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SMALL URBAN PARKS: THE BUILDING BLOCKS OF LOW CARBON CITIES

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Abstract

Background: The Low Carbon City (LCC) approach is a planning measure to help cities reduce carbon and strive for climate change mitigation. Small Urban Parks (SUP) had mushroomed in densifying cities where they can be close to people's homes and form a SUP network that connects to a larger central green space. Methodology: This paper is a brief narrative literature review that reports on several studies in SUP to explore its role in LCC. Results: SUP can play a role in LCC by reducing carbon sources, cutting down carbon emissions and strengthening carbon capture; a Strength, Weakness, Opportunity, and Threat (SWOT) analysis of SUP was devised to explore this notion. The strength of SUP lies in its function as a network to strengthen its ecosystem services. The opportunities lie in considering the suitable vegetation characteristics and landscape design. Meanwhile, its weakness is the space limitation making it less effective than larger green spaces, and the potential threat is the release of carbon due to intensive use and, consequently, intensive management. Conclusions: The SWOT analysis concludes that proper landscape planning and design within SUP and green networks connecting SUP can improve carbon capture efficiency, reduce fragmentation, and improve accessibility, ecosystem service, and microclimate at a local level.

Keywords:

Low Carbon City; Small Urban Parks; Urban Vegetation

1 Introduction

During the Industrial Revolution, the mechanised growth in the latter half of the 18th century increased human production efficiency. The wealth in resources transformed a primarily rural society into an increasingly urban one. Urban areas can vary in different parts of the world, but at its crux is the phenomenon in which an area changes in size, density and heterogeneity (Vlahov & Galea, 2002). People flood cities in urban areas are searching for the best employment opportunities, services such as health care and access to infrastructures such as transportation, housing, food and water (Vlahov & Galea, 2002). The industrial era promoted the worldview that perceived nature as a finite resource for the disposal of human use. The growth in human activities' productivity on a larger scale has vastly altered many of earth's biogeochemical cycles; the most prominent is the global carbon cycle (Malhi et al., 2002).

Fast forward to the 21st century, cities house about 60 per cent of the global population and make up 3 per cent of the world's land-use area but contribute to 70 per cent of carbon emissions (Chen et al., 2019; Wang et al., 2020). The increase in emissions has primarily changed the urban microclimate by altering key environmental and meteorological parameters (Bherwani et al., 2020). Carbon Dioxide is a high Greenhouse Gas (GHG) that is efficient in trapping wavelengths of radiation in the atmosphere and driving temperature rise, which is attributed to be one of the drivers of climate change (Malhi et al., 2002; Nowak, 1993). The temperature rise resulted in the Urban Heat Island (UHI), a human-induced phenomenon characterised by urban areas being warmer than rural areas (Oke et al., 2017).

Cities (i.e., local authorities) are not entirely at fault, but rather the consumption patterns and lifestyle of their inhabitants can be attributed to the massive level of carbon emissions in cities (Dodman & Satterthwaite, 2008). Some scholars have argued that there is no link between urbanisation and high GHG; instead, well-planned managed cities can aid climate change mitigation efforts (Dodman & Satterthwaite, 2008). Regardless, cities offer the best opportunity and the most significant challenge in the quest for decarbonisation (Munera-Echeverri et al., 2018). Cities could contribute locally where municipal governments and city stakeholders are the proponents of setting targets and implementing measures to reduce emissions (Da Silva et al., 2012). The accelerated rate of climate change has increased carbon management attention to reducing carbon dioxide's anthropogenic emission (Kennedy & Sgouridis, 2011). Among the measures that have emerged is the Low Carbon City (LCC) approach, which gained popularity in 2009 due to the global climate debate and the growing demand for carbon reduction and climate alleviation in cities (Tan et al., 2017). The planning and management of vegetation within green spaces in cities are part of the equation in the LCC approach (Tan et al., 2017). Vegetation is a cheap and smart measure in improving micro-climatic conditions and, at the same time, plays a huge role in human well-being (Arshad et al., 2020).

Research has proven that vegetation is one of the crucial sources of carbon sink in urban areas (Davies et al., 2011; Escobedo et al., 2011; Hyun-Kil Jo, Kim, et al., 2019; H-K Jo & McPherson, 2001; Nowak, 1993; Nowak & Crane, 2002; Nowak et al., 2013; C. Velasco et al., 2016). Vegetation directly and indirectly, reduce sensible heat release and air temperature (Gunawardena et al., 2017). Vegetation functions as a carbon sink through photosynthesis and carbon storage from its growth process (Gratani et al., 2016; Hyun-Kil Jo, Kim, et al., 2019; Othman et al., 2016). It directly reduces the UHI effect by removing heat-trapping carbon from the atmosphere and helps dampen the effect of climate change in urban areas (Hyun-Kil Jo, Park, et al., 2019). Moreover, vegetation can indirectly reduce carbon in the atmosphere by reducing cooling energy use and decreasing carbon emissions through evapotranspiration and blocking solar radiation (H-K Jo & McPherson, 2001).

Among the places where vegetation in cities is concentrated are green spaces, which have also long been a symbol of beauty and prosperity in cities for centuries. The garden city concept introduced by Ebenezer Howard in the late 18th century emerged to shift the traditional way cities are planned to create a space that prioritises human-environment connection. Howard's design emphasises copious green spaces within a garden city where residents should not be more than 240 yards away from a park; his plan proposed the integration of woodland and meadows within each dwelling unit which serves as smaller and accessible green spaces that are connected to a larger central park (Batchelor, 1969).

Small Urban Parks (SUP) are now a common theme in cities as the challenge of space has led to exploring new forms of green space. Large Urban Parks are not feasible in the densifying urban environment; thus, SUP distributed at regular intervals can better connect people with nature (Motazedian et al., 2020). The presence of SUP has now become a vital urban green infrastructure (Kerishnan et al., 2020; Karin Kragsig Peschardt & Stigsdotter, 2014). These parks serve as the green stepping stones and complement larger parks, filling the need for people's daily contact with nature (Nordh & Østby, 2013).

This paper examines findings from relevant literature to understand the role of SUP in mitigating carbon in cities and to consequently serve as a building block for Low Carbon Cities (LCC). It addresses the strength and opportunities of its presence within the urban fabric and potential weaknesses and threats that should be addressed. This review aims to aid relevant proponents (e.g., city planners and landscape designers) in identifying factors and features within the SUP landscape that can be leveraged to strengthen carbon in cities.

2 Methodology/Materials

This paper is a brief narrative literature review that reports on several studies in Small Urban Parks (SUP) that explores factors such as microclimate, carbon uptake or reduction. Literature on larger urban green spaces is adopted as contrast and example. A descriptive Strength, Weakness, Opportunities and Threat analysis is formulated in the findings to explore the role of SUP in Low Carbon City (LLC).

3 Methodology/Materials

3.1 Background of Small Urban Parks

The presence of SUP can be attributed to the garden city approach when Howard proposed it as a strategy to place green spaces close to people's homes and to form a network of SUP that was connected to a larger central green space. SUP has been coined in various terms, whether it is Small Public Urban Parks (Karin K Peschardt et al., 2012), SUP (Nordh et al., 2011), Pocket Parks (Ikin et al., 2013; Lin et al., 2017; Nordh & Østby, 2013). As the definition of SUP can be broad and ambiguous, the SUP addressed for this review are the spaces meant for recreation and are land-based but not encompassing spaces such as vertical or rooftop gardens. SUP is defined as a scaled downed version of larger parks, usually less than 2 ha where some vegetation is present, with an entrance and distinguishable boundaries which separate them from surrounding public space; it serves as a recreational and beautification space where the acquisition of larger parks is not possible (Karin K Peschardt et al., 2012; Karin Kragsig Peschardt & Stigsdotter, 2013). SUP is sandwiched within small available space, unused areas, vacant lots, and abandoned areas. SUP place closed to residential areas was the accessible space for rest and recreation for urban dwellers without travelling long-distance to get a glimpse of nature. During the COVID-19 outbreak in various parts of the world, where governments have placed cities under lockdown and restricted movement; thus, the importance of having green spaces close to where people dwell have gained importance various perspectives from health, planning, social justice, and equity (Uchiyama & Kohsaka, 2020).

3.2 Low Carbon Cities & Green Spaces

As cities plan for the recovery steps ahead from the global experience of the coronavirus pandemic, the impending rate of climate change cannot be ignored; thus, it is pertinent to view city planning with the dimensions of challenges posed by climate change (Banai, 2020). The LCC concept is a subset or extension of the sustainable city concept that emerged to minimise the human-inflicted carbon footprint (De Jong et al., 2015; Tan et al., 2017). Tan et al. (2017) highlighted that the LCC approach aims to achieve a high level of energy efficiency through a low-carbon source of energy and production while at the same time adopting a low-carbon consumption and behavioural lifestyle. In the low-carbon behavioural lifestyle, the green space can be part of the equation in the LCC initiative, where Zhao and Liu (2010) identifies its several roles, (1) serving as a space for carbon capture; (2) reducing carbon emission; (3) aiding in reducing the UHI; (4) reducing energy consumption through better microclimate; (5) encourage non-motorised travel; (6) promotes urban agriculture and (7) serve as a physical, educational space to promote reduced carbon emission lifestyle.

3.2 Strength, Weakness, Opportunities and Threat Analysis on Small Urban Parks in Low Carbon City

The SWOT analysis in Table 1 explores the role of SUP in LCC by three guiding principles proposed by Hu (2017) (1) reducing carbon sources, (2) cutting down carbon emissions, (3) strengthening carbon capture.

Table 1: SWOT Analysis of the role of Small Urban Parks in Carbon Reduction

Output To leverage Small Urban Parks for reducing carbon source, strengthening carbon capture, and reducing carbon emissions	**Strength (S)**	**Weakness (W)**
	Reducing solar radiation input **2.** Placed within walking distance to users, which reduces carbon footprint from travelling	Limited vegetation density and variation Not as effective as larger urban green space
Opportunities (O)	**Strategy S-O**	**Strategy W-O**
1. Physiological characteristics of vegetation Multi-layered planting and landscape design **.** Placing vegetation that requires minimal maintenance **4.** Improved vegetation density at a threshold **5.** Green Network	**S1-O1** Increase tree cover ratio **S2-O5** SUP through green networks that will reduce fragmentation, improve connectivity and user access	**W1-O1, O2, O4** Selection of vegetation characteristics, landscape design (spatial arrangement of plants) **W2-O3** Planning management and adopt adaptability characteristics
Threat (T)	**Strategy S-T**	**Strategy W-T**
Park releases more carbon than it stores from management activities **2.** Trees can be a safety hazard	**S1-T1** Carbon offset from management activities by improving microclimate and reducing demand for heating and cooling	**W2-T1** Strategic planning of tree species and its spatial arrangement to minimise risk **W1-T2** Baseline measurement an accounting of carbon uptake and footprint

3.2.1 Strength-Opportunity

Research has shown that the vegetation surrounding the built environment can cut down carbon emissions by improving the microclimate by providing a cool environment, protecting solar radiation, and indirectly reducing carbon by lowering the demand for heating and cooling (H-K Jo & McPherson, 2001). A study by Lin et al. (2017) explored the role of SUP in reducing UHI in high-rise and dense Hong Kong. The authors discovered that even the smallest park size (755 m^2) in their study area contributes to lowering the air temperature of its surroundings. Their findings suggest that efficient cooling in green space largely depends on the area exposed to solar radiation and its vegetation density, where an increase in tree cover ratio of approximately 60% in SUP can lower UHI in the daytime and nighttime. In small and large urban parks in Tapei, Chang et al. (2007) deduced that a park with 50% or more paved surface with little tree or shrub cover could be warmer than its surrounding. Thus, the opportunities to leverage SUP for direct or indirect carbon reduction is by increasing tree cover ratio (**S1-O1**) by providing more vegetation at a threshold and select trees that take less space but have better shading through its canopy coverage which consequently aims to reduce impermeable surfaces

Furthermore, the strength of SUP is its function as a network; in cities where spaces are limited, it can be wedged and dispersed in small spaces (**S2-O5**). In their results, Lin et al. (2017) inferred that carbon savings under the exact sum area sizes of more small green areas could perform better than a fewer larger green area in its role in carbon saving. Similarly, Motazedian et al. (2020) small and connected green spaces through urban corridors are a more efficient option in cities' current climate. Moreover, vegetation's heterogeneity determines the efficiency of carbon uptake, and SUP should be managed and planned as a whole system rather than an individual space to balance these ecosystem services (Mexia et al., 2018). Consequently, a connected network of parks can be designed to function together to provide a diversity of ecosystem services.

Additionally, an indirect opportunity to reduce carbon by SUP is that these spaces be easily placed close to where people work or dwell, making it accessible to the public and thus reducing the carbon footprint from travelling to larger and remote green spaces. Cities such as Freiburg in Breisgau (Germany), in Hammarby-Sjöstad in Stockholm and Malmo (Sweden), and Copenhagen (Denmark) have implemented the green precinct approach by placing copious small-scales green spaces around the city to encourage sustainable and walkable precincts with a short distance between the living and working environment (Lehmann, 2014). Thus, increasing and creating a SUP network connected by a green corridor can reduce fragmentation and improve accessibility, ecosystem service, and microclimate at a local level (**S2-O4**), reducing carbon emissions strengthening capture. Although it is also pertinent to consider the use of urban green spaces, in the face of the global pandemic, the way we use such parks has changed, with individuals avoiding crowded areas to reduce the spread of disease. Thus, planners and managers should further take this into account in small spaces such as SUP.

3.2.2 Strength-Threat

Green space in cities is often intensely managed to ensure the space is safe and attractive to users; thus, using fossil-fuel consuming equipment during management activities can release more carbon into the environment than carbon stored. A study by Vieira et al. (2018) on a large urban park (60ha) found that vegetation structure, composition and management play a significant role in climate regulation services and air purification ecosystem services. The authors found that intensively managed spaces and less complex vegetation had a lower capacity to provide these ecosystem services. Thus, comparing the findings to a space on a smaller scale that is faced with constraints of placing sufficient vegetation for carbon reduction, its capacity for regulating climate and air quality might be minuscule.

Design and management of SUP are factors to consider when leveraging it for LCC. Strohbach and Haase (2012) found that park-like design and maintenance are less effective than forest-like design and maintenance. A study by Hails and Kavanagh (2013) on conserving biodiversity in urban parks by creating zones of wild refuge, for example, patches of lawns in small parks left unmoved next to the mowed lawn. Such measures can potentially reduce the carbon released from grass maintenance. For example, E. Velasco et al. (2013) mentions that turfgrass can contribute to 25.6% of carbon uptake in urban areas, but urban planners should also factor in the intensive management practices that often increase carbon emission. Another measure put forward by Strohbach and Haase (2012) suggested that planting ground cover, ivy or small bushes require lesser maintenance than grass, which reduces emissions from motorised equipment. Meanwhile, Hunter (2011) suggested that planting designs that have herbaceous perennials will increase carbon uptake, and the transformation of lawns to low-input native species can potentially reduce GHG emissions. Thus, SUP landscape and city planners should consider a variety of vegetation that requires minimal maintenance with integrating forest-like design within SUP (**S1-T1**).

3.2.3 Weakness-Opportunity

Conversely, the limitation in size in SUP limits the vegetation density and the variation. In a study by Hyun-Kil Jo, Park, et al. (2019) in small and large urban parks (0.1 ha to 91.9 ha) in the Republic of Korea, Seoul found that the carbon uptake is limited by the distribution of extensive grass and impervious areas single-layered tree planting and the abundance of small trees. The weakness of SUP is that it is potentially less effective than larger parks in direct or indirect carbon reduction. For example, Cao et al. (2010), on urban parks in Japan, found that the cooling effect (indirect carbon reduction) is ineffective in SUP. The authors found that parks' cooling effects are only significant at 2 ha and above park together with vegetation (trees and shrubs), space, and seasonal radiation are also significant factors in determining its cooling effect.

The weakness posed by SUP in serving as a space to strengthen carbon uptake and reduce emission can potentially be overcome by improving vegetation density in a park at a certain threshold can aid in indirect carbon reduction in SUP. Lin et al. 2017 stated that increasing vegetation planting in SUP is at a threshold for reducing the daytime Urban Heat Island effect because a tree cover ratio lower than 42% might not be as effective. Furthermore, the efficiency of carbon uptake in SUP can be improved by the selection of vegetation characteristics, landscape design (spatial arrangement of plants). Meanwhile, Strassburg et al. (2010) found that the synergies between carbon stocks and species richness are strong. For example, in a study by C. Velasco et al. (2016) on urban vegetation in two neighbourhoods in Mexico and Singapore, the authors found that the first site has a larger carbon uptake for carbon compared to the latter due to the presence of large woody plants while latter which has more palm trees which are limited in their wood specific density. A review by Hami et al. (2019) on urban vegetation deduced that crown density plant species and age, planting densities, plant elements and planting patterns and arrangement are some of the essential factors to consider in addressing the role of vegetation for direct and indirect carbon reduction (**W1-O1, O3, O4)**.

In the context of SUP, according to findings by Lin et al. (2017), SUP (1.5 ha) in Melbourne, Australia, highlighted that improving the density of trees to approximately 40% canopy coverage provides better shading and cooling effect. Meanwhile, pertaining to the age of trees, C. Velasco et al. (2016) found that trees older than 100 years in a neighbourhood in Singapore covers only 1.4% of the land area but can store 8.4% of the total carbon in the neighbourhood. Moreover, vegetation's planting patterns and arrangement can also determine carbon uptake efficiency, for example, Hyun-Kil Jo (2002) suggested that multi-layered plantings with herbs, shrubs and overlapping tree layers improve continuous carbon uptake over time. In the same vein, Hyun-Kil Jo, Park, et al. (2019) added that higher vegetation density, multi-layered planting and fast-growing species of trees could improve carbon uptake. Similarly, Othman et al. (2016) deduced that the plant materials' characteristics and the right landscape design are essential factors to consider efficient carbon uptake in small green spaces. It is also important to note that SUP is highly susceptible to changes within its urban matrix; thus, as highlighted by Currie (2017) SUP should adopt adaptability characteristics to change cities over time to foster a sustainable model that provides flexibility and continuity (**W2-O3**). For example, with UHI concerns in cities, SUP can adapt its landscape features as a mitigation measure to improve the microclimate. Adopting adaptive in planting design will aid in building a resilient urban ecosystem towards the challenges posed by climate change (Hunter, 2011).

3.3.3 Weakness-Threat

The nature of SUP, due to its small size and surrounding urban environment, is subject to an array of anthropogenic pressures. Increasing tree density in SUP to improve carbon capture is not a clear-cut solution; various threats should be considered with trees in urban areas. As Akbari et al. (2001) mentions that some tree species might emit volatile organic compounds exacerbate the smog problems. Meanwhile, trees meant for urban parks need significant maintenance from safety (i.e., fire hazard, tree roots damage pipes, pavements, and foundations); thus, this may entail a high cost. The authors Akbari et al. (2001) suggest that the tree species' strategic planning and spatial arrangement is vital in minimising such risk. For SUP to play a significant role in LCC, a balance between ecological, biological, and socio-cultural diversity should be balanced. For example, the author Hunter (2011) puts forward the "designed experiments" to guide urban vegetation planting design to form a balance between ecological, aesthetic, and functional goals to create a resilient ecosystem against climate change. Thus, planners and managers should consider different combinations and comparisons of planting elements should be further explored in research and practice in SUP (**W2-T1)**.

Moreover, carbon storage's fate is at the mercy of urban expansion and greenery management; intense pruning and removing mature trees can return a large amount of carbon to the atmosphere (C. Velasco et al., 2016). Thus, the carbon uptake and footprint in SUP should be accounted for in the planning and management of these spaces **(W1-T2)**. Davies et al. (2011) highlight that accounting for carbon uptake will aid in local management recommendations or policies formation to secure this essential ecosystem service. According to Niemelä et al. (2010), carbon uptake estimates can help local authorities strengthen carbon uptake and decrease emissions with proper land-use planning. Detailed local data of ecosystem services of vegetation in SUP through integrating tools such as geographic information systems will aid managers in timely and efficient spatial analyses to put forward design and implementation strategies.

Next, in accounting for carbon, special attention should be given to mature trees because they accumulate a large amount of carbon over time. Thus, cutting down these trees can release a large amount of carbon back into the atmosphere (C. Velasco et al., 2016). Urban planners should also consider the tree mortality of vegetation for better management of vegetation, Nowak and Crane (2002) pointed out that vegetation is not a permanent source of carbon removal because carbon is released back to the atmosphere when the tree dies and if it is removed the soil may retain a fraction of that carbon. The relationship between carbon footprints in the design and maintenance of green space is explored in a study by Strohbach and Haase (2012) in Germany, where the authors found the carbon footprint in these spaces comes from the equipment's that consumes fossil fuel for activities such as tree pruning and litter (dead tree and grass removal).

4. Conclusion

SUP can play a role in LCC by reducing carbon sources, cutting down carbon emissions and strengthening carbon capture. In strengthening carbon uptake, a network of SUP connected by a green network could reduce fragmentation and improve accessibility, ecosystem service, and microclimate at a local level. Meanwhile, with space limitations, planners of SUP should consider a variety of vegetation that requires minimal maintenance, characteristics of the plant materials and the right landscape design to reduce carbon emission. It is important to note that increasing vegetation in SUP comes with various risk factors that should be accounted for in planning where measures such as appropriate spatial arrangement can minimise such risk and reduce carbon sources.

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