E N V I R O N M E N T A L   F O U N D A T I O N
(G U A R A N T E E)   L I M I T E D

URBAN GREENING FOR A COOLER COLOMBO

FINAL REPORT

06/12/2019

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1) Background - Current status of Colombo

Colombo city is the commercial capital and the largest city in Sri Lanka with the extent of 40.78 km^2, occupying 5.6% of the total extent of Colombo district. Colombo Metropolitan Region (CMR) is predominantly residential, with 42% of the land use within the city limits being residential and commercial and other industries occupying 3.5% and 4.5% respectively (JICA, 2014). According to Department of Census and Statistics (2012), Colombo district provides home to 11.4% of country's total population within a 1.01% of the total land area of the country.

While population continues to grow in Sri Lanka, it is projected that Colombo District will contain more than 90% of the country's population by 2021 (Fig. 1). Hence, CMR not only has an existing high population density but undergoes rapid development to provide the needs of the growing population within the city. Consequently, urban sprawling gives rise to a myriad of issues such as illegal encroachment, deforestation and habitat fragmentation.

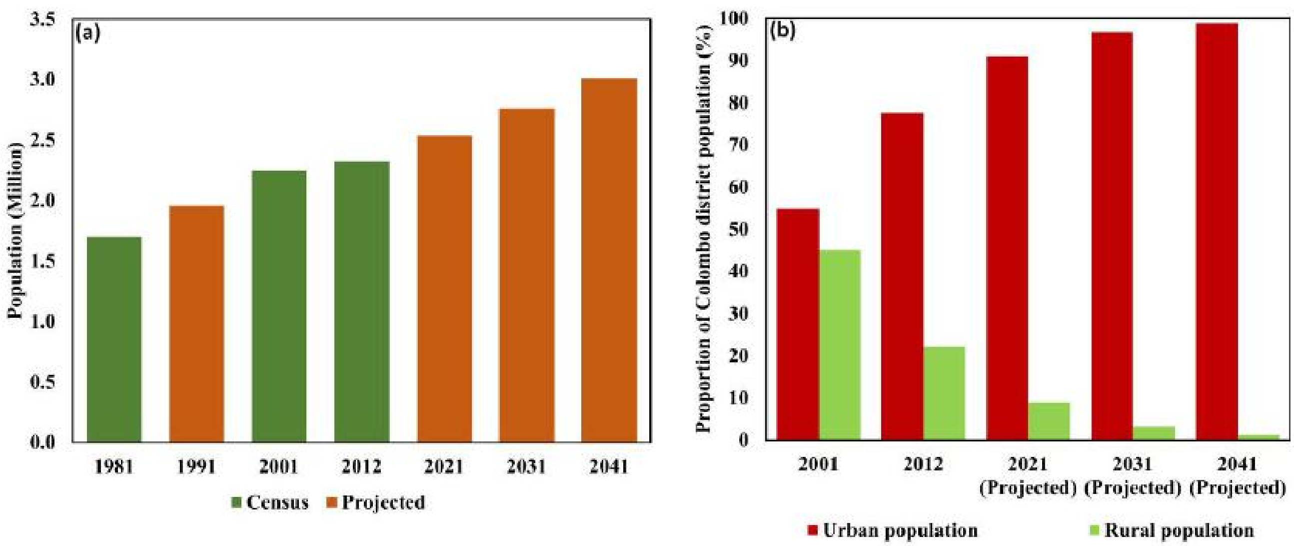

Figure 1 Projected population growth in country (a) and in urban area (b) (Rangalage et al., 2018)

The city of Colombo currently hosts more than two million people whose well-being largely depends on ecosystem services provided by remote natural areas. The fact that nature conservation in the city can contribute to human well-being and the resulting benefits are often disregarded. Urban systems in fact host many natural environments rich in biodiversity including a range of ecosystem services opportunities, and hence, should drive urban people towards increased urban forest conservation and implementation strategies. Additionally, urban green spaces such as parks, forests, green roofs, streams and community gardens promote physical activity, psychological well-being and the general public health of urban residents.

The green cover in Colombo has critically decreased from 83% in 1981 to 5.02% in 2015 (Fig. 1). The estimated per capita green space in 2015 was 7.16 m^2 (Li and Pussella, 2017). World Health Organization (WHO) has defined an area of 9 m^2 as the optimal green space that should be maintained for each person in an urban area to provide a better quality life (Khalil, 2014). Additionally, the United Nations (UN) considers cities with a per capita green space more than 30 m^2 as sustainable cities.

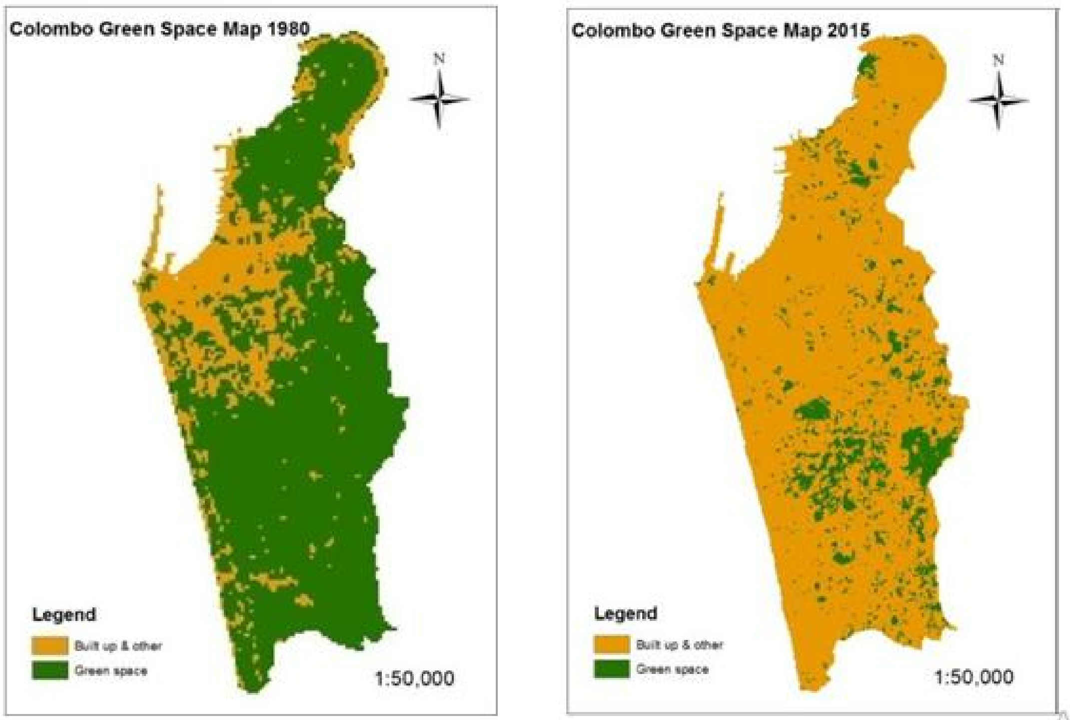

Figure 2 Change in green space in Colombo from 1980 to 2015 (Li et al., 2017)

2) Ecosystem services provided by green spaces

1) Purification of air

Air pollution in urbanized areas is predominantly caused by the emissions from transport devices and manufacturing industries. Vehicular emissions in Sri Lanka contribute to over 60% of total emissions in Colombo (Batagoda et al., 2004). Particulate matter (PM) with a diameter < 10μm (PM 10) and with <2.5 μm (PM 2.5) are considered to have long term health impacts, especially on young children and the elderly (WHO 2016). The accepted annual mean PM 10 levels as defined by the WHO and Sri Lankan standards are <20 μg/m^3 and <50 μg/m^3, respectively. Annual averages of PM 10 recorded by Central Environment Authority (CEA) at the Colombo Fort monitoring station for the period of 1998-2012 indicated values exceeding 50 μg/m^3. During a study conducted in Colombo, Dharshana and Coowanitwong (2008) observed that PM 10 has strong associations with bronchitis, emphysema and other chronic obstructive pulmonary diseases in children. Hence, it is evident that the air quality in Colombo urban region is degraded, and long term exposure can lead to diseases that would affect lives and the economy of the country.

Trees purify air by absorbing the greenhouse gas carbon dioxide (CO_2), and the leaves can entrap toxic contaminants such as sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3) and harmful particulate matter (PM). Urban trees have been found to reduce concentrations of SO_2 and ground-level O_3 by 20% (Beckett et al., 1998) while some studies have also observed that urban forests assist in lowering PM 10 concentrations by about 200 tons annually (McPherson et al., 1994, McDonald et al., 2007). Diverse species of trees have different pollutant capturing efficiencies, depending on characteristics such as leaf size, stomatal size and cuticle thickness (Freer-Smith et al., 2004). Due to high surface areas of the leaves and the tree structure that can create turbulent air particle movement, trees are more efficient in absorbing more pollution than other land cover types (Freer-Smith et al., 2004, McDonald et al., 2007).

2) Cooling

Cities are generally composed of physical structures that are built with material with varying thermal properties, including high solar reflectance, heat capacity and thermal emissivity. Additionally, manufacturing industry, transport sector and electronic devices emit heat that can contribute to increased temperatures in a city. Consequently, the difference in the temperature between the urban and rural areas can at times exceed 10 ^{0}C (Hiemstra et al., 2017). The above lead to a localized climatic phenomenon known as the Urban Heat Island (UHI), where the temperatures in the city are higher than its rural surroundings. The temperature difference is even more observed during night time, especially under calm conditions (Oke, 2002). Global climate change driven higher temperatures may exacerbate the health impacts that are already experienced in urban areas (Luber and McGeehin, 2008).

However, this can be greatly reduced by the presence of vegetation which not only provide shade by intercepting solar radiation, but also cool the environment by releasing water vapour during evapotranspiration. During a review done by Bowler et al. (2010), it was observed that parks and green areas experienced a lower average temperature, and the temperature reduction was 0.94 ^{0}C relative to the urban areas. The same review noted that air temperature beneath both individual trees and clusters of trees are lower than temperatures in an open area, at least during the day. Vegetation is also shown to enable up to 10% energy saving used for cooling buildings, simply from the decrease in temperature by 3-5 degrees Kelvin (Robitu et al., 2006).

A recent study conducted in CMR by Galagoda et al. (2018) examining the cooling effects of green facades covered with foliage, observed that the thermal cooling can be of a range between 0.2 ^{0}C-8.002 ^{0}C in comparison to a bare wall. Same study estimated that by incorporating vertical green systems into the building, an energy saving of 10.97 MW, worth US$19,000 can be saved annually.

3) Protection against storm surges

CMR includes low lying areas of the Kelani River basin which are highly prone to flooding. Land use cover modifications over time have led to changes in the soil structure and hydrologic regime, and as a consequence, the area frequently experiences flash floods during heavy precipitation events. Low infiltration capacities, due to large impermeable areas made of asphalt and concrete, reduce the ability to retain water. Floods that occurred in 2010 shut down the CMR for a week, displaced over 260,000 people in Colombo and incurred financial loss of estimated US$50 million (GFDRR 2018).

Trees can have a positive influence on urban hydrology through the increased soil-water storage and enhanced filtration into deep rooted systems. Improved seepage decreases the rate of surface overflow and recharge aquifers, where water is then slowly released into tributaries and rivers. Trees also reduce overland flow as tree canopies intercept and store water on their leaves and stems during rainfall events and this water is subsequently evaporated. Armson et al. (2013) has shown that trees and their associated tree pits can reduce run-off from asphalt by as much as 62%. Similarly, a study conducted in Beijing by Yao et al. (2015) reported that green zones, considered as areas with a vegetation cover of more than 60%, present within even a small area (~15% of total area) can contribute to a decrease in run-off by about 31%. It must be noted that the amount of rainfall intercepted depends on the tree species, the size/age of the tree and the intensity and duration of the rainfall event (Armson et al., 2013). In general it is evident that urban green spaces can significantly assist in rainfall-run-off regulation and flood mitigation in cities.

4) Biodiversity protection

Urban areas can provide habitats for rich fauna and flora, and thereby, significantly contribute to national biodiversity. CMR contains numerous freshwater bodies, national parks, streets, sanctuaries and beaches, which provide food, shelter and breeding places for more than 600 fauna species. Further, the Colombo wetland network provides habitats to numerous species, including vulnerable species such as fishing cat and Eurasian otter. Preservation of native habitats is the most ideal measure to sustain wildlife populations and conserve biodiversity. In fact, a study by Beninde et al. (2015) observed that remnant vegetation patches above 50 ha are effective in retaining sensitive avifaunal species.

However, increased removal of vegetation and destruction of sensitive ecosystems such as wetlands by infilling, threaten biodiversity and reduces the capacity to provide vital ecosystem services. Urban green spaces provide refuge for fragmented and remnant biodiversity. The connectivity provided by urban green spaces offer habitats that can help conserve biodiversity, as habitat connectivity through corridors can facilitate the movement of species between fragmented habitats. Habitat connectivity in urban landscape is vital to maintain gene flow and enable migration, dispersal and re-colonisation (Kong et al., 2010).

5) Increased aesthetics

Urban green spaces play a significant role in maintaining high standards of living by contributing to psychological and physiological health, preserving cultural heritage and by providing recreational opportunities (Wang et al., 2016). Flower beds and vegetable gardens have been observed to be preferred by the public as they provide high aesthetic and economic values in return. Aesthetic values provided by green spaces can be attributed to visual, auditory, tactile and olfactory senses that are pleased when coming in contact with defined senses of colours, shapes, textures and sounds emanated from urban gardens and forests (Chen et al., 2009, Zhou and ParvesRana, 2012). Urban greening strategies such as community gardens are also thought to provide opportunities for local health improvements and community development (Wakefield et al., 2017).

3) Green space analysis of Colombo Metropolitan Region

To analyse the current green space distribution Normalised Difference Vegetation Index (NDVI) was used. NDVI is commonly used to determine the density of vegetation on a selected terrestrial region and quantifies vegetation by measuring the difference between near-infrared (NIR) (which vegetation strongly reflects) and red light (which vegetation absorbs) as given below. NDVI for a given pixel always result in a number that ranges from -1 to +1, with high NDVI values representing healthier vegetation and low NDVI representing less or no vegetation.

$$NDVI = (NIR - RED)/(NIR + RED)$$

Landsat 8 satellite imagery and related NDVI map products created by Google Earth Engine (GEE) were used for the analysis. GEE composite maps are created from all the scenes in each eight-day period beginning from the first day of the year,continuing to the 360th day of the year. In this instance, the most recent data available for the year 2017 were used and averaged out to obtain a single map to illustrate the vegetation cover. This raster file was then transferred to a GIS platform to identify the areas with highest and lowest vegetation cover in terms of administrative authority. The spatial layer of Grama Niladhari (GN) divisions was overlaid for this purpose (Fig. 3).

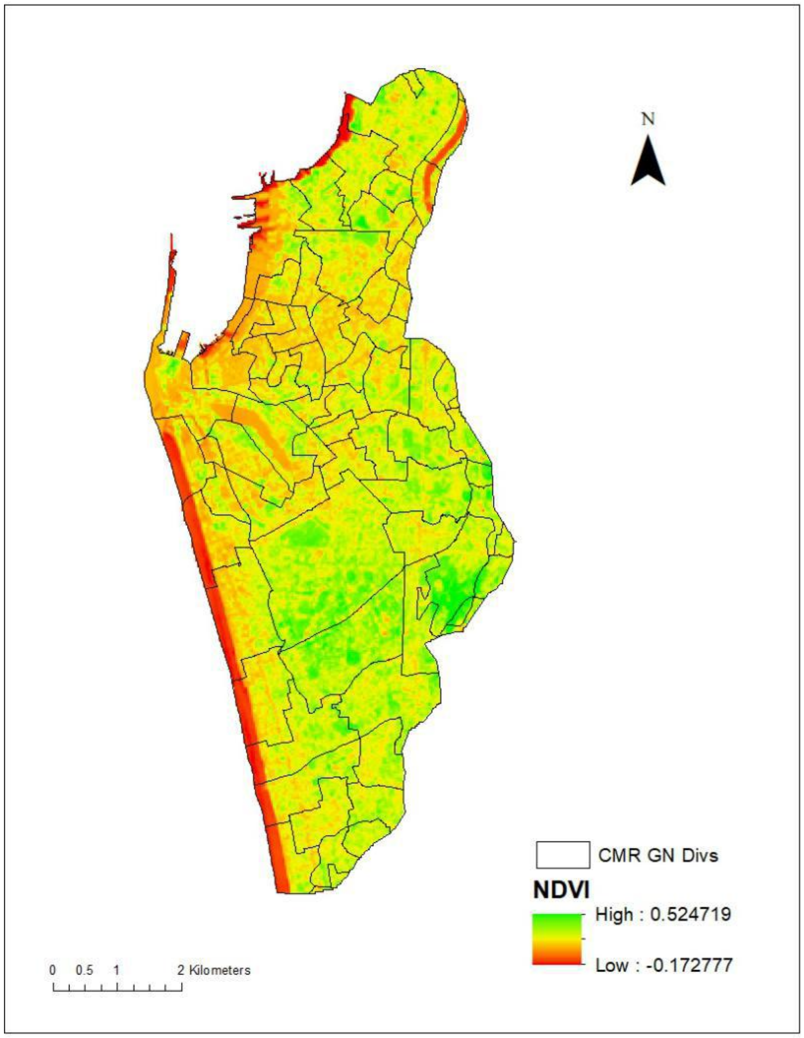

Figure 3 Normalised Difference Vegetation Index (NDVI) map of CMR based on 2017 Landsat 8 satellite imagery

The NDVI raster file was later reclassified and converted to polygon vector feature class using a natural break point of 0.22. The above threshold was chosen as very low values of NDVI (≦0.1) correspond to barren areas of rock, sand, or snow. Moderate values represent shrub and grassland (0.2 to 0.3), while high values indicate temperate and tropical rainforests (0.6 to 0.8) (Weier and Herring 2000).

Highest extent of green cover is observed in the GN division of Gothamipura with the highest NDVI of 0.5247, covering more than 50% of the GN area. The main reason for such high extent of green space is considered to be the presence of a golf course which belongs to the Royal Colombo Golf Club. Additionally, the number of buildings in the GN area is estimated to be relatively low due to the marshy nature of the area (Senanayake et al., 2013). In addition to the Gothamipura GN, Cinnamon Gardens and Thimbirigasyaya GN divisions show higher extents of green cover indicating adequate amount of green spaces for healthy living.

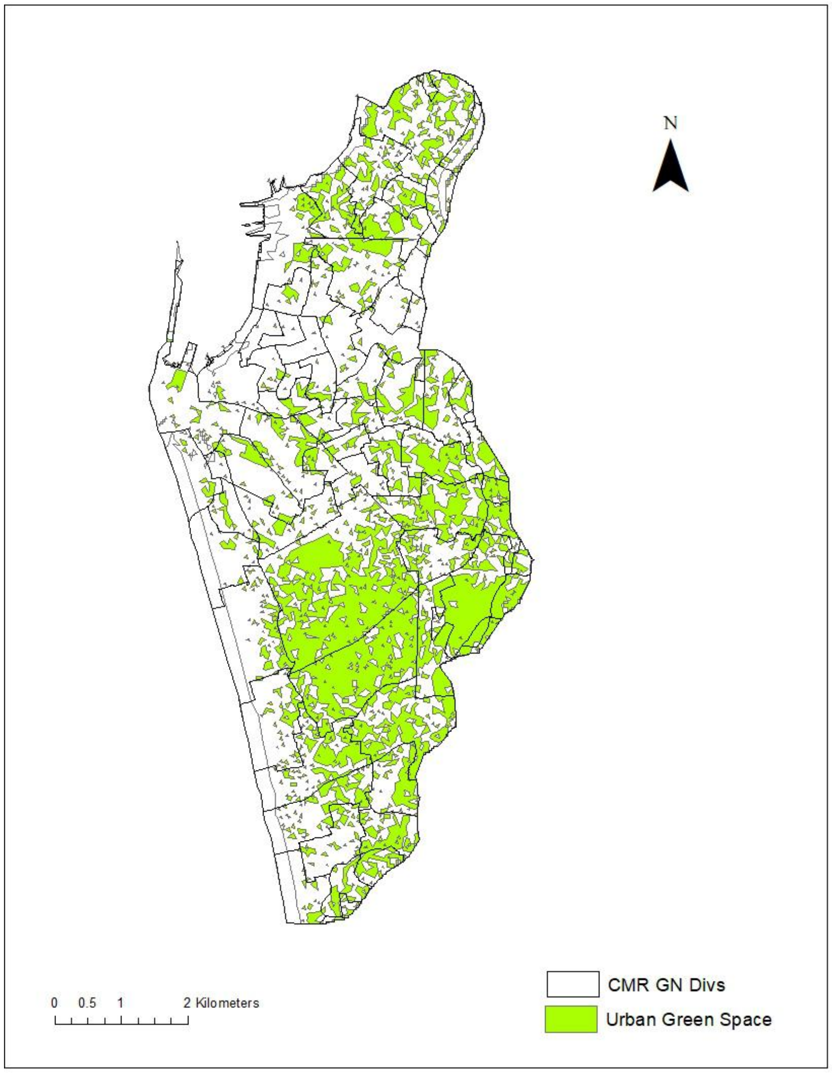

Figure 4 Green spaces within Grama Niladhari Divisions of CMR

In terms of increasing vegetation cover, opportunities exist in northern parts of CMR in the GN divisions of Grandpass North, Grandpass South, Jinthupitiya, Kochchikade North, Kochchikade South, Mangasweediya, New Bazaar and Pettah. These areas are also the commercial hubs of CMR with high population density and high levels of pollution, and therefore exhibit the highest demand for new green spaces. These results are compatible with a similar study conducted by Senanayake et al., (2013) using a different landsat satellite imagery data set. The above study also took into consideration the population density and green space per capita requirements and recommended north-central GN divisions of CMR for green cover enhancements.

4) Potential options for urban greening in Colombo Metropolitan Region

1) Urban parks

Urban parks could be considered as large green spaces that can accommodate a range of habitats and species. Large parks are also known to be cooler or have higher cooling effects. Chang et al. (2007), who compared the cooling effect of 61 parks, observed that parks over 3 ha were usually cooler than the surrounding urban areas. One of the prime examples for urban parks in Asia can be seen in Singapore, where the country has systematically introduced parks and open spaces in the form of precinct gardens, neighbourhood parks and town-parks as integral spaces of new township developments from the 1970s to 1980s (Yuen 1996). Although at the time of the urban green space development, the park provision ratio (PPR), which is park area per 1000 residents, was 0.75 ha per 1000 residents, maintaining such a ratio has become a challenge with growing population density (Tan et al., 2013). Hence, establishment of urban parks are dependent upon the nature and size of the city and the standard of living of the people within the local authority.

2) Vertical or skyscraper gardens

In the instance when the horizontal area for green space development is limited, skyscraper or vertical gardens can be established to increase the green cover. These are vertically vegetated surfaces and structures which generally involves layering buildings with levels of greenery. Flora used in these can be climbers, herbs, or small shrubs that can be planted on various three dimensional structures including, walls, pergolas, lampposts, utility poles, fences, rails, slopes, balconies or windowsills, flyovers and highways (Tian et al., 2012) (Fig. 3 and 4). Given that CMR has a significant number of high-rise buildings and the number continues to grow, there is an immense opportunity for the city to become greener through vertical and roof garden systems.

These gardens also provide opportunities to carry out urban farming, which can offer easily accessible, fresh, organic food and educate children and adults about healthy eating while creating a community of neighbours and co-workers who are conscious of and understand the importance of increasing urban green cover (Braiterman, 2011). As arable land becomes more scarce, vertical farming is proven to be an effective alternative that can enable the cultivation of more crops with less resources. Growing and harvesting a wide array of fruits, vegetables and herbs throughout the year in mega-cities or highly populated areas will enable the sale of these consumables directly to the community, and thereby, reduce transportation and post-harvest losses. Additionally, urban agriculture could assist in the improved management of organic waste in urban regions. More than 50% of the waste produced in the CMR consists of organic waste (CEA, 2008) that can be used for producing nutrient rich compost, which in return, could be provided as fertilizer for urban crop cultivation. Overall, urban agriculture can be considered as a measure for ensuring future food security with a future world population estimated to increase up to 9.6 billion by 2050.

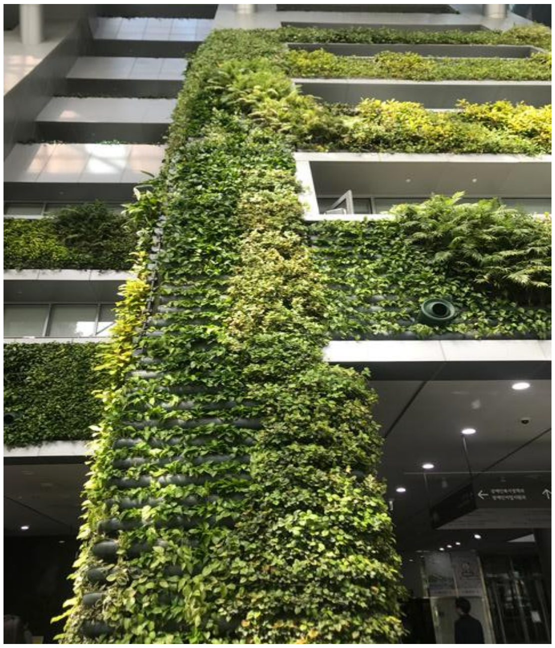

Figure 3 and 4 Indoor vertical gardens in Seoul City Hall in South Korea. The garden is seven stories high, spanning over 1516 m, and consists of approximately 65,000 plants of 14 different species.

3) Street trees (roadside greenery)

Roadside greenery is often overlooked but provide valuable services in terms of storm-water run-off and improving human health through reduced air pollution and noise regulation. Roads and associated soil compacted areas are impervious, and therefore, have low infiltration rates. During high precipitation events, these large extents of impervious areas in cities lead to increased runoff which can cause flooding, especially in the absence of proper drainage. Such flash floods are a common occurrence in CMR as observed in year 2010 where the Colombo city suffered from two major flood events in the same year. Thus trees lining the sides of the streets can play a valuable role in capturing the excess run-off and facilitating gradual infiltration of the soil. Such efforts contribute to flood regulation, recharge of groundwater and overall watershed management.

It is well noted that the weather patterns under climate change would be more erratic with varying intensity and frequency. Under such conditions storm-water regulation measures that involve biological controls such as rows of trees can be financially effective and will provide multiple ecosystem services.

Figure 5 Street tree planting in Kuala Lampur, Malaysia (Sreetharan et al., 2006)

Street trees should be planted in an effective manner as to enable undisturbed and smooth growth of the tree. Common failures include compacted soil, inadequate tree pit size, lack of soil volume for root growth and impervious areas directly above the tree (US EPA, 2015) (Fig. 6). Grey et al., (2018) observed that highest tree growth was observed in trees that were in pits that had direct access to runoff but also contained an underdrain which prevented waterlogging. In contrast, trees in the pits with no underdrain experienced mortality due to waterlogging.

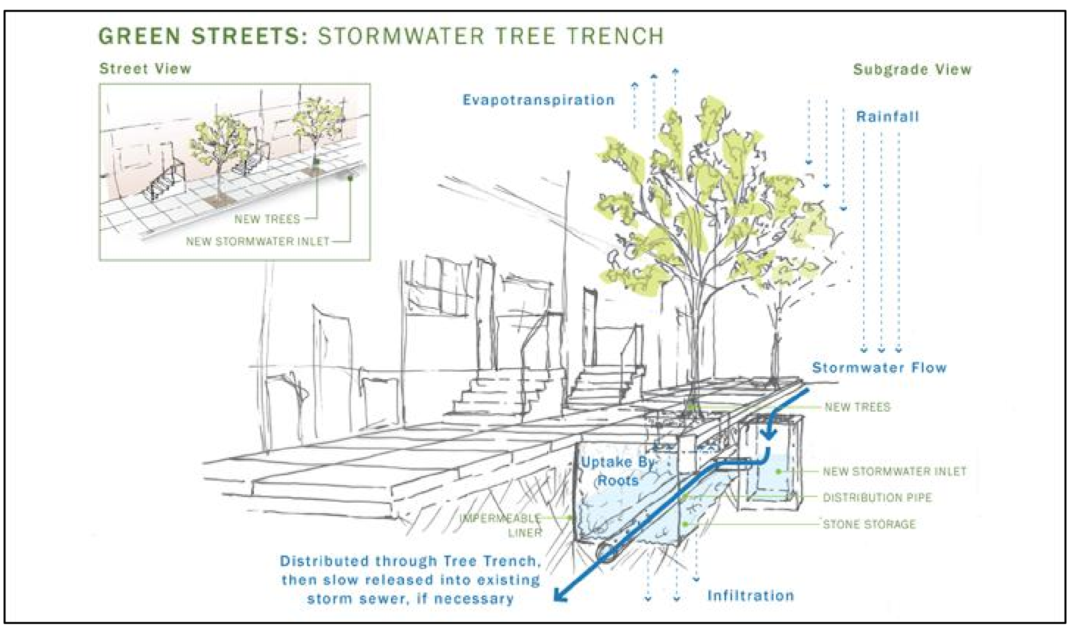

Figure 6 A well-designed street tree system (Source: Philadelphia Water Department)

5) Flora for urban greening

In Sri Lanka, although studies on urban greening are limited, sparse studies have shown the potential for using Pteridophytes (ferns) for greening indoors and outdoors. They are of high aesthetic value due to their elegant foliage that varies from simple strap-shaped fronds to the plumose fronds of the finely divided cultivars (Jones, 1987). Additionally, ferns are a favourable option for urban greening purposes as they have a year-round growth, are less prone to diseases and pest attacks and most species require less resources and maintenance (Dasgupta and Dadlani, 2011). Differing sizes of the ferns also mean that larger pteridophytes can be planted in urban parks and other scenic areas while medium-sized plants could be used indoors and on side walls of buildings (Ranil et al., 2015).

Pteridophyte species used for vertical gardening in CMR are dominated mostly by a few exotic ferns such as *Adiantum* sp. (also known as Maidenhair ferns) and *Asphenium* sp. (Bird's nest ferns) (Fig. 6) (Galagoda et al., 2018, Ranil et al., 2015). Extensive review on the possibility of using pteridophytes for the floriculture industry of Sri Lanka conducted by Ranil et al. (2015) has provided a list of fern species that have ornamental features and can be grown in a range of environmental conditions. It must be noted that most fern species are well adapted to humus rich soils,well drained, indirect, bright sunlight and fairly constant temperatures. Hence, when used for exterior walls of buildings, ferns should be grown on walls thatdo not directly face sunlight. It is recommended that experts are consulted when identifying the best fern species to be grown under local conditions.

Figure 6 Ferns of Adiantum sp. that can be found commonly in Colombo Metropolitan Region (image source: https://memim/adiantum.html.)

Ficus pumila or climbing fig is another floral species found commonly as an ornamental plant, and can also be found as lining of building walls in CMR (Galagoda et al., 2018). It is considered to be an aggressive vine that rapidly grows on any surface due to the possession of a specialised structure. The above consists of an adhesive pad that secretes a sticky compound that adheres to almost any substrate (Groot et al., 2003). *Thunbergia laurifolia* or blue trumpet vine is also another common ornamental vine species found in the tropics. It is a fast growing vine and gives bloom to flowers continuously, throughout the year. These attract pollinators and thereby provide an added ecosystem service to metropolitan regions. *T. laurifolia* leaves are known to have herbal properties and are used as an antidote for poisons and drugs, including treatment of drug addiction (Chan et al., 2011). Thus, in countries such as Thailand, *T. laurifolia* has a market value, and is used by local herbal companies to produce herbal teas and capsules. However, there are concerns of these creepers encapsulating and shading native trees leading to inhibition of growth and/or pulling them down with the weight of the vines. It is imperative that precautionary measures are taken to prevent these vines invading areas with indigenous trees.

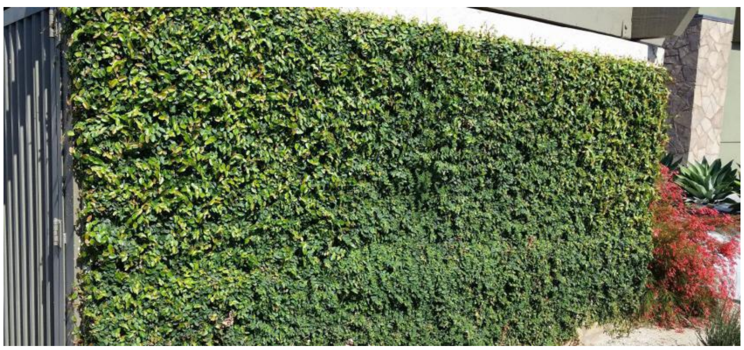

Figure 7 and 8 Ficus pumila (left) and Thunbergia laurifolia (right) found covering walls

When considering larger tree species that can be grown as street trees, it is worth exploring the already existing types in the CMR. There are only a few surveys that have been conducted with the aim of inventorying plant species in Colombo. Recent surveys conducted have recorded *Peltophorum pterocarpum* or yellow-flame (kaha maara) as well as, *Albizia saman* or rain tree (sooriya maara) as the most dominant tree species found in selected areas of Colombo (Kuruppuarachchi and Madurapperuma, 2016, Madurapperuma et al., 2015). *P. pterocarpum* has been urbanized during the colonial period, and is used effectively as a shade tree along main roads of Colombo. Mature *P. pterocarpum* trees also have a higher above and below carbon storage compared to other species such as *Salix tetrasperma* or *A. saman*. Studies recommend planting native species such as *Lagerstroemia speciose* (murutha), *Pongamia pinnata* (*magul karanda*), *Barringtonia asiatica* (mudilla) and *Phyllanthus emblica* (nelli) (Madurapperuma et al., 2015) in future tree planting programmes.

6) Urban greening for climate change mitigation and adaptation - opportunities and challenges

Nationally Determined Contributions (NDCs) developed under the Paris Climate Agreement clearly identify improvement in the forestry sector as a key area that is required to reduce Sri Lanka's carbon footprint. NDCs presented under the forestry sector include the commitment to increasing country's forest cover from 27% to 32% and incorporating urban forestry consisting of roadside planting, urban parks and tree planting in other state lands (Ministry of Mahaweli Development and Environment, 2016).

Additionally, the *National Adaptation Plan for Climate Change Impacts in Sri Lanka 2016-2025* identifies the importance of mainstreaming climate resilience in physical and urban planning infrastructure that can negate the detrimental impacts of adverse weather patterns, especially on human settlements. Under the sector action plan, actions such as introduction of green building concepts and enhancing the capacity of infrastructure in urban settlements are outlined (Climate Change Secretariat, 2016). *Western Region Megapolis Planning Project - Master Plan for 2030* clearly mentions its vision to promote green and inclusive growth of Colombo region. One of their key strategies is to develop a new generation of model cities on green fields to increase living standards. The plan also proposes to categorize sensitive ecosystems such as water bodies and wetlands and intends to link wetlands, riverside areas and coastal belts as park connectors that can be utilized by pedestrians.

Although Sri Lankan government has attempted to create a local green building movement by establishing the Green Building Council, only a mere number of <30 buildings are certified under the GREEN^{SL} Rating. The reasons for this include high initial costs, slow turnover, lack of awareness and lack of professional knowledge, which affect progression of green constructions (Thalpage and Karunasena, 2016). Without having specific policies, regulations and technical capacity related to green building in place, it is difficult to envision how the outlined actions in the NDCs and the proposed plans will be translated to ground-level realities.

It is vital that there are policies in place that identify best urban greening strategies and formulate regulatory frameworks for their implementation. To be conducive, urban greening should be formally accepted as a land use type and must be integrated into development and national physical plans, as that is a crucial step towards effective regulation and facilitation of urban greening. If this is to happen, the relevant authorities must coordinate and agree upon the type of strategies, including areas for potential greening, relevant guidelines and monitoring frameworks that are critical for successful enforcement of building regulations. As urban greening has the most direct benefits at the local level, local authorities such as *Pradeshiya Sabhas*, must be trained and educated to use appropriate guidelines when recommending and authorising specific land use development projects.

Additionally, greening concepts should be included in structured programs as part of school and tertiary curricula to enhance knowledge and skills of individuals from an early age onwards.

Professionals involved in the field of building and construction such as architects and contractors should be encouraged and incentivised to incorporate innovative greening concepts into their development initiatives.

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