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GREEN INFRASTRUCTURE: A POLICY INSTRUMENT FOR RESILIENT URBAN CITIES

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ABSTRACT

Within the field of landscape and urban planning, the concept of "green infrastructure" has seen significant development. Since green infrastructure is now a crucial component of the scoping, planning, and management of landscape resources, the level of discussion surrounding its benefits has expanded from a few research clusters to a global investigation. However, there are currently just a few studies assessing how the dynamics and meaning of green space, urban trees, and water management in cities have changed in India. Therefore, to evaluate the worth and significant influence of urban landscapes in a country where dynamic urban change is the escalating development narrative, planners and stakeholders must concentrate their professional attention on this understudied area. The present prospects for incorporating and executing green infrastructure into Indian city planning are examined in this research. considering regional or private investment as an alternative to central expansion in India. Thus, urban green infrastructure provides the four categories of ecosystem services that the Millennium Ecosystem Assessment identified: providing, regulating, sustaining, and cultural. These services offer multifaceted benefits that are integrated and interrelated, such as social, economic, cultural, and environmental advantages. Nonetheless, developing green infrastructure and preserving biodiversity in tropical cities may benefit from the information that is already available.

Keywords: Urban planning, Green infrastructure, ecosystem, green spaces, environment, biodiversity.

1. INTRODUCTION

The principle meaning of “green infrastructure” have developed extensively within landscape and urban planning (Allen III, 2012; Beatley, 2012; Kambites & Owen, 2006; Mell, 2010). The level of debate discussing its values has extended from a small number of research clusters into a global exploration of the value of green infrastructure, which has become essential part in the scoping, planning and management of landscape resources (Beatley, 2000; Davies et al., 2006; Weber & Wolf, 2000; Williamson, 2003). Although research in the UK and USA is still at the forefront of this process, there is a growing literature focussing green infrastructure in Europe and increasingly in Asia, reviewing the opportunities and importance of green infrastructure to address socio-economic and sustainability issues (Boyle et al., 2013; Lemma & Overseas Development Agency, 2012). Over the same timescale we have also seen surge in green infrastructure concept filter through into university teaching curriculums, watched the creation of number of strategies and guidance documents and witnessed green infrastructure being embedded within international (e.g. European Union) strategies and planning.

Despite the variation that are evident in the details of how and why green infrastructure is being developed between locations, there is a positive link up between the discussions of its value and its development within policy and practice (Landscape Institute, 2013; Lerner & Allen, 2012; Hostetler et al., 2011). However, although there is a visible surge in understanding of what green infrastructure is, how it can be used and what social, ecological and economic value it can deliver, there is still a lack of consensus and thought conflicts regarding how these various elements of landscape and green infrastructure should be addressed and implemented (Mell, 2013). This is not, in many cases, a negative, because as landscape planners continue to plan more sustainable places, such variation can provide alternative approaches for development that instil a more appropriate focus for investment (Wright, 2011).

Over the last decade, intense research exploring the green infrastructure planning has burgeoned (Boyle et al., 2013). Globally, there is a growing consensus of what, where, how and when investment in green infrastructure should be implemented, which is, in many locations, supported by an integrated policy-making arena (Benedict & McMahon, 2002; Goode, 2006). Green infrastructure can therefore be positioned itself as a ‘go-to’ approach in contemporary landscape planning, as it holistically focusses climate change, social development, sustainable development and economic valuation simultaneously (Mell, 2010).

Rapid urbanisation directly influences the outlook of the Indian nation as its cities continue to evolve at a higher pace. This, is due to a complex interplay of complementary and contradictory factors (Wilby, 2003; Graves et al., 2001). Although a large number of Indian cities retain remnants of historic, and in many cases colonial planning, the majority of cities have morphed into dynamic, intricate and innovative amalgamation of ecological, economic and social resources (Mabelis, 2005). Blending contemporary with traditional approaches to development is a major challenge in

India. The outcome of which has been a highly organic and in many cases informal form of development incubated alongside mainstream planning practice. Expansion, especially in the form of unorganised settlements, has thus run in parallel to national and state planning mandates. The outcome of this process has been the creation of modern cities that house significant informal and unregulated development which juxtaposes the Indian government's rhetoric of growth and wealth distribution (Mabelis, 2005). In order to understand the mechanisms which control development, as well as those investment objectives deemed appropriate, planners need to reflect upon the institutional capacity of Indian planners and stakeholders, if a sustainable approach to development is to be achieved (Wilby, 2003; Graves et al., 2001).

Moreover, further complications to this process are discussions of how liveable Indian cities are at present. Assessments of urban environments identify that the provision of housing, transport infrastructure and utilities all promote living lifestyle (Wilby, 2003; Graves et al., 2001). Furthermore, to ensure urban locations are functional, a level of interactivity between environmental, social and economic resources is well required. However, there appears to be a dilemma between this narrative and those supporting sustainable developments in India's cities. One response to this dilemma can be identified within the growing body of research focussing the value of urban greening stating that investing in "green infrastructure" acts as an important mechanism which can help deliver higher quality urban environments. At a global scale, urban greening concept propose that a range of functions can be delivered only by large scale investment in green infrastructure, with evidence from Asia, Europe and America rewriting its use in addressing urban expansion and renewal, climate change, environmental protection, the greening of infrastructure, and the delivery of widespread health benefits Landscape Institute, 2013; Hostetler et al., 2011). Each of which has been explained well by Mell (Turo and Gardiner, 2019) as the key benefits that can be used to promote investment in urban greening, and to define the multi-functional nature of urban landscapes to politicians, developers and the public.

Green infrastructure research in India though at present limited to a small number of studies evaluating changes in the dynamics and meaning of green space, urban trees and water management in the cities (Lerner & Allen, 2012). Testing the value of green infrastructure in India and the urban cities therefore requires planners and stakeholders to focus their professional attention on this under researched area to assess the value and influential impact of urban landscapes in a nation where dynamic urban change is the escalating development narrative. This paper discusses current opportunities to integrate and implement green infrastructure in the planning of Indian cities. Viewing expansion in India from central l to regional or private investment, enables to examine whether green infrastructure can be debated as a relevant tool for contemporary Indian planning.

In this paper, the detailed discussion of the role of green infrastructure in mitigating atmospheric pollution, carbon sequestration, moderation of temperature and mitigation of climate change, and management of storm water. It also discussed the biodiversity of green infrastructure and the habitat of organisms, and provide an overview of multi-dimensional value of trees in the urban areas.

Pollution mitigation and Carbon sequestration

Large-scale urbanization damages the environment by substituting artificial materials for natural landscapes (Nowak, 2006). The health of the local population is impacted by heat and other emissions linked to urbanization, in addition to the local and regional environment (Nowak, 2006). By eliminating air pollutants and changing the urban atmosphere, urban vegetation can improve the quality of the air both locally and regionally. The main way that urban trees absorb air pollutants is through their leaf stomata and other plant surface features (Mullaney et al., 2015). According to Lenschow (1986), a higher percentage of tree cover improves air quality. However, the amount of improvement in air quality caused by trees varies depending on their size, as McPherson et al. (1994) found that massive canopy trees often remove 60 to 70 times more air pollution than smaller trees.

Nowak et al. (2006) estimated that air pollution reduction by trees in cities:

- Szeged 6.5 g m^{-2} of canopy cover,
- Charleston 6.7 g m^{-2}
- Minneapolis 6.2 g m^{-2}
- Victoria 10.9 g m^{-2}
- Barcelona 9.3 g m^{-2}

In Jammu, J&K, transportation contributes significantly to air pollution, generating 54.4 tons of suspended particulate matter below 10 mm (PM10), 217.4 tons of NOx, and 14.6 tons of SO2 every day. The dense canopy of urban forests can help reduce pollution.Urban tree systems have the potential to significantly lower the nutrient concentrations in runoff from the urban catchment, claim Livesley et al. (2016). Additionally, trees have the capacity to absorb significant amounts of carbon (C) from CO2. In their 2019 study, Singh et al. calculated the carbon sequestration of street trees from Varanasi's Banaras Hindu Campus and found that they stored the most carbon (kg tree-1).

This is 9.0 × 103 in Madhuca longifolia, followed by Tectona grandis (7.0 × 103), Tamarindus indica (7.7 × 103), Mangifera indica (5.9 × 103), and Syzygium cumini (5.3 × 103). The primary factors influencing species differences in carbon sequestration and storage capacity are variations in tree size distribution (Kiss et al., 2015; Deb et al., 2016) and soil fertility (Singh et al., 2019).

Temperature moderation, Climate change mitigation

Green spaces in the built environment encourage such to occur, but in urban areas, vegetated surfaces are replaced with impervious surfaces, which reduces the shading, evaporative cooling, rainwater interception, storage, and infiltration functions of vegetative lands (Whitford et al., 2001). An urban heat island (UHI), where air temperatures are several degrees warmer than in nearby rural areas, is created by altered energy exchanges in urban areas (Wilby, 2003; Graves et al., 2001). The existence of urban canyons, the thermal characteristics of building materials, the presence of impermeable surfaces, and decreased albedo all contribute to the alteration of energy balance that causes UHI (Singh et al., 2018).

People who live in cities and towns are more likely to experience extreme heat stress and maybe heat stroke due to the UHI (Livesley et al., 2016). The dynamics of climate change impacts by urban heat island, however, are not well studied (Emmanuel and Loconsole, 2015). Due to global climate change, urbanization-related warming will grow in the future. Given its impact on human comfort and well-being, urban warming is concerning, especially during the summer (Svensson and Eliasson, 2002; Eliasson, 2000). Extreme heat events (EHEs) have been shown to increase mortality and morbidity among city dwellers (Norton et al., 2015), and climate change is predicted to increase the frequency, severity, and duration of EHEs (Alexander and Arblaster, 2009). The following are some advantages of urban tree canopy around streets and community parks:

better air and water quality,
building energy conservation,
a cooler atmosphere,
less UV radiation,
air pollution removal and carbon sequestration,
less storm water runoff,

Given the accelerating rate of urbanization and the escalating effects of global warming, most adaptive measures ought to be implemented in urban areas. In actuality, Goal 11 of the Sustainable Development Goals places a strong emphasis on creating sustainable cities, which minimize their environmental impact by expanding and strengthening green infrastructure.

In the United States alone, urban trees store more than 708 million tons of carbon dioxide (about 12.6% of yearly emissions) and absorb an additional 28.2 million tons of carbon (roughly 0.05% of annual emissions) annually, according to Nowak et al. (2013) and the US EPA (2013).

According to Sun et al. (2019), the total carbon sequestered in Beijing's urban green areas in 2014 was 956.3 Gg (1 Gg = 109 g). With total CO2 emissions predicted to be 0.43 times greater in 2030 than in 2005, Beijing is the second-highest energy-consuming metropolis in China (Feng et al., 2013). Beijing faces a significant challenge as the carbon emission reduction target of "the 13rd Five-Year Plan of Beijing (2016–2020)" calls for a 20.5% reduction in CO2 emissions per unit of GDP in 2020 compared to 2015, with 2020 expected to be the peak year for total CO2 emissions (Liu et al., 2014).

Habitat for Organisms

According to Cornelis and Hermy (2004), urban green spaces support a wide range of fauna, including insects, birds, squirrels, and monkeys. Some of these species "are so well-adapted to the urban environments that they are more abundant in cities than in surrounding natural vegetation" (Mullaney et al., 2015). The spread of small mammals, birds, butterflies, moths, beetles, and other wildlife is facilitated by street trees, which also offer connectivity between urban forest patches and between the urban forest and the adjacent rural vegetation (Mullaney et al., 2015). Because street trees' physical attributes affect faunal diversity and abundance, it is frequently advised to plant a variety of native tree species to prevent faunal homogenization (Alvey, 2006). For instance, it has been observed that Australian cities with a high percentage of native trees have higher native-bird richness and diversity than unurbanized environments (Mullaney et al., 2015). Bats and iguanas, respectively, make extensive use of native tree species in residential areas of Nicaragua and California (Mullaney et al., 2015). There are several types of public green spaces that could be used to conserve pollinators. Reducing the frequency or intensity of management and increasing the quantity of flowering plants are two common recommendations to improve the quality of these green areas for bees (Turo and Gardiner, 2019).

Economic Value of Urban Trees

Urban greenery should be given a monetary value in order to draw the attention of city planners and managers. City street trees increase property prices and promote thriving urban communities (Mullaney et al., 2015). Given the numerous advantages and ecosystem services they offer to the well-being of city inhabitants, Willis and Petrokofsky (2017) have made a compelling case that trees are in fact natural capital assets for cities. According to Killicoat et al. (2002), "urban forests are made up of trees that line our streets, fill our parks, and shade our houses." These urban forests offer a number of social, economic, and environmental advantages. According to Vailshery et al. (2013), street segments with trees experienced afternoon temperatures that were 5.6 °C lower and road surface temperatures that were 27.50 °C lower than those of exposed roads surfaces in Bangaluru. Ironically, urban street trees are typically seen more as liabilities than assets because they typically lack a market value, in contrast to traditional forestry and fruit trees (Pandit et al., 2012). A single tree can lower annual heating and cooling costs by 1.3% and 7%, respectively, while a 10% increase in tree cover has been shown to reduce overall heating and cooling energy use by 5–10% (McPherson et al., 1994).

Storm Water Management

Cities with more impermeable surfaces experience higher runoff, and the aquatic environment suffers when storm water is dumped into nearby waterways. Urbanization reduces water infiltration into the soil by increasing impermeable surface area and compaction of the soil. Urban aquatic ecosystems are destroyed, stream flows are accelerated, and surface waters are contaminated by storm water runoff (Nowak, 2006).

Building urban forests may lessen the sediment and pollutant load from storm flow systems since urban trees can decrease storm water flow. Trees grown over open, impermeable surfaces, such parking lots, can reduce storm water runoff by up to 20%, and their branches and stems can absorb and reduce up to 15% of the total rainfall, according to the US Department of Agriculture.

By channeling storm water runoff into a treatment area with plants growing in a moderately permeable soil, bio-filtration systems are being employed more and more as part of water sensitive urban design (WSUD) to both improve the quality and decrease the amount of storm water runoff. The majority of bio-filters use grasses, sedges, and rushes; however, trees might be a better option in highly urbanized areas, such as streets (Denman et al., 2011). The main focus of green infrastructure science is on solutions that increase groundwater storage by facilitating storm water penetration through rain gardens, bio-swales, and permeable pavements.

Contribution to biodiversity

The urban systems are significantly rich in species diversity, despite popular notion to the contrary. Being unique ecosystems, they provide a diversity of habitat for plants and animals such as lawns, wastelands, herbaceous borders, shrubberies and hedges, parklands, gardens, street trees, and pavement cracks and walls (see ref Singh et al., 2018 for more). For instance, the city is ideal for digger wasps, long-horned beetles, rove beetles, glow worms, springtails, and thermophilic plant species due to its high temperatures (Mabelis, 2005). The city's higher temperatures allow birds to lay more eggs annually (Klausnitzer, 1989).

For a number of animal groups, including worms, spiders, harvest-spids, springtails, carabid beetles, lady beetles, flies, scorpion flies, ants, and parasitic wasps, Mabelis (2005) noted a "shift from hydrophilic species to dry-tolerant species from the outskirts of the city to the center in Warsaw." The abundance of food has been cited as the reason for the high density of certain mammal and bird species in the city. Granivorous and omnivorous birds are comparatively more common in cities than insectivorous and carnivorous ones.

According to Gopal et al. (2015), the majority of plant species in Bangaluru's slums have economic, culinary, medicinal, or cultural significance, but the majority of the species planted in the affluent residential neighborhoods are ornamental and usually not native. Paul and Nagendra (2015) discovered that compared to other areas, especially the quickly growing periphery, the core area of Delhi (the older part of Delhi) has more green space and stable vegetation (since the Central Ridge Forest is located there and there are many avenue trees of Lutyen's Delhi). Indeed, Singh et al. (2018) contend that while designing a city, the creation of urban nature reserves should be required in order to provide space for biodiversity to thrive and to enhance the well-being of city inhabitants.

2. CONCLUSION

The afore mentioned makes it abundantly evident that urban green infrastructure offers all four types of ecosystem services—provisioning, regulating, supporting, and cultural—as identified by the Millennium Ecosystem Assessment. These services include multifunctional advantages like social, economic, cultural, and environmental benefits, all of which are integrated and interconnected. However, the information that is now accessible may be useful for building green infrastructure and conserving biodiversity in tropical cities.

It is acknowledged that little is understood about the underlying mechanisms relating to the degree of urbanization and biodiversity (both native and foreign). The following areas need more investigation:

1. Finding potential data sources and gaps in the data.
2. Determining strategies for creating smart, compact, green cities with an emphasis on multi functionality at various scales.
3. Creating both immediate and long-term strategies to reduce urban poverty by properly greening cities.
4. Being aware of the best species combination to plant in tropical cities.
5. Creating methods and resources to inform the public, planners, and decision-makers on the value of green infrastructure and urban nature preservation.

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