Sustainable Greening Strategies for Megacities in Developing Countries

A Research Proposal under the theme of Urban Ecosystems in Megacities

2018 ProSPER.NET
Young Researchers' School
Kanagawa, Japan

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1. Introduction

1.1 Urbanization and challenges

In recent decades, the world has become more urban with 54.4 percent (UN, 2016) of the population living in the cities and towns of different categories. According to one of the recent reports of United Nations Economic and Social Council, approximately, 4 billion people lived in cities in 2015 (UNESC, 2017) and it has been projected that by 2050 almost two thirds of population will live in cities.

The world is under sustained process of urbanization which has led to major socio-economic and environmental changes. The numbers of megacities (cities with population of more than 10 millions) are increasing across the globe (UN-Habitat, 2015) and more than half of the world megacities i.e. 24 out of 31 are located in "global south" or developing regions of the world (UNDESA, 2016), including six from China and five from India alone. These huge urban agglomerations exceed the carrying capacity (Mathur and Sharma, 2016; Gupta et al. 2017) of the region and requires enormous amount of resources in terms of water, food, land, forests, fuel etc. in a small area to support them. Rapid and unplanned urbanization coupled with inadequate provision of basic need and services (Tayal and Singh, 2016; Gupta et al. 2017) are increasing the vulnerabilities of populations living in most cities in developing nations. The situation further gets aggravated due to high population density, traffic congestion, increased air pollution, water scarcity, continuous loss of green area and biodiversity, increase in urban heat island (UHI) phenomenon, and cities are becoming more vulnerable and prone to most of the hydro meteorological disasters (Sudmeier-Rieux,2013; Singh, et al.2013).

Increasing demand and non-sustainable management of resources have increased man's ecological footprint that have caused degradation of ecosystem in many regions. Supporting the Malthusian Theory on carrying capacity many ecologists give arguments in the favour that economic growth is increasingly based on the depletion of "natural capital", pollution levels and declining biodiversity (Meadows et al., 1974; Rees, n.d.). No nation can survive for long if natural resources of a state are exhausted or polluted. It was explained in "*Limits to Growth*" by Meadows et al. in 1972 that global equilibrium could be designed to alter the negative growth trend and establish a harmony between economic and ecological stability that is sustainable far in future and thus forming the basis for sustainable development. The United Nations' Sustainable Development Goals (Goal no.11) have also emphasized on making cities inclusive, safe, resilient and sustainable by implementing integrated policies and plans for resource use efficiency and adaptation to climate change(UNESC, 2017).

1.2 Needs and opportunities of resilience of cities through ecosystem services

According to The Millennium Ecosystem Assessment (MEA) report, ecosystems are referred to humanity's "life-support system" providing essential "services" for existence and socio-economic well being (MEA, 2005). The services include "*regulating services*" such as regulation of floods, drought, land degradation and disease, along with "*provisioning services*" such as food and water, "*supporting services*" such as soil formation and nutrient cycling, and "*cultural services*" such as recreational, spiritual, religious and other non-material benefits. The relationship between ecosystems and cities are interlinked and is often a two-way process (Gupta et al.,2017). Ecosystems provide a multitude of physical and environmental services to cities and their residents which also help in enhancing city's resilience (Estrella and Saalismaa, 2012; Gupta, et al, 2017) by combating the adverse impact of climate change. Green Infrastructure development is a strategic planning approach that aims to develop network of green and blue spaces in urban built environment.

Figure 1: Flyover greening in China (Chinese Architectural Greening , 2011)

The concept holds different interpretation for different people. From social perspectives it refers to 'green' benefits, while for engineers it involves the integration of various techniques like green roofs, gardens and parks. Though the interpretation may be different but the benefits of these structures are manifold. Some of the benefits as mentioned in the literature are greenhouse gas mitigation such as carbon storage and removal (Velasco and Roth, 2010; Davies et al., 2011; Novak et al. 2013), air quality improvement (Freer-Smith et al, 2005; Setala, et al. 2013; Brantley, et al. 2013), water management (Gill et al, 2007; Jacobson, 2011; Ellis, 2012), reduction in energy consumption in buildings (Cameron, et al, 2012; Jafal, et al, 2012) and various social, ecological and human health benefits (Costanza, et al, 1997; Nordh, et al, 2009; Peschardt, et al, 2012).

This research proposal is focused on the greening strategies of flyovers in Delhi for enhancing the ecosystem services in the built environment. Delhi is the capital city of India and one of the top three megacities of the world, facing the consequences of population growth and unplanned urbanisation, traffic congestion, acute air pollution,

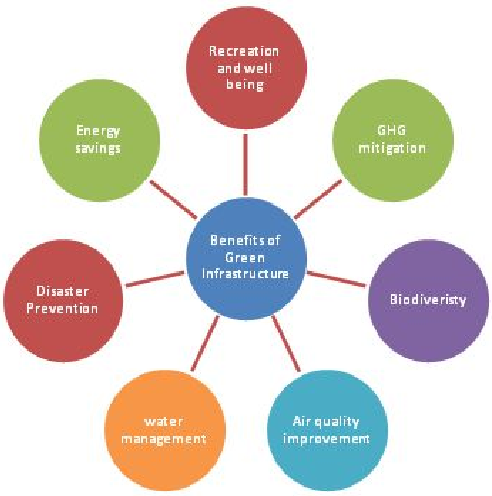

Figure 2: Benefits of green infrastructure

water scarcity, biodiversity loss and global warming. In order to support the increasing traffic, a tremendous number of flyovers were built in last two decades.Therefore, the aim is to propose a way to improve ecosystem services by greening the flyovers in New Delhi.

2. Literature review

2.1 Approaches to Urban Greening

Urban greening refers to the varied initiatives undertaken within urban areas to soften the urban landscape and make it more appealing to live in. However, compact cities in developing and developed countries are commonly beset by green space deficit (Jim, 2013) which make it difficult to achieve urban sustainable development goals. Urban greening can take in many forms depending on the suitability and availability of spaces, which is the first and foremost key requirement (Lee et al., 2015). Urban and peri-urban agriculture (UPA) is defined as "an industry placed within city (intra-urban) or on the periphery (peri-urban) of a town, city, or metropolis that cultivates, processes and distributes a variety of agricultural produce using resources, agricultural inputs and services such as human, land and water from within that urban area" (Hoornweg and Munro-Faure, 2008). Urban agriculture activities may come in different types depending on factors such as land availability and socio-economic status of the localities (Arshad, 2017). It may take in the form of 1) community gardens; 2) institutional gardens; 3) agricultural parks; 4) rooftop gardens; 5) livestock and poultry farms (depending on the planning law); and 6) aquaculture. In addition, technology-based urban agriculture are now popular and widely practiced in the form of organic farms, hydroponics, indoor gardens and urban vertical farms.

Green infrastructure (GI) on the other hand, is broadly defined as "a strategically planned network of high quality natural and semi-natural areas with other environmental features, which is designed and managed to deliver a wide range of ecosystem services and protect biodiversity in both rural and urban settings (EU, 2013). On the local level, GI practices include rain gardens, permeable pavements, green roofs, infiltration planters, trees and tree boxes, and rainwater harvesting systems. At the large scale, the preservation and restoration of natural landscapes such as forests, floodplains and wetlands are critical components of green infrastructure. Green roofs and green walls have become a rising new trend of built environments that are used as a means to mitigate a range of environmental impacts associated with urbanization and simultaneously creating aesthetic. Both approaches make use of vegetation growing on a surface, thus referring them sometimes as living roofs and walls. Mexico City implemented in 2016 an initiative of greening the 1000 plus columns supporting flyovers and elevated roads through vertical gardening with the aim to fight pollution, beautify the cityscape and reduce the stress levels of motorists. The project was expected to produce enough oxygen to support its 25,000 residents in addition to filtering more than 27,000 tons of harmful gases, capture more than 5,000 kg of suspended dust particles and processing more than 10,000 kg of heavy metals from the air annually. Vertical greening is also the most common type adapted by Shenzhen City in flyover greening, followed by fence greening and pillar greening (Zhai et al., 2012).

2.2 Impacts of Urban Greening: Its implication to society, economy and environment

2.2.1.Environmental Benefits

(i)Ecological Benefits: Urban green spaces provide a wide variety of services ranging from maintenance of biodiversity to regulation of urban climate. Among the major environmental challenge in cities is the urban heat island effect caused by the excessive heat trapped by the large areas of heat absorbing surfaces, in combination with high energy use in cities. An adequate vegetation around houses and other infrastructures and management of water bodies can help mitigate the situation (Haq, 2011). Moreover, green space has the landscape function of buffering interferential land use while enhancing environmental beauty and visual aesthetics (Liu and Shen, 2014).

(ii)Pollution Control:Cities are centers of consumption, greenhouse gas production, waste and emission of pollutants in air and water. Common air pollutants include particulate matter (PM), sulfur dioxide (SO_2), ground-level ozone (O_3), nitrogen dioxide (NO_2) and carbon monoxide (CO) which all have a detrimental health effect to city dwellers. Urban greening can reduce air pollutants directly when vegetation traps the dust and smoke particles suspended in the air. An analysis done by Liu and Shen (2014) for the city of Taipei using a model proves that the changing pattern of green space area influence air pollution and microclimate patterns. When the model is simulated for an improved space aggregation and increasing the large sized green space patch in the city, results showed that there will be less air pollution, smaller rainfall patterns and cooler temperature. Similarly, a study made by the European Commission also suggests that greening of roofs and walls with materials suitable for growing plants and softens the urban environment could keep sound levels low.

(iii)Biodiversity:The simple vegetation intervention in greening cities provide patches of habitats and greenways to serve as corridors to allow animals to move between core green areas. Moreover, green spaces do functions as protection center for reproduction of species and conservation of plants, soil and water quality (Haq, 2011).

2.2.2.Economic Benefits

(i)Energy Savings: The cooling effect of vegetation in buildings has been increasingly recognized making it one popular approach in obtaining energy efficiency strategies. The use of plants improves air circulation, provide shade and evapotranspiration that lower air temperatures and cuts the energy costs of cooling buildings. A study in Beijing, China’s 16,577 ha of green space was estimated to reduce the city’s cooling demand during summer by up to 60%, (Zhang et al. 2014).

(ii)Property Value: Areas of the city with enough greenery and aesthetically pleasing and attractive to both residents and investors. A number of empirical studies in Euro-American regions consistently demonstrate that parks and open space have positive impact on property values (Biao et al., 2012). The beautification of Singapore and Kuala Lumpur, Malaysia was considered as one of the factors that attracted significant foreign investments that assisted the rapid economic growth (Haq, 2011; PWC, 2015; Karade et al, 2017).

2.2.3.Social and Psychological Benefits

(i)Recreation and wellbeing:Outdoor refreshment has a vital role in health and high quality of life in an urbanized environment (Bell, 2007). Access to urban spaces of different types and for varying purposes has been shown to be of great importance for wellbeing. The shared usage of open spaces creates social interaction that strengthens social unity. Moreover, tranquil spaces allow for thinking, contemplation, and learning (Adams, 2014).

(ii)Human Health:All types of green space, from single green walls to large urban forests, have been associated with relief from heat stress, reduced urban heat islands effect and air pollution reductions. Despite the fact that green roofs and walls may not be as effective at cooling or reducing air pollution as compared to ground-level trees, they can provide important microclimate regulation services and reducing air pollution, particularly in densely built areas (Zupancic et al., 2015).

2.3 Green Infrastructure and its Linkages with Sustainable Development Goals

Green infrastructure (GI) designs that commonly performs a single function in the landscape date back to cities of antiquity. Green infrastructure on the other hand offers a multi-functional network that provides a more sustainable alternative to grey engineering and provides similar or even improved services to the existing grey infrastructure. When grey and green infrastructure are integrated together, a collaborative symbiosis can be achieved in the form of an infrastructure that facilitates recycling and regeneration and can maintain the functionality, sustainability and vitality of the urban ecosystem, Li et al., (2017). Green infrastructure (GI) is viewed as an innovative way in directly achieving the targets of SDG 11 (Sustainable Cities and Communities) in consideration of the various benefits that can be derived from it. However, GI may also indirectly contribute to the achievement of other targets. Among the benefits of green infrastructure as mentioned in literature include 1) water management (Targets 6.3, 6.6); 2) carbon storage and removal (Targets 13.1, 13.2); 3) reduced energy use in buildings (Targets 9.1, 9.4); 4) air quality improvement (Targets 3.9, 11.6); 5) social benefits (; 6) ecological benefits; and 7) human health and well-being benefits (Target 11.7).

2.4 Characterization and screening of suitable plant species for urban greening

Using natives in urban greening is often hampered by a knowledge gap that usually result in a stereotype landscape designs and species assemblages with a disproportionate amount of exotic species (Jim, 2012). An ecological survey could identify existing natural habitats for incorporation into the natural design while species enrichment could be incorporated into the refurbishment scheme. On the other hand, exotics should not be excluded despite promoting natives for urban greening. Natural sites could mainly hold natives, whereas semi-natural or artificial sites could be filled by a complement of natives and exotics. By providing a strategy or action plan to screen exotic species and promote suitable ones, an orderly importation could replace random introduction and likely to prevent invasion or erosion of native species. In addition, unregulated activities operating outside quarantine regime should be controlled to avoid inadvertent transfer of pest organisms and instant pathogens (Jim, 2012).

2.5 Key challenges in Urban Green Space Planning in compact city environment

2.5.1.Challenges to urban green space planning in the cities under densification

Urban population is constantly increasing and the percentage of people living in urban areas will increase from 50% in 2010 to nearly 70% by 2050 (United Nations, 2013). This will result in expansion and/or densification of urbanized areas. Because of continuous migration to urban areas, sustainable urban development is becoming the need of time. Urban sustainability has been related to urban form (Jenks and Jones, 2010a) and effective allocation of land resources. Related problems are non-efficient use of resources e.g., of land and energy causing a larger urban footprint, loss of biodiversity, environmental problems, and social inequalities (Power, 2001). Solutions lie in more sustainable urban forms including not-traditional development urban containment, the compact city and the eco-city (Jabareen, 2006).

More sustainable urban forms include neo-traditional development, urban containment, the compact city and the eco-city (Jabareen, 2006). Compact city aims to counter the negative effects of urban expansion as well as sprawl. The 'compact city' is featured by high density housing, mixed use zones, well-functioning public transport (transit-oriented development) and opportunities of cycling and walking (Burton, 2000). Nevertheless, negative effects of city densification are increasingly evident. One issue identified is the lack of urban green space in densified urban areas and the removal of green space when densifying city areas (e.g., Jim, 2004; Fuller and Gaston, 2009).

As urban sprawl can encroach countryside areas, densification can potentially threaten urban green spaces within cities and towns. In that case, green space planning and management can be very challenging since important ecosystem services are supposed to be delivered by limited green spaces.

The literature on green space planning in urban areas undergoing densification identifies several challenges:

(i)Provision of green space: Most common problem in already dense urban area is the development of new green space (Jim, 2004). Provision of new green space appears to be a serious problem also in less dense urban areas. Without planning for more public green space, infill development can decrease overall living standards in an entire neighborhood.

(ii)Social equity:Socio-economic disparity prevails among the communities within the cities and it translates into environmental injustice through uneven distribution of urban green spaces (Arshad and Routray, 2018). This appears as a general challenge for future green space planning, as a more even distribution and thus more equal accessibility of urban green space is desirable.

(iii)Residents' perspective:Only recently, the way in which residents perceive access to green space has been paid serious attention (e.g., Dempsey et al., 2012). Lo and Jim (2010a) found different attitudes of people towards green space provision in different communities. Urban green in old core area quarters has an important function for socializing and are highly appreciated by residents.

(iv)Biodiversity:Maintaining biodiversity is also a key challenge in compact city environment. Studies investigating the effect of densification on biodiversity found everything from negative to positive impacts of densification. Increasing number of residents reduces the number of bird species in pocket parks in dense urban area (Ikin et al., 2013).

(v)Institutional constraints:Institutional constraints obstructing the development of urban green space are broadly acknowledged and often stated as one major challenge to green space planning. The lack of comprehensive planning for green space is seen as a major problem (Byomkesh et al., 2012). Further, illegal building on green space which is not always prevented causes quick reduction in ration of green spaces in urban environment (Byomkesh et al., 2012).

2.5.2.Current situation in Delhi: Population growth, Land use change, Infrastructure and environmental quality

(i)Population growth:The increment in the population growth of Delhi has its roots way back in mid of 20th century when India was partitioned after the Independence (Mohan et al., 2011). Census data indicates that the population of the city was only 0.4 million with 52.76% of urban population in 1901, increased to 1.74 million with 82.40% of urban population in 1951 (i.e. increase of 3.3 times from 1901 to 1951). The annual average exponential growth rate of population of Delhi was the highest, 7.3%, during 1941-1951 due to large scale migration when India partitioned in 1947 (Economic Survey of Delhi, 2007-2008). The population reached to 13.85 million by 2001 (i.e. increase of 8 times from 1951 to 2001) with an annual average growth of 4.1%. After the Independence, the city has dramatically changed in an uncontrolled and unplanned manner to accommodate this increased population.

To control this encroachment of undesirable expansion, the city development authorities promulgated the first attempt on comprehensive urban planning for Union Territory of Delhi (UTD), "The Master Plan for Delhi 1962 (MPD-1962)" for the projected population of 47 lakhs (1 lakh = 0.1 million) by 1981. The plan projections were overshot with the fast pace of population growth by approximately 15 lakhs as the population of Delhi was 62 lakhs in 1981 (Mohan et al., 2011). The master plan was then modified in 1990 for a projected population of 128 lakhs for the year 2001 and named as MPD-2001. Keeping this projected population in mind, authorities planned the urban expansion up to Rohini in North-West, Narela in North and Dwarka in South-West. However, population again overshot by 10 lakhs and became 138 lakhs in 2001.

(ii)Land use change pattern and planning:Keeping in view of the increasing population, Delhi Development Authority (DDA) has proposed a new plan recently, "The Master Plan-2021 (MPD-2021)" to accommodate the growing population. The major part of North-West and South-West regions and some parts in South and North-East Delhi have definite plans for development and are going to be urbanized as a part of Master plan-2021.

LULC changes and urban expansion of Delhi is governed mainly by its geographical location and socioeconomic factors. Although population growth is the primary cause for rapid urbanization, the contribution from other factors such as economic development and physical factors should not be neglected (Mohan et al., 2011).

(iii)Current Land use policies in Delhi: Land use policy sets the major track for future land allocation for different uses and prescribes the interrelation of these uses. Two important features of land-use policies of Delhi in the recent past included the relocation of 90 000 industrial units from the city Centre for reasons related to pollution and the resettlement of poor people evicted from their original location to the city's outskirts (Mohan et al., 2011).

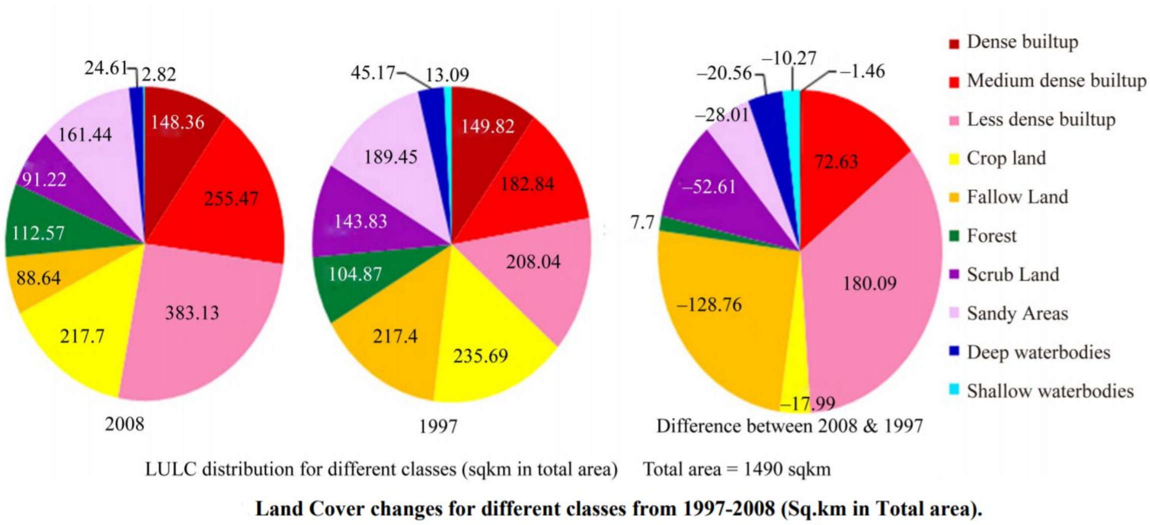

Figure 3: Land cover changes for different classes from 1997-2008 (Source: Mohan et al., 2011)

The relocation of industrial units may have reduced pollution in the city; however, almost 50 000 people lost their source of income and have faced immense hardships. Similarly, the unprecedented large- scale evictions of people from unauthorized and illegal constructions in Delhi from the year 2000 have affected poor people — who are the most vulnerable. Plans to turn Delhi into a clean city seek to evict the poor to the outskirts in favor of commercial complexes, flyovers, recreational parks, and roads for the well off.

3. Aim and objectives

3.1 Aim

This research aims to increase the resilience of cities by augmenting eco-services along with built environment. Potential places for greening megacities will be investigated, along with identifying suitable species for greening and evaluating the beneficial impacts from ecosystem services.

3.2 Research questions

- What are the spaces available for greening the city?
- What is the role of ecosystem services in reducing community's vulnerability and combating climate change?
- What are the gaps in the city development plans related to green infrastructure development?
- How can city greening improve eco-services along with urban development?

3.3 Research objectives

3.3.1 To estimate the potential spaces for developing green infrastructures in study area.
3.3.2 To identify the species that are more suitable for the study area.
3.3.3 To assess the overall impact of urban greening in the study area.

Table 1: Objectives and specific research questions for the project

Objectives	Specific Questions	Limitations/assumptions
To estimate the potential spaces for developing green infrastructures for the study area.	**Q1.** What specific spaces are to be estimated for greening?	Implementation/ maintenance
To identify the species that are more suitable for the study area.	**Q2.** What are the factors to be considered in selecting plant species for study area? **Q3.** What are the available species resilient to climate of the study area?	Limited literature available for suitable plant species in case of flyovers
To assess the overall impact of urban greening in the study area.	**Q4.** What are the indicators to measure the impacts of greening? **Q5.** What is the improvement of biodiversity in the city over time?	Availability of data/relevant literature

4. Methodology

4.1 Selection of study area

The study aims to suggest greening strategies for mega cities focusing on utilizing already built grey infrastructure. Delhi has been purposively selected as study area considering the availability of number of flyovers for installation of green wall systems. Delhi, the capital city of India is located between the 28º24′17″ and 28º53′00″N latitudes and 76°45′30″ and 77º21′30″E longitudes. Delhi, the National capital Territory situated near the western bank of river Yamuna which spreads over an area of around 1,490 km^2 is surrounded by the Himalayas in the North and the Aravali ranges in South - West.

Figure 4: Location of Delhi city (https://www.emaze.com/@ACIQTQFO)

4.2 Estimating the potential spaces for urban greening

4.2.1 To identify the potential spaces for urban greening

The first step is to highlight the spaces to be used to install the greening systems. Among many different available options, including outer facades of the residential and commercial buildings, boundary walls of institutional entities, inside walls of underpasses and flyover structures, this study focuses on flyover structures only. Potential surfaces to be taken under consideration for installing greening system are columns of flyover and parapets along the roadways of flyover.

First, a pre-feasibility will be run to highlight the structures to be included. Pre-feasibility will include structural criteria, surface design criteria, and maintenance plan. Flyovers not meeting these criteria will be excluded from the project.

- Structural criteria will take care of load bearing capacity
- Surface design includes shape of surface (plain or curved) and finished surface material
- Maintenance plan to project the possibility of watering and trimming etc.

4.2.2 Define and categorize urban green spaces in specific context of Delhi city

Once after the potential areas have been highlighted, next is to categorize these surfaces for specific greening system to be installed. Based on the structural capacity, surface design and maintenance plan, suitable greening system will be identified for all the available surfaces selected in the previous step.

Green walls can be subdivided in two main systems: green facades and living walls. Green facades are based on the application of climbing or hanging plants along the wall. Green facades can be classified as direct or indirect. Direct green facades are the ones in which plants are attached directly to the wall. Indirect green facades include a supporting structure for vegetation.

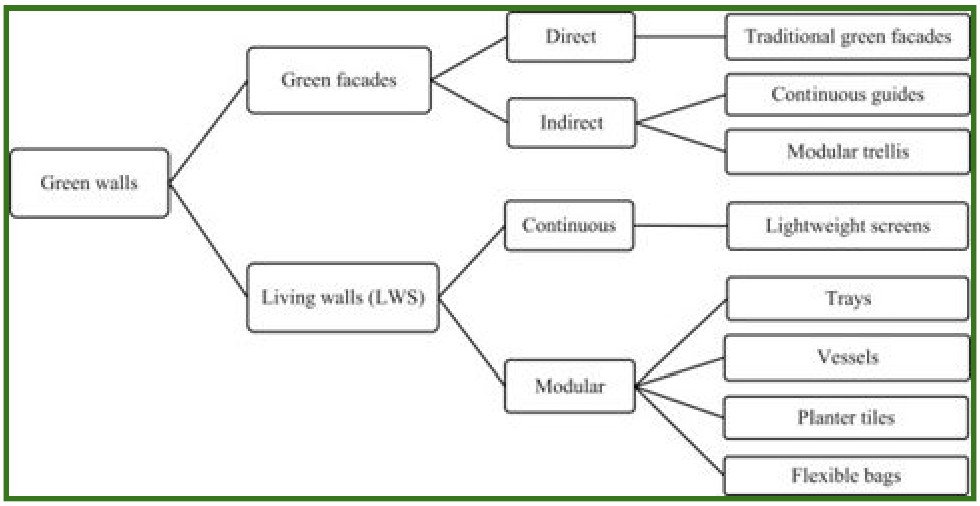

Figure 5. Categorization of green wall systems (Source:Haaland and Bosch, 2015)

Living walls are a quite recent area of innovation in the field of wall cladding. They emerged to allow the integration of green walls in high buildings. Living wall systems (LWS) can be classified as continuous or modular, according to their application method. Continuous LWS are based on the application of lightweight and permeable screens in which plants are inserted individually. Modular LWS are elements with a specific dimension, which include the growing media where plants can grow.

4.2.3 System requirements

Based on the system chosen for any area, system requirements will be estimated. Different greening system will have different basic system requirement and the cost will also vary. For every system, per unit area cost of installation and maintenance will be estimated. After estimation of cost, selection of specific greening system for each area will be revisited.

a) Supporting elements

b) Growing media

c) Vegetation

d) Drainage

e) Irrigation

f) Installation and maintenance

g) Environmental performance and costs

4.3 Selection of suitable system type and plant type

4.3.1 Vertical greening on the flyover columns

There are three basic components need to be considered to design the vertical greeneries: system type, plant type and irrigation. Different systems have been developed for vertical greeneries such as

Cassette System, Planter system, pocket system and support system. A specific suitable design system will be selected considering about the dimension of the flyovers and budgets. The position of drainage will be designed as well such as at the base of flyovers according to the designed system.

Figure 6: Common Greening Systems (National Parks Board , 2017)

It is also important to note that there are numerous plants available in greening studies or projects around the world. The suitable plant types for this flyovers greening project in Delhi needs to be figured out to achieve better resilience to climate change with focus on the use of native plant species. The environmental factors or climatic conditions around the proposed flyovers will be investigated, including solar radiation, wind speed, humidity and rainfall amount across the year. Therefore, based on the climatic conditions, suitable species will be selected according to their preference on sunlight and water demand. As some plant species also attract birds or butterflies, the importance of biodiversities needs to be considered when choosing the suitable plant type. Budget is also one of the considerations when choosing species. Maintenance is considered as well so that for some flyovers not easily accessible, some drought-tolerant and slow-growing plant species are preferred. Some suitable species are illustrated in Figure 7.

Figure 7: Some suitable species for vertical greening in India: *Hedera helix, Philodendron scandens* and *Trachelospermum jasminoides* (Afreen, 2017)

4.3.2 Parapets greening along the roadways of flyovers

Different from vertical greening on the newly built frameworks, parapets greening along the roadways of flyovers require a lot of considerations on the additional loads applied on the flyover beams and columns. Therefore, the amount of soil needed and the water weight that the structure can support is important. Similar to flyover column greening, the same environment factors need to be taken into consideration. A drought resistant plant type is more suitable for parapet greening if the column is not able resist additional load from water irrigation. Moreover, the height of plants also needs to be controlled as a result of wind effects. Wind drag may cause the failure of high plants and endanger the vehicles on the flyovers. Trimming in the maintenance may be required if the plant species chosen grow too high.

4.4. Impact Assessment of Flyover Greening in the Study Area

4.4.1 Baseline and Monitoring of Environmental Indicators

Air Quality Parameters

Air quality monitoring stations (18-20) are located in different sites of New Delhi. Baseline data (last 3-5 years) on ambient air quality of the sites to be chosen for the flyover greening project will be retrieved. Important air quality parameters to be considered are: **Particulate Matter (PM)** including **PM_{10}** and **$PM_{2.5}$**, **Sulfur Dioxide (SO_2)**, **ground level ozone (O_3)**, **Nitrogen Dioxide (NO_2)** and **Carbon Monoxide (CO)**. Monthly average will be recorded for the monitoring of air quality indicators.

Microclimate Parameters for Urban Heat Island (UHI) Effect

Microclimate characterization (averaged weather parameters) will be done before the implementation of flyover greening. Climatic parameters to be measured and monitored will be limited to **Minimum Temperature (T_{min})**, **Maximum Temperature (T_{max})** and **Relative Humidity (RH)** since these are the primary parameters that can be influenced by plant introduction in the city through shading and evapotranspiration effect. The recorded daily weather parameters will be averaged monthly.

Leaf transpiration rate

The leaf transpiration rate measurement is necessary in factor of the temperature measurement because the temperature may also depend on the light transmitted through the leaf, as there are different plant species with different leaf transpiration rate. The leaf transpiration rate of different plants will be measured using the cobalt chloride test. The initial dry cobalt chloride paper is blue in color. This paper will be placed on the leaf of different plant species along with a glass slide above it and will be left under sun light. Due to leaf transpiration, the water vapor will be released from leaves and this water vapor will be absorbed by cobalt chloride paper which is in blue color and will turn into pink color when wet. The plant leaves which take less time to change the color have high leaf transpiration rate compared to other plant. This will also provide information on the contribution of plants to the amount of RH in the air.

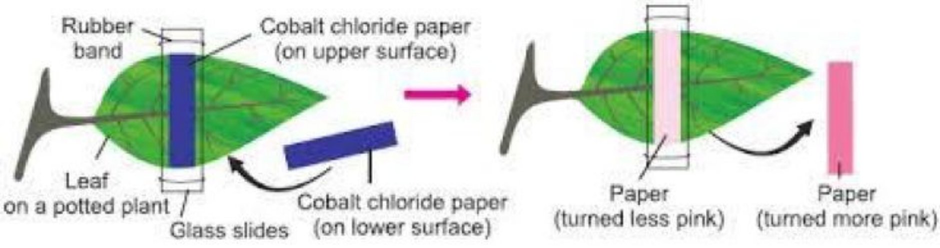

Figure 8 : Cobalt chlorine experiment

Biodiversity Monitoring

Increase of biodiversity in an ecosystem is as indicator of its health and stability. The introduction of vegetation in the urban environment will provide a potential microhabitat for insects, mammals and reptiles. **Documentation** and a **Diversity Index Analysis (Simpson's Diversity Index)** will be applied to assess the improvement of biodiversity over time.

4.5.Techniques of data collection and analysis

Literature review will be beneficial in gaining insights of our research objectives and will help us to design concrete data collection and analysis techniques.

4.5.1.Mixed method approach

This research requires in-depth information about the free spaces for vegetation on flyover, suitable species for flyover greening and parameters considering impact assessment of flyover greening.
That's why we need to do some measurements, experiments and monitoring for collecting primary qualitative data regarding free spaces on flyover, ambient environmental and weather condition of the study area and determining baseline data for assessing the impacts of flyover greening. Also, we need to collect some information from city dwellers and City Corporation and secondary data from various publications, Government and Non-government organizations.

Due to the anticipated difficulties- a mixed method approach, using both quantitative and qualitative methodology should be adopted (Creswell, 2003). A mixed method approach will assist in validating quantitative data with the subjective experiences of members of the city community.

Table 2: Data collection at a glance

Specific Research Questions	Mode	Techniques of data collection	Sources of Data
Q1. What specific spaces are to be estimated for greening?	Quantitative and Qualitative	Secondary data collection	Delhi Public Works Department(PWD), Municipal Corporation of Delhi(MCD), National Highway Authority of India(NHAI)
	Qualitative	Primary Data collection by direct measurements	Study area (Flyover)
Q2. What are the factors to be considered in selecting plant species for study area?	Quantitative and Qualitative	Secondary Data collection	Literature Review

Q3. What are the available species resilient to climate of the study area?	Quantitative and Qualitative	Secondary data collection	Literature Review
	Quantitative and Qualitative	Primary Data collection by monitoring plants growth and adaptation.	Study area (Flyover)
Q4. What are the indicators to measure the impacts of greening?	Quantitative and Qualitative	Primary Data collection by monitoring selected air quality and weather parameters and biodiversity	Study area
Q5. What is the base line data available?	Quantitative and Qualitative	Secondary Data collection	CPCB, SPCB, IMD
	Quantitative and Qualitative	Primary Data collection By monitoring ambient environmental and weather condition.	Study area (Flyover)
Q6. What are the impacts of flyover greening on study area?	Quantitative, Qualitative and Exploratory	Primary Data collection by monitoring ambient environmental and weather condition. Interviews with community members and academics, Review of Governmental documents.	Study area

5. Timeline

Planned submission	**Expected time to complete the project (in months)**											
Project Component	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Literature Review												
Data collection												
Data analysis												
Policy brief												
Write up												

References

F. Afreen (2017). Top 10 ornamental plants for vertical garden. Retrieved from: https://www.greenmylife.in/top-10-ornamental-plants-vertical-garden/

Arshad, Hamid H.S. (2017). Land use planning for urban agriculture in cities of Pakistan: An Empirical Study (Doctoral dissertation). Asian Institute of Technology, Thailand.

Cameron, R., Blanusa, T., Taylor, J., Salisbury, A., Halstead, A., Henricot, B., Thompson, K. (2012). The domestic garden e its contribution to urban green infrastructure. Urban Forestry and Urban Greening. 11 (2): 129-137.

Chinese Architecture Greening. (2011) Available from URL: http://www.a-green.cn/document/201108/article4966.htm

Costanza, R., d'arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., and van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. Nature 387 (6630): 253-260.

Creswell, J. W. (2003). Research design: Qualitative, quantitative, and mixed method approaches. 2nd Edition, Sage Publications, Inc. Thousand Oaks, California.

Davies, Z., Edmondson, J., Heinemeyer, A., Leake, J., Gaston, K. (2011). Mapping an urban ecosystem service: quantifying above-ground carbon storage at a citywide scale. Journal of Applied Ecology. 48 (5): 1125-1134.

Ellis, J. (2012). Sustainable surface water management and green infrastructure in UK urban catchment planning. Journal of Environmental Planning and Management. 56 (1): 24-41

Estrella, M. & Saalismaa, N. (2012).The Role of Ecosystem Management for Disaster Risk Reduction. In Gupta, A.K., & Nair, S.S (Eds.), *Ecosystem Approach to Disaster Risk Reduction* (pp.5-44). National Institute of Disaster Management, New Delhi.

Escalada, M. and Heong, K. L. (2007). Focus group discussion. Available from URL: https://devcompage.files.wordpress.com/2007/11/7-focus-group-discussion.pdf.

Gill, S., Handley, J., Ennos, A., Pauleit, S. (2007). Adapting cities for climate change: the role of the green infrastructure. Built Environment. 33 (1): 115-133.

Gupta,A.K., Singh,S., Wajih,S.A., Mani,N., Singh,A.K.(2017). Urban Resilience and Sustainability through Peri-urban Ecosystems: Integrating Climate Change Adaptation and Disaster Risk Reduction. GEAG, Gorakhpur (U.P.) India.

Haq, S.M.A. 2011. Urban green spaces and an integrative approach to sustainable environment. Journal of Environmental Protection. 2: 601-608

Hsiao-Lan Liu and Yu-Sheng Shen. 2014. The impact of green space changes on air pollution and microclimates: A case study of the Taipei metropolitan area. Sustainability. 6: 8827 - 8855

Hoornweg, D. and Munro-Faure P. 2008. Urban Agriculture for Sustainable Poverty Alleviation and Food Security. Position Paper. FAO. Africa

Jim, C.Y. (2013). Sustainable urban greening strategies for compact cities in developing and developed economies. Urban Ecosystem. 16: 741-76.

Karade R M, Kuchi V S and Salma Z.(2017). The Role of Green Space for Sustainable Landscape Development in Urban Areas Int. Arch. App. Sci. Technol; 8 (2): 76-79.

Lee, A.C.K., Jordan, H.C., Horsley, J. 2015. Value of green spaces in promoting healthy living and wellbeing: prospects for planning. Risk Management and Health Policy. 8: 131-137

Li, F., Liu, X., Zhang, X., Zhao, D., Liu, H., Zhou, C. 2017. Urban ecological infrastructure: an integrated network for ecosystem services and sustainable urban systems. Journal of Cleaner Production. 163 S12-S18.

National Parks Board. (2017). Retried from:
https://www.nparks.gov.sg/~/media/srg/files/nparks-greenery-handbook_1.pdf?la=en

Jacobson, C.R. (2011). Identification and quantification of the hydrological impacts of imperviousness in urban catchments: a review. Journal of Environmental Management. 92 (6): 1438-1448

Jaffal I, Ouldboukhitine S, Belarbi R. (2012). A comprehensive study of the impact of green roofs on building energy performance. Renewable Energy 43:157–64.

Mathur, M and Sharma, K (2016*). Modelling Urban Carrying Capacity and Measuring Quality of life using System Dynamics*. New Delhi: TERI.

Meadows, D.H., Meadows, D.L., Randers, J. & Behrens W.W.(1974). The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind. New York: Universe Books.

Millennium Ecosystem Assessment (2005). Ecosystems and Human Well-being: Wetland and Water Synthesis. World Resources Institute, Washington, DC.
Nordh, H., Hartig, T., Hagerhall, C. M. & Fry, G. (2009). Components of small urban parks that predict the possibility for restoration. Urban Forestry & Urban Greening, 8: 225-235.

Peschardt, K., Schipperijn, J. & Stigsdotter, U. K. (2012). Use of Small Public Urban Green Spaces (SPUGS). Urban Forestry & Urban Greening, 11: 235-244.

PWC (2015). *Greater Kuala Lumpur, Malaysia: Launchpad to Southeast Asia-An investment guide.* 2nd Edition. Retrieved from https://www.pwc.com/my/en/assets/publications/1506-investkl.pdf.

Ree, E.W (n.d). *Carrying capacity and sustainability: walking Malthus ghost*. Introduction to Sustainable Development. Retrieved from http://www.eolss.net/sample-chapters/c13/e1-45-04-11.pdf.

Singh, S., Nair, S.S., & Gupta, A.K. (2013). Ecosystem Services for Disaster Risk Reduction: A Case Study of Wetland in East Delhi Region, India. *Global Jour. on Human Social Science, Geog., Geo-Sciences, Env.Disaster Mgt, 13* (4), 37-47.

Tayal,S. and Singh,S**.** (2016). *Sustainable Urban Development: Necessity of Integrating Water-Energy-Food Dimensions in Developmental Policies*. New Delhi: TERI.

UN-ESC (2017). *Progress towards the Sustainable Development Goals: Report of the Secretary-General.* Retrieved from http://www.un.org/ga/search/view_doc.asp?symbol=E/2017/66&Lang=E.

UNDESA (2016). The world's cities in 2016. Retrieved from http://www.un.org/en/development/desa/population/publications/pdf/urbanization/the_worlds_cities_in_2016_data_booklet.pdf.

UN-HABITAT (2015).*The State of Asian and Pacific Cities 2015: Urban Transformation shifting from quantity to quality*.http://www.unescap.org/sites/default/files/The%20State%20of%20Asian%20and%20Pacific%20Cities%202015.pdf.

Velasco, E., Roth, M. (2010). Cities as net sources of CO2: review of atmospheric CO2 exchange in urban environments measured by Eddy covariance technique. Geography Compass 4 (9): 1238-1259

Zupancic, M.P.H., Westmacott, C., Bulthuis, M. 2015. The impact of green space on heat and air pollution in urban communities: A meta-narrative systematic review. Retrieved from https://davidsuzuki.org/wp-content/uploads/2017/09/impact-green-space-heat-air-pollution-urban-communities.pdf