how are they interrelated?
(4) What ES synergies promote UGS conservation and what tradeoffs deter conservation?
(5) What relevant recommendations do the studies offer to optimize the multifunctionality of UGS both as a resilient natural landscape and a place of sociocultural importance for urban residents?

The simplest approach to constructing a POS tagging dataset is to use a pre-existing solution, such as a programming language library or an online tool. The ISMA translator, available at http://www.translator.am/am/index.html, is an excellent option, requiring no technical knowledge or IT skills, and is capable of annotating vast amounts of data. The critical technologies employed are data preprocessing, web scraping, and data cleaning techniques, which can be implemented using the Python programming language.

The ISMA Translator is an online machine translation tool that features a rule-based POS tagging system and can also perform grammar and spelling analysis for Armenian language text. The system has demonstrated remarkable accuracy in processing Armenian text, making it an ideal tool for annotating POS tagging. While ISMA offers other types of grammar analysis, such as stem, gender, and article identification, it is not infallible and may occasionally make mistakes or fail to analyze certain word groups. As a result, the database generated through testing only includes tags related to parts of speech and grammatical numbers.

METHODS

A preliminary review of the selected key literature of the UGS ES, recently published reviews [40, 41], and the PSALSAR methods proposed by Mengist and colleagues (2020) [46] provided the basis for determining our interdisciplinary research scope and literature search strategy.

Article Search, Screening, and Data Extraction Strategy

We conducted the literature search between April and May 2020 in two databases (Academic Search Ultimate and Environment Complete within the EBSCOhost search engine) by following the recognized protocols for systematic reviews outlined in Pullin and Stewart (2006) [47] as a guide (Figure 1). We arranged the Boolean search string as: "urban green space or urban parks or urban greenery or urban greening or urban green zone" (TI) OR "ecosystem services or environmental services or ecological services" (AB) AND "regulating services or cultural services or supporting services or provisioning services" (AB) AND "outcomes or benefits or effects or impacts" (AB).

After a general overview of the total number of articles and a series of the screening process, we determined that selecting articles published between 2010 and 2019 (89% of the peer-reviewed were published during this time with full-text articles available) would facilitate the most recent and up-to-date synthesis [39, 48]. Additionally, to compensate for an extremely low number of articles in the provisioning services category and to increase reference points, we included eight articles related to the provisioning potential of UGS through a random search, even though doing so would add non-empirical studies in the data pool [41].

Analytical Framework and Data Analysis

We operationalized the extracted data category as coded datasets of key components of interest for the systematic review (Table 1).

First, two authors (removed for anonymity) independently coded a portion of the selected articles to assess the intercoder reliability of the extracted data category and entered them into a Microsoft Excel spreadsheet for descriptive statistical and inferential analyses using SPSS [49, 50] and qualitative thematic content analysis. Second, for inferential analysis, we used Phi and Cramer's V, the indirect representation of Pearson's Chi-square, to assess the drivers of UGS ES categories as the coefficient Phi is designed to measure the association between categorical variables and adjust uneven sample sizes [51].

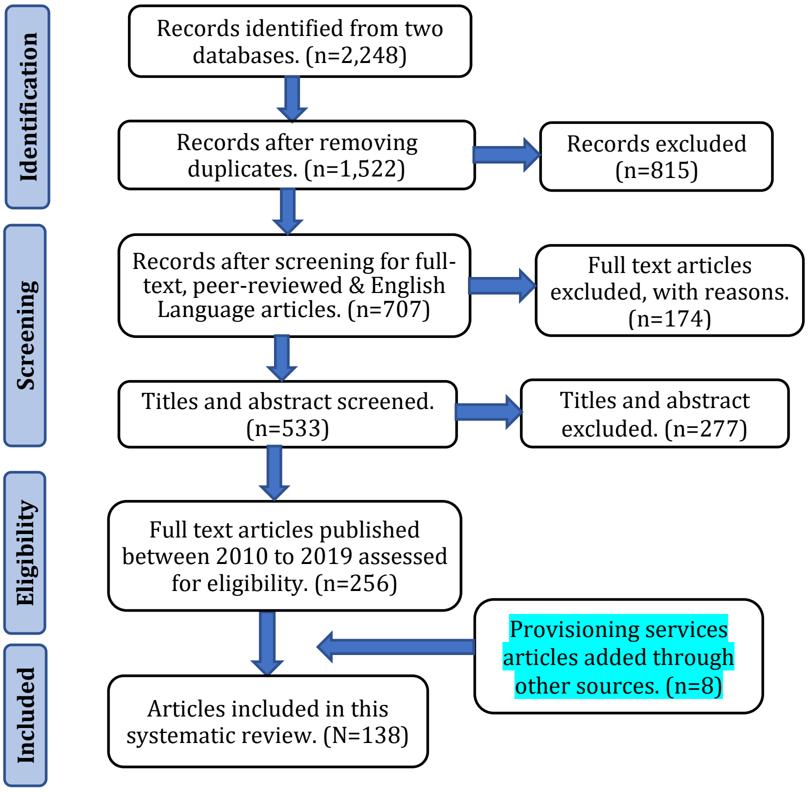

FIGURE 1: PRISMA Literature Search Flow diagram depicting the literature screening process for this research. doi: https://doi.org/10.1371/journal.pone.0140833.g001 [129].

TABLE 1: Qualitative evidence synthesis (QES) (Macura et al. 2019) and quantitative analysis framework utilized in this systematic review. The details have been modified after; Kosanic and Petzold, 2020; Mengist et al. 2020 [41, 46].

Criteria	Extracted Datasets	Considered code categories where applicable
Metadata	Autor(s) Journal/Discipline Year Published	Environment and Ecology Social Sciences Economics and Business General 2010 to 2019
Study Location/ Eco-climatic regions/ UGS characteristics	Country and WB Regions (World Bank, 2021) [127]	East Asia and Pacific Europe and Central Asia Latin America & the Caribbean Middle East and North Africa North America South Asia Sub-Saharan Africa
WB Country by Income (World Bank, 2021)	Low-income Lower-middle-income Upper-middle-income High-income economies	WB Country by Income (World Bank, 2021)
Eco-climatic region by Köppen-Geiger climate classification [128]	Equatorial, Arid, Warm temperate, Boreal, Polar	Eco-climatic region by Köppen-Geiger climate classification [128]
Studied UGS type, size, configuration	Single/multiple UGS area/size range UGS type formal/informal	Studied UGS type, size, configuration

Criteria	Extracted Datasets	Considered code categories where applicable
Method	Nature of data	Natural science Social Science
	Type of data Collection	Field study, Open source/GIS-based, Experiment/simulation Qualitative Survey, Quantitative Survey
	Research Methods	Qualitative, Quantitative, Mixed methods
	Response Variables	*ES category dependent. See the results section for details.*
	Data calculation/analysis	Software, Descriptive, Equation, Model, Others

Table 1 Contd.

Ecosystem Services, Drivers, Functions and Recommendations	Studied UGS Ecosystem Services (Millennium Ecosystem Assessment, 2005)	Supporting Regulating Cultural Provisioning
	Positive outcomes or benefits or effects or impacts	*ES category dependent. See the results section for details.*
	Negative outcomes or benefits or effects or impacts	*ES category dependent. See the results section for details.*
	Recommendations for resilient UGS and to minimize tradeoffs.	*Organized by outcome category and Eco-climatic region. See the results section for details.*
Miscellaneous	Study Gaps/Limitations	Inadequate factors Inadequate study instruments Limited official/opensource data
	Future Prospects	Effective policy, planning and management Future studies Multistakeholder involvement Subsidy valuation

Subsequently, we adopted qualitative evidence synthesis (QES) described by Macura and colleagues (2019) [52] to form the thematic analytical framework, building upon a pilot review and data extracted from the selected articles that documented conservation and management approaches. Due to the wide range of studied locations, study methodology variability, and examined parameters, meta-analysis and critical appraisal weren't deemed applicable for heterogeneous literature mapping. Meanwhile, to uniformly code the geographical regions of studied countries and the corresponding socioeconomic status, we utilized the open-access World Bank categorization. Likewise, for climatic and eco-region information, we referred to the publicly available and updated Google Earth version of Köppen-Geiger climate map based on temperature and precipitation observation for the period of 1986-2010 [53, 54]. Finally, although we reviewed 138 articles, we based our descriptive analysis on 154 studied locations reported in the articles where applicable.

RESULTS

1. Publication trend and geographical characteristics of study location and dominating UGS ES category?

The yearly published articles that met the research criteria peaked in 2017 (27 articles; 19.56%), with the lowest number of articles in 2012 (2.9%; Figure 2). Although our result showed the confirmation of UGS ES studies in all inhabited continents (World Bank categorizations), the cities in the European and Central Asian region (50 locations; 30.47%; Figure 4) showed the highest representation. Individual countries with the most studied locations were the USA (22; 14%), China (18; 11.6%), Australia (7; 4.5%), Brazil (7; 4.5%, and Italy (6; 3.8%) (See Figure 3). Supporting and cultural services ES categories (51; 37% each) were the most commonly studied ES categories, followed by regulating services (27; 20%) and provisioning services (9; 7%) (Figure 5). Though not depicted in figures, the study site characteristics in the reviewed articles ranged from typical natural or semi-natural urban parks [55-57], urban forests [58, 59], vacant lots [12], demolished or ruderal sites [60, 61] and urban agricultural parks [62], thus encompassing broad UGS typologies characteristic to urban situations. Multiple UGS were the subject of most of the articles (98; 71%) either within the same country or spanning multiple countries in addition to two indoor experiments (2; 1%) and a global study [11].

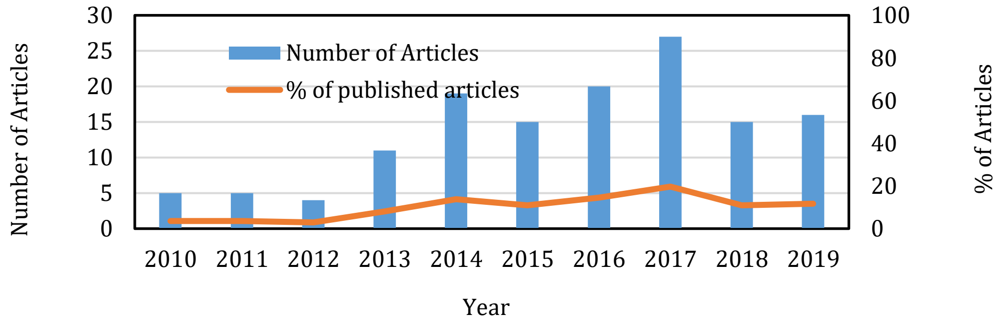

FIGURE 2: Number and percent of articles published per year of publication. The number of articles is shown in the primary axis as raw number (blue shaded bars) and the percentage of article in the secondary axis.

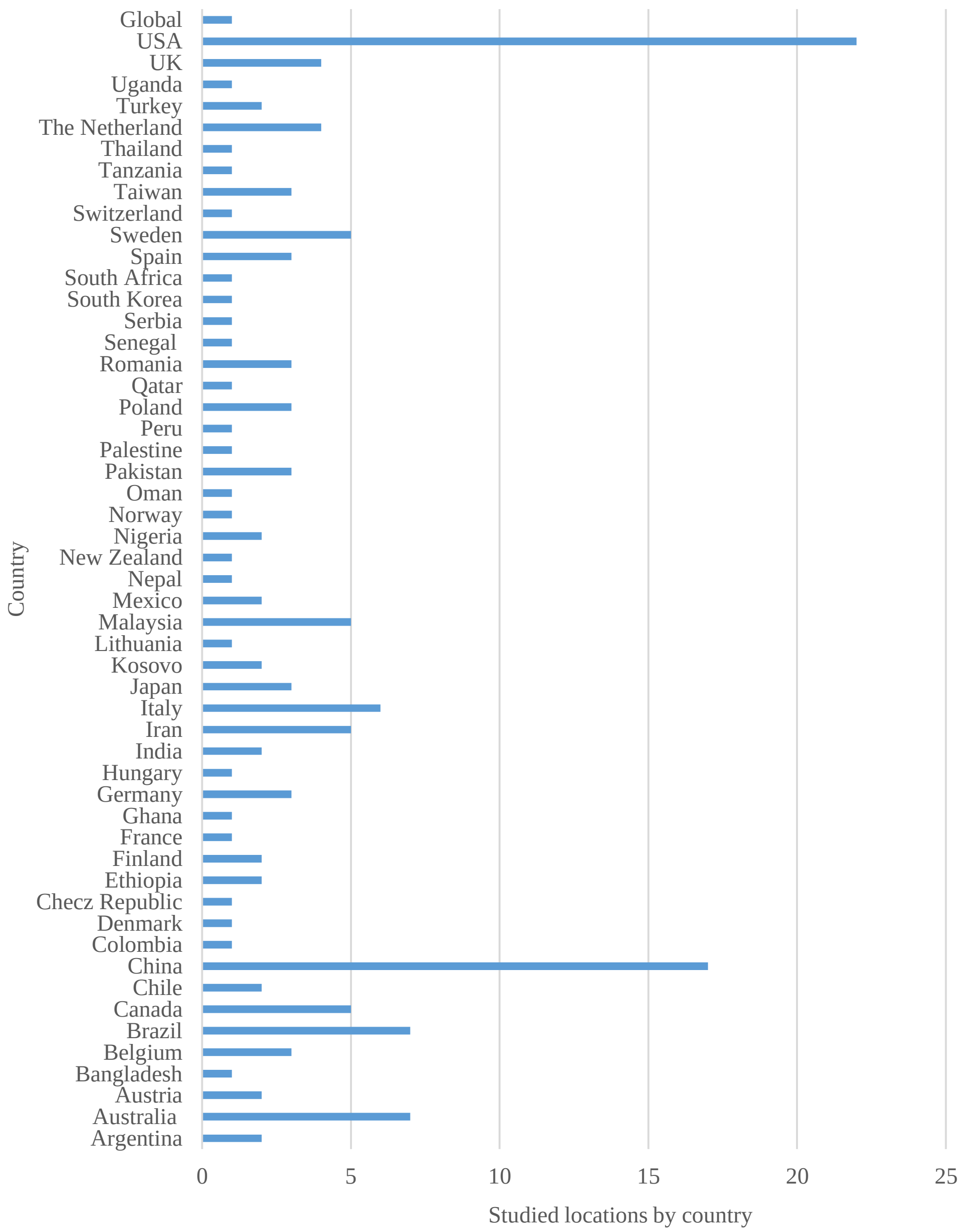

FIGURE 3: The number of studied locations by country. The 138 articles reviewed in this review reported studies conducted in 154 locations in 52 countries. The figure also includes an article representing a global study.

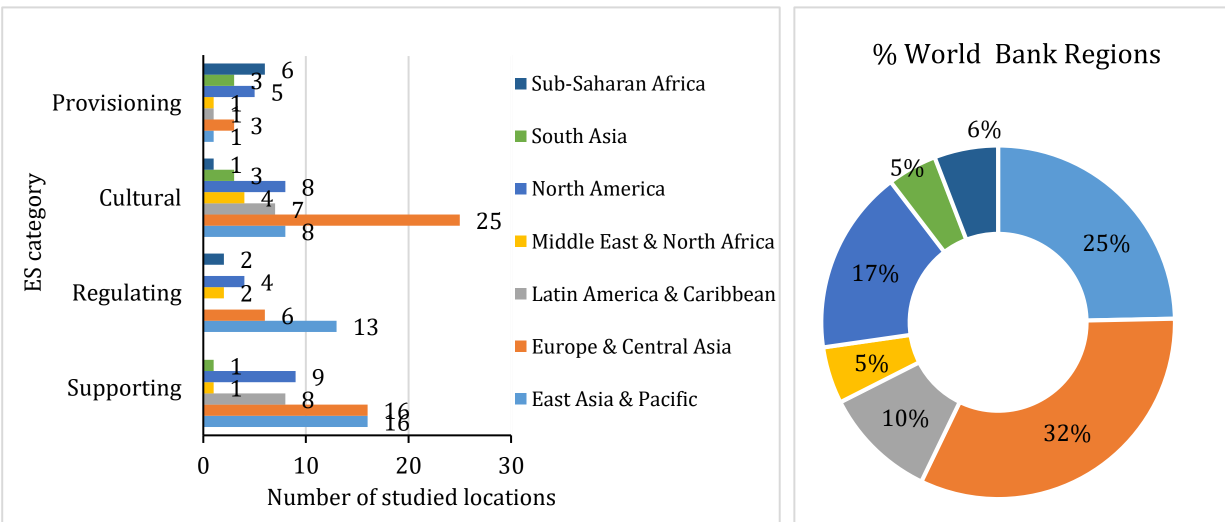

FIGURE 4: Number of studied locations in each ES category by the 7 World Bank regions (left) and the overall proportion of those regions (right). Figures are based on 154 UGS locations studied in 138 articles.

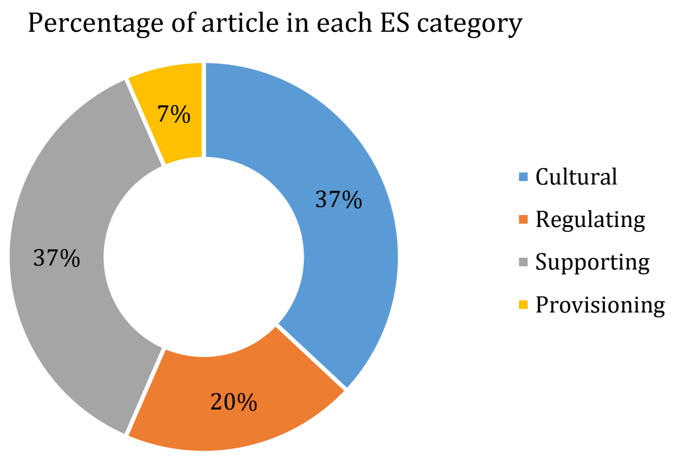

FIGURE 5: The proportion of studied UGS ES categories.

2. How do climatic and economic conditions impact the state of UGS ES study around the world?

Climate (K¨oppen-Geiger) and economic conditions (WB) were two major factors that determined the number of articles in each category. Climatologically, the number of studies from the warm temperate region was higher for all ES categories (Figure 6). Individual ES category-wise, a greater number of articles from the arid regions in the cultural services indicate the study efforts to understand non-material benefits in the arid climate.

Economically, high-income and upper-middle-income locations had a high number of articles in all ES categories comprising a total of approximately 90% of articles (Figure 7). When these results were analyzed using Cramer's V, the climate zone of the study location and income group (WB categorization) exhibited strong associations with the studied ES categories individually (income group: V=0.402, p<0.000; climate zone: V= 0.479, p<0.000) and in conjunction (V =0.559, p < 0.000) (Tables 2a & 2b). The combined association was the strongest for Cultural, Provision and Supporting services.

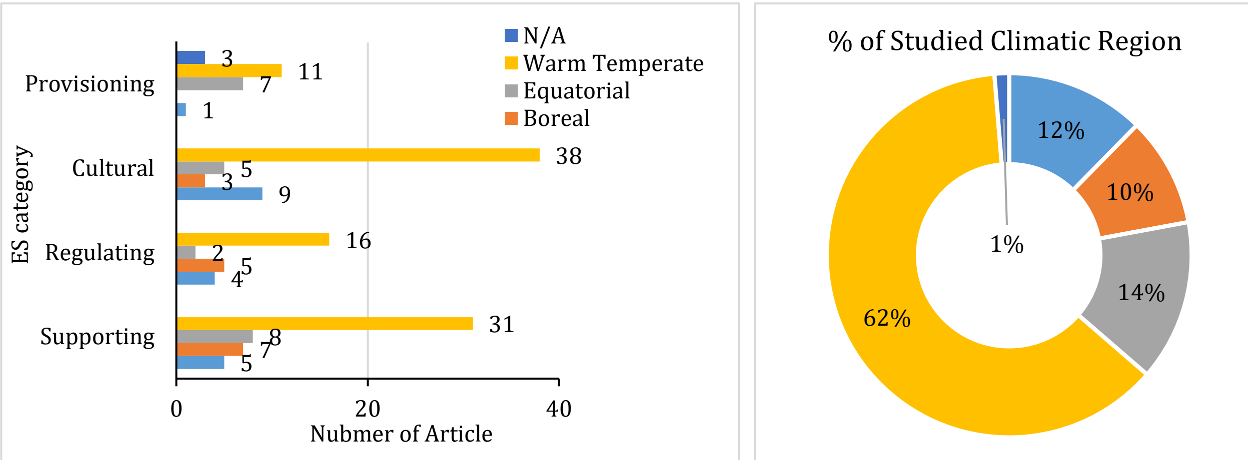

FIGURE 6: The number of studied locations in each ES category by climatic zones (left) and % overall climatic zones studied (right). The figures are based on 154 studied locations reported in 138 articles.

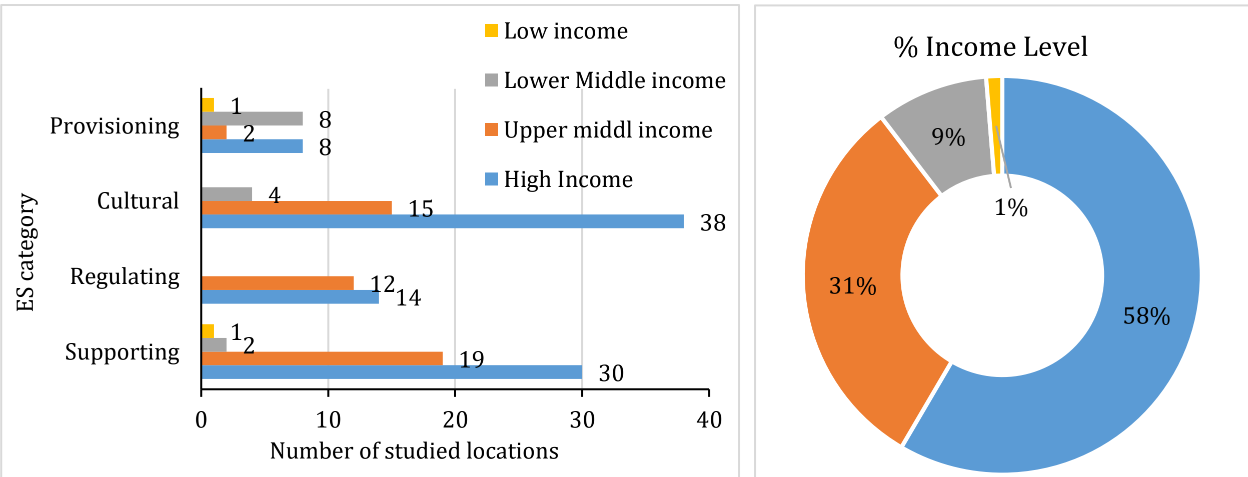

FIGURE 7: The number of studied locations in each ES category by income level (left) and % overall income level of studied countries (Right). The results are based on 154 UGS locations studied in 138 articles.

TABLE 2a: Measures of association between coded variables.

Measures of Association	*Cramer's V*	*P-value*
Values based on 138 articles		
Climatic zone of the research area and ES Category, n=135	*0.173*	*0.209*
Income Level and Positive Results for ES Category Supporting, n=51	*0.458*	*0.019***
Income Group and Positive Results for ES Category Regulating, n=27	*0.342*	*0.533*
Income Level and Positive Results for ES Category Cultural, n=51	*0.358*	*0.666*
Income Group and Positive Results for ES Category Provisioning, n=8	*0.816*	*0.069**
Income Group and Negative Results for ES Category Regulating, n=27	*0.427*	*0.295*
Income Group and Negative Results for ES Category Supporting, n=51	*0.492*	*0.075**
Income Group and Negative Results for ES Category Cultural, n=51	*0.445*	*0.064**
Income Group and Negative Results for ES Category Provisioning, n=8	*0.816*	*0.255*
Income Group and Coded Study Limitations, n=90	*0.163*	*0.272*
ES Category and Coded Future Directions, n=129	*0.196*	*0.093**
Values based on 154 study locations		
Studied ES Category by Income Group	*0.402*	*0.000*
Studied ES Category by Climate Zone	*0.479*	*0.000*
Climate Zone and Income Level association on the ES category		
Overall	*0.559*	*0.000*
Supporting	*0.413*	*0.008***
Regulating	*0.290*	*0.606*
Cultural	*0.482*	*0.000*
Provisioning	*0.688*	*0.001***

** Significant association at a 5% level of significance
* Significant association at a 10% level of significance

TABLE 2b: Interpretation guide to Phi and Cramer's V (Akoglu, 2018).

Phi and Cramer's V	Interpretation
>0.25	Very Strong
>0.15	Strong
>0.10	Moderate
>0.05	Weak
>0	No or very weak

3. What are the ecological and social drivers of UGS ES studies that determine the extent of positive and negative outcomes in each ES category, and how are they interrelated?

We standardized the study instruments and the variables utilized in the articles to descriptively assess the ecological and social drivers that determined the extent of positive and negative outcomes and their interrelations. This step was also important to assess synergies and tradeoffs described in the following section thematically. Overall, the methods utilized in the articles consisted of a quantitative research approach (102 articles; 74%), followed by mixed methods (28 articles; 20%) and purely qualitative (8 articles; 6%) under three broad groups of response variables which were natural science, social science and geospatial data (Figure 8). Subsequently, we standardized the explanatory variables in terms of biophysical and sociocultural modeling techniques described elsewhere [63-65] (Figure 9).

As a biophysical modeling technique, the internal/external factor (representing built space outside the UGS and distance to residential areas and other nearby green space), along with wildlife surveys with plant population/diversity factors (44 articles), comprised the dominant way to assess supporting services and demonstrate ecological health, habitat characteristics and their capacity to support wildlife [33, 61, 66]. On the other hand, the biophysical factor of weather/climate with plant coverage dominated the regulating services to demonstrate cooling intensity, microclimatic regulation, and pollution mitigation [67-69]. Likewise, the nine articles in the provisioning services category assessed the role of bees in food security [62, 70], the potential of urban forestry [71, 72], the role of natural areas in water security [73], and the current UPA condition along with the future potential in global and regional scales [11, 74]. In the cultural services articles, qualitative and quantitative sociocultural modeling determined socioeconomic [75, 76], socioecological [77, 78], and Quality of Life (QoL) benefits [79, 80].

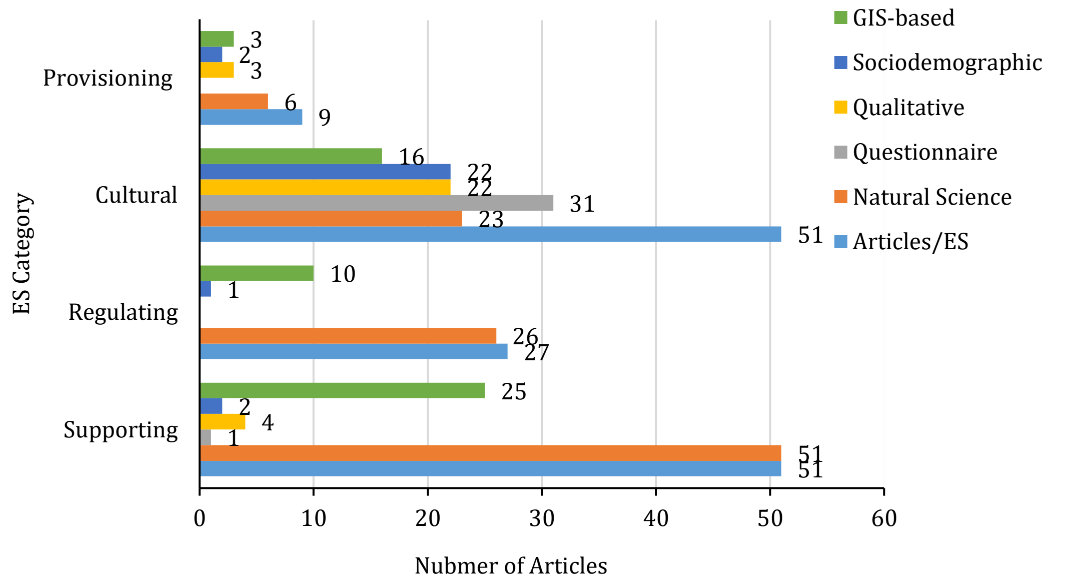

FIGURE 8: The number of articles in each ES category and the nature of response variables measured in the reviewed articles. Blue bars are the total number of articles in each category.

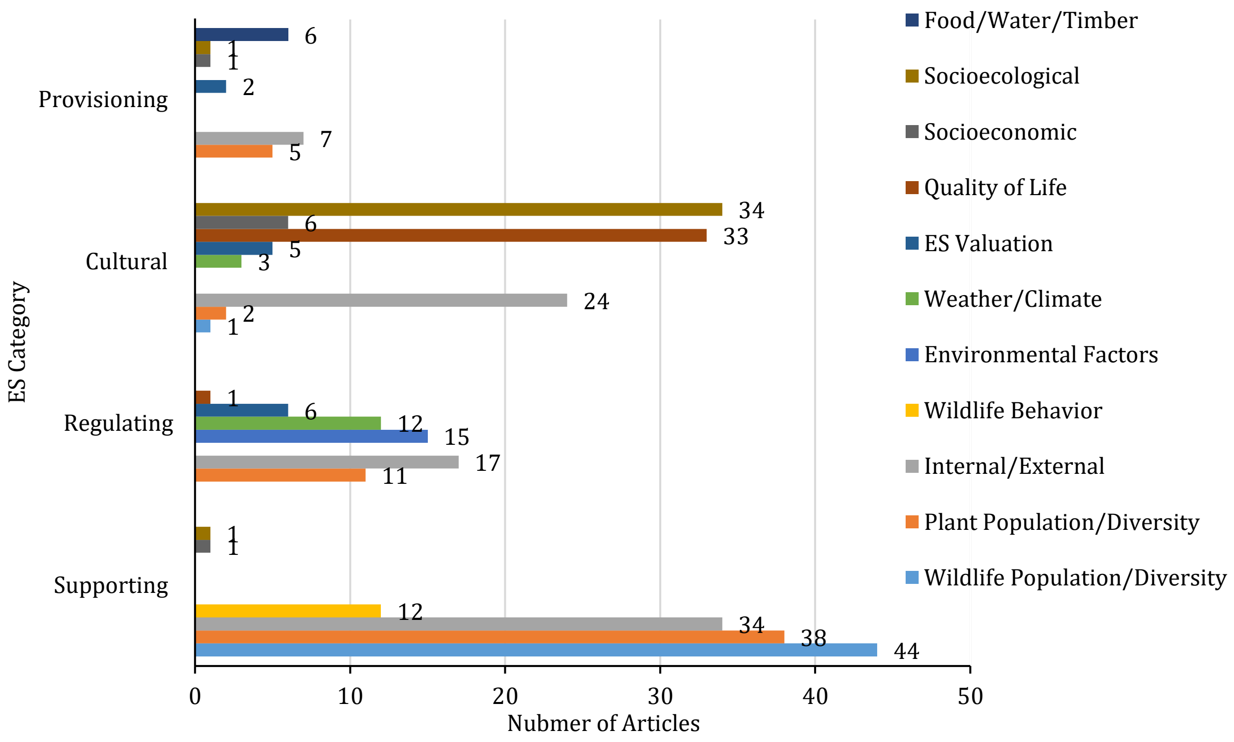

FIGURE 9: Sociocultural (labeled in red) and biophysical explanatory (labeled in purple) variables assessed in each ES category.

4. What are the synergies and tradeoffs in the UGS ES concept identified in the literature?

As a part of the thematic analysis, we reinterpreted and coded positive and negative themes and outcomes in each ES category (Tables 3 and 4) to make them relevant to UGS ecosystems services and present insights into synergies and tradeoffs of UGS ES that either promote or deter conservation. One hundred twenty-eight articles reported positive outcomes, and 105 articles reported negative effects.

The qualitative analysis indicated that size, area, and natural vegetation characteristics of UGS containing diverse vegetation with heterogeneous habitat, connectivity, and peripheral natural landscape would provide high biodiversity, especially for native, rare, and sensitive wildlife such as butterflies [59, 61, 80], mammals [81], and birds [8, 55]. Similarly, vegetation heterogeneity, composition, and configuration are often denoted in terms of normalized differential vegetation index (NDVI) and larger park area enhanced urban cooling intensity (UCI) [69, 83, 84], rainwater interception [85, 86], carbon sequestration [87, 88], urban soil naturalization [89], air pollution mitigation [67] and urban water purification [90, 91].

Size, area, habitat heterogeneity, and proximity were also critical in enhancing QoL parameters such as mental/physical wellbeing and socioecological and socioeconomic values. For instance, significant mental/physical wellbeing, stress relief [79, 92], and physical health improvement [79, 93] occurred by regularly spending time in UGS.

The UGS components, such as aesthetics elements (water view, native plants, tree shades) [94], ambiance [95], the opportunity for conservation volunteerism [96], and accessibility to UGS [97] were conducive to the socioecological mindset of nature relatedness [78, 98] providing enhanced thermal perception [99, 100], conservation motivation [77, 101] and environmental education opportunities [60, 102]. The socioecological perspective further produced socioeconomic significance primarily through real estate value [103] and Willingness to Pay [104] in an urban context.

Provisioning services benefits mainly focused on urban and urban-periurban agriculture (UA & UPA)-derived ES that showed significant country-to-country variation. In a global study, UA provided food security as well as economic and environmental benefits such as energy savings and environmental regulation [11]. Interestingly, UPA was essential for survival in developing countries [105], whereas in developed countries, it provided locally produced, lucrative agricultural outputs [74, 106].

There was minimal focus on the potential of urban forestry and healthy watersheds for urban residents across the global and local context, possibly due to size constraints and aesthetic focus characteristic of urban areas.

The ES aspects of UGS are not complete without considering the tradeoffs that may deter conservation. Unlike the ES synergies mentioned above, UGS also has certain outputs that carry negative impacts and incur social and economic costs for human society [107]. Analysis of these disservices further reveals an interesting trend. For supporting services, over-management and adverse impacts related to habitat decline and unintended consequences of built-up areas and human interactions were common in high- and middle-income countries [11, 57, 108]. These effects then manifest as impaired regulating services such as reduced air/water pollution mitigation, thereby adversely impacting the type of cultural services (e.g., QoL and socioeconomic benefits) UGS offers. The cascading effects make it difficult for provisioning services to function, causing dwindling water resources and decreased potential for food production and natural resources [71, 73, 74, 105, 106].

TABLE 3: Positive outcomes and/or benefits of UGS ES in the reviewed articles (n=128) with corresponding recommendations. () The number in parentheses represents the number of articles that reported positive outcomes. Of 138 articles, 122 included recommendations to increase UGS ES resiliency and/or mitigate the negative outcomes. These recommendations were divided into three broad themes and then assigned based on the coded outcomes. See Appendix B for further details on recommendations extracted from the reviewed articles.

ES Category/ Reported Synergies	Coded Positive outcomes	Summary Recommendations to Enhance the positive outcomes
	SUPPORTING	
Endangered/ endemic/ Sensitive Habitat	Habitat heterogeneity for endangered/sensitive species (6)	**Habitat Conservation Approach** Diverse, unmanaged, semi-natural, native habitat for butterflies. Introduce locally extinct and native nectar plants for butterflies. Diverse native, heterogenous semi-natural habitat, fruit/berry plant, large area, natural corridor and wetland for birds. Establish monitoring of bioindicator organisms to assess park health. A mix of coniferous and deciduous trees to promote lichen growth. Maintain habitat heterogeneity connectivity for arthropod diversity. Maintain a healthy predator/prey population for mammals. Minimal management for cavity nester. Maintain quality habitat and surrounding landscape to support food production and pest control. Ecological corridor for threatened species (e.g., European squirrel) Moderate urbanization for microbial fauna.
Habitat Composition/Biodiversity	Park area/connectivity/heterogeneity/peripheral habitat for richness/abundance (23) Species-specific habitat (9) Minimal Management for Biodiversity (4)	
Habitat Composition/configuration	Habitat Description (5)	
	REGULATING	
Environmental Regulation	Air Pollution (Carbon/Dust/SO2/ NOx/PM and/or TE/Pollen/VOC) Mitigation (12) Stormwater Regulation (4) Water quality mitigation (1)	**Functional Green Space Approach** Establish heterogeneous, dense UGS with high NDVI, high LAI, large canopies and water bodies for cooling effects. Prioritize high DBH/biomass trees, heterogeneity, curvilinear design and minimal management for carbon sequestration and mitigate climate change. Increase green UGS ratio/capita for clean air. Plant broad-leaved semi-evergreen trees and composite tree shrubs to mitigate particulate matter (e.g., PM2.5). Plant deciduous trees for winter thermal comfort. Retention of organic matter and naturalization for soil carbons storage and overall soil health. Large area and dense vegetation for pollution control. Establish large trees with furrowed bark in high rainfall, and small tress with smooth bark in low rainfall areas.
Weather Regulation	Cooling effect by water and/or vegetation (9)	

	CULTURAL	
Quality of Life	Physical/mental wellbeing (11)	**Socioecological/ Functional Greenspace Approach** Establish multistakeholder conservation strategies, e.g., conservation volunteerism, residence-led private/public garden management, community garden, and cultural integration.
	Recreation Choices (3)	Promote people-oriented UGS for stress relief, thermal comfort, noise buffer and health benefits. Designate proportionate sociocultural, spatial, and temporal allocation of UGS within the appropriate distance.
	Socialization Motivators (8)	Limit trees with high allergenicity.
Socioecological Value	Conservation Motivators (8)	Integrate native and sociocultural aesthetic elements to promote a sense of place, environmental education, biophilia, inspiration, and biophysical nature-relatedness/orientation.
	Environmental Education (8)	Consider demolished area naturalization and vacant lot greening for health benefits and native wildlife. Preserve large parks, green corridors, and large trees and limit built-up/impervious areas.
	Thermal Comfort (3)	
Socioeconomic Value	Real Estate Value (3)	
	Willingness to Pay (2)	
	PROVISIONING	
Urban Agriculture	Food source/security (6)	**Socioecological/Functional Greenspace Approach**
Urban Forestry	Timber Resource (2)	Policy and planning to increase UA resilience and sustainability for urban socioecological health.
Watershed Health	Water Security (1)	Implement policies such as arthropod conservation, land-sparring, permaculture and governance measures to support UPA. Preserve green space to sustain/maximize water sources.

TABLE 4: Negative Effects or impacts due to mismanagement or lack of adequate UGS (n=108) with corresponding recommendations. () The number in parentheses represents the number of articles that reported negative outcomes. 122 articles included recommendations to increase UGS ES resiliency and/or mitigate the negative outcomes. These recommendations were divided into three broad themes and then assigned based on the coded outcomes. See the Appendix for further details on recommendations extracted from the reviewed articles.

ES Category/ Reported Tradeoffs	Coded Negative Outcomes	Summary Recommendations to mitigate the negative outcomes
	SUPPORTING	
Inadequate Policy & Planning	Over management (2)	**Habitat Conservation / Socioecological Approach** Minimal management to promote ecological restoration.
Wildlife//biodiversity decline	Exotic/Invasive dominant (5)	Plant pest/disease and traffic pollution tolerant plants for street trees.
	Habitat decline for richness/abundance (17)	Apply monitoring and control strategies such as natural predators for nuisance species. Use a good mix of native and exotic vegetation if unavoidable. Minimize and manage introduced plant and animal populations. Reduce the feral populations of synanthropic predators. Apply monitoring and control strategy for nuisance/invasive species.
	Human-wildlife conflict (4)	
	Local extinction (9)	Adopt strategies (e.g., no feeding) to reduce human-wildlife conflict. Establish diverse, unmanaged, semi-natural, native habitats to increase heterogeneity and ecosystem resiliency.
	Resident/generalist dominant (5)	Introduce locally extinct and native nectar plants to promote arthropod populations.
	Species homogenization (2)	

	REGULATING	
Impaired Environmental Regulation	Decline in soil condition (2) Diminished air/water pollution mitigation (2) Diminished carbon sequestration (3)	**Functional Greenspace Approach** Retention of organic matter and naturalization for soil carbons storage and overall soil health. Prioritize high DBH/biomass trees, heterogeneity, curvilinear design and minimal management for carbon sequestration and mitigate climate change.
Impaired Weather Regulation	Decreased cooling (9)	Preserve green space to sustain/maximize water sources. Establish heterogeneous, dense UGS with high NDVI, high LAI, large canopies and water bodies for cooling effects.

Table 4 Contd.

	CULTURAL	
Ecosystem Disservice	Adverse health impact (2) Disproportionate UGS (9) Socioeconomic Disadvantage (5) Park visit deterrents (18)	**Socioecological Approach** Limit trees with high allergenicity. Designate proportionate sociocultural, spatial, and temporal allocation of UGS within the appropriate distance. Integrate native and sociocultural aesthetic elements to promote a sense of place, environmental education, biophilia, inspiration, and biophysical nature-relatedness/orientation. Establish multistakeholder conservation strategies, e.g., conservation volunteerism, residence-led private/public garden management, community garden, and cultural integration.
Inadequate Policy & Planning	Over management (1) Undermanagement (4)	
	PROVISIONING	
Impaired Production Potential	Uncertain contribution of pollinators (1)	**Functional Greenspace Approach** Preserve green space to sustain/maximize water sources.
Inadequate Policy & Planning	Dwindling water source (1) Environmental Consequences (3) Loss of native flora (1)	Emphasize on resilience and sustainability of UPA. Implement policies such as arthropod conservation, land-sparring, permaculture and governance measures to support UPA, increase native flora/fauna and overall ecosystem resiliency. Diversify UPA to food production capacity to offset the cost of stormwater management and energy cost and for urban resiliency. Minimize forest harvest to prevent nuisance and invasive plants.

DISCUSSION

1. *The Global State of UGS*

We synthesized 138 articles to document the unique and critical UGS ES functions in global cities. This number represented approximately 6% of the initially identified references (cf. [46]-5.6%; [109]- 0.7% and [110]- 2.8%). The robust volume of UGS ES-related articles published in the 10-year duration included in this review coincides with the post-framework-conceptualization era by the Millennium Ecosystem Assessment [18, 111]. The effective governance, management and policy push to optimize these unique landscapes is undoubtedly growing.

A sustainable UGS approach could counter the population pressure and intense urbanization, ameliorating the vulnerabilities to climate change catastrophes such as storm surges and flooding, heat stress, drought and water scarcity [105, 112]. Europe and North American UGS were disproportionately highly studied, suggesting the active role of academia and research efforts to document the benefits and guide ecologically sound policy decisions. Whether that results in the integration of sustainable green infrastructure planning and development and restoration of ecologically sensitive areas in these countries is inconclusive from this review.

Similarly, the single Asian country China represented the highest number of UGS ES studies. This can be attributed to the scientific efforts to unravel the environmental and human impacts of ongoing intense urbanization and the accompanying loss of natural areas. The comparatively low number of articles from other Asian and African countries reflects the economic and social conditions that hinder UGS research, allocation, and maintenance and possibly its resiliency from mitigating urbanization pressure and climate change impacts.

2. *ES Focus of UGS studies*

As a human-dominated landscape, UGS undoubtedly values cultural ES [113], and such rewarding non-material and indirect benefits people derive from UGS are only possible if UGS is ecologically viable enough to support a certain degree of native wildlife. These two services are also well defined in the studied UGS context (altogether 74%), contrary to a review of the mountain [46] and coastal [114] ecosystem services where regulating and provisioning services were the main focus.

Unsurprisingly, direct consumptive uses and indirect values such as disease regulation, wastewater treatment, spiritual and religious value, and medicine were underrepresented in the reviewed articles.

The reasons could be that the sparse distribution of UGS complicates the funding and study design, resulting in disinterest from the scientists and other stakeholders. A strict management regime already in place, especially in developed countries, perhaps also deter the focus on consumptive and indirect benefits. Therefore, privately owned gardens (residential, community and commercial green space) could provide a crucial option to enhance those benefits while focusing on natural resources and food provisioning to a certain degree. Hence, the ecological management approach of privately owned gardens has the potential to increase conservation value through enhanced connectivity and heterogeneity if the aesthetic focus is minimized. However, studies from various geographical locations and pertinent management guidance on the ecological practices [115] of home and community gardens in different cultures are lacking. Contrary to Asia and Africa, where subsistence is a main focus, Europe and North American countries consider UGS an ornamental component of a city primarily set aside for recreation and human wellbeing. Moreover, despite the extensive research on the sustainability of urban and peri-urban agriculture (UPA) for urban resilience, provisioning and regulating services focus hasn't been a part of the framework of UGS conservation and management. More research is needed from an ethnobotanical [116], environmental and ecological point of view suitable for each region.

3. Factors Impacting UGS ES Review Outcomes

Several factors impacted the outcomes of this systematic review in terms of the geographical gaps, analyses, and proposed management recommendations. First, additional databases, especially the ones that contain adequately and accurately translated articles published in languages other than English, especially from Asia and Africa, in addition to much-needed international collaborations on UGS ES studies, will help close the geographic and geopolitical gaps and perhaps also compensate for the low number of articles in the provisioning service category. Second, the climatic factor was one of the determining factors for the overall frequency of the articles. This coincides with the fact that most urban areas are also located in warm or sub-tropical climates [42]. Meanwhile, the disproportionate representation of articles from upper-middle- or high-income countries necessitates a broader scope to equalize the sample size and reach a definite conclusion. Third, of the 138 articles we reviewed, 89 mentioned the limitations and challenges of conducting UGS ES studies not dependent on the income level of UGS location, nonetheless impacting the management recommendations we summarized (Table 3, Appendix B). In this review, the most commonly coded limitations were the inadequate factors (e.g., the lack of comprehensive UGS composition and configuration data such as shape and size, park orientation in relation to climate and weather), inadequate study instrument (included small sample sizes, empirical-study-based biased sampling, etc.) and the limited official/open-source data (discrepancy/lack of high-resolution spatial data, limited/inaccurate data). Future studies should consider these limitations for review studies and when making management decisions for resilient UGS conservations.

4. Conservation and Management Recommendations

While efforts and programs exist to restore and conserve UGS, management recommendations are complex due to variable conditions in urban natural areas [38]. This systematic review synthesizes the tight fundamental link the ES concept creates between people and nature that may help build a resilient UGS and open doors to integrated adaptive UGS planning, management [107], and conservation. The general (Table 3, Appendix B) and eco-climatological (Appendix C) recommendation categories we identified in this review propose untangling complex functions encompassing biophysical, economic, and social factors. Amid rapid urbanization, the ability to guide evidence-based and essential policy decisions will determine the myriad benefits of UGS from ecological and socioeconomic resilience points of view. Applying deliberate efforts to meet ecological and social needs ensures natural space, resiliency, and ecological viability [25]. In addition to optimum functionality, integration of human dimensions [117], at the very least, is critical to achieving ecological resiliency, multifunctionality, and sustainability outcomes.

5. Future Prospects

Due to the complex dynamics of UGS functions [118], future researchers and managers will need to consider several challenges, including but not limited to ecosystem disservices, biodiversity threats such as invasive species [38, 119], and challenges of managing the wildland-urban interface [120] to better adapt to the changing climate [7]. These are compounded by high urbanization that may limit ecosystem services [30], making ecosystem disservice part of UGS fabric depending on geographic, economic, and climatic conditions. Fortunately, these disservices could be overcome by adequate policy and planning, stakeholder engagement and appropriate guidelines/positive attitude toward addressing these issues that include critical components such as environmental justice [121], social equality [122], and sustainability goals [37, 123].

6. Resiliency as a Part of ES Concept Rationale

Can the ecosystem service concept serve as a rationale for UGS expansion and conservation? The results of this interdisciplinary and comprehensive systematic review point to a positive direction providing evidence-based grounds to adopt locally suitable management practices. The synthesized evidence proves that UGS enhances all four ecosystem services, presenting an opportunity to promote the normative value of UGS as a viable ecosystem and link its multifunctional benefits to human wellbeing and sustainable urban development [124]. Broadly, these conscious and deliberate efforts correspond to adequate heterogeneous natural area allocation, community-based policy planning and management [125], public-private collaboration for research [38], stakeholder engagement, and room for adaptation for the current and future needs. The manifestation of these adaptations should crisscross all ES categories unique to environmental conditions, geography, microclimate, and socioeconomic status [76]. Evidently, in the dynamic human and nature nexus of UGS, planning and conservation strategies that worked just a few years ago may not work in the current context when weighing and maximizing the ES concept. Therefore, we propose revisiting the management recommendations compiled in this review as required, further amalgamating social and natural sciences in a multidisciplinary approach and reinforcing the link between traditional ecological knowledge, science, and public policies [126]. The strategy could lead to "integrative adaptive management of ecosystems," in which natural and human components are harmoniously integrated to achieve ecological resilience and sustainable urban infrastructures. Thus we conclude that the ecosystem service concept could be a perfect rationale to instigate and promote UGS conservation for the sake of people and the environment.

Acknowledgments: This research was completed as a part of a graduate degree project, thus without outside funding. We greatly appreciate graduate students Jason Swartz and Aerran Reilly's constructive feedback during the manuscript writing process. We declare no conflict of interest in this research project.

REFERENCES

[1] Blondel, J. 2006. The 'design' of Mediterranean landscapes: a millennial story of humans and ecological systems during the historic period. Human Ecology 34(5):713-729. http://dx.doi.org/10.1007/s10745-006-9030-4.

[2] McLain, R., Hurley, P., Emery, M., & Poe, M. (2014). Gathering "wild" food in the city: Rethinking the role of foraging in urban ecosystem planning and management. Local Environment: Subversive and Interstitial Food Spaces, 19(2), 220-240. http://dx.doi.org/10.1080/13549839.2013.841659.

[3] Vargas-Hernández, José & Pallagst, Karina & Hammer, Patricia. (2018). Urban Green Spaces as a Component of an Ecosystem Functions, Services, Users, Community Involvement, initiatives and Actions. International Journal of Environmental Sciences & Natural Resources, 8. 1-16. http://doi.org/10.19080/IJESNR.2018.08.555730.

[4] López-Santiago, C. A., Oteros-Rozas, E., Martín-López, B., Plieninger, T., González Martín, E., & González, J. A. (2014). Using visual stimuli to explore the social perceptions of ecosystem services in cultural landscapes: the case of transhumance in Mediterranean Spain. Ecology and Society, 19(2). https://doi.org/10.5751/es-06401-190227.

[5] Wilcolve, D. S., Rothstein, D., Dubow, J., Phillips, A., & Losos, E. (1998). Quantifying Threats to Imperiled Species in the United States. BioScience, 48(8), 607–615. https://doi.org/10.2307/1313420.

[6] Seto, K. C., Guneralp, B., & Hutyra, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. Proceedings of the National Academy of Sciences, 109(40), 16083–16088. https://doi.org/10.1073/pnas.1211658109

[7] Govindarajulu, D. (2014). Urban green space planning for climate adaptation in Indian cities. Urban Climate, 10, 35–41. https://doi.org/10.1016/j.uclim.2014.09.006.

[8] Turner, R. K., & Daily, G. C. (2007). The Ecosystem Services Framework and Natural Capital Conservation. Environmental and Resource Economics, 39(1), 25–35. https://doi.org/10.1007/s10640-007-9176-6.

[9] Lovell, S. T., & Taylor, J. R. (2013). Supplying urban ecosystem services through multifunctional green infrastructure in the United States. Landscape Ecology, 28(8), 1447–1463. https://doi.org/10.1007/s10980-013-9912-y

[10] UN World Urbanization Prospects - Population Division - United Nations. (2018). Retrieved from UN.org website: https://population.un.org/wup/

[11] Clinton, N., Stuhlmacher, M., Miles, A., Uludere Aragon, N., Wagner, M., Georgescu, M., Herwig, C., & Gong, P. (2018). A Global Geospatial Ecosystem Services Estimate of Urban Agriculture. Earth's Future, 6(1), 40–60. https://doi-org.proxy-sru.klnpa.org/10.1002/2017EF000536

[12] Ruppert, C. D. D., Byrne, J. A., & Lo, A. Y. (2016). Memories of vacant lots: how and why residents used informal urban green space as children and teenagers in Brisbane, Australia, and Sapporo, Japan. Children's Geographies, 14(3), 340–355. https://doi-org.proxy-sru.klnpa.org/10.1080/14733285.2015.1048427

[13] Carnol, M., Baeten, L., Branquart, E., Grégoire, J.-C., Heughebaert, A., Muys, B., … Verheyen, K. (2014). Ecosystem services of mixed species forest stands and monocultures: comparing practitioners' and scientists' perceptions with formal scientific knowledge. Forestry: An International Journal of Forest Research, 87(5), 639–653. https://doi.org/10.1093/forestry/cpu024

[14] Green, O., Garmestani, A., Albro, S., Ban, N., Berland, A., Burkman, C., Gardiner, M., Gunderson, L., Hopton, M., Schoon, M., & Shuster, W. (2016). Adaptive governance to promote ecosystem services in urban green spaces. Urban Ecosystems, 19(1), 77–93. https://doi.org/10.1007/s11252-015-0476-2.

[15] Egerer, M., Fouch, N., Anderson, E. C., & Clarke, M. (2020). Socioecological connectivity differs in magnitude and direction across urban landscapes. Scientific Reports, 10(1). https://doi.org/10.1038/s41598-020-61230-9.

[16] Vallés-Planells, M., Galiana, F., & Van Eetvelde, V. (2014). A Classification of Landscape Services to Support Local Landscape Planning. Ecology & Society, 19(1), 481–491. https://doi.org/10.5751/ES-06251-190144.

[17] Potschin, M., & Haines-Young, R. (2012). Landscapes, sustainability and the place-based analysis of ecosystem services. Landscape Ecology, 28(6), 1053–1065. https://doi.org/10.1007/s10980-012-9756-x.

[18] Millennium Ecosystem Assessment. (2005). Ecosystems and Human Wellbeing: Synthesis. Island Press, Washington, DC.

[19] Jennings, V., Floyd, M. F., Shanahan, D., Coutts, C., & Sinykin, A. (2017). Emerging issues in urban ecology: implications for research, social justice, human health, and wellbeing. Population and Environment, 39(1), 69–86. https://doi.org/10.1007/s11111-017-0276-0.

[20] Cardinale, B. J., Duffy, J. E., Gonzalez, A., Hooper, D. U., Perrings, C., Venail, P., … Naeem, S. (2012). Biodiversity loss and its impact on humanity. Nature, 486(7401), 59–67. https://doi.org/10.1038/nature11148

[21] Scholz, M., & Uzomah, V. C. (2013). Rapid decision support tool based on novel ecosystem service variables for retrofitting of permeable pavement systems in the presence of trees. Science of the Total Environment, 458-460(458-460), 486–498. https://doi.org/10.1016/j.scitotenv.2013.04.062.

[22] Bagstad, K. J., Johnson, G. W., Voigt, B., & Villa, F. (2013). Spatial dynamics of ecosystem service flows: A comprehensive approach to quantifying actual services. Ecosystem Services, 4, 117–125. https://doi.org/10.1016/j.ecoser.2012.07.012.

[23] Riechers, M., Barkmann, J., & Tscharntke, T. (2016). Perceptions of cultural ecosystem services from urban green. Ecosystem Services, 17, 33–39. https://doi.org/10.1016/j.ecoser.2015.11.007.

[24] Zoderer, B. M., Lupo Stanghellini, P. S., Tasser, E., Walde, J., Wieser, H., & Tappeiner, U. (2016). Exploring sociocultural values of ecosystem service categories in the Central Alps: the influence of socio-demographic factors and landscape type. Regional Environmental Change, 16(7), 2033–2044. https://doi.org/10.1007/s10113-015-0922-y

[25] Howe, C., Suich, H., Vira, B., Mace, G. M. 2014. Creating win-sins from tradeoffs? Ecosystem services for human wellbeing: a meta-analysis of ecosystem service tradeoffs and synergies in the real world. Global Environ. Change 28, 263-275. https://doi.org/10.1002/pan3.10050

[26] Mell, I. C., Henneberry, J., Hehl-Lange, S., & Keskin, B. (2013). Promoting urban greening: Valuing the development of green infrastructure investments in the urban core of Manchester, UK. Urban Forestry & Urban Greening, 12(3), 296–306. https://doi.org/10.1016/j.ufug.2013.04.006

[27] TEEB (2010) The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB.

[28] Chen, C., Tabssum, N., & Nguyen, H. P. (2019). Study on Ancient Chu Town Urban Green Space Evolution and Ecological and Environmental Benefits. Nature Environment & Pollution Technology, 18(5), 1733–1738.

[29] Dronova, I. (2017). Environmental heterogeneity as a bridge between ecosystem service and visual quality objectives in management, planning and design. Landscape and Urban Planning, 163(163), 90–106. https://doi.org/10.1016/j.landurbplan.2017.03.005

[30] Beichler, S. A., Bastian, O., Haase, D., Heiland, S., Kabisch, N., & Müller, F. (2017). Does the Ecosystem Service Concept Reach its Limits in Urban Environments? Landscape Online, 51(51), 1–21. https://doi.org/10.3097/lo.201751

[31] Brown, K. H., & Jameton, A. L. (2000). Public Health Implications of Urban Agriculture. Journal of Public Health Policy, 21(1), 20. https://doi.org/10.2307/3343472

[32] Galicia, L., & Zarco-Arista, A. E. (2014). Multiple ecosystem services, possible tradeoffs and synergies in a temperate forest ecosystem in Mexico: a review. International Journal of Biodiversity Science, Ecosystem Services & Management, 10(4), 275–288. https://doi-org.proxy-sru.klnpa.org/10.1080/21513732.2014.973907.

[33] Jasmani, Z., Ravn, H., & Bosch, C. (2017). The influence of small urban parks characteristics on bird diversity: A case study of Petaling Jaya, Malaysia. Urban Ecosystems, 20(1), 227–243. https://doi-org.proxy-sru.klnpa.org/10.1007/s11252-016-0584-7

[34] del Río-Mena, T., Willemen, L., Tesfamariam, G. T., Beukes, O., & Nelson, A. (2020). Remote sensing for mapping ecosystem services to support evaluation of ecological restoration interventions in an arid landscape. Ecological Indicators, 113(113), 106182. https://doi.org/10.1016/j.ecolind.2020.106182

[35] Tallis, H., Kareiva, P., Marvier, M., & Chang, A. (2008). An ecosystem services framework to support both practical conservation and economic development. Proceedings of the National Academy of Sciences, 105(28), 9457–9464. https://doi.org/10.1073/pnas.0705797105

[36] Sutherland, W. J., Pullin, A. S., Dolman, P. M., & Knight, T. M. (2004). The need for evidence-based conservation. Trends in Ecology & Evolution, 19(6), 305–308. https://doi.org/10.1016/j.tree.2004.03.018.

[37] Frantzeskaki, N., Kabisch, N., & Mcphearson, T. (2016). Advancing urban environmental governance: Understanding theories, practices and processes shaping urban sustainability and resilience. Environmental Science and Policy, 62, 1-6. http://dx.doi.org/10.1016/j.envsci.2016.05.008.

[38] Forgione, H. M., Pregitzer, C. C., Charlop-Powers, S., & Gunther, B. (2016). Advancing urban ecosystem governance in New York City: Shifting towards a unified perspective for conservation management. Environmental Science & Policy, 62, 127–132. https://doi.org/10.1016/j.envsci.2016.02.012.

[39] Ruoso, L., Plant, R., Maurel, P., Dupaquier, C., Roche, P., Bonin, M., & Irstea, I. (2015). Reading ecosystem services at the local scale through a territorial approach: The case of peri-urban agriculture in the Thau Lagoon, Southern France. Ecology and Society, 20(3), 11. http://dx.doi.org/10.5751/ES-07694-200311.

[40] Clucas, B., Parker, I. D., & Feldpausch-Parker, A. M. (2018). A systematic review of the relationship between urban agriculture and biodiversity. Urban Ecosystems, 21(4), 635–643. https://doi.org/10.1007/s11252-018-0748-8.

[41] Kosanic, A., & Petzold, J. (2020). A systematic review of cultural ecosystem services and human wellbeing. Ecosystem Services, 45(45), 101168. https://doi.org/10.1016/j.ecoser.2020.101168.

[42] Richards, D., Masoudi, M., Oh, R. R. Y., Yando, E. S., Zhang, J., Friess, D. A., … Edwards, P. J. (2019). Global Variation in Climate, Human Development, and Population Density Has Implications for Urban Ecosystem Services. Sustainability, 11(22), 6200. https://doi.org/10.3390/su11226200

[43] Chen, S., Sleipness, O., Xu, Y., Park, K., & Christensen, K. (2020). A systematic review of alternative protocols for evaluating non-spatial dimensions of urban parks. Urban Forestry & Urban Greening, 53, 126718. https://doi.org/10.1016/j.ufug.2020.126718.

[44] Venkataramanan, V., Packman, A. I., Peters, D. R., Lopez, D., McCuskey, D. J., McDonald, R. I., … Young, S. L. (2019). A systematic review of the human health and social wellbeing outcomes of green infrastructure for stormwater and flood management. Journal of Environmental Management, 246, 868–880. https://doi.org/10.1016/j.jenvman.2019.05.028.

[45] Russo, A., Escobedo, F. J., Cirella, G. T., & Zerbe, S. (2017). Edible green infrastructure: An approach and review of provisioning ecosystem services and disservices in urban environments. Agriculture, Ecosystems & Environment, 242, 53–66. https://doi.org/10.1016/j.agee.2017.03.026.

[46] Mengist, W., Soromessa, T., & Legese, G. (2020). Ecosystem services research in mountainous regions: A systematic literature review on current knowledge and research gaps. Science of the Total Environment, 702. https://doi.org/10.1016/j.scitotenv.2019.134581.

[47] Pullin, A. S., & Stewart, G. B. (2006). Guidelines for Systematic Review in Conservation and Environmental Management. Conservation Biology, 20(6), 1647–1656. https://doi.org/10.1111/j.15231739.2006.00485.x.

[48] Nielsen, A., van den Bosch, M., Maruthaveeran, S., & van den Bosch, C. (2014). Species richness in urban parks and its drivers: A review of empirical evidence. Urban Ecosystems, 17(1), 305–327. https://doi-org.proxy-sru.klnpa.org/10.1007/s11252-013-0316-1.

[49] Dickinson, D. C., & Hobbs, R. J. (2017). Cultural ecosystem services: Characteristics, challenges and lessons for urban green space research. Ecosystem Services, 25(25), 179–194. https://doi.org/10.1016/j.ecoser.2017.04.014

[50] Colding, J. (2007). "Ecological land-use complementation" for building resilience in urban ecosystems. Landscape and Urban Planning, 81(1-2), 46–55. https://doi.org/10.1016/j.landurbplan.2006.10.016

[51] Gingrich. P. (1992). Introductory Statistics for the Social Sciences. University of Regina. http://uregina.ca/~gingrich/text.htm

[52] Macura, B., Suškevičs, M., Garside, R., Hannes, K., Rees, R., & Rodela, R. (2019). Systematic reviews of qualitative evidence for environmental policy and management: an overview of different methodological options. Environmental Evidence, 8(1). https://doi.org/10.1186/s13750-019-0168-0.

[53] Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel, 2006: World Map of the Köppen-Geiger climate classification updated. Meteorol. Z., 15, 259-263. DOI: 10.1127/0941-2948/2006/0130.

[54] Rubel, F., Brugger, K., Haslinger, K., & Auer, I. (2017). The climate of the European Alps: Shift of very high resolution Köppen-Geiger climate zones 1800–2100. Meteorologische Zeitschrift, 26(2), 115–125. https://doi.org/10.1127/metz/2016/0816.

[55] Tucakov, M. J. (2010). Species Composition and Number of Breeding Birds in Urban Parks in Novi Sad. Matica Srpska Proceedings for Natural Sciences, 118, 143–149. https://doi.org/10.2298/ZMSPN1018143T.

[56] Carpaneto, G. M., Mazziotta, A., Coletti, G., Luiselli, L., & Audisio, P. (2010). Conflict between insect conservation and public safety: the case study of a saproxylic beetle (Osmoderma eremita) in urban parks. Journal of Insect Conservation, 14(5), 555–565. https://doi.org/10.1007/s10841-010-9283-5.

[57] Gehrt, S. D., Wilson, E. C., Brown, J. L., & Anchor, C. (2013). Population Ecology of Free-Roaming Cats and Interference Competition by Coyotes in Urban Parks. PLoS ONE, 8(9), 1. https://doi.org/10.1371/journal.pone.0075718.

[58] [58] Nero, B. F., & Anning, A. K. (2018). Variations in soil characteristics among urban green spaces in Kumasi, Ghana. Environmental Earth Sciences, 77(8), 1. https://doi.org/10.1007/s12665-018-7441-3.

[59] Melo, D. H. A., Duarte, M., Mielke, O. H. H., Robbins, R. K., & Freitas, A. V. L. (2019). Butterflies (Lepidoptera: Papilionoidea) of an urban park in northeastern Brazil. Biota Neotropica (Edicao Em Iingles), 19(1), 1–10. https://doi.org/10.1590/1676-0611-BN-2018-0614.

[60] Walker, C., Colton Flynn, K., Ovando-Montejo, G., Ellis, E., & Frazier, A. (2017). Does demolition improve biodiversity? Linking urban green space and socioeconomic characteristics to avian richness in a shrinking city. Urban Ecosystems, 20(6), 1191–1202. https://doi-org.proxy-sru.klnpa.org/10.1007/s11252-017-0671-4.

[61] Aguilera, G., Ekroos, J., Persson, A. S., Pettersson, L. B., & Öckinger, E. (2019). Intensive management reduces butterfly diversity over time in urban green spaces. Urban Ecosystems, 22(2), 335–344. https://doi.org/10.1007/s11252-018-0818-y.

[62] Langellotto, G., Melathopoulos, A., Messer, I., Anderson, A., McClintock, N., & Costner, L. (2018). Garden Pollinators and the Potential for Ecosystem Service Flow to Urban and Peri-Urban Agriculture. Sustainability, 10(6), 2047. https://doi.org/10.3390/su10062047.

[63] García-Llorente, M., Iniesta-Arandia, I., Willaarts, B., Harrison, P., Berry, P., Bayo, M. del M., … Martín-López, B. (2015). Biophysical and sociocultural factors underlying spatial tradeoffs of ecosystem services in semiarid watersheds. Ecology and Society, 20(3). https://doi.org/10.5751/ES-07785-200339

[64] Meacham, M., Queiroz, C., Norström, A. V., & Peterson, G. D. (2016). Social-ecological drivers of multiple ecosystem services: what variables explain patterns of ecosystem services across the Norrström drainage basin? Ecology & Society, 21(1), 359–383. https://doi-org.proxy-sru.klnpa.org/10.5751/ES-08077-210114.

[65] Vanos, J. K., Warland, J. S., Gillespie, T. J., Slater, G. A., Brown, R. D., & Kenny, N. A. (2012). Human Energy Budget Modeling in Urban Parks in Toronto and Applications to Emergency Heat Stress Preparedness. Journal of Applied Meteorology and Climatology, 51(9), 1639–1653. https://doi.org/10.1175/jamc-d-11-0245.1.

[66] Mata, L., Threlfall, C. G., Williams, N. S. G., Hahs, A. K., Malipatil, M., Stork, N. E., & Livesley, S. J. (2017). Conserving herbivorous and predatory insects in urban green spaces. Scientific Reports, 40970. https://doi.org/10.1038/srep40970.

[67] Kim, G., & Coseo, P. (2018). Urban Park Systems to Support Sustainability: The Role of Urban Parks Systems in Hot Arid Urban Climates. Forests, 9(7), 439. https://doi.org/10.3390/f9070439.

[68] Xu, H., Li, S., Su, J.-Q., Nie, S.-A., Gibson, V., Li, H., & Zhu, Y.-G. (2014). Does urbanization shape bacterial community composition in urban park soils? A case study in 16 representative Chinese cities based on the pyrosequencing method. FEMS Microbiology Ecology, 87(1), 182–192. https://doi.org/10.1111/1574-6941.12215.

[69] Yang, C., He, X., Yu, L., Yang, J., Yan, F., Bu, K., ... Zhang, S. (2017). The Cooling Effect of Urban Parks and Its Monthly Variations in a Snow Climate City. Remote Sensing, 9(10), 1066. https://doi.org/10.3390/rs9101066.

[70] Potter, A., & LeBuhn, G. (2015). Pollination service to urban agriculture in San Francisco, CA. Urban Ecosystems, 18(3), 885–893. https://doi.org/10.1007/s11252-015-0435-y.

[71] Tessier, J. T. (2010). Effect of Forest Harvest on the Vegetation of an Urban Park. Northeastern Naturalist, 17(2), 273–284. https://doi.org/10.1656/045.017.0210.

[72] Zainal, N., & Ismail, S. Mohd. (2019). Urban park trees valuation in Taman Tasik Seremban, Negeri Sembilan, Malaysia Using Thyer Method. Malayan Nature Journal, 71(4), 499–511.

[73] Jujnovsky, J., González-Martínez, T. M., Cantoral-Uriza, E. A., & Almeida-Leñero, L. (2012). Assessment of Water Supply as an Ecosystem Service in a Rural-Urban Watershed in Southwestern Mexico City. Environmental Management, 49(3), 690–702. https://doi.org/10.1007/s00267-011-9804-3.

[74] Wilhelm, J. A., & Smith, R. G. (2017). Ecosystem services and land sparing potential of urban and peri-urban agriculture: A review. Renewable Agriculture and Food Systems, 33(5), 481–494. https://doi.org/10.1017/s1742170517000205.

[75] Peters, K. (2010). Being Together in Urban Parks: Connecting Public Space, Leisure, and Diversity. Leisure Sciences, 32(5), 418–433. https://doi.org/10.1080/01490400.2010.510987

[76] Stodolska, M., Shinew, K., Acevedo, J., & Izenstark, D. (2011). Perceptions of Urban Parks as Havens and Contested Terrains by Mexican-Americans in Chicago Neighborhoods. Leisure Sciences, 33(2), 103–126. https://doi.org/10.1080/01490400.2011.550220

[77] Coldwell, D. F., & Evans, K. L. (2017). Contrasting effects of visiting urban green-space and the countryside on biodiversity knowledge and conservation support. PLoS ONE, 12(3), 1–18. https://doi.org/10.1371/journal.pone.0174376

[78] Lin, B. B., Fuller, R. A., Bush, R., Gaston, K. J., & Shanahan, D. F. (2014). Opportunity or Orientation? Who Uses Urban Parks and Why. PLoS ONE, 9(1), e87422. https://doi.org/10.1371/journal.pone.0087422.

[79] Hedblom, M., Gunnarsson, B., Iravani, B., Knez, I., Schaefer, M., Thorsson, P., & Lundström, J. N. (2019). Reduction of physiological stress by urban green space in a multisensory virtual experiment. Scientific Reports, 9(1), 1–11. https://doi.org/10.1038/s41598-019-46099-7.

[80] Tamosiunas, A., Grazuleviciene, R., Luksiene, D., Dedele, A., Reklaitiene, R., Baceviciene, M., ... Nieuwenhuijsen, M. J. (2014). Accessibility and use of urban green spaces, and cardiovascular health: findings from a Kaunas cohort study. Environmental Health, 13(1). https://doi.org/10.1186/1476-069x-13-20.

[81] Sing, K.-W., Jusoh, W. F. A., Hashim, N. R., & Wilson, J.-J. (2016). Urban parks: refuges for tropical butterflies in Southeast Asia? Urban Ecosystems, 19(3), 1131–1147. https://doi.org/10.1007/s11252-016-0542-4.

[82] de Oliveira Martins, T., Bunhuolo, S. P., Filho, H. O., & Lacher Jr., T. E. (2016). Large and medium-sized mammals in the urban park Cinturão Verde, Cianorte, northwestern Paraná. CheckList, 12(2), 1–10. https://doi.org/10.15560/12.2.185.

[83] Peris, S., & Montelongo, T. (2014). Birds and small urban parks: a study in a high plateau city. Turkish Journal of Zoology, 38(3), 316–325. https://doi.org/10.3906/zoo-1305-20.

[84] Tura, T. T., Soromessa, T., Leta, S., Argew, M., & Eshetu, Z. (2016). Urban church forests for local temperature regulation: Implications the role of managing and incorporating urban green space in urban planning. Taiwania, 61(4), 305–313. https://doi.org/10.6165/tai.2016.61.305

[85] Zhang, J., Gou, Z., & Shutter, L. (2019). Effects of internal and external planning factors on park cooling intensity: field measurement of urban parks in Gold Coast, Australia. AIMS Environmental Science, 8(6), 417–434. https://doi.org/10.3934/environsci.2019.6.417

[86] Schooling, J., & Carlyle-Moses, D. (2015). The influence of rainfall depth class and deciduous tree traits on stemflow production in an urban park. Urban Ecosystems, 18(4), 1261–1284. https://doi.org/10.1007/s11252-015-0441-0.

[87] Van Stan II, J. T., Levia, D. F., & Jenkins, R. B. (2015). Forest Canopy Interception Loss Across Temporal Scales: Implications for Urban Greening Initiatives. Professional Geographer, 67(1), 41–51. https://doi.org/10.1080/00330124.2014.888628

[88] Gu, H., Zhen, W Y., Xu, D. W., Huang, Y., Zheng, L., & Ma, J. (2018). Seasonal Dynamics of Carbon Dioxide Concentration and its Influencing Factors in Urban Park Green Spaces in Northeast China. Nature Environment & Pollution Technology, 17(1), 329–337.

[89] Yoon, T., Seo, K., Park, G., Son, Y., & Son, Y. (2016). Surface Soil Carbon Storage in Urban Green Spaces in Three Major South Korean Cities. Forests, 7(12), 115. https://doi.org/10.3390/f7060115.

[90] Millward, A. A., Paudel, K., & Briggs, S. E. (2011). Naturalization as a strategy for improving soil physical characteristics in a forested urban park. Urban Ecosystems, 14(2), 261–278. https://doi.org/10.1007/s11252-010-0153-4.

[91] Karavoltsos, S., Sakellari, A., Antonopoulou, M., Dassenakis, M., & Scoullos, M. (2010). Evaluation of water quality in an urban park for environmental sensitization: A large scale simulation model. Desalination & Water Treatment, 13(1–3), 328–335. https://doi.org/10.5004/dwt.2010.1040.

[92] Tang, S., Wang, L. C., & Wu, X. G. (2019). Valuation of Wetland Ecosystem Services in Rapidly Urbanizing Region: A Case Study of the Nanjing Jiangbei New Area, China. Applied Ecology & Environmental Research, 17(5), 10909–10927. https://doi.org/10.15666/aeer/1705_1090910927.

[93] Zhou, C., Yan, L., Yu, L., Wei, H., Guan, H., Shang, C., … Bao, J. (2018). Effect of Short-term Forest Bathing in Urban Parks on Perceived Anxiety of Young-adults: A Pilot Study in Guiyang, Southwest China. Chinese Geographical Science, 29(1), 139–150. https://doi.org/10.1007/s11769-018-0987-x

[94] South, E. C., Kondo, M. C., Cheney, R. A., & Branas, C. C. (2015). Neighborhood Blight, Stress, and Health: A Walking Trial of Urban Greening and Ambulatory Heart Rate. American Journal of Public Health, 105(5), 909–913. https://doi.org/10.2105/AJPH.2014.302526

[95] Hami, A., & Maruthaveeran, S. (2018). Public Perception and Perceived Landscape Function of Urban Park Trees in Tabriz, Iran. Landscape Online, 62, 1–16. https://doi-org.proxy-sru.klnpa.org/10.3097/LO.201862

[96] Tsai, K.-T., & Lin, Y.-H. (2018). Identification of urban park activity intensity at different thermal environments and visible sky by using sound levels. International Journal of Biometeorology, 62(11), 1987–1994. https://doi.org/10.1007/s00484-018-1603-6.

[97] Christie, M. A. (2017). Benefit Nature, Benefit Self, & Benefit Others: Older Adults and their Volunteer Experiences of Engagement in a Conservation Themed Urban Park. Journal of Therapeutic Horticulture, 27(2), 19–38. https://www.jstor.org/stable/26598031.

[98] Qureshi, S., Breuste, J. H., & Jim, C. Y. (2013). Differential community and the perception of urban green spaces and their contents in the megacity of Karachi, Pakistan. Urban Ecosystems, 16(4), 853–870. https://doi.org/10.1007/s11252-012-0285-9

[99] Shanahan, D., Fuller, R., Lin, B., Gaston, K., & Bush, R. (2015). What is the role of trees and remnant vegetation in attracting people to urban parks? Landscape Ecology, 30(1), 153–165. https://doi.org/10.1007/s10980-014-0113-0.

[100] Aram, F., Solgi, E., Higueras García, E., Mosavi, A., & R. Várkonyi-Kóczy, A. (2019). The Cooling Effect of Large-Scale Urban Parks on Surrounding Area Thermal Comfort. Energies, 12(20), 3904. https://doi.org/10.3390/en12203904

[101] Wang, Y., de Groot, R., Bakker, F., Wörtche, H., & Leemans, R. (2017). Thermal comfort in urban green spaces: a survey on a Dutch university campus. International Journal of Biometeorology, 61(1), 87–101. https://doi.org/10.1007/s00484-016-1193-0.

[102] Areola, A. A., & Ikporukpo C. O. (2018). Social Ecology and Urban Green Spaces in Ibadan, Nigeria. Journal of Applied Sciences & Environmental Management, 22(7), 1111–1120. https://doi.org/10.4314/jasem.v22i7.19

[103] Schmidt, K., Walz, A., Jones, I., & Metzger, M. J. (2016). The Sociocultural Value of Upland Regions in the Vicinity of Cities in Comparison With Urban Green Spaces. Mountain Research & Development, 36(4), 465–474. https://doi.org/10.1659/MRD-JOURNAL-D-16-00044.1

[104] Czembrowski, P., Łaszkiewicz, E., Kronenberg, J., Engström, G., & Andersson, E. (2019). Valuing individual characteristics and the multifunctionality of urban green spaces: The integration of sociotope mapping and hedonic pricing. PLOS ONE, 14(3), e0212277. https://doi.org/10.1371/journal.pone.0212277.

[105] Olbińska, K. (2018). The Value of Urban Parks in Lodz. Real Estate Management & Valuation, 26(1), 73–88.https://doi.org/10.2478/remav-2018-0007.

[106] Padgham, J., Jabbour, J., & Dietrich, K. (2015). Managing change and building resilience: A multi-stressor analysis of urban and peri-urban agriculture in Africa and Asia. Urban Climate, 12, 183-204.

[107] Olsson, E., Kerselaers, E., Søderkvist Kristensen, L., Primdahl, J., Rogge, E., & Wästfelt, A. (2016). Peri-Urban Food Production and Its Relation to Urban Resilience. Sustainability, 8(12), 1340. https://doi.org/10.3390/su8121340

[108] Baur, J. W. R., Tynon, J. F., Ries, P., & Rosenberger, R. S. (2014). Urban Parks and Attitudes about Ecosystem Services: Does Park Use Matter? Journal of Park & Recreation Administration, 32(4), 19–34.

[109] Zhou, D., & Chu, L. (2012). How would size, age, human disturbance, and vegetation structure affect bird communities of urban parks in different seasons? Journal of Ornithology, 153(4), 1101–1112. https://doi.org/10.1007/s10336-012-0839-x.

[110] Perevochtchikova, M., De la Mora-De la Mora, G., Hernández Flores, J. Á., Marín, W., Langle Flores, A., Ramos Bueno, A., & Rojo Negrete, I. A. (2019). Systematic review of integrated studies on functional and thematic ecosystem services in Latin America, 1992–2017. Ecosystem Services, 36, 100900. https://doi.org/10.1016/j.ecoser.2019.100900.

[111] Yang, Y.C.E., Passarelli, S., Lovell, R.J., Ringler, C., 2018. Gendered perspectives of ecosystem services: a systematic review. Ecosyst. Serv. 31, 58–67. https://doi.org/10.1016/j.ecoser.2018.03.015.

[112] Simpson, R. (2011). The "ecosystem service framework" a critical assessment. The United Nations Environmental Program. http://bioecon-network.org/pages/publications/UNEP_publications/05%20Ecosystem%20Service%20Framework.pdf (Accessed 10 Dec 2021)

[113] Sutherland, W. J., Gardner, T., Bogich, T. L., Bradbury, R. B., Clothier, B., Jonsson, M., … Dicks, L. V. (2014). Solution Scanning as a Key Policy Tool: Identifying Management Interventions to Help Maintain and Enhance Regulating Ecosystem Services. Ecology and Society, 19(2). https://doi.org/10.5751/es-06082-190203.

[114] Camps-Calvet, M., Langemeyer, J., Calvet-Mir, L., & Gómez-Baggethun, E. (2016). Ecosystem services provided by urban gardens in Barcelona, Spain: Insights for policy and planning. Environmental Science & Policy, 62, 14–23. https://doi.org/10.1016/j.envsci.2016.01.007.

[115] Liquete, C., Cid, N., Lanzanova, D., Grizzetti, B., & Reynaud, A. (2016). Perspectives on the link between ecosystem services and biodiversity: The assessment of the nursery function. Ecological Indicators, 63, 249–257. https://doi.org/10.1016/j.ecolind.2015.11.058.

[116] Gregory, M., Leslie, M., & Drinkwater, T. (2016). Agroecological and social characteristics of New York city community gardens: Contributions to urban food security, ecosystem services, and environmental education. Urban Ecosystems, 19(2), 763-794. DOI 10.1007/s11252-015-0505-1

[117] Vogl, C. R., Vogl-Lukasser, B., & Puri, R. K. (2004). Tools and Methods for Data Collection in Ethnobotanical Studies of Homegardens. Field Methods, 16(3), 285–306. https://doi.org/10.1177/1525822x04266844.

[118] Bennett, N. J., Roth, R., Klain, S. C., Chan, K., Christie, P., Clark, D. A., … Wyborn, C. (2017). Conservation social science: Understanding and integrating human dimensions to improve conservation. Biological Conservation, 205, 93–108. https://doi.org/10.1016/j.biocon.2016.10.006.

[119] Speak, A., Escobedo, F. J., Russo, A., & Zerbe, S. (2018). An ecosystem service-disservice ratio: Using composite indicators to assess the net benefits of urban trees. Ecological Indicators, 95(95), 544–553. https://doi.org/10.1016/j.ecolind.2018.07.048.

[120] DiCicco, J. M. (2014). Long-Term Urban Park Ecological Restoration: A Case Study of Prospect Park, Brooklyn, New York. Ecological Restoration, 32(3), 314–326. https://doi.org/10.3368/er.32.3.314

[121] Depietri, Y., & Orenstein, D. E. (2020). Managing fire risk at the wildland-urban interface requires reconciliation of tradeoffs between regulating and cultural ecosystem services. Ecosystem Services, 44, 101108. https://doi.org/10.1016/j.ecoser.2020.101108.

[122] Salmond, J. A., Tadaki, M., Vardoulakis, S., Arbuthnott, K., Coutts, A., Demuzere, M., … Wheeler, B. W. (2016). Health and climate related ecosystem services provided by street trees in the urban environment. Environmental Health, 15(S1). https://doi.org/10.1186/s12940-016-0103-6

[123] Thierfelder, H., & Kabisch, N. (2016). Viewpoint Berlin: Strategic urban development in Berlin – Challenges for future urban green space development. Environmental Science & Policy, 62, 120–122. https://doi.org/10.1016/j.envsci.2015.09.004

[124] Seymour, M. (2012). Just sustainability in urban parks. Local Environment, 17(2), 167–185. https://doi.org/10.1080/13549839.2011.646968

[125] Cilliers, S., Cilliers, J., Lubbe, R., & Siebert, S. (2012). Ecosystem services of urban green spaces in African countries—perspectives and challenges. Urban Ecosystems, 16(4), 681-702. https://doi.org/10.1007/s11252-012-0254-3.

[126] Jorgensen, A., & Gobster, P. H. (2010). Shades of Green: Measuring the Ecology of Urban Green Space in the Context of Human Health and Wellbeing. Nature and Culture, 5(3). https://doi.org/10.3167/nc.2010.050307

[127] Jim, C. Y. (2012). Sustainable urban greening strategies for compact cities in developing and developed economies. Urban Ecosystems, 16(4), 741–761. https://doi.org/10.1007/s11252-012-0268-x.

[128] World Bank. (2021). World Bank Country and Lending Groups – World Bank Data Help Desk. Retrieved from Worldbank.org website: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups.

[129] Beck, H. E., Zimmermann, N. E., McVicar, T. R., Vergopolan, N., Berg, A., & Wood, E. F. (2018). Present and future Köppen-Geiger climate classification maps at 1-km resolution. Scientific Data, 5, 180214. https://doi.org/10.1038/sdata.2018.214.

[130] Anderson, L. (2015). The Role of Tourism and Recreation in the Spread of Non-Native Species: A Systematic Review and Meta-Analysis. PLOS ONE, 10(10), e0140833. https://doi.org/10.1371/journal.pone.0140833

APPENDIX

Appendix A Full list of articles, data extraction, and analysis strategy available upon request.

Appendix B General management recommendations/interventions suggested by authors of articles included in the review (Modified after Larson et al. 2016). Articles with the same recommendations were combined for conciseness. * Percentages do not sum to 100 because some articles made more than one management recommendation. **This portion of the articles is not included in the References.

Recommendation Themes/Category	Recommendation Summary	Articles	Frequency (%)*
Socioecological Approach.	Establish multistakeholder conservation strategies, e.g., conservation volunteerism, residence-led private/public garden management, community garden, and cultural integration. Promote people-oriented UGS for stress relief, thermal comfort, noise buffer and health benefits. Designate proportionate sociocultural, spatial, and temporal allocation of UGS within the appropriate distance. Limit trees with high allergenicity. Integrate native and sociocultural aesthetic elements to promote a sense of place, environmental education, biophilia, inspiration, and biophysical nature-relatedness/orientation. Adopt strategies to reduce human-wildlife conflict. Consider demolished area naturalization and vacant lot greening for health benefits and native wildlife. Plant pest/disease and traffic pollution tolerant plants for street trees. Preserve large parks, green corridors, and large trees and limit built-up/impervious areas. Policy and planning to increase UA resilience and sustainability for urban socioecological health. Apply monitoring and control strategies such as natural predators for nuisance species. Implement policies such as arthropod conservation, land-sparring, permaculture and governance measures to support UPA. Diversify UPA to food production capacity to offset the cost of stormwater management and energy cost and for urban resilience.	Hedblom et al. 2019; Czembrowski et al. 2019; Goker et al. 2019; Zhou et al. 2019; Wu 2018; Tsai and Lin 2018; Hami and Maruthaveeran 2018; Areola and Ikporukpo 2018; Koramaz and Türkoğlu 2018; Jochner-Oette et al. 2018; Dadfar and Heydari 2017; Olbińska 2017 Pinheir et al. 2017; Loret de Mola et al. 2017; Walker et al. 2017; Typhina et al. 2017 Coldwell and Evans 2017 Gunnarsso et al. 2017; Jasmani et al. 2017; Mata et al. 2017; da Silva Junior and Santos 2017; Rouhi et al. 2016 Schmidt et al. 2016; Aletta et al. 2016; Wilson et al. 2016 Rupprecht et al. 2016; Leveau and Leveau 2016; South et al. 2015; Hashem 2015; Sander-Regier and Etowa 2015; Shanahan et al. 2015; Carnol et al. 2015; Baur et al. 2014; Bruton and Floyd 2014 Alam et al. 2014; Voigt et al. 2014; Santiago et al. 2014 Tamosiunas et al. 2014; Lin et al. 2014; Qureshi et al. 2013 Gehrt et al. 2013; Zhou and Chu 2012; Cucu et al. 2011 Balaj et al. 2011; Clinton et al. 2018; Potter and LeBuhn 2015 Gregory et al. 2015; Langellotto et al. 2018; Padgham et al. 2015; Olsson et al. 2016; Wilhelm and Smith 2017;	37
Functional Greenspace Approach	Establish heterogeneous, dense UGS with high NDVI, high LAI, large canopies and water bodies for cooling effects. Prioritize high DBH/biomass trees, heterogeneity, curvilinear design and minimal management for carbon sequestration and mitigate climate change. Increase green UGS ratio/capita for clean air. Plant broad-leaved semi-evergreen trees, composite tree shrub to mitigate particulate matter (e.g., PM2.5). Plant deciduous trees for winter thermal comfort. Retention of organic matter and naturalization for soil carbons storage and overall soil health. Large area and dense vegetation for pollution control. Establish large trees with furrowed bark in high rainfall and small trees with smooth bark in low rainfall areas. Minimize forest harvest to prevent nuisance and invasive plants. Preserve green space to sustain/maximize water sources. Emphasize on resilience and sustainability of UPA.	Zhang et al. 2019; Aram et al. 2019; Tang et al. 2019; Othman et al. 2019; Othman et al. 2019; Moreno-García 2019 Goker et al. 2019; Przybysz et al. 2019; Kim and Coseo 2018 Rabou 2018; Karimi Afshar et al. 2018; Amoatey et al. 2018 Toparlar et al. 2017; Gu et al. 2017; Yang et al. 2017; Xu et al. 2017; Tura et al. 2016 Yoon et al. 2016; Wang et al. 2015; Schooling and Carlyle-Moses 2015; Kiss et al. 2015 Van Stan II et al. 2015; Odindi et al. 2015; Gratani and Varone 2014; Ren et al. 2013; Nagendra and Gopal 2011; Millward et al. 2011; Peters 2010; Tessier 2010; Clinton et al. 2018; Gregory et al. 2015 Jujnovsky et al. 2012; Padgham et al. 2015; Olsson et al. 2016; Wilhelm and Smith 2017	27

Recommendation Themes/Category	Recommendation Summary	Articles	Frequency (%)*
Habitat Conservation Approach	Diverse, unmanaged, semi-natural, native habitat for butterflies. Introduce locally extinct and native nectar plants for butterfly. Diverse native, heterogenous semi-natural habitat, fruit/berry plant, large area, natural corridor and wetland for birds. Establish monitoring of bioindicator organism to assess park health. Mix of coniferous and deciduous trees to promote lichen growth. Use good mix of native and exotic vegetation if unavoidable. Maintain habitat heterogeneity connectivity for arthropod diversity. Reduce introduced plants and manage synanthropic predators for small birds. Maintain healthy predator/prey population for mammals. Minimal management for cavity nester. Maintain quality habitat and surrounding landscape to support food production and pest control. Ecological corridor for threatened species (e.g., European squirrel) Apply monitoring and control strategy for nuisance/invasive species. Moderate urbanization for microbial fauna.	Aguilera et al. 2019; Chaiyarat et al. 2019; Melo et al. 2019 Manu et al. 2018; Schütz and Schulze 2018; Igueroa et al. 2018; Dale 2017; McDonald et al. 2017; Walker et al. 2017 Matthies et al. 2017; Bonança et al. 2017; Jasmani et al. 2017 Mata et al. 2017; dos Santos Cosac and Silvano 2016; de Souza-Campana et al. 2016; Sing et al. 2016; Battisti and Dodaro 2016; Leveau and Leveau 2016; Tam and Bonebrake 2016; de Oliveira Martins et al. 2016; Chang and Lee 2016; Su et al. 2015; Bennett et al. 2014; Park et al. 2014; Rézouki et al. 2014 Dodaro and Battisti 2014; Xu et al. 2014; Moorhead 2013; Kenaga et al. 2013; Latta et al. 2103; Nagy and Rockwell 2013; Hepcan 2013; Zhou and Chu 2012; Carpaneto et al. 2010; Potter and LeBuhn 2015 Gregory et al. 2015; Langellotto et al. 2018	25
No recommendations			16

Appendix C Summary of Recommendations/Interventions for different ecoclimatic regions

Eco-climatic regions	Recommendation Summary
Arid Regions	Choose desert-adapted woody plants for thermal regulation, water/energy conservation, pollution mitigation, recreational, and socioeconomic value. High ratio of deciduous trees to increase biomass to maintain low CO_2 in arid urban areas. Increase NDVI to enhance AGC, maintain low ambient CO_2, and mitigate climate change.
Subtropical Coastal Regions	Plant dense vegetation around the built areas and along the sea to create synergistic and sustaining cooling effects of both sea and vegetation. The socioecological approach in UGS development and management for both people and wildlife. Naturalization, buffer zones to support both generalist and specialist birds. Unmanaged semi-natural habitat for butterfly diversity.
Areas with high rain events	Select large trees with large crowns and rough bark to maximize canopy interception loss. Minimize the impervious surface by <50% in built areas.
Areas with small rain events	Select small trees with smooth bark to reduce evapotranspiration and recharge aquafers.
Areas with short vegetative season	Plant hardy and pollution-tolerant coniferous and semi-evergreen species to efficiently remove pollutants (trace elements and PM) from the air due to their efficiency in removing pollutants.
Tropical Regions	Implement a hybrid & curvilinear spatial design. Increase biomass with hybrid spatial and curvilinear design for greater carbon sequestration rate, alleviate UHI and global warming. Minimize the allocation of open space according to the park size/area.
Cold Regions	Plant deciduous trees and maintain cold-tolerant grassy areas in cold regions for winter thermal regulation and comfort. Implement planning and management of UGS according to people's thermal preferences, especially in cold regions.