

PLANNING 'TREE-COVER' IS PASSIVE MEANS FOR LOW CARBON CITIES

1.0 Introduction

Cities are sporadically growing at the expense of greeneries, which instigates environmental deterioration (air, water, and micro climate) and thereby affecting people's health (respiratory diseases, heat strokes, tuberculosis, stress and psychological problems and so on.). In today's context, any discussion of city planning and urban design, which does not address these issues, has little meaning (Moughtin and Shirley 2005). The greeneries are an important part of complex urban system; gives several benefits to the urban communities environmentally, economically, recreationally and aesthetically (Li et al 2004). The vanishing greeneries oversimplify many aspects of the environmental process and triggers problems like urban heat island effect, air pollution, more-runoff, ground water depletion, and so on (Setchell, 1995; Alberti, 1999; Whitford, Ennos, Handley 2001). As a consequence the cities become enervated to keep up the people's wellbeing (Cacciola, Sarva and Polosa 2002; Norberg, 1999; de Hollander and Staatsen, 2003). The instantaneous change in the urban environment due to the green-cover loss is 'the rising air temperature', generally referred as 'the urban heat island effect, which affects people's health also increases energy requirement of their space cooling systems (Heisler, 1986; Kjelgren and Montague's, 1998; McPherson, Simpson and Scott, 2002, Akbari, Kurn, Bretz and Hanford, 1997). More the energy consumption more the electricity production, thus speed up the global warming by increasing the atmospheric green house gases. Intensifying vehicular traffics is another major source of urban air pollution. Of late, poor air quality becomes prime health issue of many cities (Ahmad 1990).

In the densely urbanized areas having trees are easier than having green spaces. 'Trees' by its nature habitually ameliorates the air quality by means of sequestration, interception and filtration (Nowak, 1993; Jo and Mcpherson, 1995; Akbari, 2002; www.americanforest.org). American Forests Association study (americanforests.org) on Chicago urban forest revealed that a single tree with a trunk circumference of 30 inches per year, removes 200 pounds of carbon dioxide, 1.1 pounds of ozone, and 2 pounds each of sulfur dioxide, particulates and nitrogen dioxide. The study find out that 19% of Chicago's urban tree cover removed up to 2,027 tons of particulate matter per year. Nowak and Crane (1998) estimated that 17,821 metric tons of air pollution was removed by trees in New York City in 1994, equivalent to a monetary value of \$9,465. Using the Urban Forest Effect (UFORE) model, Nowak and Crane quantified the amount of air pollution removed at Atlanta and Baltimore respectively 1,196 tons (monetary value of \$6,474) and 499 tons (monetary value of \$2709). At Northwest Chicago, Jo and Mcpherson (1995) noticed that the annual net carbon storage rates in the green spaces of two residential blocks are 0.49 kg/m² and 0.32 kg/m² respectively. American Forests (americanforests.org) researches substantiate that an acre of tree-cover absorbs about 2.6 tons of carbon dioxide per year and a single tree stores about 13 pounds of carbon annually. According to some estimates, one hectare of mixed forest can remove 15tons of particulates per year from the air (Bolund and Hunhammar 1999). Akbari's (2002) study indicates that urban trees play a major role in sequestering the Co₂ and thereby delay global warming. During the Los Angele study, he found that a single urban tree snatches 18 kg of combusted carbon annually, in contrast to one that grows in the forest which could sequesters only 4.5–11 kg. In another analysis for Baton Rouge, Sacramento, and Salt Lake City, Akbari estimated that planting an average of four shade trees per house (each with a top view cross section of 50 m²) would lead to an annual reduction in carbon emissions from the power plants of 16,000tons, 41,000tons, and 9000 tons, respectively (the per-tree reduction in

carbon emissions is about 10–11 kg per year). These reductions only account for the direct reduction in the net cooling- and heating-energy use of buildings.

The above studies imply that “Trees” improves the urban environment in a passive way; however, current urban tree-cover improvement efforts are often not carried out decisively. Hence, ‘trees’ are standing as a green element rather than contributing to the environmental benefits. ‘Trees’ can improve the urban environment only when it is spatially integrated within the city planning. It requires more than general knowledge of tree’s benefits, and moreover needs complete understanding of the local conditions. Keeping that in mind, this study attempts to evolve framework to integrate trees in the city planning using Chennai as the case study area. It also elaborates the method to establish Tree-cover in the densely built urban milieu, through proposing the same for Chennai city.

2.0 Back ground of the study area

The study area, ‘Chennai city’ located in southern India, lies between 12° 09’, 80° 12 NE and 13° 09’, 80° 19’NE. It has population of 6.04 million in an area of 170.47 sq.km. The city is situated in a hot climatic zone, experiencing tropical maritime monsoons. The minimum temperature ranges from 21° C to 24° C in the month of December to February and the average daily maximum temperature is 37° C during the month of May. The minimum monthly rainfall ranges from 6mm to 10mm in the month of February and a maximum rainfall of 320mm has been recorded during the month of November. The city’s terrain is more or less a flat plain with scattered hillocks, gently sloping toward the Bay of Bengal in the east. The soil type is broadly classified into red loamy soil (in the inland), sandy soil (along the coastal belt), clayey soil (along low lying areas) and lateritic soil (on some barren lands). The mean wind speed in the city is 4.055 m/s at a height of 15m. The area of study is limited within the corporation boundary of Chennai city (Figure 4a). For administrative purposes the study area is divided into 16 planning units, which subdivided into 157 wards.

The population density of Chennai city was about 24,682 per square kilometer as per the census of 2001. The city of Chennai is growing at an average of 25% in a decade with the expense of green space by means of attrition and fragmentation. Rapid urbanization plus vehicle congestion increased the gaseous pollutants (SO₂, NO_x), respirable particulates and suspended particulates (SPM, RSPM) in the ambient air of Chennai city. Compare to gaseous pollutants (SO₂, NO_x), the particulate pollutant levels are high in Chennai. Nearly 95% of the population is exposed to concentrations in excess of the ‘WHO’ air quality norms, thus respiratory symptoms and disorders are significantly higher in a polluted area (Pitani et al 2004).

3.0 Need for the study

Trees are one of the prominent elements, rapidly getting deducted during the urbanization process. That significantly impaired cities most of the natural processes. As cities grow both intensively and extensively, availability of tree’s services across the urban landscape is spatially not uniform; hence within a city some areas are highly polluted than others. To overcome these prevailing situations, tree-cover development needs planned approach.

4.0 Methodology

The methodology for planning Chennai’s tree-cover consists of four steps. First, to understand the spatial implication of the tree-cover change on environment, second, evolving spatial strategies for tree-cover plan, third, propose tree-cover plan and finally identify appropriate mechanism for implementations.

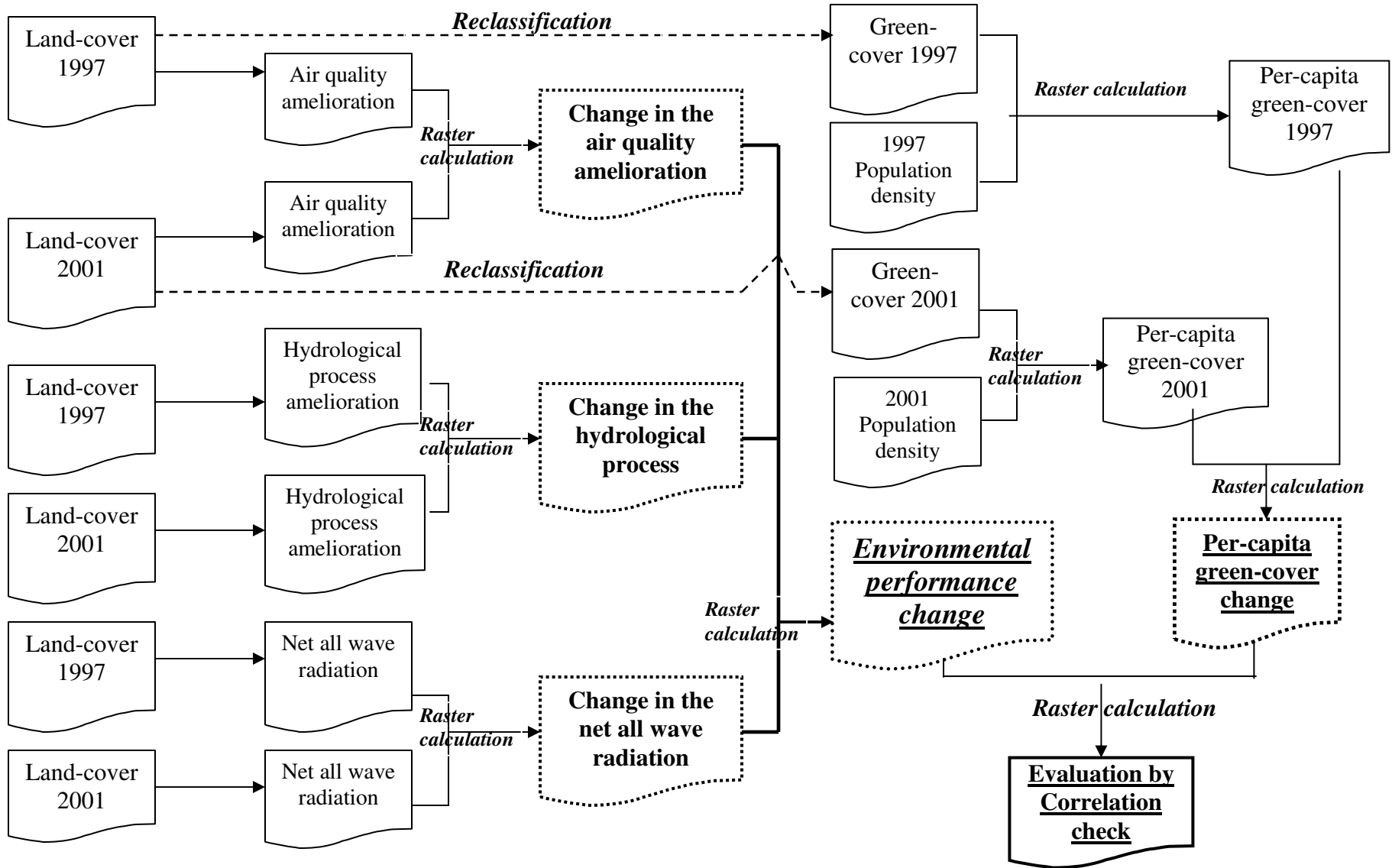


Figure 1. GIS Model

5.0 The spatial implication of the tree-cover change on environment

City's environmental performance can be broadly defined as its capacity to support human health, by providing quality air, water, livable climatic conditions and so on. In the densely built-milieu these components are maintained and refreshed continuously by the functions of the tree-cover. The reduction in the tree covered area affects urban-system's self-rejuvenating capacity and thereby city's environmental performance. This step examines degree of influence of tree-cover change on Chennai's environmental performance between the years 1997 – 2001. To appraise the influence of the Tree-cover change on the city's environmental performance, a GIS model was built based on Map Algebra concept (Tomlin, 1994). This model was built utilizing the three tree-cover services as variables. They are air quality amelioration service, micro-climatic amelioration service and hydrological process regulation service. Using these as parameters, the GIS model was constructed in the model builder as shown in the Figure 1. The ward-wise environmental performance change of Chennai city is worked out by calculating the mean percent change of all the above mentioned environmental services of the tree-cover between the years 1997 and 2001. The outcome (Figure.2) impeccably shows variation in the environmental performance across the city and in some parts it had been reduced to 38%.

6.0 Evolving spatial strategies for tree-cover plan

In any given site, within the spatial unit, the interaction between the individual tree and other elements (such as animals, air, water, soil, and other plants) determines the topological processes at the local level (evapotranspiration, air purification, controlling the surface solar radiation, intercepting the precipitation, and infiltration, etc). Then, the link between the individual tree and the group of trees enables the horizontal natural processes between different spatial units (street, block, neighborhood, planning district and region), such as, flow of energy, water, air and other organic matters across the city. In short, the tree-cover can improve the urban environment only when it is spatially integrated with other elements. This can be achieved by carrying out the plantation strategically through understanding the local conditions. The process of evolving green-cover strategies for Chennai city consist two parts, namely, study phase, and analysis phase.

6.1 Study phase

The study phase evaluates the existing condition of the city in two steps. First, it reviews the landscape situation of Chennai city through assessing various issues that influence the trees. Second, it identifies problems and constraints for the 'Tree-cover' development.

6.1.1 Landscape condition of the city

Chennai does not have much of green space, except the Guindy National Park which has an area of 270.57 ha, and it is under reserve forest category. This area has sparse vegetative cover. After 1951, the per capita green-cover area of the city declined to 0.00007 ha from 0.00021 ha due to population growth (office of the Chennai wildlife warden). The landscape condition of the city is broadly appraised under three topics, namely below-ground, above-ground, and on-ground situations. The typical situation at these three levels in terms of social, environmental and management issues are listed in Table 1.

6.1.2 Problems and constraints

The amount of tree-cover at different spatial scale is determined by inter- and intra-scale factors. For instance, plot level greenery is influenced by the inter-scale factors like plot orientation, soil condition, onsite functions, available area and so on. Concurrently, they are influenced by intra-scale factors, like the physiographic condition of the city, built morphology of

the surroundings, administrative zoning, land use, development regulation and so on. By appraising these complex conditions, issues and constraints for tree cover at various scales are identified (Table 2).

6.2 Analysis phase

All these problems and constraints put forth different requisites at different scales. At the city level it demands adequate trees to ameliorate the environment, like urban heat island reduction, ground water level improvement, and biodiversity enhancement and so on. At ward scale, needs to enhance the local natural process to meet the city level demands, in terms of, enhance carbon sequestration, reduce surface radiation absorption, improve infiltration process, and runoff reduction. This could be achieved only by means of site-specific intervention at further lower level i.e. increasing the plot level trees to interfere the environmental process at their root (atmospheric, hydrological and climatic process). The analysis phase identified the following objectives (Figure 3) for the tree-cover planning.

- a. Identify plants that meet various requirements of the site (Figure 3a).
- b. Interconnect the fragmented isolated green patches (Figure 3b).
- c. Institute connectivity among inter- and intra-scale tree groves (Figure 3c).
- d. Establish hierarchy of wooded area within the densely built-up area (Figure 3d).
- e. Protect ecologically sensitive areas (Figure 3e).
- f. Link the street- and plot-level trees (Figure 3f).

7.0 Tree-cover plan

In order to accomplish the above objectives, the tree-cover planning tries to include three aspects; They are, (a). Increase the amount of tree-cover, (b). Interlink the trees at different level, (c). and restore the natural process by means of the above two. To achieve this two types of area are delineated within the city which could enhance the natural processes. The areas are, 'Patches' (chunk of space - wooded remnants, groves, or bigger open space, etc) – for topological processes and 'Corridor elements' (linear spaces - like banks of water bodies, row of trees, etc) – for horizontal processes.

The potential areas that could function as patches in Chennai city are:







- Areas under protection, for example Guindy National Park, Adyar creek, wetlands and the Theosophical Society area.
- The huge green-spaces of the institutional areas like IIT, Anna University, CLRI campus, and so on, and places that offer recreational values like public parks, memorials, lands like cemeteries, and so on.
- Wooden remnants in the public and private lands.

Some of the linear space / corridor elements, which can link those above patches, are

- Natural areas like water fronts and flood plains of Adyar River, Coovam River, Buckingham Canal and other water bodies and their draining channels within the city.
- Greenbelts in and the around industrial areas.
- Wooded streets.

These two types of spaces are identified in the city at three levels, namely street-level, ward-level and city-level.

Table 1. Landscape situation of the Chennai city

	The typical scene	The typical activities	Environmental issues	Social issues	Management issues
Above ground		The electrical lines, the telephone lines, TV -cable lines are the main overhead utility lines.	Attrition and fragmentation of natural areas. Stunted tree growth due to chopping of branches by the utility department. Poor visual quality. Loss of habitat and biodiversity.	Missing sense of ownership of the street trees among the public.	Requires separate department to monitor the green-cover activities.
					
Below ground		The sewer and storm water line, cables, The telephone lines, optical fiber lines, and electrical lines.	Disturbance to the soil structure and quality. Cause damage to the nearby plants, by chopping the roots and exposing them to the sun light. Often that leads to mortality of plant.	Less number of social groups, NGO's involvement in improving the tree-cover.	Missing coordination between various departments.
					
On ground		Water tanks, hand pumps, parking, informal shops, vendors, slums, dumping the wastes debris and encroachments, etc.	Increased paved surfaces, runoff, surface radiation etc. reduces the available space for plantation. Loss of ground water level and Poor air quality, and reduced infiltration	Publics having less knowledge about plants, species selection, plantation, and maintenance.	Missing long term planning strategies to raise the proportion of large-stature trees for greater canopy effects.
					
					Imbalance between the plantation process and tree removal.

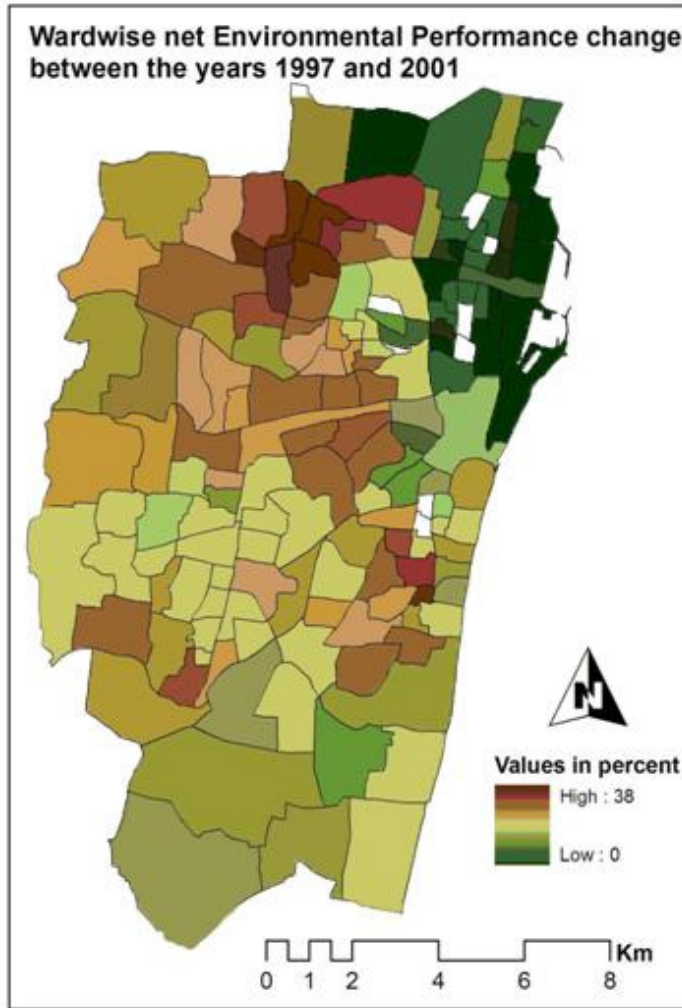


Figure 2. Environmental performance change

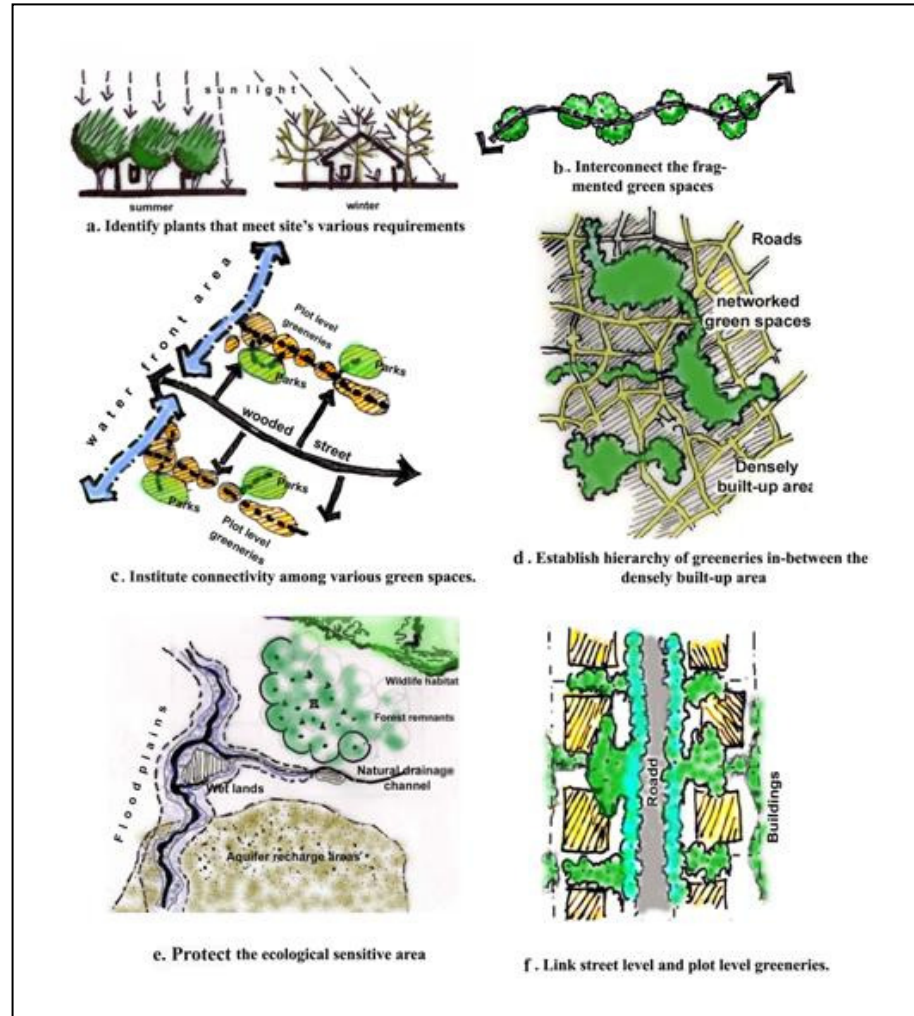


Figure 3. Objectives for Tree-cover planning

Table 2. Problem and constraints for developing the green-cover network

Design scale	Issues	Constraints
City level	<p>Fragmentation and attrition of green-space.</p> <p>Uneven distribution of green-spaces.</p> <p>Threat to the ecologically sensitive areas such as aquifers, water fronts, river mouths and not giving importance to them.</p> <p>Less Biodiversity.</p>	<p>No separate department to take care Chennai's green space.</p> <p>Lack of continuity in the existing green space</p> <p>Pace of urbanization.</p> <p>Imprecise records on environmentally sensitive areas.</p>
Neighborhood or ward level	<p>Violation of development regulation.</p> <p>Reduced functional and ecological diversity of green space.</p> <p>Missing framework for plantation for different land use.</p> <p>Encroachment of environmentally sensitive area.</p>	<p>Development pressure due to Intensifying population density.</p> <p>Increased impervious areas.</p> <p>Missing urban ordinance to protect the public greeneries.</p> <p>Attitude like ready to compromise on the green spaces.</p>
Street level green cover plan	<p>Plantation without any vision</p> <p>Conflict between trees and other urban activities.</p> <p>Lack of maintenance</p> <p>Disturbance from heavy traffics and vehicular pollutions</p> <p>Continuous disturbance from the urban utility departments</p>	<p>In adequate space.</p> <p>Absence of appropriate system to safeguard street trees.</p> <p>Missing authority to take care of urban tree.</p> <p>Increasing traffic volume.</p> <p>Missing coordination among different urban departments.</p>
Plot level green-cover plan	<p>Most of the plantations are shrubs and ground covers</p> <p>Most of the areas are covered by pavements</p> <p>Illegal conversion of green spaces into commercial or rentable spaces.</p> <p>Greeneries are mainly looked as ornamentation rather than element to improve their living environment.</p>	<p>Fear of property damage by the tree.</p> <p>Space deficiency and water scarcity.</p> <p>Absence of development regulation for greeneries.</p> <p>Lack of motivation.</p> <p>No guidance from the urban forest department.</p>

7.1 At city-level

Many researches emphasized that the planning that aims to enhance the natural process should start with identifying the processes at work in nature (Mcharg 1969, McHarg 1970). Therefore sensitive areas, such as ground water recharging area, atmospheric carbon sinking area, i.e. wetlands, wild life habitats and so on, are identified first, for the city-level tree-cover. The flood plains of Adyar and Cooum River, wetlands in and around Velechery area, salt pans in the Ennore area are some of the ecologically sensitive areas identified to increase Chennai's city-level tree-cover (Figure 4d).

7.2 At ward-level

The ward-level plan intends to allocate trees evenly across the city for everyone's benefits. To do this potential space for tree-cover increment are identified at the ward-level. Loose-fit landscapes like gap sites, parks, community reserves, cemeteries, islands of road intersections, natural water bodies and forest remnants are some of the potential areas identified to develop the trees at Chennai's ward-level (Figure 4c).

7.3 At street-level

The street margins are often used for plantation in the city. However, the narrowness and increasing traffic volumes are the major constraints for new plantation along the roads. One of the potential opportunities identified from onsite observation is encouraging the plot owners to plant trees in their front setback (Figure 6b). The trees in the front setback of adjacent plots together can form linear element for Chennai's road (Figure 6e). In turn plot owners will enjoy benefits like, good air, physical comfort, noise reduction and so on. Some of the possible methods of plantations for different situation are shown in Figure 6a, 6c, 6d. The potential street-level tree-cover for Chennai is identified as shown in Figure 4b.

8.0 The Tree-cover plan for Chennai city

Through linking the city-scale, ward-scale, and street-scale trees together, the tree-cover plan for Chennai city is proposed as shown in Figure 5. In addition, increasing tree plantation in the plot could strengthen the natural process at the root of the issue itself. However, it can be achieved only by encouraging the individuals, by offering some benefits like tax concession or development concession for maintaining the trees.

9.0 Mechanism for implementation

The success of any planning proposal ultimately depends on their effective implementation. In today's context bureaucratically increasing the tree-cover in the urban area is a difficult task due to numerous reasons. On the other hand, engaging the people in planning, funding and maintaining the trees are the most appropriate methods. Most of the successful park developments in the developed countries explicitly demonstrated this fact. For instance, Cedar Lake Park – the much used green-space of Minneapolis was built with the help of its citizens. In the other case at Philadelphia, Norris Square Park and the surrounding neighborhoods are reclaimed from the brazen drug dealers with the help of perseverance and commitment of the community for community greening program (Garvin and Berens 1997). Besides, tree-cover plan requires appropriate implementation mechanism. The different mechanisms to implement the tree-cover have been analyzed including engaging the people of Chennai. They are grouped under three headings which are listed in Table 3.

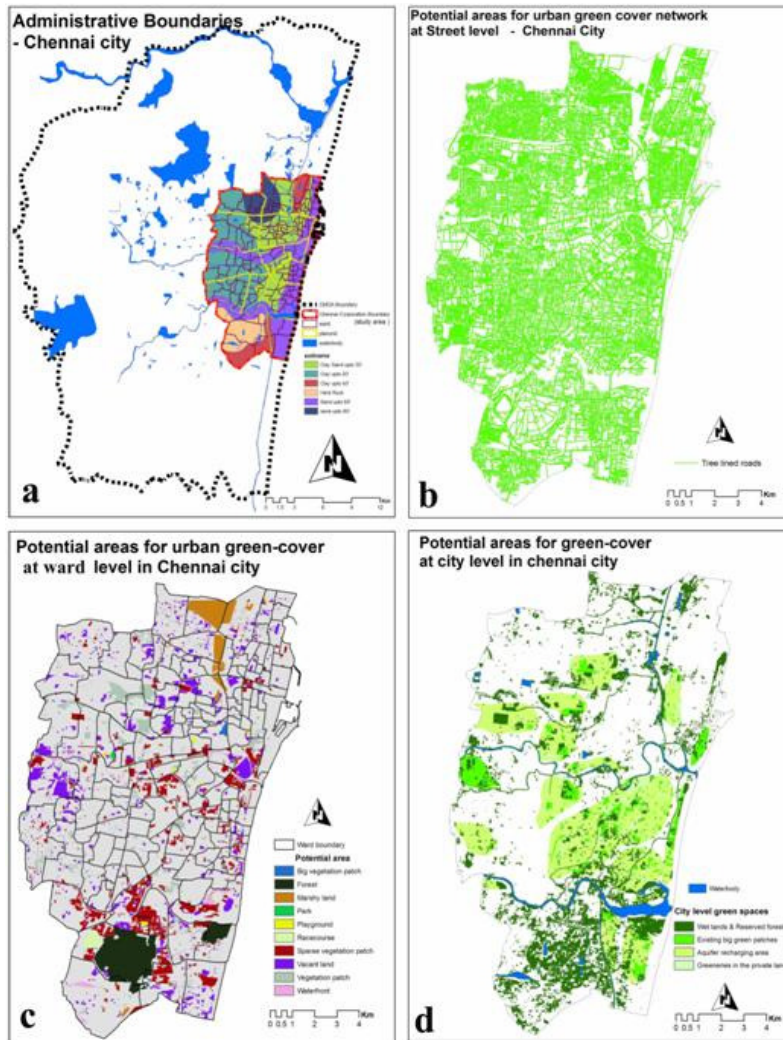


Figure 4. Tree-cover plan at various levels

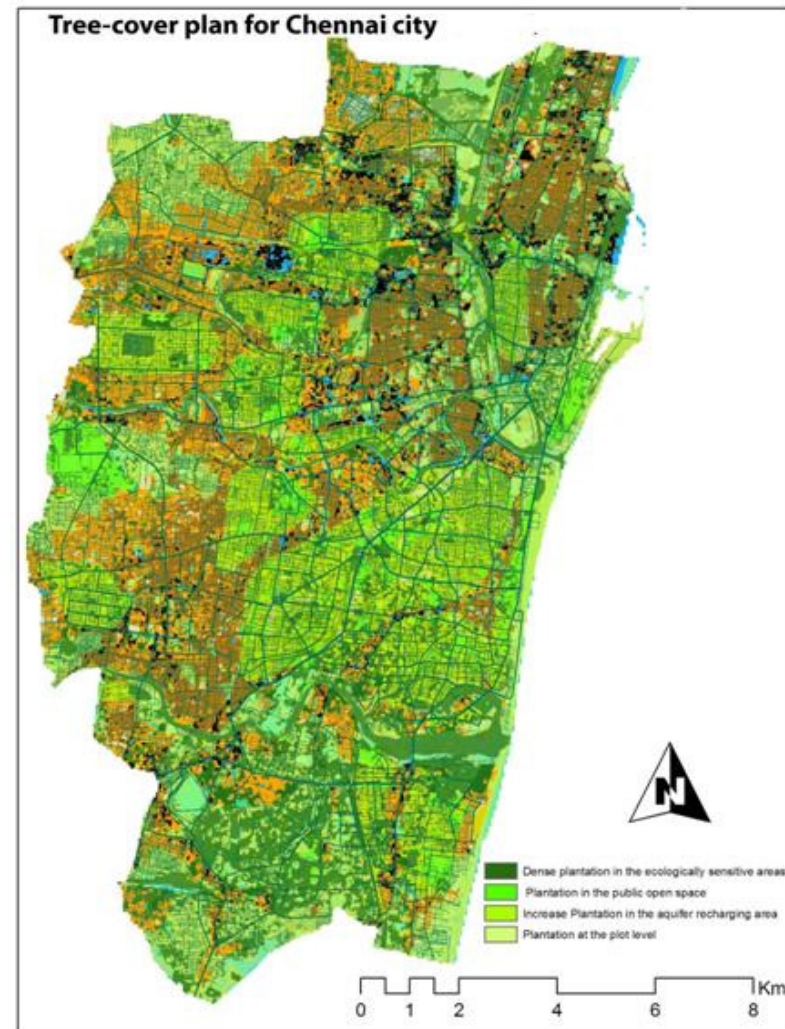


Figure 5. Tree-cover plan for Chennai city

Table 3. Implementation mechanisms

Implementation mechanisms	Type	Description	Such areas could be
Possession of sensitive areas	Complete possession	Any public or private land within Chennai city that supports the ecological processes should be acquired and maintained as green-cover patch.	Ground water recharging areas , areas having higher biodiversity and habitat value, areas potential enough to mitigate the natural calamity such as flooding / land slide, etc.
	leasing out	Leasing the acquired land only for greenery activities, like, growing woodland such as groves, orchard, etc	Flood plains, aquifer recharging area, etc.
Development control techniques	Zoning	Through regulation, all lands are targeted for the Tree-cover development.	Private properties, mainly residential areas.
	Legislation	Protect the Chennai city's green-space through appropriate act, in order to sustain the natural process such as air quality amelioration, ground water recharging and urban heat island mitigation	Parks, play fields and open space in the state.
	Prominent ownership	Possession the lands by means of legislation, which is ecologically very sensitive.	Coastal fronts, water fronts, flood plains, wet lands and habitat of endanger species.
Public participation by means of incentives	Legal agreement	Legal agreement with the land owner, part of his property will be maintained as woodlands against tax benefits.	Plot size exceeding more than one acre
	Incentives	High-density residential or commercial area developers can be permitted additional floor area in exchange maintaining green space or wooded area on the ground.	High density residential areas in the northeast part of the Chennai city
	Easement	It is similar to the development restriction, portion of the property will be brought under easement to support the natural process. That will be maintained as Tree-covered area.	Areas that support natural drain, aquifer recharging areas, and wild life corridor etc.

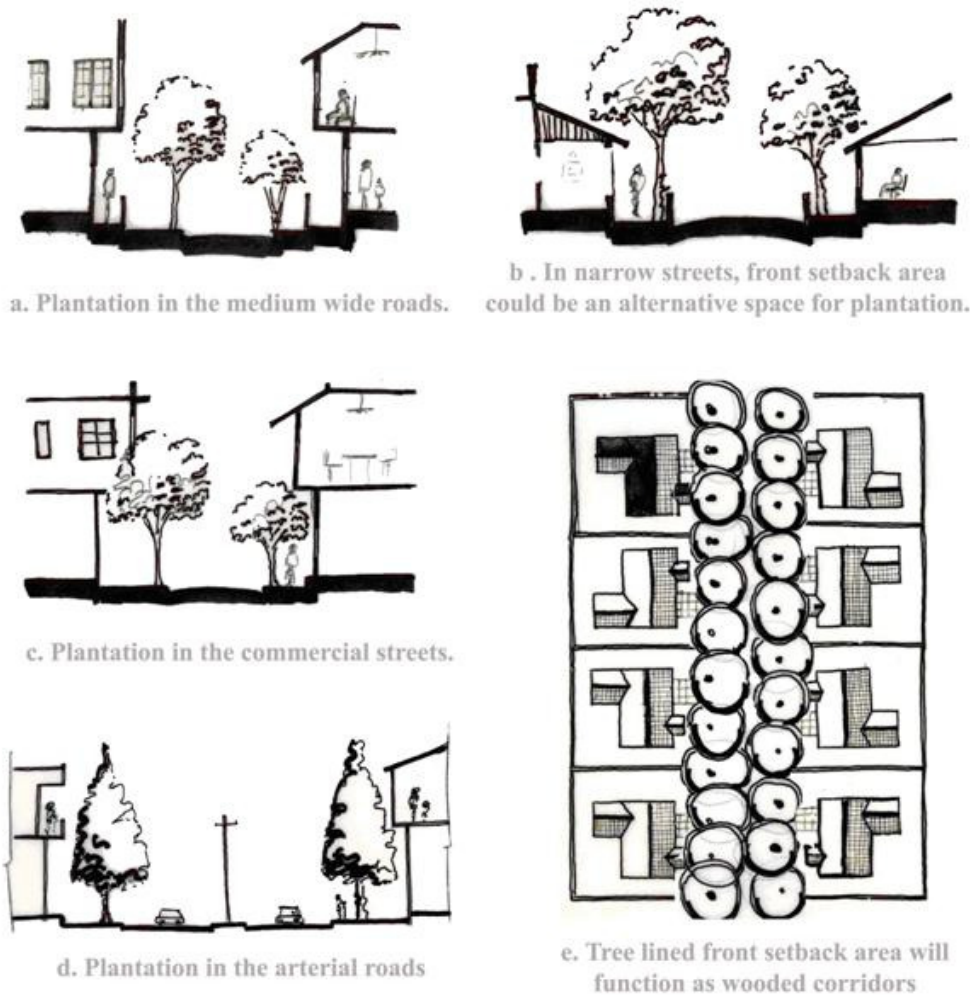


Figure 6. Street level tree plantation for various conditions

10.0 Conclusion

Tree-cover planning is more than just establishing the wood-lands or parks. The wooded-spaces, by its very nature serve so many diverse ends, i.e. act like carbon sink, protects soil condition, climatic condition, support wild life, reduce solar irradiation from hard surfaces and so on. Therefore, while implementing the tree-cover, the prime objectives should be identified for each case and then combined as effectively as possible with the other benefits. It is possible to achieve the collateral benefits in the urban areas without compromising the prime objectives. For instance, the woodland that protects the aquifer area could also serve as a recreational space for the local people. Therefore, the planning process must identify the specific use or range of uses appropriate for each site's tree-cover development. While doing so, the plan must also indicate the type of species to be planted, and category of wooded area to be developed. Lastly, the plan should look ahead and establish the appropriate woodlands, which can concord with future development rather than conflict.

References

- Ahmad Azaharuddin (1990) Urban air pollution and the occurrence of Bronchitis in Kuala Lumpur, *Energy and Buildings* Vol 15- 16, 775-790.
- Akbari Hashem, Kurn Dan M., Bretz Sarah E., Hanford James W. (1997) Peak power and cooling energy savings of shade trees. *Energy and Buildings* 25, 139-148.
- Akbari H. (2002) Shade trees reduce building energy use and CO2 emissions from power plants. *Environmental Pollution* Vol 116 (1), S119-S126.
- Alberti Marina (1999) Modeling the urban ecosystem: a conceptual framework, *Environment and Planning B: planning and Design* 26, 605-630.
- Bolund Per, Hunhammar Sven (1999) Ecosystem services in the urban areas. *Ecological Economics* 29, 293-301.
- Cacciola R.R., Sarva M., Polosa R (2002) Adverse respiratory effects and allergic susceptibility in relation to particulate air pollution: flirting with disaster. –Review article. *Allergy* 57, 281-286.
- de Hollander Augustinus E.M., Staatsen Brigit A.M.(2003) Health, environment and quality of life: an epidemiological perspective on urban development. *Landscape and Urban Planning*. 65, 53-62.
- Jo Hyun-Kil, McPherson Gregory E. (1995) Carbon Storage and Flux in Urban Residential Green space. *Journal of Environmental Management* 45, 109 – 133.
- Garvin Alexander and Berens Gayle (1997). Urban parks and Open space. Washington DC, ULI- The Urban Land Institute.
- Gujarati Damodar N. (1988) Basic Econometrics. Third Edition, McGraw-Hill, Inc, New York.
- Heisler M. Gordon, 1986. Effects of individual trees on the solar radiation climate of small buildings, *Urban Ecology* 9, 337- 359.
- Kjelgren Roger and Montague Thayne (1998) Urban Tree Transpiration over Turf and Asphalt Surfaces, *Atmospheric Environment* 32(1), 35-41.
- Li Feng, Wang Rusong, Paulussen Juergen, Liu Xusheng (2005) “Comprehensive concept planning of urban greening based on ecological principles: a case study in Beijing, China”, *Landscape and Urban Planning* Vol 72 No. 4 May pp 325-336.
- McHarg Ian. L (1969). Design with Nature. Garden City, Doublday / Natural History Press, New York.
- Mcharg Ian L. (1970). ‘Open space for natural process’ in Metropolitan Open Space and Natural Process’, David A. Wallace (Editor), University of Pennsylvania Press, Philadelphia, pp 10-52.
- McPherson Gregory E. Simpson James R, Klaus I Scott (2002). *Actualizing Microclimate and air quality benefits with parking lot shade ordinances*. USDA (in press)
- Moughtin Cliff, Shirley Peter (2005) *Urban Design: Green Dimension*, Elsevier Publishers, Oxford.

Norberg Jon (1999) Linking Nature's services to ecosystems: some general ecological concepts. *Ecological Economics* 29, 183-202.

Nowak David J (1993) Atmospheric Carbon reduction by urban trees. *Journal of Environmental Management* 37, 207 – 217.

Nowak David J., Crane Daniel E (1998) The Urban Forest Effects (UFORE) Model: Quantifying urban forest structure and Functions. USDA Forest Services, *Integrated Tools Proceedings USA* August 16-20.

Pitani Shankar Ravi, Balakrishnan Kalpana, Sankar Sambandam, Ramaswamy Padmavathi (2004) "Comparative Health Risk Assessment For Environmental Pollution In North Chennai, India." <http://paa2004.princeton.edu/download.asp?submissionId=40704> accessed on 27th July 2009

Setchell A.Charles (1995) The growing environmental crisis in the world's mega cities, *TWPR* 17, 1- 18.

Tomlin, C.D (1994) Map algebra: one perspective. *Landscape and Urban Planning* 30, 3- 12

Whitford V., Ennos A.R., Handley J.F (2001) 'City form and natural process'- indicators for the ecological performance of urban areas and their application to Meyseyside, UK. *Landscape and Urban Planning* 57, 91-103.

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