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# An Ecological Framework for Greening Cities

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# An Ecological Framework for Greening Cities

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## I. Introduction

An eminent scientist, E.O Wilson coined the term '*Biophillia*' which essentially means an intrinsic emotional need of human beings to connect with nature (Benfield 2014). What this signifies is, being in close contact with nature results in a natural burst of energy, happiness and mental peace in an individual. Until recently, urban greening was thought to achieve only the purpose of aesthetics and provision of recreational opportunities to the residents. With climate change becoming a reality, the side effects of unplanned urbanization, such as increased temperature and heat island effect, are further pronounced (Ziska, Gebhard et al. 2003). Planned Urban Greening has the potential to act as an active adaptation strategy to combat climate change.

Michelle de Roo (Roo, Kuypers et al. 2011) highlights how greening in the form of street trees, green roofs, walls, parks and gardens, contributes to moderating the impacts of the urban heat island effect. Mitigation of urban heat islands can potentially reduce a country's energy use in air conditioning by 20% and save over $10B per year in energy use (Akbari, Pomerantz et al. 2001). Small scale parks have the potential of achieving more cooling as compared to a single large park. Studies show that a coverage of 25% greenery can reduce the concentration of particulate matter in the air by 10% (Steward, 2002 from (Cavanagh, Zawar-Reza et al. 2009)). Thus, greening, if properly planned in cities, has the potential to positively impact the varied side-effects attributed to urbanization.

Urban greenery is also found to have the potential to promote biodiversity (Roo, Kuypers et al. 2011). The diverse human activities in cities creates and maintains a variety of unique habitats ranging from fairly natural ones to highly modified ones, which sometimes may contain endangered species (Niemelä 1999). Having ecological corridors which connect green spaces throughout the city could raise the value of the urban ecological system (Hiemstra J.A. et al. 2008). City-wide parks can further enhance urban biodiversity by providing habitats for birds, insects and small mammals.

Greener environments are found to encourage people to spend more time outdoors, which in turn increases the rates of social interaction, and thereby the happiness index of a city (Mass et al. 2006). A green network through ecological corridors can also provide safe routes for pedestrians and cyclists. Small scale parks in the form of pocket parks and community parks in different zones ranging from residential, institutional, corporate, commercial to educational areas can provide a much-needed break from one's daily hectic schedule, which can rejuvenate a person's mind and body. Mental health is found to improve with exposure to greenery due to reduction of depression and stress; exposure to greenery can also increase employee productivity and result in employees taking up fewer sick days (Tzoulas, Korpela et al. 2007, Dop 2014). Green spaces at a small scale also serve as active and passive recreational spaces which give citizens the option to maintain physical fitness, thus further improving the health and quality of living of the society.

Thus, to harness the full potential of green cover in a city, a thorough background research on factors such as biodiversity, climate, soil type, habitation, etc., in and around the proposed site is necessary. The greening process, rather than being limited to the setting up of parks and amenities, should be a process of adaptation that helps mitigate and counter the loss of natural landscapes resulting from urbanization. Greening, if well planned, can influence an urban landscape right from a city level to community and down to an individual's mental and physical wellbeing. Integrating greening strategies right from the nascent

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phase of a new city is critical for maintaining the sustainability of the city.

This paper aims to synthesize a framework for a greening strategy based on principles of ecology and sustainability.

## II. Materials and Methods

The framework was developed for Naya Raipur – an upcoming capital for the state of Chhattisgarh, India. However, the basic principles and steps could be adapted and/or adopted for implementation elsewhere.

The greening plan for a city considers many complex interlinked factors such as identification of different zones of the city (residential, institutional, etc.) and the area to be dedicated in each zone for different greening models (parks, water bodies, etc.). Due consideration also needs to be given to the present land-use type, soil quality, native flora and the quantum and distribution of rainfall. The needs and expectations of stakeholders must also be accounted for. Special attention should be given to unique land uses such as botanical garden and eco-park as predefined in the city plan. Considering these factors, an approach has been developed and the same is presented in Figure 1 and the steps are discussed in this section.

*Steps 1 & 2:* Assessment of current and proposed land use pattern along with stratification of zones.

The first step in designing a greening strategy is to develop an understanding of the current and proposed land use pattern. This step involves assessment of area under different land use categories proposed for development in a city. A city could have several zones, sub zones and sectors.

*Step 3: Development of baseline*

Prior to designing a greening strategy, it is necessary to develop a baseline scenario to capture the current status of the landscape. To develop the baseline scenario, existing data on the biophysical characteristics of the region from literature and from the Forest Department will have to be collected. Additionally, field studies need to be carried out to assess the status of land categories and resources. The baseline scenario includes current land-use patterns with area under different land-use categories, a map of the land-use pattern, plant diversity in different land categories, bird diversity, and biomass and carbon stock estimations using standard ecological methods. These baseline data serve as a benchmark for future comparison, to help assess the impact of the proposed and implemented developmental activities.

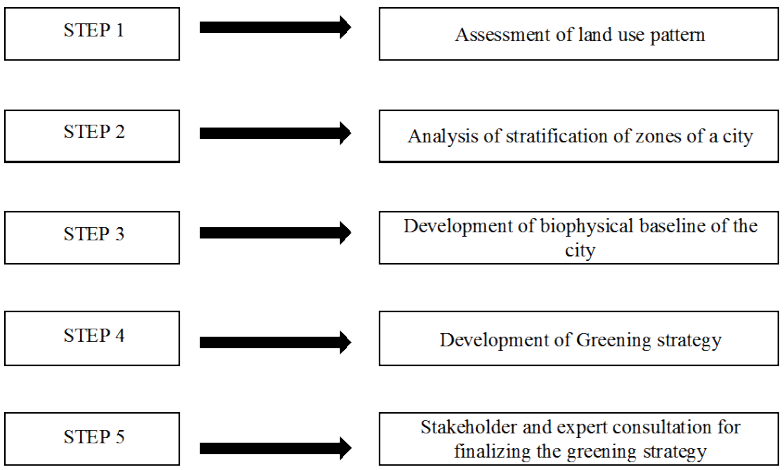


*Figure 1:* Broad approach for development of a greening strategy

*Step 4: Development of greening strategy*

The main element of greening strategy is the development of a Greening Implementation Model (GIM), customized for different zones of a city, keeping in mind specific needs and objectives of a zone. This study defines GIM as "A module prepared for meeting a set of primary and secondary objectives, keeping in mind the features of the urban areas such as residential areas, market places, educational institutions and so on." The GIM has been developed considering the primary and secondary objectives of a zone and provides information on the objectives, components of the model, area of implementation, benefits, scientific rationale and an illustration.

*Step 5: Stakeholder and expert consultation for selection and finalization of the GIM and species choice*

This step involves consultation of various stakeholders, including local village representatives, forest department officials, local school teachers, nursery professionals, NGOs, academicians and local/national level forestry and horticulture experts.

## III. Results And Discussion

Here, the principles adopted for development of a greening strategy, the criteria adopted for development of GIM, the species choice, and the development of some unique implementation models is discussed.

*a) Principles for greening Naya Raipur*

Green spaces in a city should be designed to act as versatile spaces that can be adapted for future needs. Generosity in provision of space for greening is important as it bolsters mental health and physical activity levels while also providing a range of 'free' ecosystem services. The main goal of greening is to provide a healthy and wholesome environment for its citizens and, at the same time, promote biodiversity, offer ecosystem services, raise awareness of environmental conservation, protect the city's environment, and ameliorate climate locally. Such greening efforts also need to consider future climate and try to build in a certain amount of adaptability in the green cover to climate change through species selection and diversity.

The key principles adopted to design the greening strategy of Naya Raipur are:

- Mitigate the adverse effects of urbanization to enhance the quality of life in the city by providing physiological, sociological, economic and aesthetic benefits
- Improve health and propagate activities which promote physical well-being as well as help in stress relief and relaxation
- Reduce atmospheric, noise, water and soil pollution
- Promote conservation of flora and fauna (trees, birds, butterflies etc.)
- Provide opportunities for tourism
- Create awareness about conservation of flora and fauna and co-existence with nature
- Regulate the microclimate and help in temperature moderation
- Enhance ecosystem services like water conservation, prevention of soil erosion, etc.

*b) Greening objectives*

The main zones in a city are residential, recreational, industrial, and commercial, which could be further sub-divided into sub-zones. For example, the residential zone could be classified as 'higher-income residential area' and 'economically weaker sections residential area' sub-zones (Table 1). The characteristic features of the zones and sub-zones would therefore determine the objectives of greening, which are further classified here as primary and secondary features. The rationale for this categorization is that a zone can have several sub-zones or components and in them, a hierarchy of objectives is to be addressed. However, for selection of models and tree species, it is necessary to focus on the key objectives for a given sub-zone. Table 2 presents the primary and secondary objectives of different zones planned for a city.

*Table 1:* Illustration of features, primary and secondary objectives for key zones of a city

| Zones | Sub Zone | Features and components of zones | |
|---|---|---|---|
| | | *Main* | *Secondary* |
| Residential | High income areas | Individual bungalows, apartments, intra-sectoral roads | Schools, playgrounds, temples, small market complexes, club houses |
| | Economically weaker areas | Small row houses, apartment blocks, intra –sectoral roads | Schools, playgrounds, parks, community centre, temples, weekly markets |
| Public/ semi-public spaces | Educational | School and college campuses, university campus, research institution campus | Small parks, playgrounds, sports centres, hostel complexes, gardens, parking spaces, intra-sectoral roads/ avenues |
| | Medical | Hospitals, Medical, college campus, health centres | Recovery centres, old-age homes, gardens, waterfronts, parking spaces, intra-sectoral roads |
| | Official: Government | Government Office complex, independent offices, corporate offices, | Post offices, secretariat buildings, police stations, pocket parks, gardens, parking spaces |
| Transport | City arterial roads | Wide roads (width 60–100 m) | Roundabouts, local bus stations, multiple lanes, large road dividers (high pollution |
| | | | areas) |
| | Intra-sectoral roads | Roads of medium width, lanes and by-lanes | Bus stops, road dividers, footpaths |
| | Parking areas | Parking areas | Open spaces High pollution |
| | | (where organized recreational/ leisure activities | Sports fields, open lawns, badminton courts, cricket/ |

| | | | |
|---|---|---|---|
| Recreational (including parks) | Active | happen), Sports complex, playgrounds, | football grounds, exhibition grounds, community centres |
| | Passive | Medium sized city wide parks, walking/ jogging paths(utilized for non-organized recreation and relaxation) | Large urban forests, waterfronts, sit outs, natural forests and Plantations, etc. |
| | Dedicated parks (eco-parks, botanical gardens) | Large dedicated or theme parks / gardens | Large areas dedicated to specific themes |

The primary objective largely determines the selection of tree species. These objectives include promotion of aesthetics, growing of fruits, etc. to supplement children's nutrition, recreation, biodiversity conservation, education and awareness, health, pollution abatement, and provision of shade. The criteria for developing a GIM and the species-mix are based on the features of the zone (e.g., breadth of roads and pollution levels) and the primary and secondary objectives of greening.

*Table 2:* Objectives of greening of different zones and sub zones of a city

| Zones | Sub Zone | Objectives of Greening | |
|---|---|---|---|
| | | *Main* | *Secondary* |
| Residential | High income areas | Aesthetic: Promoting flowering trees for beauty, recreation and relaxation | Promoting shade, habitat for birds, nutrition and carbon sequestration |
| | Economically weaker areas | Nutrition: Promotion of nutrition among communities | Promoting shade and flowering trees |
| Public/ semi-public spaces | Educational | Education & awareness: Promoting education and awareness related to biodiversity and promoting nutrition | Promoting outdoor recreation & relaxation in form open green spaces, positively influencing health & indirectly carbon sequestration |
| | Medical | Health: Promoting good health in the form of green cover, providing beauty, clean air, noise free environment and ample oxygen for inhabitants | Generating awareness on nutritional value of trees, and improving biodiversity and indirectly enhancing beauty and carbon sequestration |
| | Official: Government | Aesthetic: Promoting flowering trees for beauty, recreation and relaxation from the daily work schedule | Promoting plant and bird biodiversity conservation and awareness, carbon sequestration |
| Transport | City arterial roads | Pollution abatement: Reducing pollution and dust levels by introducing trees with pollution absorption characteristics | Improving aesthetics by promoting flowering trees for beauty, shade and biodiversity and carbon sequestration |
| | Intra-sectoral roads | Pollution abatement: Reducing pollution and dust level | Improving aesthetics by promoting flowering trees, biodiversity conservation and carbon sequestration |
| | Parking areas | Shade, pollution abatement: Reducing pollution and dust levels Shade trees to protect vehicles from heat | Improving aesthetics by promoting flowering trees for beauty, biodiversity conservation and carbon sequestration |
| Recreational (including parks) | Active | Recreation & health: Provision of activities to promote health, fitness, physical strength and stamina | Promoting social, educational and cultural activities and programmes |
| | Passive | Biodiversity conservation: Promoting shade, tree and bird biodiversity | Promotion of relaxation and mental peace, education and awareness on biodiversity, carbon sequestration |
| | Dedicated parks (eco-parks, botanical gardens) | Education & biodiversity conservation: Promoting trees to represent various ecological features, educational, conservation values | Promotion of relaxation and mental peace and awareness on biodiversity, carbon sequestration |

*c) Greening Implementation Models for various zones*

Each zone has sub zones and each sub zone consists of a number of components which determine its greening strategy. For example, the higher-income residential area sub zone may include parks, bungalows parking spaces, etc. and the economically-weaker sections residential area sub zone may include apartment complexes, market places, pocket parks, etc. Each of these components will have a different objective for greening, depending on its unique features as discussed in the previous section. This will in turn determine the greening model to be adopted, and the choice of species. Figure 2 presents a list of Greening Implementation Models as well as some Unique Greening Implementation Models.

**Greening Implementation Models**

1. Pocket Park
2. Neighborhood Parks
3. City Arterial Roads
4. Intra-sectoral Roads
5. Urban Villages
6. Small Educational Campuses
7. Large Education Campus
8. Community spaces
9. Sports Complex
10. Large Office Complexes
11. Smaller Offices
12. Religious Complex
13. Markets & Shopping Complexes
14. Weekly Markets
15. Parking Areas
16. Large Medical Campus
17. Small Medical Campus
18. Recreational Water Bodies
19. Boundaries

**Unique Greening Implementation Models**

1. Eco – park 2. Botanical Garden 3. Green Belt

*Figure 2:* Greening Implementation models and Unique Models Conceived for Greening

Each planned sector in the city consists of a number of components like broad roads, narrow roads, logistics hub, hospital and schools. Table 3 provides an illustration of the application of GIMs in different sectors, and includes components of each zone as well as the Greening Implementation Model.

*Table 3:* Illustration of zones, sub zones and corresponding greening implementation models

| Zone | Greening Models recommended for each zone and sub-zones | | |
|---|---|---|---|
| Residential | Higher income | 1. Pocket park | 6. Intra-sectoral roads |
| | | 2. Neighbourhood park | 7. Parking spaces |
| | | 3. Small playground | 8. Institutions (educational/ health) |
| | | 4. Religious complex | 9. Community spaces |
| | | 5. Market and shopping complex | |
| | Economically weaker section | 1. Pocket park | 5. Intra-sectoral roads |
| | | 2. Neighbourhood park | 6. Institutions (educational/ health) |
| | | 3. Religious complex | 7. Community spaces |
| | | 4. Weekly market places | |
| Public places | Educational | 1. Educational complex | 5. Sports complex |
| | | 2. Playgrounds | 6. Intra-sectoral roads |
| | | 3. Community spaces | 7. Small medical campus |
| | | 4. Boundaries | |
| | Medical | 1. Small/ Large medical campus | 4. Religious complex |
| | | 2. Pocket park | 5. Intra-sectoral roads |
| | | 3. Boundaries | 6. Parking spaces |
| | Official | 1. Boundaries | 4. Large and small office complexes |
| | | 2. Pocket parks | 5. Intra-sectoral Roads |
| Transport | City Arterial | City arterial roads (60 m and 100 m) | |
| | Intra – sectoral | Intra-sectoral roads (24/18/12 m models) | |
| | Parking areas | Parking spaces | |

*d) Species choice for Greening Implementation Models*

Each GIM has a mix of species which is quite exhaustive. The species selected are suited to the soils and the climatic conditions of the region, partial to indigenous species. However, under urban forestry programmes, the goal is also to have a large diversity of tree species for enhancing biodiversity, education and awareness and for aesthetics. Therefore, species from other regions could also be included. Figure 3 provides an illustration using intra-sectoral roads as an example.

The selection of tree species for different GIMs was determined by the following factors:

- Utility of the species to meet the objectives of the zone
- Nativity of the tree species with a focus largely on local or native species; however, exotic species from outside the region or even country are included for some models
- Evergreen or deciduous nature of the tree species: focus is largely on evergreen tree species, to

provide shade and greenery during different seasons of year

- Form of the tree: height (tall, medium or short) and crown spread (narrow cylindrical or broad round)
- Suitability to the soil and rainfall: poor growing condition pertaining to soil and moisture availability can be mitigated to a large extent by adopting a suitable package of practices that provides for use of fertile soil and farm yard manure, along with provision for watering of plants during dry period
- Ease of raising nurseries: this is considered while suggesting, particularly primary species for each model
- Perennial tree and shrub species: the focus is largely on perennial tree and shrub species, to minimise planting and maintenance activities

**Objectives:** To provide aesthetic appeal as well as shade to city lanes and by-lanes. To combat pollution and to facilitate dust and particulate matter reduction along with temperature moderation. To promote overall greening of the city along with carbon sequestration.

| **Components** | **Areas of implementation:** |
|---|---|
| Medium to tall trees with high to medium canopy<br>Dividers if present would be dominated by bushy and flowering shrubs. | Intra-sectoral roads: 24 m wide<br>Intra-sectoral roads: 18 m wide<br>Intra-sectoral roads: 12 m wide |

**Benefits:**

| | | |
|---|---|---|
| Pollution and dust reduction | Beauty and aesthetic value | Shade provision |
| Temperature moderation | Biodiversity Facilitating | rainwater harvesting |
| Increasing road safety | Carbon sequestration | |

**Scientific rationale:** Trees in general play a central role in enhancing a roadway's liveability (Dumbaugh and Gattis 2005). Judicious placement of not only large trees but also grasses, climbing ivy and other plants along the roads can reduce the concentration of NO2 at street level by as much as 40% and that of PM by 60% along with resulting temperature differentials of 5–15 °C (Burden 2008; Pugh et al. 2012). Roadside trees facilitate rainwater percolation and reduce run-off rates by 30%. Comparison of treeless streets with treed streets show reductions in run-of-the-road crashes and overall crash severity (Ewing 2003); apart from this, speed differentials of 5–24 km/h are noted in treed streets as compared to those without trees, thus proving that street trees promote road safety.

**Species Choice**

| **Primary species** | **Secondary species** | |
|---|---|---|
| 1. *Cassia fistula* | *Pterocarpus marsupium* | *Erythrina suberosa* |
| 2. *Pterospermum acerifolium* | *Jacaranda mimosifolia* | *Moringa oleifera* |
| 3. *Pongamia pinnata:* | *Muntingia calabura* | *Soymida febrifuga* |
| 4. *Thespesia populnea* | Malpighia emarginata | *Solanum grandiflorum* |
| 5. *Morus alba, M. nigra* | *Stereospermum chelonoides* | *Azadirachta indica* |
| 6. *Diospyros melanoxylon* | *Toona ciliata* | |

*Figure 3:* Illustration of a GIM: Intra-Sectoral Roads

*e) Unique Greening Implementation Models*

The botanical garden, eco-park (ecological park) and green belt models are considered as unique zones, each with a large dedicated area that can be used for conservation, recreation and educational purposes. The presence of such parks in urban areas helps people realize the importance of biodiversity and nature. Further, the green belt will help protect a city from high velocity winds and livestock intrusion from neighbouring areas. Such areas not only provide diverse recreation and educational opportunities but are likely to attain additional conservation significance under impending climate change.

*i. Botanical Garden Model*

Botanical gardens provide an opportunity to inform the public on taxonomy, biodiversity inventory, conservation biology, restoration ecology, and ethno-botany, with the main purpose of scientific research, conservation education and awareness-creation among people (BGCI 2009). Components of a botanical garden have been developed keeping in mind the following goals of; (i) recreation, (ii) education, (iii) conservation, and (iv) research. Figure 4 presents different components of a botanical garden.

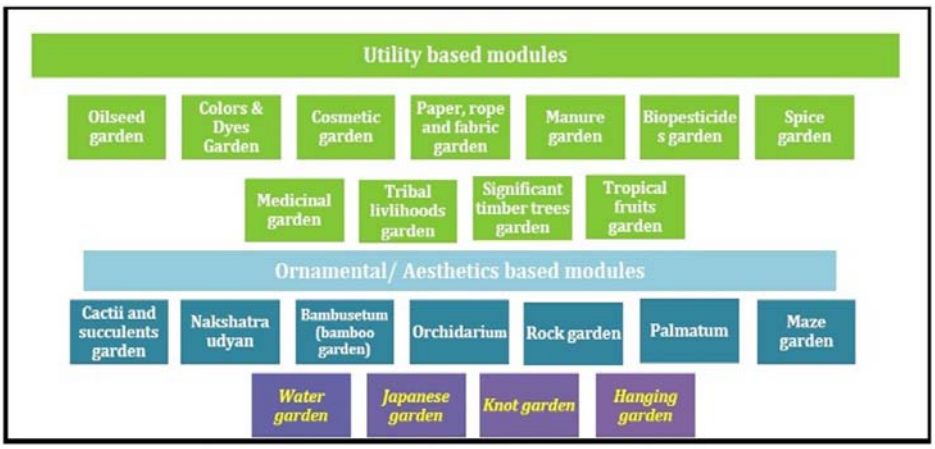


*Figure 4:* Botanical garden module

A large number of tree species, both native and exotic, are included along with themed gardens. Other components include a plant museum - housing information on plant species around the world, a seed bank centre, a research and development centre, and an education and training centre, etc. A number of tree species and perennial shrubs are identified and recommended for each module.

ii. *The eco-park model*

The concept of an eco-park (or an ecological park) is aimed at developing a demonstration area exhibiting local as well as national forest (ecosystem) types with the purpose of promoting conservation, education and recreation. The main purpose is to develop appreciation of the diversity of forest types by creating awareness and promote conservation of native forest ecosystems. Several modules are proposed under the eco-park model. Under each module, a set of dominant or key species characterizing the module is included. An eco-park could be designed to meet the following objectives:

- Demonstrate the diversity of forest types of a region
- Showcase endangered flora from the region and create awareness
- Encourage research on native forest types of a region
- Generate opportunities for education and training relating to biodiversity conservation.

iii. *Green belt module*

The main purpose of the green belt is to improve urban ecological conditions by purifying the atmospheric environment by abating pollution, regulating local microclimate, protecting local water resources, restoring degenerated ecosystems, enhancing urban biodiversity (Binford and Buchenau 1993; Bolund and Hunhammar 1999) and meeting the fodder, fuelwood and non-timber product needs of rural communities residing in the neigbouring areas. The strategy adopted for the green belt has been developed considering the following principles:

- Make available a substantial chunk of green area readily accessible to city dwellers for recreation, and to enhance the aesthetics of the city, apart from other ecological benefits.
- Regenerate a part of the green belt with high-density plantations of fast-growing species, and the remaining area with silvo-pasture species, to generate fodder for cattle for communities residing in rural areas adjoining the city.
- Ensure that the green belt acts as a buffer to the entire city, protecting it from high velocity winds and livestock intrusion, along with moderating the microclimate of the region.

## IV. Conclusions

The framework for the greening strategy presented in this paper represents how consideration from an ecological, social and educational perspective redefines the concept of a smart city to being ecologically, and climatically smart. Customization of greenery to address local concerns and facilitate the flow of ecosystem services like the provision of nutrients and fodder, along with regulatory services such as climate amelioration, further enhances the performance of a green system. The framework inculcates the significance of conservation not only in the very wiring of the city, but also in its habitants, through its focus on research and awareness. Knitting a green grid to embrace neighborhoods, communities, villages and public spaces breathes vitality into the animate as well as inanimate entities, transforming cities that are traditionally concrete jungles to a living and breathing city.

## IV. Acknowledgements

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