Received 07 March 2022: accepted 27 July 2022.
Available online 03 August 2022

Bring Nature Back to the City; Keep Invasive Species Out

Ahmed O. El-Kholei [1] **Mohammad S. Abido** [2]

[1] Professor of Urban Planning, Department of Architectural Engineering, Menofia University, ahmed.elkholei@sh-eng.menofia.edu.eg
[2] Professor of Ecology and Biodiversity (Former), Department of Natural Resources and Environment, Arabian Gulf University

ABSTRACT

Cities are the drivers of economic growth but pollute the environment and deplete natural resources. Nature-based Solutions (NbS) and Ecosystem-based Adaptation (EbA) offer many answers to mitigate and adapt to climate change. Without understanding the threats associated with these solutions, bringing nature back to the city might cause undesired side effects such as introducing and proliferating invasive species. Contemporary literature on invasive species evolves from the urban ecology discipline. The paper explores contemporary literature to highlight the gap between ecologists and design professionals. We found that research published between 2017-2021 and indexed on Scopus that dealt with urban issues and invasive species yielded 4,556 publications, of which only 88 publications that design professionals prepared to indicate a gap between urban ecologists and design professionals explaining the persistence of the problem and concerns that ecologists raise. We conducted a bibliometric analysis. Results indicate three clusters: (1) Pressures such as climate change; (2) State urban ecosystems; and (3) Responses in the form of land use plans and urban designs. NbS and EbA are instrumental in responding to climate change. Planners must design and build cities to minimize the adverse effects of urbanization while maximizing the ecological processes by allowing nature conservation actions within urban environments. One of the criteria for evaluating design and planning alternatives is to check for the risk of introducing invasive species. Design experts must be aware of the risks of invasive species, which require research to update present guidelines and introduce the topic in the architectural and planning curricula.

KEYWORDS: Biodiversity; City planning; Landscape, Alien species; Urban design.

إعادة الطبيعة للمدينة بدون الأنواع الغازية

الملخص

ستظل المدن هي المحرك للنمو الاقتصادي. ومع ذلك، فإنها تلوث البيئة، وتنبعث منها غازات الدفيئة المسببة لتغيير المناخ، وتستنزف الموارد الطبيعية. تقدم الحلول القائمة على الطبيعة (NbS) والتكيف القائم على النظام الإيكولوجي (EbA) العديد من الإجابات للتخفيف من تغير المناخ والتكيف معه، بما في ذلك إعادة الطبيعة إلى المدينة. لكن بدون فهم التهديدات المرتبطة بهذه الحلول، فإن إعادة الطبيعة إلى المدينة قد تسبب آثارا جانبية غير مرغوب فيها وعلى رأسها إدخال ونشر الأنواع الغازية. يجمع علماء البيئة الحضريون باللوم على المدينة في إدخال ونشر الأنواع الغازية على شكل نباتات وحيوانات إلى المتنزهات والحدائق السكنية الخاصة. وتشير الأدبيات المتعلقة بالأنواع الغازية إلى إنها تهدد البيئة وصحة بشر. تستكشف الورقة الأدبيات المعاصرة لتسليط الضوء على الفجوة بين علماء البيئة والعاملين في مجالات التصميم والتخطيط الحضري. باستخدام سلاسل بحث مختلفة، وجدنا أن الأبحاث المنشورة والخاصة بقضايا البيئة الحضرية والأنواع الغازية بين عامي ٢٠١٧-٢٠٢١ والمفهرسة على Scopus تصل الي ٤,٥٥٦ منشوراً، نشر المخططون والمصممون الحضريون ٨٨ منشورا فقط مما يشير إلى وجود فجوة بين علماء البيئة الحضرية والمسؤولين عن تخطيط المدينة. لقد أخضعنا المنشورات للتحليل ببليومتري. وتشير النتائج إلى وجود ثلاث مجموعات: أولا، الضغوط التي يسببها تغير المناخ؛ وثانيا، حالة النظم الإيكولوجية الحضرية، والثالثة هي الاستجابات في شكل مخططات استخدامات الأراضي والتصاميم الحضرية. لكل من NbS وEbA دور فعال في الاستجابة لتغير المناخ.

لذلك يجب على المخططين تصميم وبناء المدن لتقليل الآثار الضارة للتحضر مع تعظيم العمليات البيئية من خلال السماح بإجراءات الحفاظ على الطبيعة داخل البيئات الحضرية. من معايير تقييم بدائل التصميم والتخطيط هو التحقق من خطر إدخال الأنواع الغازية. يجب أن يكون خبراء التصميم الحضري على دراية بمخاطر الأنواع الغازية، والتي تتطلب إجراء أبحاث لتحديث المبادئ التوجيهية الحالية وإدخال الموضوع في المناهج المعمارية والتخطيطية.

الكلمات الدالة:

التنوع البيولوجي؛ تنسيق المواقع؛ الأنواع الدخيلة؛ التصميم الحضري؛ تخطيط المدن والبلدات.

INTRODUCTION

Cities have evolved into the cradle of innovation and the site of production since the industrial revolution. They are hubs for production and consumption. For example, the State of New York's gross domestic product is greater than that of Spain or South Korea. (Tavares, 2016). Cities occupy about 2% of the Earth's surface; nevertheless, they cause and face many environmental challenges, including environmental degradation and climate change impacts. For instance, cities emit up to 70% of Greenhouse Gases (GHGs)[1] that contribute to climate change (World bank, 2010; UN-HABITAT, 2011). One of the recent moves to mitigate and adapt to climate change is to bring nature back to the city through Nature-based Solutions (NbS) and Ecosystem-based Adaptation (EbA),[2] which include replacing grey infrastructures[3] with green and blue ones.[4] The urban environmental crisis needs better town and city planning practices.

1 IMPACTS OF URBANIZATION ON THE ENVIRONMENT

Urban environmental effects go beyond climate change, thus undermining the attempts for sustainable urban development. Adverse impacts of urbanization include modifying land cover and uses, besides altering waterways. Cities are the locality for trade and shipping. Consequently, cities are where the illegal wildlife trade takes place. It is a multibillion-dollar industry involving the illegal harvesting and trade of live animals, plants, parts, and products derived from them World bank, 2019; UNODC, 2016).

Urbanization drives global biodiversity decline (Gaertner, Wilson, et al., 2017; Gao et al., 2021). It causes biodiversity losses through fragmentation, degradation, destruction of habitats, and biotic homogenization (Bar-Massada et al., 2014; Hansen et al., 2005; Kühn & Klotz, 2006; McKinney, 2006). Research indicates that urbanization frequently increases the biodiversity of non-native species while decreasing the biodiversity of native species, thus decreasing overall species richness[5] and an increase in total biomass[6] and species abundance.[7] Besides, cities' environment is conducive to alien species spread that can become invasive under proper circumstances. For instance, exotic plants dominated the landscape structure of some cities around the World (Dehnen-Schmutz, 2011; Gavier-Pizarro et al., 2010; Naghavi et al., 2015).

Cities are the hub for trade and shipping. Therefore, they are responsible for spreading invasive species.[8] For example, ports and harbours introduce invasive species into native marine environments and freshwater bodies (Berlingieri, 2016). Ballast water is fresh, or saltwater stored in ships' ballast tanks to provide stability and manoeuvrability when vessels are not carrying cargo. Ballast water often includes invasive species.

The heat island phenomenon is an attribute of cities (Al Blooshi et al., 2018; Nwakaire et al., 2020). It occurs when the city's central areas have higher mean temperatures than the hinterlands due partly to the ability of a surface to reflect light and the increased surface area of buildings to absorb solar radiation. In urban areas, concrete, cement, and metal surfaces absorb heat energy rather than reflect it, contributing to higher urban temperatures.

The current environmental crisis is both a symptom and an outcome of capitalism's consumerism culture. It results from neoliberal policies that weaken governments' ability to control national economies. Neoliberalism changed the geographies of production by globalizing markets and establishing free trade agreements, which resulted in relocating manufacturing plants to cities of developing countries, which will continue to grow, thus exacerbating urban environmental problems.

Climate change and biosphere integrity are two planetary boundaries that anthropogenic activities are driving and altering how Earth Systems work. Cities are the location of anthropogenic activities. Transgression of planetary boundaries jeopardizes and undermines the status of Earth Systems, in which modern societies have evolved (Steffen et al., 2015).

In the wake of the twentieth century, the evils of the industrial revolution were obvious and required attention. Howard (1902) introduced the garden city as a model to bring nature into the city. Frederick Law Olmsted and Calvert Vaux prepared the designs for several urban parks, including Central Park, New York City, to improve the living conditions of city residents (Blodgett, 1976). However, these efforts fell short of protecting urban ecosystems and the environment, as Carson (1962) proved. Attempting to assess progress in protecting the environment, Tolba and El-Kholy (1992) concluded that issues and problems discussed in the Environment and Humanity Conference[9] are the same and have gone worse.

There have been efforts to face contemporary urban environmental challenges. Professionally, in 1990-91, UN-HABITAT and UNEP established the Sustainable Cities Programme and implemented projects in many cities worldwide to foster environmentally sustainable urban development (UN-HABITAT, n.d.). Cities Alliance[10] devised a four-step participatory planning tool to prepare City Development Strategy (CDS) to alleviate urban poverty (Cities Alliance, 2016). Sustaining the environment is central to CDS preparation and implementation. However, the attention of these institutions shifted to more specific environmental topics, such as energy efficiency, climate change adaptation and mitigation measures, and disaster risk reduction, besides transportation and mobility. Focusing on specific challenges left other urban environmental problems barely addressed, such as maintaining biodiversity richness (Dodman et al., 2013).

Meanwhile, scholars generated and shared research findings for sustainable urban development. Haughton and Hunter (1996) discussed the impacts of urbanization on water resources and air quality, then outlined principles for a sustainable city. Haughton (1997) outlined models for city-environment interaction.

NbS is one of the initiatives to bring nature back into the city. Mata et al. (2020) argued that design professionals[11] responsible for constructing the built environment could illustrate the importance of green and blue infrastructures in bringing nature back into the city. Faivre et al. (2017) showed that the European Commission (EC) started in 2013 to implement initiatives to employ NbS to bring nature back into the city and resolve environmental problems. After surveying citizens' opinions on NbS projects,

the EC formulated a research agenda and called for improving the executing capacities to deploy more NbS projects.

EbA applies NbS to mitigate and adapt to climate change. Today the UN Environment and the Global Environment Facility promote applying NbS and EbA projects in urban environments. In 2014, both institutions sponsored EbA projects in El Salvador, Jamaica, and Mexico over 48 months of advocating EbA. The projects aimed to incorporate EbA into medium- and long-term urban planning and strengthen the climate change resilience of susceptible urban communities living in three medium-sized[12] Latin American and Caribbean cities (UNEP, 2014). Both institutions sponsored activities of CityAdapt [13] in Pacific-Asia to mainstream NbS within planning by offering tools to help local governments plan for climate change adaptation while also reducing greenhouse gas emissions from their cities by maintaining their ecosystems (CityAdapt, 2017, 2021).

Many scholars focused on bringing nature back to the city to ease environmental problems and assure sustainable urban development. McIntosh and Pontius (2017) provided an account of anthropogenic activities on the global landscape. Others considered nature a healer for human illness (Barakat et al., 2019; Marcus & Barnes, 1999). Walsh et al. (2015) evaluated mitigation and adaptation measures in cities. Citizen participation continued to be central to planning sustainable urban development (Giddings et al., 2015).

Besides those resulting from a design perspective, another set of research findings emerges from urban ecologists. Turner, Nakamura, and Dinetti (2004) found that most people live in low-biodiversity communities in cities worldwide. These discoveries have a terrible and rarely discussed effect as humanity becomes increasingly urbanized. Hundreds of millions of people may miss out on the benefits of nature or the opportunity to acquire an appreciation for it.

The literature map, [14] Figure (1, indicates drivers and pressures (blue rectangles), the state of the urban environment (rectangle at the center of the diagram), and the responses (rectangle in green). Drivers and pressures include climate change (Blekking et al., 2022; Kaykhosravi et al., 2020; Bastin et al., 2019; Majumder et al., 2018). Air pollution and energy are other drivers of urban environmental crises (Chien et al., 2022; Zhang et al., 2022; Liu et al., 2015). Bansal et al. (2022) and Lawson et al. (2021) highlighted linkages between human settlements and water resources. Zaninotto & Dajoz (2022) and Apostolopoulou (2020) highlighted the adverse impacts of urbanization on biodiversity. Invasive species affect biodiversity richness and abundance, and without proper urban management, the likelihood of spreading invasive species increases (Le Louarn et al., 2018; Mehraj et al., 2021; Oertli et al., 2018; Santana Marques et al., 2020; Shiferaw et al., 2019). Zhou and Chen (2018) emphasized the role of land use and cover changes in degrading the built environment. Responses came in research that Kumar et al. (2021), Elder and Gerlak (2019), and Palomo et al. (2013) provided.

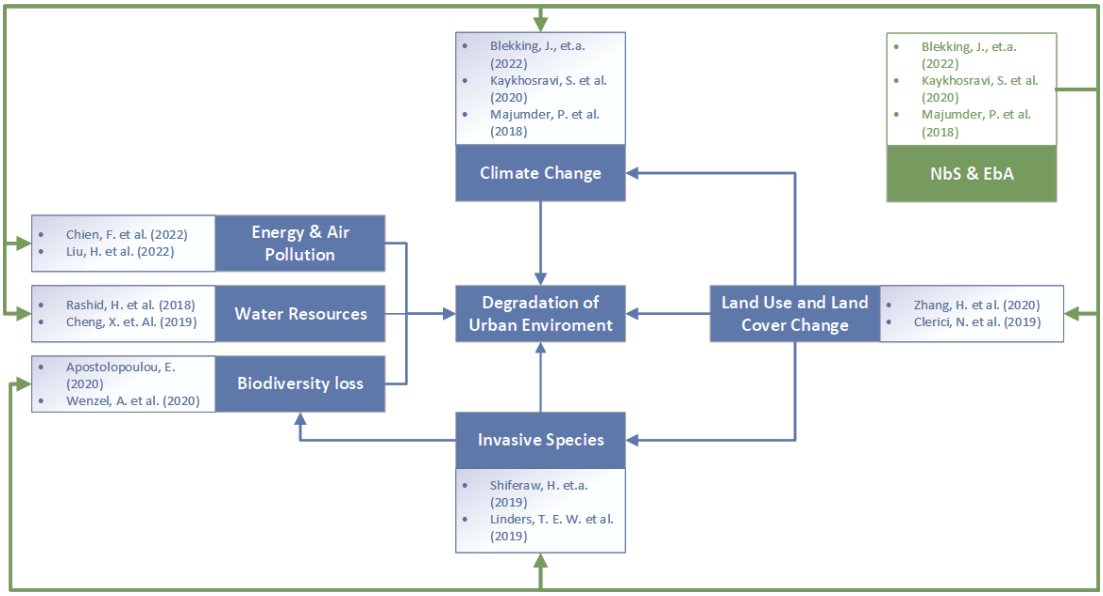

Figure (1) Literature map (Source: The authors)

In brief, Figure (2 is a schematic diagram that summarizes the arguments and results of urban ecologists' research. Globalization and neoliberal policies accelerated urban growth, leading to land use and cover changes. These changes, as mentioned earlier, have a profound impact on the spread of alien and invasive species, thus resulting in biodiversity loss. Unfortunately, a limited number of their recommendations transformed into design guidelines for planners, urban designers, and landscape architects to follow. Consequently, the issue of biodiversity loss continues to persist.

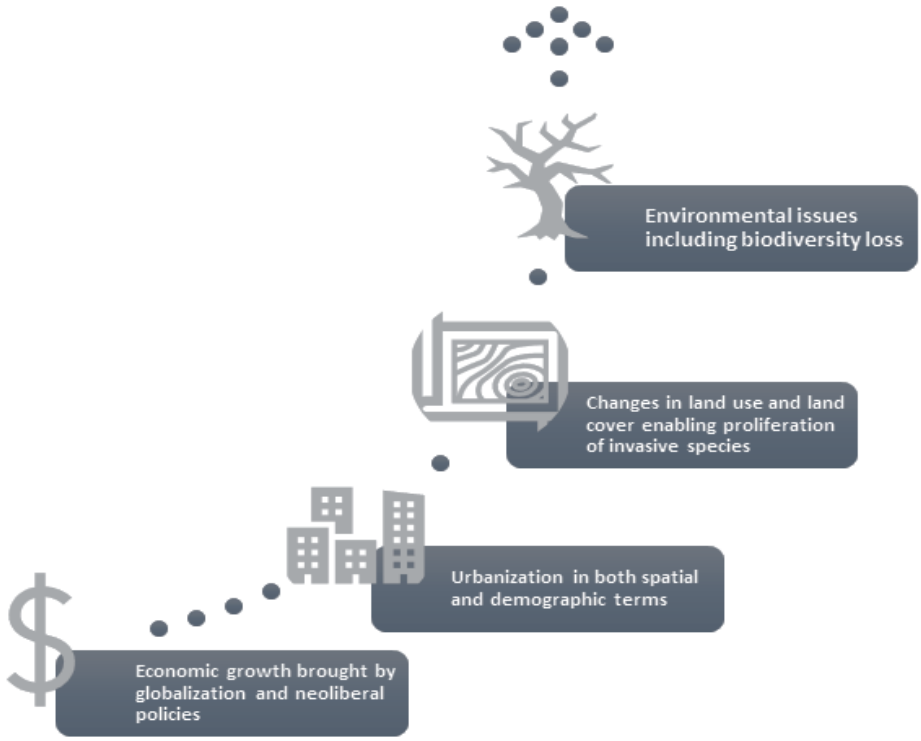

Figure (2) Schematic diagram summarizing the issue from urban ecologists' view (Source: The authors)

2 THE RESEARCH PROBLEM

Employing NbS and urban EbA requires maintaining natural ecosystems within and around the city. Bringing nature back to the city requires cautiously designing and managing human-made open spaces, parks, and infrastructures to contribute to biodiversity richness. However, without a fundamental understanding of the linkages between urban planning and design on one hand and biodiversity richness and abundance, the introduction of invasive species is a risk that could have profound economic, social, and environmental losses.

Santiago-Alarcon & MacGregor-Fors (Santiago-Alarcon & MacGregor-Fors, 2020), Yigitcanlar & Teriman (2015), and Wu (2014) represent scholars from both sides. They agreed on the need for cross-disciplinary research methods. Kuhn (1970) proposed an episodic model in which periods of conceptual continuity and cumulative advancement, which he referred to as normal science, were broken up by periods of revolutionary research. During scientific revolutions, scholars discover anomalies, which lead to new paradigms. New research directives change, and new paradigms ask new questions using existing data, moving beyond the prior paradigm's puzzle-solving techniques. Juxtaposing Kuhn's view with those of Santiago-Alarcon & MacGregor-Fors (2020), Yigitcanlar & Teriman (2015), and Wu (2014), besides reports indicating modest progress in achieving targets of SDG 11 suggest anomalies in the field of the urban environment that hinder realizing sustainable urban development.

It seems that those who belong to the stream of design professionals have not paid attention to issues of biodiversity loss in urban areas as the results of the urban ecologists suggest. There is an apparent knowledge gap between knowledge and work where professionals' designs and practices deviate from urban ecologists' results. Many scholars from the design and planning disciplines did not cover the issues of biodiversity loss in urban areas.

As explained by the results of urban environmental research, the continuing problem of biodiversity in the city suffers from the concern of planners and designers on other critical environmental issues such as energy and resource use but did not include vital loss issues. Parizi (n.d.) argued for introducing steps by 2020 to prevent the introduction and considerably decrease the effect of invasive alien species on terrestrial and aquatic ecosystems, and to manage or destroy priority species. showing the importance of considering the issue of invasive species in landscape architecture projects.

There is a need to provide the design professionals with an integrated, holistic view of the importance of addressing the issue of invasive species in urban settlements. The problem is that risks are probably equal to those associated with climate change. For example, Kumar Rai and Singh (2020) argued that Invasive Alien Plant Species (IAPS) are among the most important drivers of biodiversity loss, affecting ecological services and socio-economic conditions through various methods. IAPS compound the impact of climatic and land-use changes. IAPS management is necessary for biosecurity and risk assessment, requiring integrated transdisciplinary research.

It is essential to differentiate between alien or naturalized and invasive species. Alien species are non-native but established species. Those threatening native species and biodiversity ecologists generally refer to invasive species.[15] A species must quickly adapt to its new environment to be invasive. It must proliferate rapidly, harming property, the economy, or the region's native plants and animals. Humans mistakenly

introduce many invasive species to new regions. In general, prior work on invasive species is limited to the contribution of urban ecologists.

This paper aims to point out the gap between knowledge and professional practices. Because of the knowledge gap, practices overlook research findings and aspects of the city's biodiversity that urban researchers do not address. The paper addresses the following research questions:

1. What are the current efforts to address the issue, and how effective are they?
2. Where is the research community moving?

3 MATERIALS AND METHODS

The conceptual framework for inquiry adopts the Drivers and Pressures, State, Impact, and Response (DPSIR) to examine the interconnectedness between human activities and the urban environment (European Environment Agency, 1995). Figure (3 depicts the DPSIR and the keywords then used for data gathering.

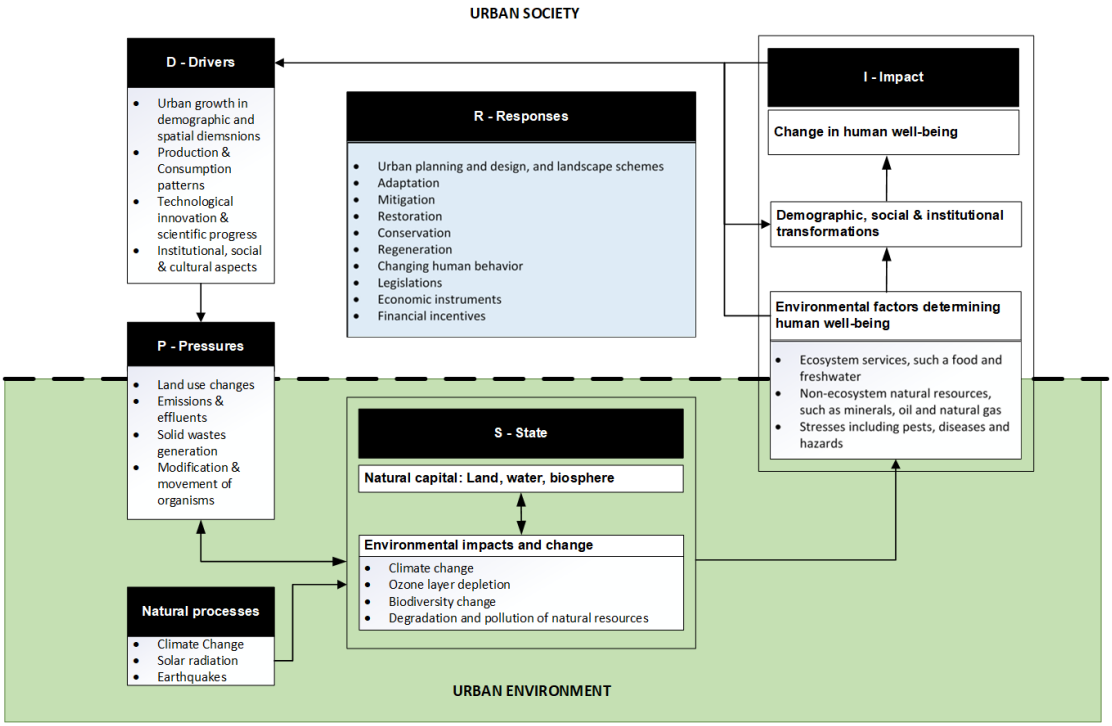

Figure (3) Conceptual model for analysis (Source: adapted from Jäger, J. (2008)

We adopted a qualitative research methodology to answer the two research questions. We focused on contemporary published literature, searching for meanings, concepts, definitions, characteristics, metaphors, and symbols. We wanted to capture the issues addressed, the research methods employed, the conclusions and implications, and then investigate where the research community is heading.

Scopus combines authoritative, full-text scientific, technical, and health journals with intelligent, simple capabilities to help users stay informed and perform more effectively and efficiently in their professions. We used Scopus because it is a huge, multidisciplinary database that provides access to scholarly research in the following fields: Physical Sciences and Engineering, including Chemical Engineering, Chemistry, Computer Science, Engineering, and Materials Science. Elsevier, the firm

that owns Scopus, is reputable and publishes some of the top journals, such as Journal of Urban Management, Regional Science and Urban Economics, Journal of Urban Economics, and Cities, which are peer-reviewed.

We searched published research between 2017-2021 that Scopus[16] indexed. We used the following strings to search the database: 'urban OR urbanization OR city;' 'invasive species;' 'biodiversity OR biological;' 'risk AND spatial analysis.' We used the following string' urban AND NbS AND landscape AND blue OR green' to extract the references that death with bringing nature back to the city.

We downloaded the results as files in Research Information Systems (RIS) format,[17] which we imported into Mendeley,[18] to cite the references in this paper. We used VOSViewer to visualize the data and conduct cluster analysis[19] to determine the different groups of published research. It is a program that allows researchers to develop and visualize bibliometric networks. Citation, bibliographic coupling, co-citation, or co-authorship relationships are elements used to build these networks, including journals, researchers, or individual articles. VOSviewer also includes text mining capabilities to build and envision co-occurrence linkages of relevant phrases retrieved from a group of scientific articles (van Eck & Waltman, 2020).

Using the DPSIR framework, we selected 145 published research based on titles, keywords, and abstracts, i.e., about 3.2% of the entire dataset. The sample size is not an issue in qualitative research. It is the purpose that matters.

Atlas.ti comes with various features to help conduct a thorough, methodical examination of the papers they acquired. We imported the 145 RIS files into Atlas.ti to develop a network using the DPSIR framework. The software makes it simple to generate networks that show correlations between codes based on their combined frequency of quotations. The software also generates a code co-occurrence table, which includes the joint frequencies of each pair of codes, showing a relationship between them—a c-coefficient is a number that goes from zero to one.[20] We compute it using **Error! Reference source not found.**.

Equation 1

$$c = \frac{n_{1-2}}{(n_1 + n_2) - n_{1-2}}$$

where:

c is a coefficient for each shared presence between two symbols.

$n_{1\text{-}2}$ is the joint quotations that two codes share.

n_1 is the number of quotations in Code 1.

n2 is the number of quotations in Code 2.

The research technique we used is a three-step method, Noticing-Collecting-Thinking (Friese, 2019; Seidel, 1998). The first step, i.e., Noticing, is to investigate the data by reading the 145 abstracts thoroughly. The second step is to code the data. Coding is locating a passage in a text, looking for and recognizing concepts, and discovering relationships among them. The results of the VOSViewer guided the coding process, where we collected and sorted the words in the data into the following five codes: (a) Drivers and Pressures; (b) Impacts; (c) Research Methods; (d) Responses; and (e) State. The coding process is like a puzzle analogy, where a person sorts the bits and pieces of information to solve the puzzle. We generated word clouds[21] to assure accuracy and precision before coding. The last step is thinking about the facts and bits and pieces of information the researchers elicit from the data. It is an iterative process where the researchers re-coded, merged, and deleted codes. For a deeper

understanding of the landscape of contemporary literature, we calculated the co-occurrence coefficient

The data consist of 4,556 references, Table (1, of which three were not in English. It is crucial to point out that Scopus index only original articles from refereed journals because Scopus publishes high-quality refereed research.[22] A journal article reports the results of an original inquiry. Its format is appropriate for various fields and diverse studies, explaining why many research institutions use published journal articles as a primary criterion when considering promoting a candidate to a professorship.

Table (1) Data stratified by item

Item	Count	%
Journal articles	4,524	99.30
Conference articles	18	0.40
Books and Book Sections	8	0.18
Miscellaneous	6	0.13
Total	**4,556**	**100.00**

Only 88 of the 4,556 references dealt with NbS, EbA, landscape, and blue and green infrastructures. Table (2 exhibits the publications stratified by type.

Table (2) Publication type (The authors)

	Publication Type	Number
1	Journal Article	71
	Conference Proceedings	1
2	Books and Book Section	14
3	Generic	1
4	Miscellaneous	1
	Total	**88**

Source: (The authors)

4 RESULTS

Tables 1 and 2 show that approximately 2.0% of the published work indexed in Scopus dealt with NbS, EbA, landscape, and blue and green infrastructures. It indicates that the area of NbS and EbA is relatively novel, requiring more attention from ecologists and scholars who belong to the design profession.

4.1 Findings from Abstracts and Keywords

The following result indicates that urban ecologists do most published work. Scholars and journals seldom include researchers from the humanities and social sciences. Our results show that thirty scholars, who belong to the design profession, published around 543 publications, i.e., approximately 12% of the indexed publications dealing with invasive species. Thirty journals aiming for urban ecology published about 51% of the articles. Atop of them is Ecology and Evolution and Biological Invasions, published 307 and 198 articles, respectively.

Based on the affiliation of the scholars, it seems that research institutions in the USA were the most active by publishing 1,121 articles in the past five years. China, the United Kingdom, and Australia came second, third, and fourth on the list with 350, 300,

and 196 publications, respectively, Figure (4. Unfortunately, the data showed no recent publications on the issue in the Arab World.

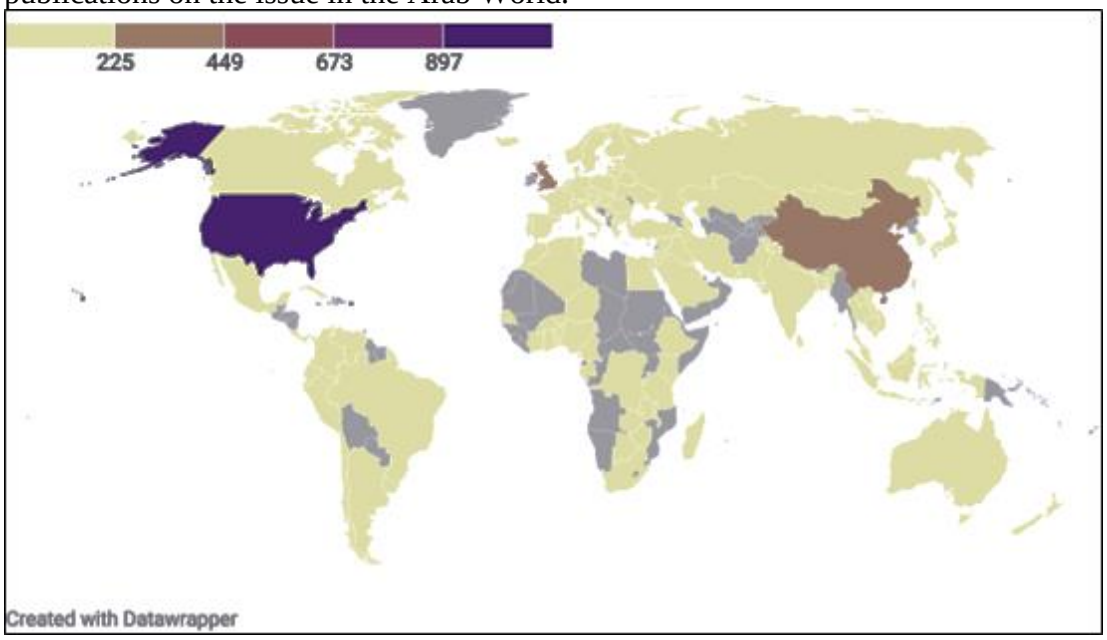

Figure (4) Published research stratified by country, 2017-2021 (Source: The authors)

Based on our review of the abstracts, there is no accepted universal list of invasive species. IUCN's Global Invasive Species Database is the only available database at the country level, though it lacks scientific validation. Furthermore, ambiguous terminologies on the invasion ecology regarding clarity of theories, hypotheses, and terminologies still exist. Hence, whatever species in a country or a region is invasive might not be the case in another place, thus explaining the variation in the number of published papers among countries. Colautti and MacIsaac (2004) proposed a naming system based on biogeography rather than taxonomy to prevent the confusing, subjective, and negative terminology that often plagues the debate on invasive species, even in scholarly literature.

The driver to examine invasive species is the share of the agricultural production in the national economy and the damage that invasive species cause. The USA has the highest number of published papers (1,121) and identified invasive species (6,221) (US Department of Agriculture, n.d.). However, according to the per capita share of published papers, New Zealand, Australia, and Portugal lead other countries with 15.40, 7.63, and 6.96 published papers per capita. The share of the agricultural sector in the GDP of these three countries is 5.81% (New Zealand), 2.09% (Australia), and 2.07% (Portugal) (World Bank, 2021).

Based on the top one thousand keywords, 130 mentioned a species that belongs to the animal kingdom, such as bats and the cane toad. Bees, arthropods, arthropods, and other insects constituted about 13 keywords. Another 98 keywords belong to the plant kingdom, including acacia (*Acacia* spp.) and garlic mustard (*Alliaria petiolate*). Finally, the keyword ecosystem, such as salt marsh, rivers, and streams, occurred 108 times.

Figure (5 is a network exhibiting the main clusters of one thousand keywords with the highest occurrences in the literature. The circle area illustrates the occurrences of the keyword in the indexed papers. Its color indicates to which cluster the keyword belongs. The location of the circle and links indicate its association and strength of linkages with other keywords.

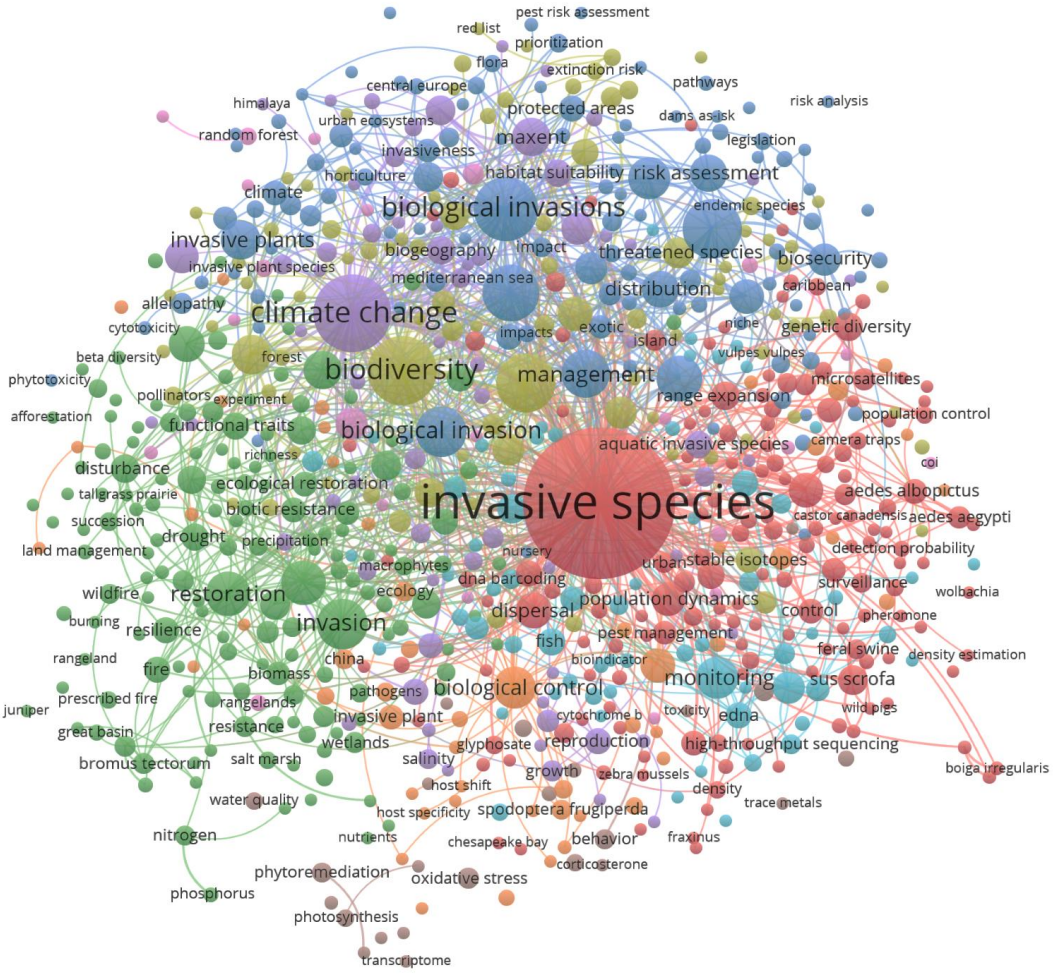

Figure (5) Network of the main clusters of one thousand keywords (Source: The authors).

Consequently, keywords fall into at least three main clusters, Figure (5. The first is invasive species, i.e., the red circle, including keywords, such as population dynamics, urban, and pest management. The second notable cluster is climate change which includes maxent software biogeography. Keywords in the green circles, such as restoration, drought, biotic resistance, and biomass, belong to impacts and responses. Finally, keywords in blue circles, such as biological invasions and risk assessment and analysis, fit into another cluster indicating research methods and techniques. However, the figure does not exhibit linkages between the urban environment and invasive species.

Results suggest that 83 keywords indicate commonly used research methods, techniques, and tools. They include camera trap, citizen science, decision support model, distribution modeling, expert knowledge, remote sensing, geographic information system, modeling, non-invasive sampling, vegetation classification, and species distribution models.

There seems to be limited attention to the connections between the urban environment and invasive species. The overlay of the analysis, Figure 6, suggests dates

when the keywords emerged in the literature. As the legend indicates, climate change, threatened species, and water quality were keywords linked to invasive species that emerged in the literature in 2020, indicating the linkages between the various environmental issues in a city.

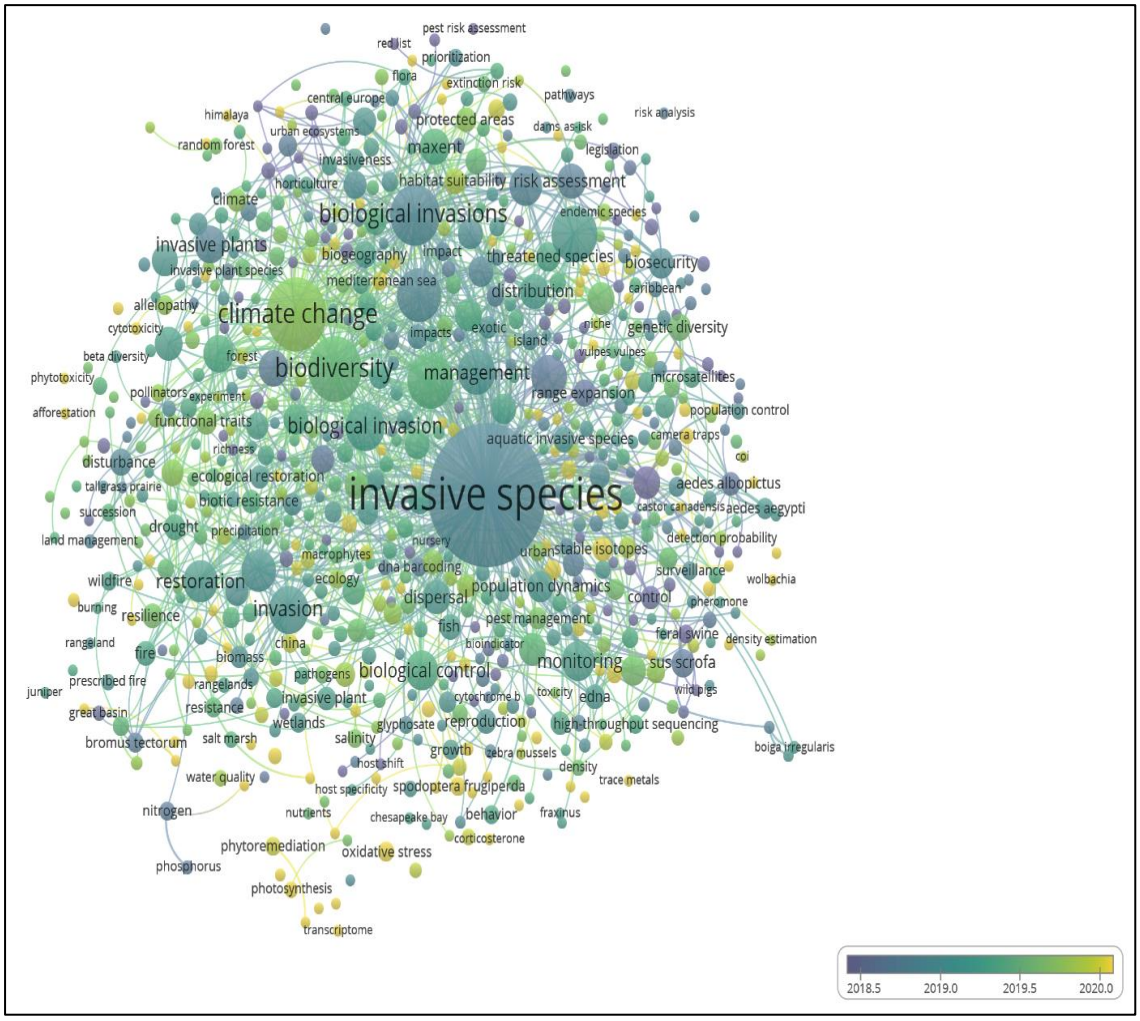

Figure (6) Overlay of keywords (Source: The authors)

However, the use of keywords is not enough. The researchers subjected abstracts of references with complete bibliographic information to a query to generate a word cloud of words with the highest occurrence. Word clouds are statistical measures of word frequency. They give words that appear more frequently in abstracts subject to analysis more emphasis. The bolder the word, the more frequently it appeared in the text subjected to the analysis.

The keyword invasive species fall at the crux of the literature, as the generated word cloud, Figure (7, suggests. The upper group of words consists of two clusters where the term invasive is at the center. The figure includes habitat, biodiversity, community, management, and wildlife on the upper right hand. Distribution, experiment, sampling, temperature, climate, assessment, effects, methods, analysis, spatial, and scale are words that fell on the top left hand and freshwater and lake. Some words with no significant importance, such as many, data, and including, appeared in the word cloud. They are like outliers in a regression analysis. Removing them is tampering with the data.

Figure (7) Word cloud of keywords (Source: The authors)

Figure (8 depicts keywords with the highest occurrence and total link strength. They include invasive species, climate change, biodiversity, biological invasions, and alien species. Conversely, keywords such as urban vegetation, urban habitats, the urban environment, spatial analysis, and road ecology occurred only nine times each, and urban areas occurred ten times, implying they have the least occurrence and total link strength.

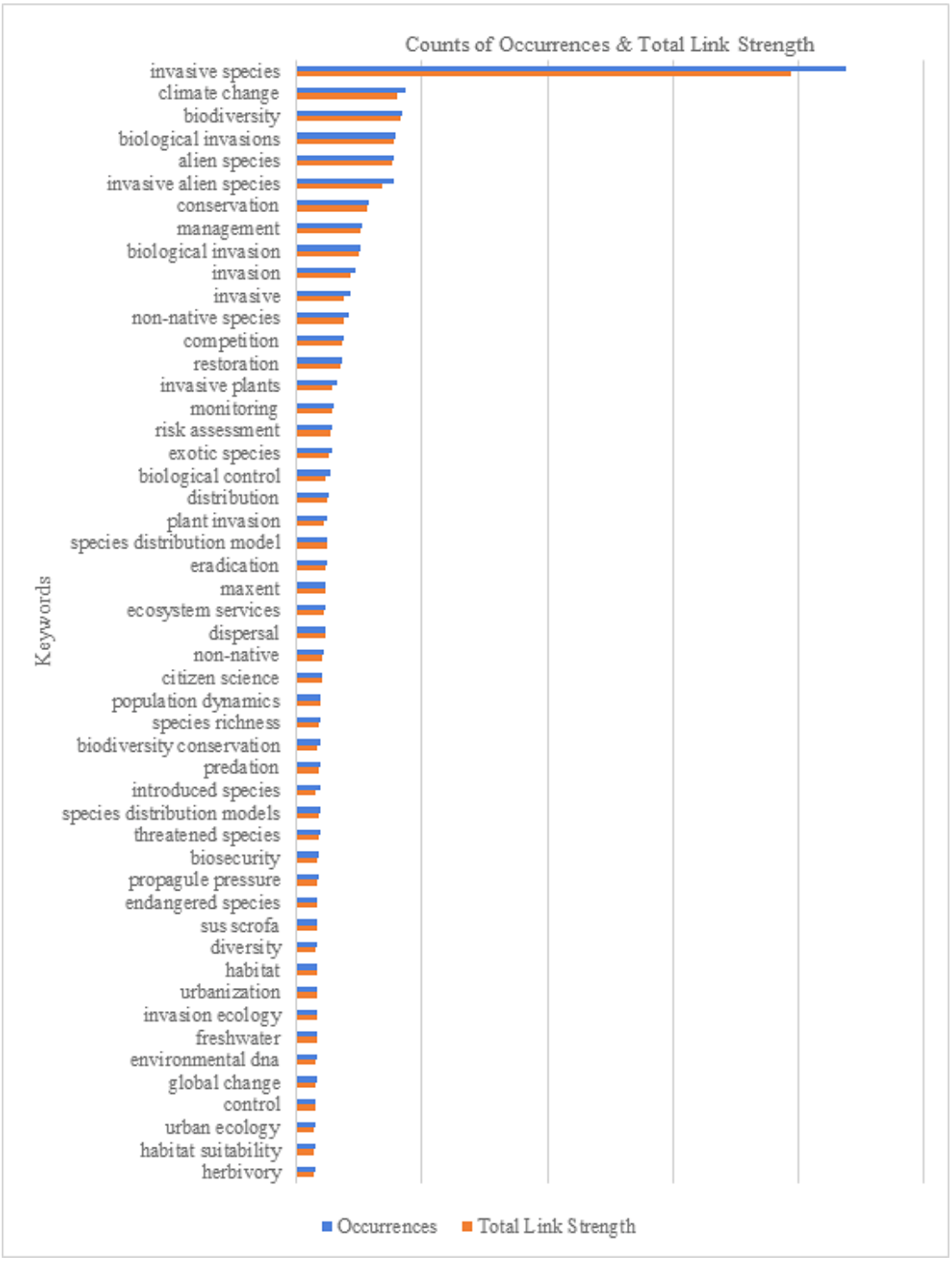

Figure (8) Keywords with the highest occurrence and total link strength (Source: The authors)

4.2 Research Topics and Methods

Most keywords indicate the state of the urban environments, such as migration and land-use change, and responses, such as restoration and control, followed by pressures, such as human activities and habitat alteration, Figure (9. Few publications dealt with impacts, such as trophic cascade and invasion risk. Fewer scholars addressed drivers, such as stakeholders and wildlife trade.

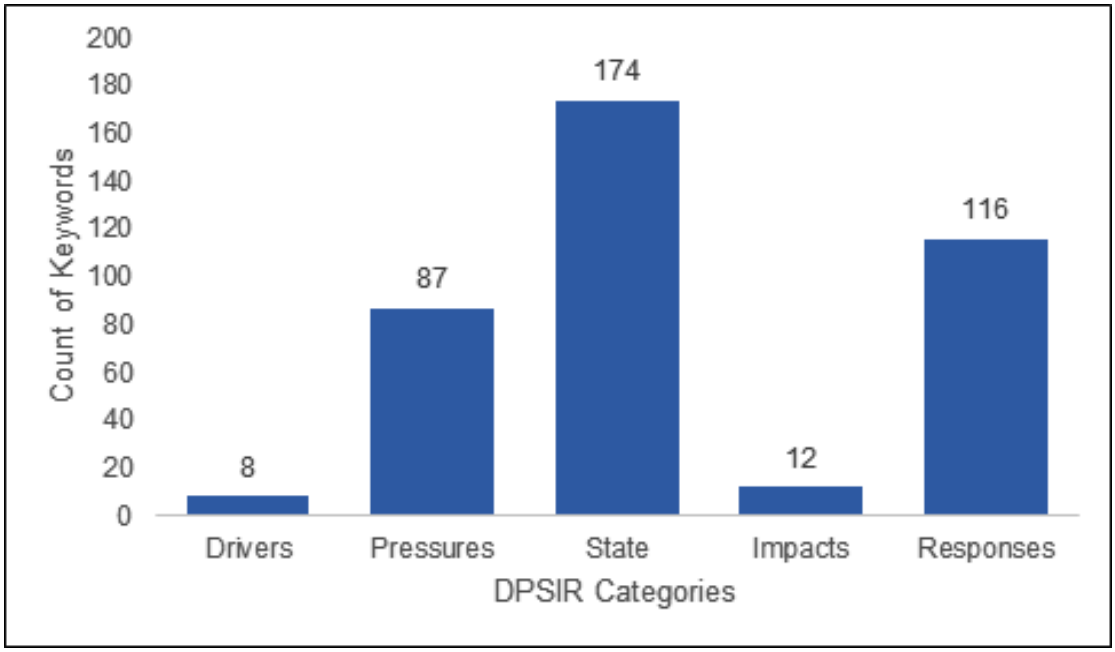

Figure (9) Keywords stratified by DPSIR categories (Source: The authors).

Scholars used research methods to investigate the State, Responses, and Impacts, Figure (10. There are 3,685 quotations grounded in the code Research Methods, of which 1,655 are jointly grounded in the code State. The co-occurrence coefficient is 0.18. Despite being low yet suggests that most researchers focus on investigating the state of an ecosystem. As the figure suggests, few researchers investigated Driving Forces and Pressures, including institutional framework, urban planning, and urban design.

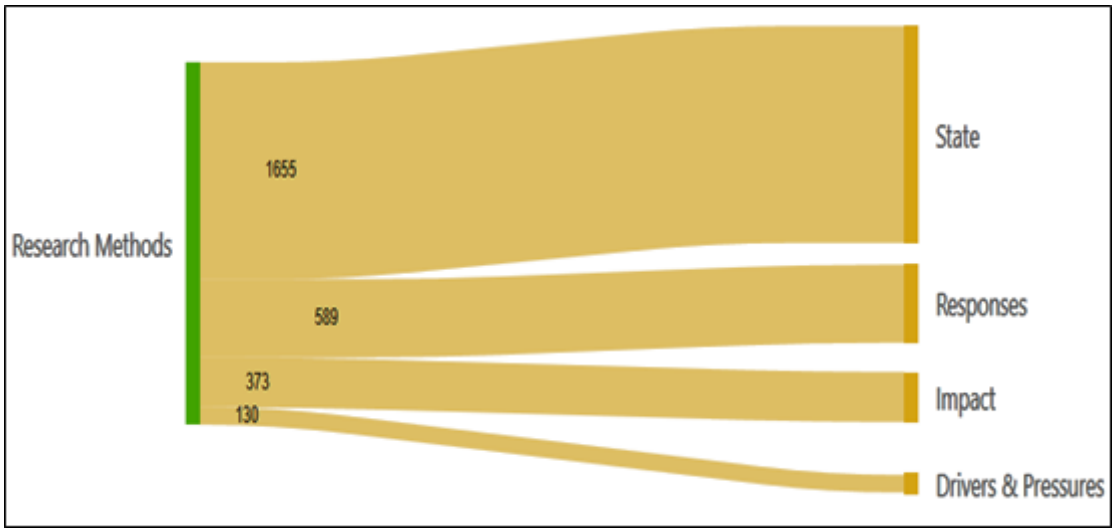

Figure (10) Research methods focus on State (Source: The authors)

In addition, applied research methods, such as remote sensing and citizen science, examine drivers and pressures, impact, and the state of an ecosystem. Based on inspecting the selected papers, Driving Forces and Pressures are the cause of the impacts and are associated with the state of an ecosystem, as Figure 11 depicts. Therefore, recommended responses address the Driving Forces and Pressures, impacts, and ecosystem state.

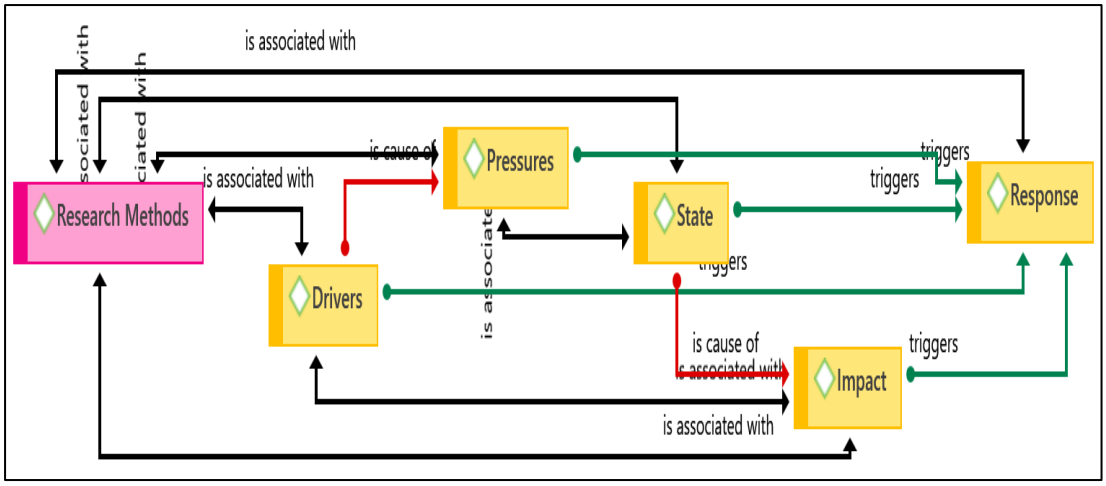

Figure (11) Conceptual model of relationships among interrogated research topics (Source: The authors)

Results from the co-occurrence analysis, Table (3, show that State has the highest number of grounded quotations reaching 7,273; Impacts come next with 4,339 grounded quotations. The result suggests a relationship between state and impact in the examined papers, where the joint count reached 2,233, and the c-coefficient was 0.24.

Table (3) Results of code co-occurrence analysis

		Drivers & Pressures Count GR=1,298	Impacts Count Gr=4,339	Research Methods Count Gr=3,685	Responses Count Gr=3,685	State Count Gr=7,273
Drivers & Pressures Gr=1,298	Count	0				
	Coefficient	0.00				
Impacts Gr=4,339	Count	199	0			
	Coefficient	0.04	0.00			
Research Methods Gr=3,685	Count	130	373	0		
	Coefficient	0.03	0.05	0.00		
Responses Gr=3,685	Count	156	404	589	0	
	Coefficient	0.04	0.06	0.10	0.00	
State Count Gr=7,273	Count	571	2,233	1,655	813	0
	Coefficient	0.07	0.24	0.18	0.09	0.00

(Source: The authors)

4.3 Publications on Bringing Nature Back

The results show three clusters of publications that dealt with issues regarding the urban environment and bringing nature back to the city using NbS, Table (4. The first cluster is climate change includes the keywords adaptation, climate change, global

warming, and greenhouse gases. These keywords address the drivers that affect the urban environment. Responses are the second cluster, consisting of the following keywords: development, land uses, urban, and urbanization. Finally, the last cluster of keywords is about the state of the urban environment represented by biodiversity, ecosystem services, and sustainability. The table suggests that climate change is the keyword with the highest total link strength in the 88 publications used in the analysis.

Table (4) Keywords in the literature on bringing nature back (Source: The authors)

Keywords	Occurrences	Total Link Strength
Cluster 1: State -- Environmental Science and Management		
biodiversity	3	1
ecosystem services	3	2
sustainability	3	1
Cluster 2: Drivers and Pressures -- Climate Change		
adaptation	3	3
climate change	11	6
global warming	3	3
greenhouse gases	3	2
Cluster 3: Response -- Urban design and planning		
development	3	2
land-use	3	3
urban	3	2
urbanization	7	3

(Source: The authors)

Figure (12 shows the network depicting the linkages among the three clusters and their keyword. The figure suggests that land use links climate change and urbanization. Urban transformations in both demographic and economic terms bring spatial changes that require demand for energy, which contributes to emitting GHGs, i.e., the cause of climate change and global warming.

Despite those three words that belong to the third cluster having similar occurrences, the keyword sustainability does not seem bold and clear in the figure as it was on the screen, indicating a lightweight. Located on the far-right side of the figure and with no linkages to the first cluster in red, there is little association between these two clusters in the examined literature without linkages.

Association between urbanization and sustainability attracted the attention of researchers in 2015. Figure 13 overlays the three clusters and the keywords spread between 2005-2020. The figure suggests that attention to linkages between urbanization and climate change started between 2010 and 2015. A quick review of the abstract of the 88 documents suggests that researchers focused on issues such as blue and green infrastructures as measures for mitigating drivers of climate change and adapting to its outcome. However, almost none of them paid attention to invasive species.

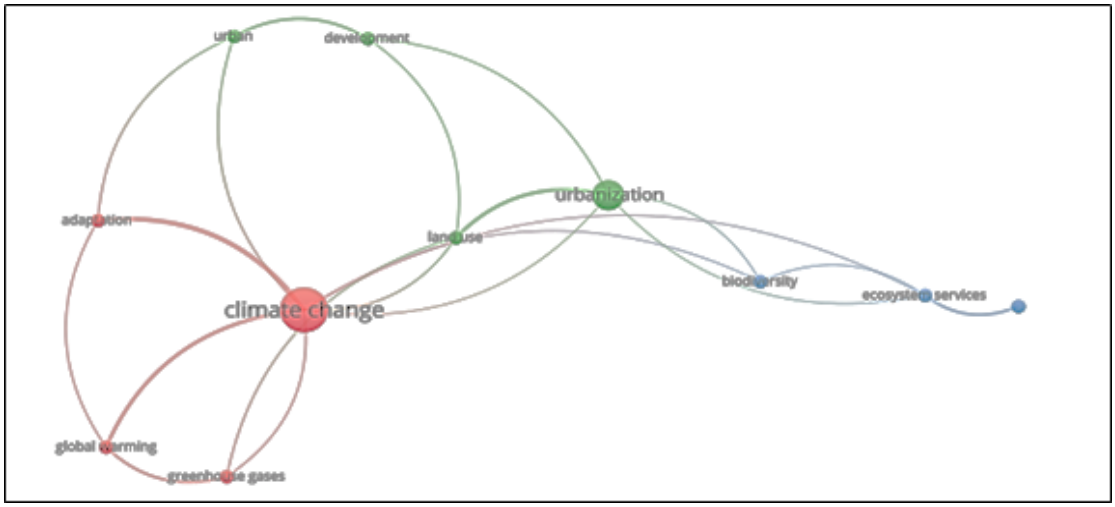

Figure (12) Network of keywords in the literature on bringing nature back (Source: The authors)

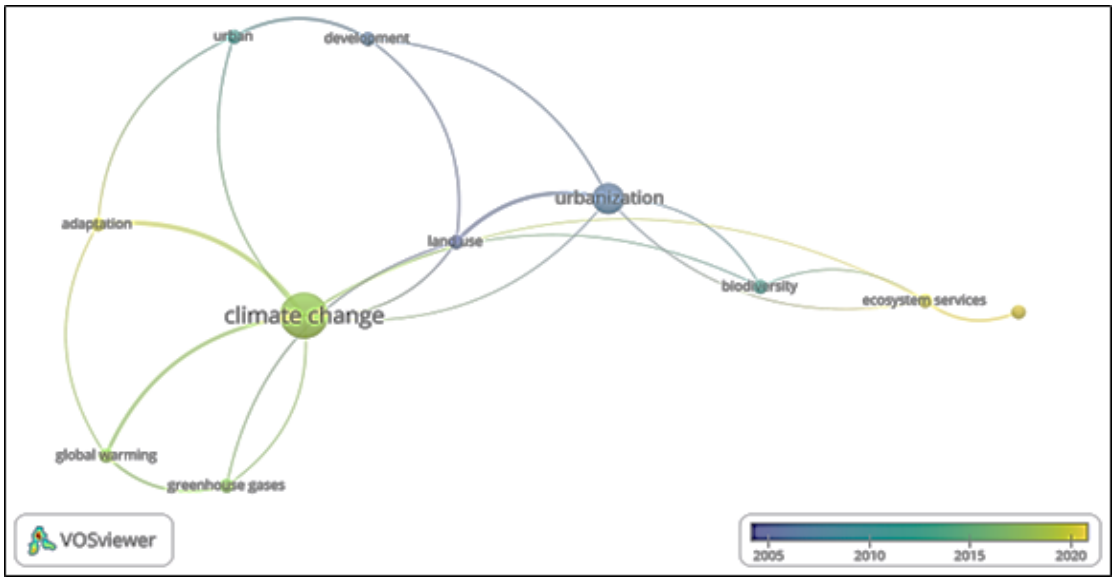

Figure (13) Overlay of keywords in the literature on bringing nature back (Source: The authors)

5 DISCUSSION

The city continues to be the reason for many environmental issues. As cities remain the driver of economic growth, they continue to pollute natural resources with all sorts of waste besides depleting them through exploitative use. The research interest of scholars who belong to humanities and social sciences include, but are not limited to, water resources (Bao & Fang, 2012; Chang et al., 2020; Rodriguez & Delpla, 2017). Urban air quality (Agarwal et al., 2020; Kerimray et al., 2020) is another area of research. Buccolieri et al. (2018) and Rasidi et al. (2012) discussed greening cities, and Sahar et al. (2018) examined waste-to-energy. Graells et al. (2021), Papatheochari & Coccossis (2019), and Keyvanfar et al. (2018) investigated coastal zone management.

Urbanization has severe impacts on ecosystems. Scholars who belong to life sciences argue that cities play a pivotal role in introducing and spreading invasive species (Hui, Richardson and Visser, 2017; Padayachee et al., 2017). Accordingly, some scholars proposed means for managing and controlling invasive species, such as

Gaertner et al. (2017). They offered a decision-making framework for controlling invasive species in urban environments in Cape Town.

Results suggest interest in NbS, EbA, landscape, and blue and green infrastructures as measures to mitigate the reasons for climate change and adapt to it. Without a constructive dialogue and mainstreaming of the issues of invasive species in the planning education and practices, the likelihood of biodiversity will continue and cause economic, social, and environmental losses. Accordingly, there is a need to develop design guidelines to assure the successful implementation of NbS and EbA initiatives without enabling the spread of invasive species.

Relationships between invasive species and the urban environment require attention. Our investigation shows a gap between scholars from life sciences and those who belong to the design profession responsible for developing the urban environment. Scholars from both groups must work together to understand the driving forces, pressures, and impacts and thus propose solutions regarding land-use planning, zoning, and urban design, among other things that could curb the proliferation of invasive species.

The results also suggest no universally adopted criterion for determining what constitutes an invasive species. Determining whether a species is invasive depends on its harm to the economy, humans' health, and the environment. Hence, a species might be invasive in one region but not in another.

Localizing the SDGs enables nations to attain SDG-specific targets (Budalamah et al., 2019). Target 15.8.[23] Unlike most SDG targets scheduled by 2030, Target 15.8 must be met by 2020. Only six of the Aichi objectives for 2020 have been partially met, according to a UN report released in September 2020. In the past decade, the world has failed to accomplish a single goal to halt the loss of animals and life-sustaining ecosystems (Greenfield, 2020). Planning and managing metropolitan areas are measures to limit the spread of invasive species and their impacts on the environment (Ritchie & Mispy, 2018). Without paying attention to the impacts of urbanization on biodiversity, there is no hope for protecting life-supporting ecosystems.

Meanwhile, because natural scientists, including urban ecologists, ignore critical human aspects in setting plans for protecting the environment, their schemes usually fail short of achieving their aims. Krauss (2022) wrote, "[t]here has been little critical social-science analysis of how SDG 15,[24] its targets and indicators understand conservation….The article argues that SDG 15, its targets and indicators thus perpetuate ideas of conservation which exacerbate inequalities and prevent transforming our world." Krauss affirms Parizi's argument mentioned earlier.

The analysis shows the need to generate information to support proper planning and management. Unfortunately, at the moment, the SDG-Tracker website lack any data for Target 15.8 indicator (Ritchie & Mispy, 2018). Lacking a precise criterion for defining what an invasive species is might be the reason for this situation. However, many developed countries, such as the USA and Western European countries, identified invasive species from their perspective. Then again, the problem is more complex in many developing nations, such as the case of the Arab region. Therefore, lacking a nationally determined definition of invasive species and the city's part in enabling the introduction and establishment of invasive species could have profound economic, environmental, social, and health implications.

Recent research indicates linkages between the outbreak of COVID-19 and invasive species. Changes in human behavior that the COVID-19 pandemic brought can have various implications on biodiversity, but nothing is known about how this would affect invasive alien species (IAS). Measures taken by society to combat the

spread of COVID-19 can have short- and long-term effects on IAS. Reduced human interference in natural ecosystems can boost IAS activity and speed up their spread in the short run. Furthermore, management agencies have lowered control actions, allowing IAS to thrive in some cases, and continuous monitoring systems have been disrupted, making detecting, and managing biological invaders more difficult. Because of the fear of zoonotic illnesses, long-term effects could include global changes to wildlife commerce, increasing releases of captive-bred species, and heightened public awareness of the risks of infections spreading among animal populations. Modifying IAS management during and after lockdowns requires long-term data collecting and sharing (Lo Parrino et al., 2021).

6 CONCLUSION

Urbanization continues to be the reason for many environmental challenges. Cities remain to be the engine of economic expansion. However, they also continue to harm the environment with various types of waste and pollution and deplete natural resources via unsustainable use.

An integrated, holistic understanding of the necessity of addressing the issue of invasive species in urban settlements is required for design professionals. It is a situation that poses hazards that are likely to be comparable to those posed by climate change.

The available literature on invasive species and the planning of built-up environments is minimal. Cities are critical in introducing and spreading invasive species. Some academics offered a decision-making framework for controlling invasive species in urban environments to manage and control invasive species. This proposal is at the heart of urban planning and management. However, how would urban planners, landscape architects, and other design professionals mainstream such proposals if they do not acknowledge the issue?

Recently, many scholars and practitioners called for bringing nature back to the city. It is a plea that rests on the concept of Nature-based Solutions. They aim to mitigate the causes of climate change and adapt to its adverse impacts. However, NbS should also be sensitive to the issue of introducing invasive species through blue and green infrastructures.

Planners must plan cities to minimize the adverse impacts of urbanization while maximizing ecological activities by enabling conservation action within urban landscapes. Pursuing conservation outcomes for species whose global distribution that a human-modified landscape contains is most pronounced through green infrastructure, thus transforming urban areas into more wildlife-friendly environments. Many policies are concerned with community benefits and mitigating the adverse effects of urban development. Urban greening policies are critical for revitalizing communities, lowering healthcare costs, and improving quality of life.

One of the challenges of addressing the issue of invasive species in the urban environment is lacking a criterion for deciding whether a species is invasive. The impact of a species on the economy, human health, and the environment determines if it is invasive. As a result, a species may be invasive in one area but not another.

Design professionals responsible for designing and managing a human settlement use their technical knowledge in analytical activities to elaborate schemes to ensure their city’s sustainability. One of the sources of this technical knowledge is understanding urban ecology, as it encourages the coexistence of humans and wildlife in urban spaces that are resilient and sustainable. When properly integrated, urban

ecology can support reducing air and water pollution while enabling city residents' food production, transportation, and housing. We recommend including an urban ecologist in the planning team and considering the urban ecology issues when conducting environmental impact assessments when reviewing new urban developments before construction.

ENDNOTES

[1] These are gases in the atmosphere that affect the energy balance of the planet. They are responsible for the so-called greenhouse effect. Carbon dioxide (CO_2), methane, and nitrous oxide, the most well-known greenhouse gases, can all be present in low concentrations in the environment.
[2] Ecosystem-based adaptation refers to a variety of climate change adaptation strategies. They all entail the management of ecosystems and their services to lessen human communities' vulnerability to the effects of climate change.
[3] Roads, sewerage, and other urban structures are known as grey infrastructure.
[4] Trees, lawns, hedgerows, parks, fields, and woods are examples of green infrastructure. Rivers, canals, ponds, wetlands, floodplains, and water treatment facilities are examples of blue infrastructure.
[5] The number of species in a community.
[6] The total mass of living material measured over a specific area is known as biomass.
[7] The number of individuals per species.
[8] An invasive species is a newly introduced organism that overpopulates and negatively impacts its new environment.
[9] The first UN Conference on environment held in Stockholm, Sweden in 1972.
[10] A global partnership fighting urban poverty and supporting cities to deliver sustainable development
[11] Civil engineers, landscape architects, urban designers, architects, and urban planners
[12] According to World Population Review, a medium city has a population of 100,000 to 300,000 people and offers a wide range of services, but not all.
[13] CityAdapt is a Global Environment Facility and UN Environment joint project. It provides tools to help local governments plan for climate change adaptation while also reducing greenhouse gas emissions from their cities by maintaining their ecosystems.
[14] It is a graphical layout or a diagrammatic depiction of the research issue. It enables researchers to identify and organize the vast number of arguments in the context of their studies.
[15] Alien species are known in Arabic as الدخيلة while invasive are called الغازية
[16] Scopus is an abstract and citation database created by Elsevier in 2004. Scopus has roughly 36,377 titles from 11,678 publishers, including 34,346 peer-reviewed journals in the top-level topic fields of biological sciences, social sciences, physical sciences, and health sciences.
[17] An RIS file is a bibliographic citation made up of a sequence of lines separated by two-character codes and a value.
[18] A free web and desktop reference management solution that allows them to store, organize, and search all of references in one place.
[19] Cluster Analysis in Data Mining refers to the process of identifying a group of objects that are like one another but distinct from those in other groups.
[20] The c-coefficient is a number that varies from 0 to 1. When the coefficient is zero, there is complete independence between the two codes; when it equals one, there is perfect linkage.
[21] These are graphical visualization of qualitative data, such as open-ended response, documents, and the like. Word clouds enable researchers to figure out what the common subjects are across the interrogated data by enlarging the most used words.
[22] Elsevier, the owner of Scopus and ScienceDirect, is a legitimate publisher. The boycotts and unfavorable reviews are due to company's reported excessive costs, not the quality of the publication.
[23] It states that "by 2020, countries must implement steps to prevent the introduction of invasive alien species and considerably minimize their impact on land and aquatic ecosystems, and control or destroy priority species".
[24] SDG 15 is about "Life on land."

ACKNOWLEDGMENTS

We acknowledge the comments from three anonymous reviewers on the submitted and revised draft of the manuscript. We extend our thanks to Prof. Tarek Wafeeq, Prof.

Ahmed M. Yousry, Prof. Ashraf M. Salama, and Dr. Ghada Yassein for their thoughts, discussions, and comments on an early draft of the paper. The research did not receive any financial support.

REFERENCES

Agarwal, A., Kaushik, A., Kumar, S., & Mishra, R. K. (2020). Comparative study on air quality status in Indian and Chinese cities before and during the COVID-19 lockdown period. *Air Quality, Atmosphere and Health*, *13*(10), 1167–1178. https://doi.org/10.1007/s11869-020-00881-z

Al Blooshi, L. S., Ksiksi, T. S., Nassar, A., & Abuelgasim, A. (2018). The impact of desert urbanization on land surface temperature in the United Arab Emirates (UAE). *Proceedings - 39th Asian Conference on Remote Sensing: Remote Sensing Enabling Prosperity, ACRS 2018*, *1*, 480–491. https://www2.scopus.com/inward/record.uri?eid=2-s2.0-85071891035&partnerID=40&md5=b0b8289c4d00c19be4765a5f8dd6421f

Apostolopoulou, E. (2020). *Nature swapped and nature lost: Biodiversity offsetting, urbanization and social justice*. Springer Nature.

Bansal, V., Jagadisan, S., & Sen, J. (2022). Water Urbanism and Multifunctional Landscapes. In R. Bhadouria, S. Upadhyay, S. Tripathi, & P. Singh (Eds.), *Urban Ecology and Global Climate Change* (pp. 85–103). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781119807216.CH5

Bao, C., & Fang, C. lin. (2012). Water Resources Flows Related to Urbanization in China: Challenges and Perspectives for Water Management and Urban Development. *Water Resources Management*, *26*(2), 531–552. https://doi.org/10.1007/s11269-011-9930-y

Bar-Massada, A., Radeloff, V. C., & Stewart, S. I. (2014). Biotic and abiotic effects of human settlements in the wildland-urban interface. *BioScience* 64(5), pp. 429–437). https://doi.org/10.1093/biosci/biu039

Barakat, H. A.-E.-R., Bakr, A., & El-Sayad, Z. (2019). Nature as a healer for autistic children. *Alexandria Engineering Journal*, *58*(1), 353–366. https://doi.org/https://doi.org/10.1016/j.aej.2018.10.014

Bastin, J. F., Clark, E., Elliott, T., Hart, S., van den Hoogen, J., Hordijki, I., Ma, H., Majumder, S., Manoli, G., Maschler, J., Mo, L., Routh, D., Yu, K., Zohner, C. M., & Crowther, T. W. (2019). Understanding climate change from a global analysis of city analogues. *PLOS ONE*, *14*(7), e0217592. https://doi.org/10.1371/JOURNAL.PONE.0217592

Berlingieri, F. (2015). *International Maritime Conventions* (Volume 3): Protection of the Marine Environment (1st ed.). Informa Law from Routledge. https://doi.org/10.4324/9781315778297

Blekking, J., Giroux, S., Waldman, K., Battersby, J., Tuholske, C., Robeson, S. M., & Siame, G. (2022). The impacts of climate change and urbanization on food retailers in urban sub-Saharan Africa. *Current Opinion in Environmental Sustainability*, *55*, 101169. https://doi.org/10.1016/J.COSUST.2022.101169

Blodgett, G. (1976). Frederick Law Olmsted: Landscape architecture as conservative reform. *Journal of American History*, *62*(4), 869–889. https://doi.org/10.2307/1903842

Budalamah, L. H., El-Kholei, A. O., & Al-Jayoussi, O. R. (2019). Harnessing value-based financing for achieving SDGs: Social innovation model for Arab municipalities. *Arab Gulf Journal of Scientific Research*, *37*(3), 1–19. https://doi.org/10.51758/AGJSR-03-2019-0009

Carson, R. (1962). *Silent Spring*. Houghton Mifflin.

Chang, I. S., Zhao, M., Chen, Y., Guo, X., Zhu, Y., Wu, J., & Yuan, T. (2020). Evaluation on the integrated water resources management in China's major cities -- Based on City Blueprint® Approach. *Journal of Cleaner Production*, *262*, 121410. https://doi.org/10.1016/j.jclepro.2020.121410

Chien, F., Hsu, C. C., Ozturk, I., Sharif, A., & Sadiq, M. (2022). The role of renewable energy and urbanization towards greenhouse gas emission in top Asian countries: Evidence from advance panel estimations. *Renewable Energy*, *186*, 207–216. https://doi.org/10.1016/J.RENENE.2021.12.118

Cities Alliance. (2016). *City Development Strategy*. An Online Toolkit for How to Plan and Implement a City Development Strategy. https://city-development.org/

CityAdapt. (2017). *Policy Brief: Urban Ecosystem-based Adaptation in Asia-Pacific*. UNEP

CityAdapt. (2021). *What is CityAdapt?* CityAdapt. https://cityadapt.com/en/cityadapt/what-is-cityadapt/

Dehnen-Schmutz, K. (2011). Determining non-invasiveness in ornamental plants to build green lists. *Journal of Applied Ecology*, *48*(6), 1374–1380. https://doi.org/10.1111/j.1365-2664.2011.02061.x

Dodman, D., McGranaham, G., & Dalal-Clayton, B. (2013). *Integrating the Environment in Urban Planning and Management*. United Nations Environment Programme. https://stg-wedocs.unep.org/handle/20.500.11822/8540

Elder, A. D., & Gerlak, A. K. (2019). Interrogating rainwater harvesting as Do-It-Yourself (DIY) Urbanism. *Geoforum*, *104*, 46–54. https://doi.org/10.1016/J.GEOFORUM.2019.06.007

European Environment Agency. (1995). Europe's Environment - The Dobris Assessment. In *Europe's Environment-The Dobris Assessment*. https://www.eea.europa.eu/publications/92-826-5409-5

Faivre, N., Fritz, M., Freitas, T., de Boissezon, B., & Vandewoestijne, S. (2017). Nature-Based Solutions in the EU: Innovating with nature to address social, economic and environmental challenges. *Environmental Research*, *159*, 509–518. https://doi.org/10.1016/J.ENVRES.2017.08.032

Friese, S. (2019). *Qualitative data analysis with ATLAS.ti* (Third Edit). SAGE.

Gaertner, M., Novoa, A., Fried, J., & Richardson, D. M. (2017). Managing invasive species in cities: a decision support framework applied to Cape Town. *Biological Invasions*, *19*(12), 3707–3723. https://doi.org/10.1007/s10530-017-1587-x

Gaertner, M., Wilson, J. R. U., Cadotte, M. W., MacIvor, J. S., Zenni, R. D., & Richardson, D. M. (2017). Non-native species in urban environments: patterns, processes, impacts and challenges. *Biological Invasions*, *19*(12), 3461–3469. https://doi.org/10.1007/s10530-017-1598-7

Gao, Z., Song, K., Pan, Y., Malkinson, D., Zhang, X., Jia, B., Xia, T., Guo, X., Liang, H., Huang, S., Da, L., Van Bodegom, P. M., & Cieraad, E. (2021). Drivers of spontaneous plant richness patterns in urban green space within a biodiversity hotspot. *Urban Forestry and Urban Greening*, *61*. https://doi.org/10.1016/j.ufug.2021.127098

Gavier-Pizarro, G. I., Radeloff, V. C., Stewart, S. I., Huebner, C. D., & Keuler, N. S. (2010). Housing is positively associated with invasive exotic plant species richness in New England, USA. *Ecological Applications*, *20*(7), 1913–1925. https://doi.org/10.1890/09-2168.1

Giddings, B., Porter, G., Paterson, E., & Theobald, K. (2010). Participation in sustainability appraisal planning policy. In *Proceedings of the Institution of Civil Engineers - Municipal Engineer* 163(2), 115–123. https://doi.org/10.1680/muen.2010.163.2.115

Hansen, A. J., Knight, R. L., Marzluff, J. M., Powell, S., Brown, K., Gude, P. H., & Jones, K. (2005). Effects of exurban development on biodiversity: Patterns, mechanisms, and research needs. In *Ecological Applications* 15(6), 1893–1905. https://doi.org/10.1890/05-5221

Haughton, G. (1997). Developing sustainable urban development models. *Cities*, *14*(4), 189–195. https://doi.org/10.1016/S0264-2751(97)00002-4

Haughton, G., & Hunter, C. (1996). *Sustainable Cities*. Regional Studies Association. https://doi.org/10.1007/s13762-013-0491-x

Howard, E. (1902). *Garden Cities of To-morrow* (F. J. Osborn (ed.); 2nd ed.). Swan Sonnenschein & Co.

Jäger, J., Arreola, M. E., Chenje, M., Pintér, L., & Raibhandari, P. (2008). *IEA Training Manual, A training manual on integrated environmental assessment and reporting, Training Module 1, The GEO approach to integrated environmental assessment.* United Nations Environment Programme (UNEP) and International Institute for Sustainable Development (IISD). https://www.unep.org/resources/report/training-manual-integrated-environmental-assessment-and-reporting-training-module

Kaykhosravi, S., Khan, U. T., & Jadidi, M. A. (2020). The effect of climate change and urbanization on the demand for low impact development for three Canadian cities. *Water (Switzerland)*, *12*(5), 1–23. https://doi.org/10.3390/W12051280

Kerimray, A., Baimatova, N., Ibragimova, O. P., Bukenov, B., Kenessov, B., Plotitsyn, P., & Karaca, F. (2020). Assessing air quality changes in large cities during COVID-19 lockdowns: The impacts of traffic-free urban conditions in Almaty, Kazakhstan. *Science of the Total Environment*, *730*, 139179. https://doi.org/10.1016/j.scitotenv.2020.139179

Krauss, J. E. (2022). Unpacking SDG 15, its targets and indicators: tracing ideas of conservation. *Globalization*, 1–16. https://doi.org/10.1080/14747731.2022.2035480

Kühn, I., & Klotz, S. (2006). Urbanization and homogenization - Comparing the floras of urban and rural areas in Germany. *Biological Conservation*, *127*(3), 292–300. https://doi.org/10.1016/j.biocon.2005.06.033

Kuhn, T. S. (1970). *The structure of scientific revolutions* (2nd ed.). Chicago: University of Chicago Press. ISBN: 0-226-45803-2

Kumar, J. P. P. J., Ragumaran, S., Nandagopal, G., Ravichandran, V., Mallavarapu, R. M., & Missimer, T. M. (2021). Green method of stemming the tide of invasive marine and freshwater organisms by natural filtration of shipping ballast water. *Environmental Science and Pollution Research*, *28*(5), 5116–5125. https://doi.org/10.1007/s11356-020-10839-4

Lawson, G., Guaralda, M., & Nguyen, P. N. (2021). Water urbanism and "living with flooding": a case study in the Mekong Delta, Vietnam. *Housing and Society*, *49*(2), 150–186. https://doi.org/10.1080/08882746.2021.1978041

Le Louarn, M., Clergeau, P., Strubbe, D., & Deschamps-Cottin, M. (2018). Dynamic species distribution models reveal spatiotemporal habitat shifts in native range-expanding versus non-native invasive birds in an urban area. *Journal of Avian Biology*, *49*(4), jav-01527. https://doi.org/10.1111/jav.01527

Liu, H., Ma, W., Qian, J., Cai, J., Ye, X., Li, J., & Wang, X. (2015). Effect of urbanization on the urban meteorology and air pollution in Hangzhou. *Journal of Meteorological Research*, *29*(6), 950–965. https://doi.org/10.1007/s13351-015-5013-y.

Lo Parrino, E., Falaschi, M., Manenti, R., & Ficetola, G. F. (2021). Lockdown policy effects on invasive species: a perspective. *Biodiversity*, 122(1-2), 35–40.

Majumder, P., Majumder, M., & Saha, A. K. (2018). Climate Change and Urbanization Impact on Hydropower Plant by Neural Network-Based Decision-Making Methods: Identification of the Most Significant Parameter. *Water Conservation Science and Engineering 2018*, *3*(3), 169–179. https://doi.org/10.1007/S41101-018-0048-4

Marcus, C. C., & Barnes, M. (1999). *Healing gardens: Therapeutic benefits and design recommendations*. John Wiley & Sons.

Mata, L., Ramalho, C. E., Kennedy, J., Parris, K. M., Valentine, L., Miller, M., Bekessy, S., Hurley, S., & Cumpston, Z. (2020). Bringing nature back into cities. *People and Nature*, *2*(2), 350–368. https://doi.org/10.1002/pan3.10088

McIntosh, A., & Pontius, J. (2017). Human Impacts on the Global Landscape. In A. McIntosh & J. B. T.-S. and the G. E. Pontius (Eds.), *Science and the Global Environment* (pp. 361–470). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-12-801712-8.00004-4

McKinney, M. L. (2006). Urbanization as a major cause of biotic homogenization. *Biological Conservation*, *127*(3), 247–260. https://doi.org/10.1016/j.biocon.2005.09.005

Mehraj, G., Khuroo, A. A., Hamid, M., Muzafar, I., Rashid, I., & Malik, A. H. (2021). Floristic diversity and correlates of naturalization of alien flora in urban green spaces of Srinagar city. *Urban Ecosystems*. 24, 1231–1244

Naghavi, M., Wang, H., Lozano, R., Davis, A., Liang, X., Zhou, M., Vollset, S. E., Abbasoglu Ozgoren, A., Abdalla, S., Abd-Allah, F., Abdel Aziz, M. I., Abera, S. F., Aboyans, V., Abraham, B., Abraham, J. P., Abuabara, K. E., Abubakar, I., Abu-Raddad, L. J., Abu-Rmeileh, N. M. E., … Temesgen, A. M. (2015). Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990-2013: A systematic analysis for the Global Burden of Disease Study 2013. *The Lancet*, *385*(9963), 117–171. https://doi.org/10.1016/S0140-6736(14)61682-2

Nwakaire, C. M., Onn, C. C., Yap, S. P., Yuen, C. W., & Onodagu, P. D. (2020). Urban Heat Island Studies with emphasis on urban pavements: A review. *Sustainable Cities and Society*, *63*, 102476. https://doi.org/https://doi.org/10.1016/j.scs.2020.102476

Oertli, B., Boissezon, A., Rosset, V., & Ilg, C. (2018). Alien aquatic plants in wetlands of a large

European city (Geneva, Switzerland): from diagnosis to risk assessment. *Urban Ecosystems*, *21*(2), 245–261. https://doi.org/10.1007/s11252-017-0719-5

Palomo, I., Martín-López, B., Potschin, M., Haines-Young, R., & Montes, C. (2013). National Parks, buffer zones and surrounding lands: Mapping ecosystem service flows. *Ecosystem Services*, *4*, 104–116. https://doi.org/10.1016/j.ecoser.2012.09.001

Parizi, A. (n.d.). SDG 6 Clean Water and Sanitation. In M. C. A. de Medina (Ed.), *A Landscape Architecture Guide to the 17 Sustainable Development Goals*. International Federation of Landscape Architects (IFLA).

Ritchie, R., & Mispy, O.-O. (2018). *Goal 15: Life on Land - SDG Tracker*. Measuring Progress towards the Sustainable Development Goals. https://sdg-tracker.org/biodiversity

Rodriguez, M., & Delpla, I. (2017). Climate Changes and Drinking Water in Sustainable Cities: Impacts and Adaptation. *WIT Transactions on Ecology and the Environment*, *223*, 573–582. https://doi.org/10.2495/SC170501

Santana Marques, P., Resende Manna, L., Clara Frauendorf, T., Zandonà, E., Mazzoni, R., & El-Sabaawi, R. (2020). Urbanization can increase the invasive potential of alien species. *Journal of Animal Ecology*, *89*(10), 2345–2355. https://doi.org/10.1111/1365-2656.13293

Santiago-Alarcon, D., & MacGregor-Fors, I. (2020). Cities and pandemics: Urban areas are ground zero for the transmission of emerging human infectious diseases. *Journal of Urban Ecology*, *6*(1), 1–3. https://doi.org/10.1093/jue/juaa012

Seidel, J. V. (1998). Qualitative Data Analysis. In *The Ethnography : A User's Guide*. Qualis Research. www.qualisresearch.com

Shiferaw, H., Bewket, W., Alamirew, T., Zeleke, G., Teketay, D., Bekele, K., Schaffner, U., & Eckert, S. (2019). Implications of land use/land cover dynamics and Prosopis invasion on ecosystem service values in Afar Region, Ethiopia. *Science of The Total Environment*, *675*, 354–366. https://doi.org/10.1016/J.SCITOTENV.2019.04.220

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., De Vries, W., De Wit, C. A., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B., & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223), 736–748. https://doi.org/10.1126/science.1259855

Tavares, R. (2016). *Forget Nations: Cities Will Transform the Way We Conduct Foreign Affairs*. World Economic Forum | Cities and Urbanization. https://www.weforum.org/agenda/2016/10/forget-the-nation-state-cities-will-transform-the-way-we-conduct-foreign-affairs

Tolba, M. K., & El-Kholy, O. A. (1992). *The World Environment 1972-1992: Two Decades of Challenge*. United Nations Environment Programme.

UN-HABITAT. (n.d.). *Sustainable Cities and Localizing Agenda 21 Programmes*. Sustainable Cities Programme. Retrieved December 22, 2021, from https://mirror.unhabitat.org/content.asp?typeid=19&catid=540&cid=5025

UN-HABITAT. (2011). *Hot Cities: battle-ground for Climate Change*. www.unhabitat.org

UNEP. (2014). *Building climate resilience of urban systems through Ecosystem-based Adaptation (EbA) in Latin America and the Caribbean*.

UNODC. (2016). *World Wildlife Crime Report Trafficking in protected species*. https://www.unodc.org/images/data-and-analysis/Wildlife/World_Wildlife_Crime_Report_2016_final.pdf

van Eck, N. J., & Waltman, L. (2020). VOSviewer manual. In *VOSviewer manual* (Issue November). Centre for Science and Technology Studies, Leiden University. http://www.vosviewer.com/documentation/Manual_VOSviewer_1.6.1.pdf

World Bank. (2021). *World Development Indicators 2020*. DataBank. https://databank.worldbank.org/source/world-development-indicators

World Bank. (2019). Illegal Logging, Fishing, and Wildlife Trade : The Costs and How to Combat it. World Bank, Washington, DC. http://hdl.handle.net/10986/32806

World Bank. (2010). Cities and Climate Change : An Urgent Agenda. Urban development series;

knowledge papers no. 10. Washington, DC. http://hdl.handle.net/10986/17381

Wu, J. (2014). Urban ecology and sustainability: The state-of-the-science and future directions. *Landscape and Urban Planning*, *125*, 209–221. https://doi.org/10.1016/j.landurbplan.2014.01.018

Yigitcanlar, T., & Teriman, S. (2015). Rethinking sustainable urban development: towards an integrated planning and development process. *International Journal of Environmental Science and Technology*, *12*(1), 341–352. https://doi.org/10.1007/s13762-013-0491-x

Zaninotto, V., & Dajoz, I. (2022). Keeping Up with Insect Pollinators in Paris. *Animals*, *12*, 1–13. https://doi.org/https://doi.org/10.3390/ani12070923

Zhang, J., Liu, M., & Bi, J. (2022). Urban greenhouse gas emission peaking paths and embedded health co-benefits: A multicases comparison study in China. *Applied Energy*, *311*, 118740. https://doi.org/10.1016/J.APENERGY.2022.118740

Zhou, X., & Chen, H. (2018). Impact of urbanization-related land use land cover changes and urban morphology changes on the urban heat island phenomenon. *Science of The Total Environment*, *635*, 1467–1476. https://doi.org/10.1016/J.SCITOTENV.2018.04.091