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Urban biodiversity conservation a basic concept of sustainable urbanism: a systematic review.

La conservación de la biodiversidad urbana un concepto básico del urbanismo sostenible: una revisión sistemática.

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ABSTRACT

Delhi is a highly urbanized city in India. The rapid increase in population and unplanned development of infrastructure within the built-up environment is continuously damaging the urban and peri-urban green spaces of Delhi. Our modern indoor bound lifestyle is distancing us from the natural world. Through this paper, we have tried to review the possible contributions of both blue and green infrastructure on the urban environment and also on the wellbeing of the urban dweller. In continuation, this review article provides an interdisciplinary overview of the scientifically grounded knowledge on urban biodiversity and conservation, how it benefits urban ecosystems through their services, and finally integration of urban biodiversity into urban planning. At the outcome, knowledge gaps and opportunities for future research under the theme "Green Urbanism" has been critically reviewed.

Key words: Conservation, Ecosystem services, Human health, Urban Biodiversity, Urban green.

RESUMEN

Delhi es una ciudad muy urbanizada de la India. El rápido aumento de la población y el desarrollo no planificado de infraestructura dentro del entorno edificado está dañando continuamente los espacios verdes urbanos y periurbanos de Delhi. Nuestro estilo de vida moderno en interiores nos está distanciando del mundo natural. A través de este trabajo, hemos tratado de revisar las posibles contribuciones de la infraestructura azul y verde sobre el

entorno urbano y también sobre el bienestar del habitante urbano. A continuación, este artículo de revisión proporciona una visión general interdisciplinaria del conocimiento con base científica sobre la biodiversidad urbana y la conservación, cómo beneficia a los ecosistemas urbanos a través de sus servicios y, finalmente, la integración de la biodiversidad urbana en la planificación urbana. Como resultado, se revisaron críticamente las brechas de conocimiento y las oportunidades para futuras investigaciones bajo el tema "Urbanismo verde".

Palabras clave: Conservación, Servicios ecosistémicos, Salud humana, Biodiversidad urbana, Verde urbano.

INTRODUCTION

Nature has been our home and part of our lives since ancient times. Our modern lifestyle has already separated us from the natural world, Over 50% of the world population is already living in urban setups and it is predicted by the United Nations (2018) that this proportion will reach up to 66 % by 2050. Worldwide urbanization happens at the cost of the global loss of biodiversity (Hoornweg et al. 2016) and causes significant transformations in the functioning of a global ecosystem (McPherson et al. 2016). Few decades of our modern lifestyle is like a blink of an eye if we compare it with the over 2 million years of human existence.

In present-day cities are also attracting a lot of wildlife from the surrounding natural habitat and several times we have also witnessed it. Worldwide there are large numbers of examples where wild animals have been adapted to urban setups, for example, a large number of peregrine falcons nesting in skyscrapers of Manhattan, the number of fruit bats choose to roost in the trees of the Colombian city, or the incredible leopards of Mumbai (Ossola & Niemela 2017). The innumerable wild species of birds, smaller mammals, amphibians, reptiles, astonishing butterflies, and other insects who have made cities as their homes, ultimately create a semi-wild habitat where human and wildlife coexist together and thus this system makes an excellent open-air educational laboratory on the environment. For a long, specifically in developing countries, overpopulation has caused numerous species (flora and fauna) to go extinct as a result of habitat and the whole ecosystem being altered, degraded, or ultimately destroyed. Even peri-urban areas and agricultural fields were also not spared and are progressively cleaned to build new settlements within these urban complex networks.

This paper aims to integrate the literature on the core concepts of Urban agglomeration, Urban Biodiversity, Green infrastructure, and cost of urban health i.e, well being of urban dwellers. For that, we have done a critical review of the available literature from the past 10 years on urban biodiversity in association with the environment and human well-being. This

literature will not only help in developing a clear concept of the new urbanism but also open a window for future research opportunities in the field of urban biodiversity.

MATERIALS AND METHODS

A systematic review of the journal database was undertaken. Electronic databases were restricted to PubMed, Web of Science, Google Scholar, and Scopus. In the present review article, peer-reviewed publications only in the English language were selected. Using the keywords of Urban Biodiversity, Green infrastructure, Urban greening, Ecosystem health, and public health, the relevant articles from the random journals were tagged and classified. After that articles were critically evaluated by conducting a strength and weakness analysis of the design and interpretation of the study. A total of 774 articles were found on a global scale, out of which 13 studies satisfied the inclusion criteria, the rest of the studies were excluded for their non-relevance with the topic (Fig. 1). Publications only in the English language were included in this study.

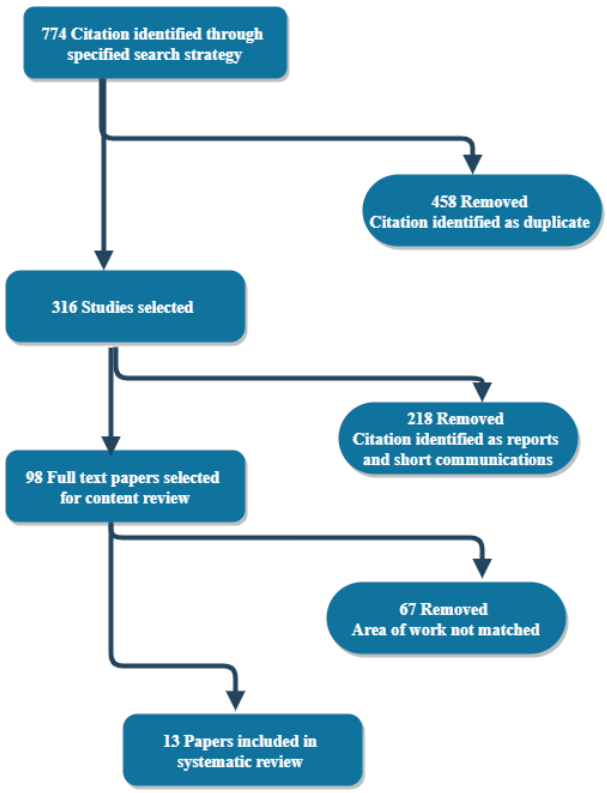

Figure 1. Algorithm for study selection in review manuscript.

Since the first Convention on Biological Diversity (CBD) held in Rio de Janeiro, Brazil in 1992, the research on urban biodiversity in academic publications has experienced exponential growth (Fig. 2).

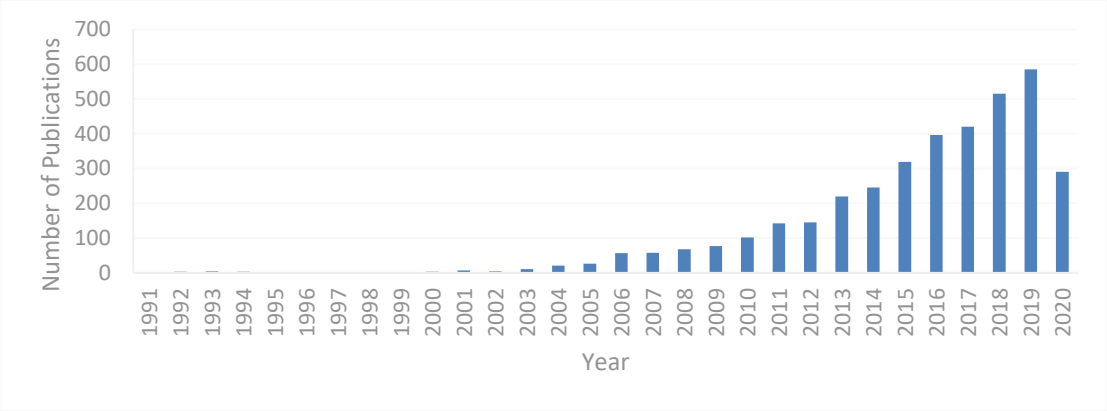

Figure 2. Number of academic publications published globally having in their title, abstract or keywords the terms *urban biodiversity* as censed in the Scopus database (on 20 July 2020 (www.scopus.com).

Glossary of used definitions are given below:

Biodiversity: Biodiversity includes species, genetic, and ecosystem diversity. (Convention on Biological Diversity, www.cbd.int/convention, accessed May 2020; Hammen & Settele 2011).

Urban Biodiversity: Urban biodiversity or Urban biological Diversity is a complex amalgamation of rich varieties of Urban species, Ecosystems, and habitats. It is an ecological term that is frequently and interchangeably used with urban green space and urban green infrastructure (Muller et al. 2013).

Urban Green infrastructure: A strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services (EC 2013). Hence, urban green infrastructure describes planned urban green areas as well as blue urban subsystems (coastal zones, rivers, and standing water) interrelated with their rural counterparts and with the urban grey infrastructure (built-up areas) for example urban forests, urban parks, vegetable gardens, etc.

Ecosystem services: The ecosystem service approach was introduced as a trans-disciplinary framework to describe the contribution of ecosystems for human well-being (TEEB 2010). Urban ecosystem services can be defined as the benefits humans derive from urban green infrastructure and other unplanned green and blue spaces in cities.

Ecosystem Disservices: These are the negative effects of urban ecosystems on human well being (Lyytimaki & Sipila 2009), including both external biophysical impacts on humans and negative psychological experiences inherent to human relations with the biosphere, as well as negative effects on the human society or parts of it.

Green care: It is the enhancement of green infrastructure of cities which can indirectly facilitate innovative nature-based health solutions, in other words, care of people using green infrastructure.

RESULT AND DISCUSSION

Urban Biodiversity and Ecosystem services: The concept of the linkage between urban biodiversity and human beings is slowly getting hidden due to the unplanned development of urban markets, transport networks, new industries, continuously increasing urban agglomeration, and sprawling building development projects (Gomez-Baggethun & de Groot, 2010). The increasing disconnection between people and the ecosystem has resulted in the loss of awareness about human dependency on ecosystems which was referred to by Miller (2005) as the *extinction of experience*.

However recent research works showed that humans appear to be losing direct interaction with biodiversity and natural ecosystems. But instead of decoupling from the natural ecosystems, humans are becoming more dependent on them and their natural capital (Wiedmann et al. 2015) and as a result, actual demands for ecosystem services are increasing at a steady rate (Guo et al. 2010, Gomez-Baggethun et al. 2013). For example, urban consumers are estimated to account for 60% of global water use (Grimm et al. 2008) and major cities are responsible for 60-70% of the world's anthropogenic greenhouse gas emissions (McGranahan & Satterthwaite 2014). Urban inhabitants produce about 6 million tons of waste per day, which accounts for two to four times the amount of waste produced by their rural counterparts (Hoornweg & Bhada-Tata 2012).

Many cities are embedded with high biodiversity both at the species or ecosystem level (CBD 2012). We all know from ancient times that the cities were developed in biodiversity-rich areas, such as near riverfronts or near the sea to facilitate transportation and food supply. But this is not the case in modern cities (which are not primarily driven by these geographical

factors) where urbanization still takes place within or near to local biodiversity hot spots (Guneralp & Seto 2013). Urbanization can not be seen as a threat to local urban biodiversity as cities are unique ecosystems in themselves and are seen to provide niche and habitat to various species of urban flora and fauna (Boada & Maneja 2016). For example, biodiversity richness and abundance of insect species are found more in urban counterparts in comparison to the rural counterpart (Carre et al. 2009). Species diversity of urban setup is further enhanced by the introduction of exotic species by humans. In a plant diversity study in Beijing, it was seen that almost 53% of plant species in the city were exotics (Zhao et al. 2010). Moreover big and old cities were found to have more exotic species in terms of density and diversity in comparison to new and smaller cities (Muller et al. 2013). Mexia et al. (2018) also reported carbon sequestration by urban vegetation was positively influenced by tree density and species composition.

Human not only affect urban species and ecosystem but also gets numerous benefits from urban green infrastructure in the form of *ecosystem services*. It has been well documented that the price of real estate is positively correlated with the vicinity of green spaces (Tyrvain and Miettinen 2000). Research also suggests that it is ecologically and economically positive for cities to develop a green space network which will help in the overall well being of communities and also offers new employment opportunities to the managers (gardeners, arborists, horticulturists, etc) of the green spaces (Anderson & Minor, 2017). Urban green areas can mitigate the impact of water stress, heat, carbon emission, and pollution cycles (Ossola & Livesley, 2016). Urban garden provides an antiquity for humans, it serves as a tool for oxygenation and pollution abatement. But at the same time, some studies say that urban green spaces produce health problems due to the presence of allergic plant species in a small area, which ultimately releases a lot of allergic pollen grains into the atmosphere as seen in the city of Cordoba, Spain (Velasco-Jimenez et al. 2020). Rapid urbanization trying to meet the aesthetic and recreational needs of local residents, which involves the massive use of ornamental flora which are either exotics or of low biodiversity importance and also cause high allergic pollen (Guardia et al. 2006), besides this introduction of new species of unknown allergen (Garcia et al. 1997, Trigo et al. 1999). Not all pollen grains have protein that causes allergy and, among those pollen grains with allergenic proteins, not all have the same allergen potency (Behrendt & Becker 2001), so it is very convenient to know these characteristics of pollen grains.

As per the Classification of Ecosystem Services (CICES, www.cices.eu, accessed April 2020), services are generally divided into 4 broad categories i.e. *Habitat/Sustaining, provisioning, regulating, and cultural ecosystem services.*

A) Habitat or Supporting services: These are the core ecological processes and functions needed to sustain all other services, including water and nutrient cycles (MA 2005).

B) Provisioning services: It describes the production of materials matter by urban green spaces to humans, such as food, drinking water, and raw materials.

C) Regulating services: These services include the regulation of air quality, local temperature, moderating floods, prevention of soil erosion. These services are getting the most attention from urban planners and researchers (Haase et al. 2014)

D) Cultural services: These are non-materialistic and intangible benefits that humans are getting from urban green spaces through spiritual enrichment, cognitive development, learning, reflection, and place attachment (Chan et al. 2012). However, their intangible nature makes the quantitative and assessment difficult and needs further research. There is another model by Tzoulas et al (2007), where ecosystem services are linked to even more elaborated aspects of health; *Ecosystem health*, *community*, *socio-economic*, *physical*, and *psychological health* (stress, Positive attitude, and cognitive capacity).

Interestingly *Ecosystem disservices* are divided into three separate categories *physical, psychological, and societal* which are discussed below.

A) Physical disservices: This includes the physical distress caused to human by urban biodiversity, for example, pollen allergy, Bites of insects like mosquitoes, scorpion, bugs or other, Bites of other animals like snakes, monkeys, etc, Physical destruction caused by falling branches on urban infrastructure, and need of leaf foliage removal from roads roofs, etc.

B) Psychological disservices: It describes negative feelings associated with urban green spaces such as fear and disgust related to nature, animal phobia, feeling of unsafety from dense green areas like urban parks and forests especially during night time.

C) Societal disservices: It describes the negative impacts that are indirectly associated with urban green spaces, such as an increased number of crimes in urban parks. Table 1 & Table 2 documented several ecosystem services that are majorly offered by the Urban forests & Urban parks.

Table 1: Classification of major ecosystem services related to urban forests and trees.

Category	Ecosystem services	Examples	Refrences
Regulating services	Run off mitigation	Water retention by leaves of the plants	Escobedo et al (2011)
	Global Climate regulation	Carbon sequestration by urban trees and shrubs	Kordowski and Kuttler (2010); Paoletti et al (2011)
	Air quality mitigation	Removal and fixation of air pollutants (NOx, SOx, PM_{10}) by tree leaves	Nowak et al (2006); Baro et al (2014)
	Noise reduction	Sound pollution mitigation by sound absorbing vegetation	Ozer et al (2008)
	Local climate regulation	Micro climate effect through shading and evapotranspiration	Yuan and Bauer (2007)
Maintenance services	Biodiversity conservation	Habitat for species of birds, smaller mammals, reptiles, amphibians and insects	Kong et al (2010)
Cultural services	Aesthetic value	Aesthetic appeal of urban trees	Tyrvainen and Miettinen (2000); Yang and Webster (2016)
	Recreational value	Stress reduction through urban forests	Hammitt (2000); Arnberger (2006)

Provisioing services	Food supply	Fruits and nuts from the residential trees	Lafontaine- Messier et al (2016)

Table 2: Classification of major ecosystem services related to urban parks

Category	Ecosystem services	Examples	Refrences
Regulating services	Stormwater and runoff regulation	Ground Recharge zones during flooding and water retention by urban vegetation	Kubal et al (2009)
	Local climate regulation	Micro climatic effect through shading and evapotranspiration	Bowler et al (2010)
Maintenance services	Biodiversity awareness and conservation	Local habitats for urban flora and fauna	Cornelis and Hermy (2004)
Cultural services	Recreational value	Space for diverse activities like jogging, playing, etc	Maas (2006); Hussain et al (2010); Stodolska et al (2011)
	Nature education and learning	Learning through frequent observation and contact with urban biodiversity	Langemeyer et al (2015)
	Social cohesion	Places for social gatherings	Fan et al. (2011); Peters et al (2010)
Provisioing services	-	-	-

It has appeared in a recent study that the presence of biodiversity or increment of biodiversity can directly benefit health by enabling secure food production, preventing the spread of infectious diseases, and giving nature-based treatments (Bernstein 2014). In another study reported increasing plant abundance can help to mitigate air pollution and thereby lessen rates of cardiovascular and respiratory infections (Clark et al. 2014). Few reports already stated that exposure to microbial diversity (arising from the species richness of native flowering plant species and land use types in the wider environment) is a potential pathway through which health advantages, such as lower prevalence of hypersensitivity may arise (von Hertzen et al. 2011, Hanski et al. 2012). According to the '*Biodiversity hypothesis',* reduced contact of people with natural environmental features and biodiversity may adversely affect the human commensal microbiota and its immune-modulatory capacity and lead to immune dysfunction and chronic inflammatory disorder (von Hertzen et al. 2011, Hanski et al. 2012, Ruokolainen et al. 2015). Summarily disturbance of ecosystems, and in particular biodiversity loss, may affect human health negatively, an increase in the spread of zoonotic diseases (Jones et al. 2008, Ostfeld 2009, Keesing et al. 2010) or declined access to food, clean water, and raw materials (Sandifer et al. 2015). Changes in land use may reduce air and water quality which may increase the risk of respiratory problems and lung cancer (Wall et al. 2015). On the other hand, also some studies were suggesting that biodiversity cannot always be judged as positive; and it has some negative aspects too, for example, allergies are one group of human diseases caused by the diversity of pollen, debris, and proteins impacting the immune system (Hammen & Settele 2011).

Pereira et al. (2005) conducted interviews with inhabitants of a rural and especially agricultural community in Portugal. Participants did not explicitly associate biodiversity with their self-reported well-being but did mention the importance of biodiversity in supporting environmental quality. Biodiversity was associated with both positive and negative assessments; it was related to aesthetic and positively valued appraisals, but also negative effects are the result of harvest damage, livelihood loss through wildlife predation which resulting in a negative impact on their business and on a long term on their well-being. Pereira et al. (2005) explained that agriculture is dependent on intentional, human-coordinated control of biodiversity and that negative assessments of biodiversity or on the other hand indistinct connection with well-being may have been a function of this specific study population.

In a study, Lovell et al. (2014) analyzed and reviewed 12 previous studies on the correlation of Biodiversity with human well being, out of 12 studies 9 studies showed one or more positive relationships. According to Lovell et al. (2014), there is evidence to suggest that

biodiverse natural environments promote better health through exposure to pleasant environments or encouragement of health-promoting behaviors. A considerable number of studies have shown a connection between greater biodiversity and better physiological health (Sandifer et al. 2015), exposure to environmental biodiversity improves the maintenance of healthy immune systems and reduces the prevalence of inflammatory-based diseases (Hanski et al 2012, Rook 2013, Bernstein 2014, Hough 2014).

Barton et al. (2009) conducted a survey for visitors in areas with high natural and heritage value, with half the sample interviewed before entering the site and the other half as they were leaving the site. Those leaving the areas reported less anger, depression, and confusion, more vigor, and slightly better self-esteem compared with the ones interviewed before entering the area. In other studies Cracknell et al. (2016) observed better mood and decreased anger in response to viewing increased diversity of fish in a public aquarium, Similar positive results were also reported in the study by Fuller et al. (2007), where plant and bird species richness were objectively measured, as well as the number of habitat types were significant positive predictors of subjective well-being. In contrast, Dallimer et al. (2012) found that the biodiversity of plants, butterflies, and birds to be predictive of these affective aspects of subjective psychological well-being. A study from Italy (Scopelliti et al. 2012) involving five urban and peri-urban outdoor environments, observed that high biodiverse environments were rated as more restorative and more psychologically and physically beneficial than low biodiverse environments. Similar results were also shown in another study where Carrus et al. (2015) reported that, compared to low diversity environments, high-biodiversity environments were rated as more restorative and psychologically beneficial. Contrary to the findings above, Marselle et al. (2015) reported that perceived bird biodiversity was positively related to negative affect after a walk. The studies above concern short-term effective response. However, studies related to long-term affective well-being have found either no link between exposure to more biodiverse urban environments and mental health (Shanahan et al. 2016) or even found negative links (Huby et al. 2006). Some studies have been reported no relationship between biodiversity and social well-being (Shanahan et al. 2016), while others have provided mixed evidence. For instance, in a study of residents of Australian urban areas, Luck et al. (2011) assessed relationships between biodiversity and personal well-being (life satisfaction), neighborhood well-being (satisfaction with the local area), and personal connection to nature. Neighborhood well-being was most strongly and positively predicted by bird species richness and vegetation cover, while personal well-being and connection to nature were more weakly predicted by these biodiversity variables. In all cases, demographic factors (e.g. age, gender, and education) were strong and more consistent predictors of well-being.

In another study, Cai et al. (2020) correlated the effect of varied green space types on atmospheric PM2.5 and concluded that although green spaces are highly capable of reducing the PM2.5, but there is an involvement of other meteorological parameters also, so simply correlating Green spaces and PM2.5 concentration will be inaccurate, without taking in the meteorological parameters especially wind speed. They also highlighted the importance of grasslands as a tool for the reduction of PM2.5. They showed that the forest combined with grasses is more effective in reducing PM2.5 than these individual entities (Cai et al. 2020). In a study from China showed Impervious surfaces in modern cities can be used for re-vegetation by applying the theory of Bonsai. Most existing buildings and grey infrastructure have substantially created impermeable surfaces which directly affect the urban microclimate and impacting urban sustainable development and resilience. So the technology of Urban Special Re-vegetation (USR) which involves the installation of green roofs, Vertical greening of buildings, Container gardening, and planting street trees can be referred to (Wang et al. 2020).

The generality still lacks to what extent higher biodiversity delivers more ecosystem services (Duncan et al. 2016; Ricketts et al. 2011). Robust assessments on urban biodiversity from a broader perspective beyond species diversity such as the *City Biodiversity Index (*developed under the United Nations Convention on Biological Diversity) is urgently needed to underscore the mounting evidence indicating urban biodiversity as critically important for the endurance and sustained provision of ecosystem services (Gomez-Baggethun et al. 2013). Research on urban Disservices is still in its infancy state and not much work has been carried out in this negative aspect of urban biodiversity (von-Dohren & Haase 2015). In future study further arrangement and evaluation of potential and actual ecosystem services are required to relate the human and urban biodiversity more realistically.

As conclusions, urban biodiversity is a new topic and needs a lot of understandings, it requires interdisciplinary research with the involvement of ecologists, urban planners, or health practitioners. There is a need to identify diverse urban biodiversity hotspots within cities and priority should be given to monitor and to restore them. There is also a need to understand the ecology of urban green and blue areas and how they are contributing to the well being of the environment and humans in more quantifiable ways. There is a quest for the particular identification of specific ecosystem services that are impacting human health either positively or negatively. Also, we need to understand which component of biodiversity is directly contributing to the environmental well being. Robust methodologies are needed to quantify the ecosystem services. A clear understanding is also needed to know more about the time duration of biodiversity exposure which is affecting human well-being. This review although indicates the better health of human beings depending directly on the dynamics of biodiversity, but till

now many questions remain unanswered. So further detailed research is needed to understand closely the field of Urban Biodiversity.

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