

Chapter 12

Restoring Urban Green Cover of Chennai City: An Ecological Approach



A. Meenatchi Sundaram

Abstract Green cover has a more significant role in linking the atmosphere, lithosphere, hydrosphere, biosphere and anthroposphere on the earth. The reduction of green space has consequential liability in most of the environmental issues we are facing. ‘Impervious land covers,’ the characteristic features of the cities and the prime swallower of urban green cover, are prominent environmental indicators for a wide range of urban environmental issues. The previous literature shows that instigating appropriate green cover could alleviate the urban environmental problems, such as air pollution, water scarcity and urban heat island, the three major issues that tremble the urban quality of life. Ecological spatial strategies in the green cover plan could strengthen the urban ecosystem by protecting environmentally sensitive areas, connecting the fragmented natural areas and easing the flow or movement of energy, matter and species across the urban landscape. Trees are essential biophysical elements; considering the ecological concepts in the ‘green cover restoration’ is critical to assure the future sustainability of our cities. Through adapting the patches, corridor and matrix-based spatial concepts, this study developed four-level strategies for the urban green cover restoration of Chennai city.

Keywords Ecosystem service · Urban green space · Natural process · Environmental performance · Restoration · Natural process

12.1 Introduction

The cultural and scientific developments blinded us to the fact of our permanent dependence on the dynamic capacity of ecosystem services; thus, many societies have become philosophically, mentally and physically separated from the biophysical milieu [1]. Today, the fundamental capacity of the ecosystem services to support

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the quality of life in the urban area reached the threshold because of the rapid conversion of the biophysical elements in the urbanization process. Several empirical studies such as impacts of air pollution on urban population [2], urban heat island-related death study [3] and the health loss due to physical environmental condition study [4] clearly show the degrading quality of life in the cities.

The research on the ecological performance of the urban area [5] noted that the percentage of green space significantly influences the ecological functions in the metropolitan area. The amount of tree cover is the primary indicator of the city's environmental performance and one way to gauge the available ecological services in the town. Nurturing greenery is equal to providing essential urban infrastructures [6] and necessary for quality of life. These and many current studies on the urban ecosystem indicate that the sustainability of our cities lies in the green spaces.

Trees are the most prominent, functional and flexible biophysical elements of the urban ecosystem. Trees generally improve the urban environment by maintaining atmospheric gas balance, facilitating hydrological processes and altering the urban microclimate [7]. Trees are performing three primary ecological services in the ecosystem, namely, production (foods, goods, etc.), maintenance (nutrients, CO₂, water, etc.) and organizing or regulating functions (energy, material flow as well as absorbing human-induced disturbance like pollution) [8]. Trees are one of the natural capitals [9], whose yield and services are the sustainable, year after year; hence, maintaining such natural capital is the minimum necessary condition for future sustainability.

Many studies extensively elaborated the cost benefits of trees' services in the urban environment [7, 10–15], especially in terms of air purification, hydrological regulation and mitigation of urban heat island. Seldom, the relationship between the tree cover and the natural processes is considered in the urban green cover improvement activity. The Nanjing case study [16] found that a lack of theoretical basis or holistic framework is missing at different scales of green space planning. Further, a comprehensive planning framework based on the landscape ecological principle is indispensable to maximize the ecological benefits of green space in the city. To do that, it is necessary to treat the urban forest as a continuum, an integrated system for rational management, which requires a broad spectrum of attention, moving away from a piecemeal approach to the overall package [6].

12.2 Need for Ecological Framework for Green Cover Improvement

Among seventeen significant ecosystem functions [9], gas regulation (air filtration), hydrological regulation and microclimate regulation have a major bearing on the urban environment. Researches on urban green support that trees have a significant bearing on these three services in the city's environmental functions. Therefore,

understanding the landscape ecology principle would provide a better framework for urban green cover improvement activities.

The spatial pattern of the elements in the landscape influences a number of natural processes that are ecologically important [17]. The three critical spatial characteristics of the landscape that affect the natural process are structure, function and change [18]. 'Structure' refers to the spatial relationships between distinctive ecosystems and elements in the landscape concerning sizes, shapes, numbers and configurations. 'Function' refers to the relationship between the spatial aspects, and 'change' refers to the modification in the structure and function [17]. Patches, corridors and matrix are the prime types of landscape structures, which synthesize the overall landscape. The various combinations of those structural features in the landscape affect the ecological functions. The function and structural characteristics of landscape influence each other; each is the cause and the origin of others [19]. The 'spatial solution' is a framework to answer the current environmental issues like global climatic change, water loss, agricultural soil loss and so on [20]. The three major areas that frequently adapt the spatial concepts to conserve the natural processes are forest management planning, suburban or rural landscape planning and greenway planning.

Jack Ahern [21] suggests protective, defensive, offensive and opportunistic strategies for sustainable landscape planning. He elaborates on the context of the application of each of the strategies in the following way. The protective strategies protect the sustainable processes and patterns of the landscapes. The defensive strategy arrests the ongoing negative processes. An offensive method employs nature development to build new elements in the already disturbed landscapes. As the name suggests, the opportunistic strategies recognize the unique opportunities in the landscape and integrate them using other planning strategies for sustainability. Among Ahern's four concepts, the defensive and offensive approaches would be more appropriate for the urban green cover planning because most of our cities do not have any significant 'natural' areas or most of them are highly fragmented to support the ecological functions.

The above literature personifies that the landscape ecology could provide an appropriate conceptual framework for the urban green restoration plan to properly synthesize the green covers and the natural process in a city. Accordingly, this paper is attempting to develop a conceptual framework for the urban green cover plan. Then, it proposes an actionable urban green cover restoration plan for Chennai city, at the city level, neighbourhood level, street level and plot level to reinstate the natural processes.

12.3 Study Area

The city of Chennai, popularly known as Madras, is one among the four major metropolitan cities located in Southern India (13°5'2"N, 80°16'12"E), on the Bay of Bengal. It is the capital of Tamil Nadu state and a fast-growing metropolitan city. Its

physical area expanded from 176 to 426 km² between the years 1997 and 2011. Chennai city's population grew at an average of 25% per decade. Chennai is situated in a hot climate zone, experiencing tropical maritime monsoon type. The minimum temperature ranges from 21 to 24 °C from December to February, and the average daily maximum temperature is 37 °C during May. The minimum monthly rainfall ranges from 6 to 10 mm in February, and Maximum rainfall of 320 mm is recorded in November. The green cover of Chennai city is 6.25% (Forest Survey of India 2011); the vegetative cover falls under the sparse category. For administrative purposes, the entire city is divided into 16 planning unit areas, further subdivided into ward units. Ward is the smallest unit in the administrative area.

12.4 Restoring Urban Green Cover

Comprehending the required ecological objectives and identifying the necessary spatial strategies according to the situations are critical for landscape planning [22]. The spatial approach needed for the green cover restoration plan is carried out in the following steps:

1. The city's environmental performance is assessed based on the existing green cover.
2. Then, the spatial scenario of the environmental performance across the city is detected.
3. According to the situation, the spatial strategies for green cover restoration evolved.
4. Finally, the urban green cover restoration plan was developed for the city.

The environmental performance of Chennai city was assessed based on the change in three primary green cover services, namely:

- Air purification service.
- Regulating the hydrological processes.
- Staying poised the urban microclimatic processes.

Based on the net services, the city is classified into different environmental performance zones.

12.4.1 *Assessing the City's Environmental Performance*

The detailed study [23] on the seven types of urban ecosystems in Stockholm found that street trees and urban forests play a significant role in the city's ecosystem services, mainly air filtration and rainwater recharging and microclimate regulation. The environmental performance of the Chennai city gauged in terms of air purification, microclimate and hydrological process changes with respect to the green cover.

Then, the changes are computed in each of these services to understand the environmental performance change due to green cover loss. Based on the net services, the city is classified into different environmental performance zones.

12.4.1.1 Changes in the Per Capita Air Purification Service

Trees purify urban air by stomatal absorption and dry deposition of various air pollutants [24]. The canopy stomatal model [25] is applied to estimate the air pollution removal by Chennai’s tree cover.

That is $F = Vd * C$, where F is the pollutant flux, Vd is deposition velocity and C is pollution concentration.

The functional relationships between land cover and urban air quality have been built in the ArcGIS Spatial Analyst (Fig. 12.1) by employing the above model. The pollution removed by tree cover for the particular period is quantified by multiplying the tree canopy area with the net average hourly pollutant flux for that period across the city. The pollutant flux for the different pollutants is calculated separately (Fig. 12.2), and then the average net change of the pollutant across Chennai city is computed.

Pollution removed by tree cover is estimated separately at the micro level, summed up at ward level and divided by population level to know the per capita change. And the net per capita change between two periods has been calculated at ward level through subtracting. All the above steps are carried out in the ArcGIS

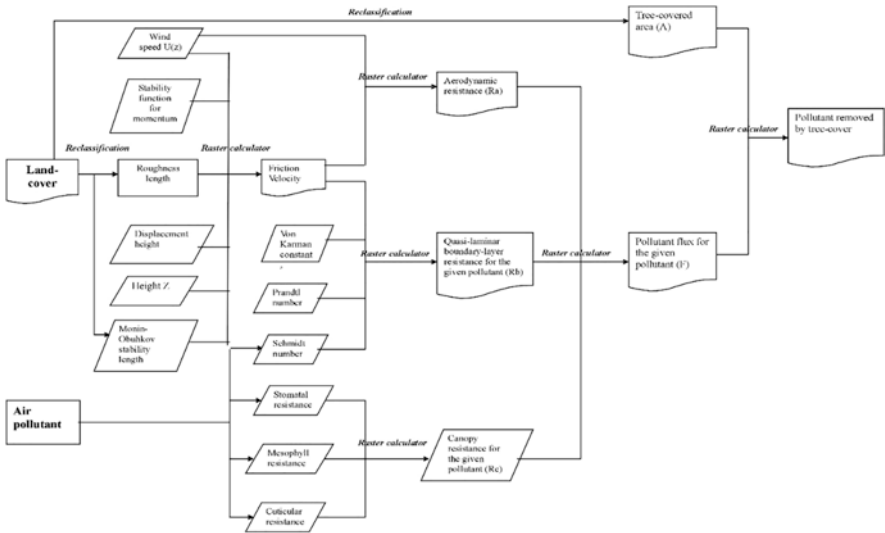


Fig. 12.1 Functional relationships between land cover and urban air quality

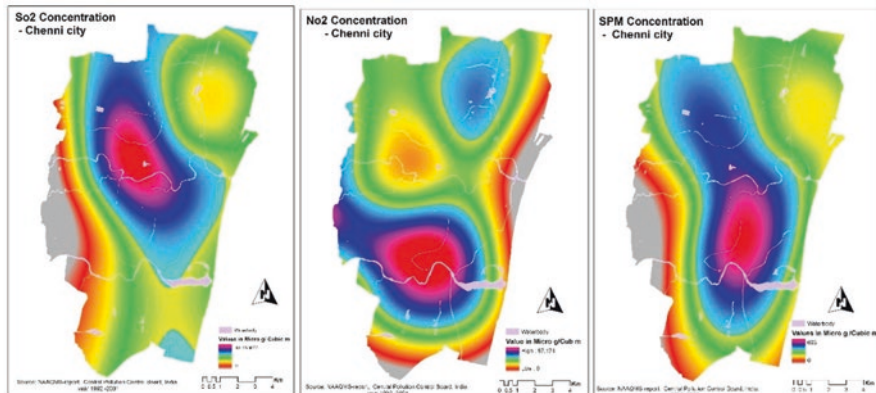


Fig. 12.2 So₂, No₂ and SPM pollutant concentrations

Spatial Analyst. The final result (Fig. 12.3) shows that pollution removal by a natural process in the city has been gone down considerably across the city and at some wards to the extent of 99% reduced.

12.4.1.2 Changes in the Per Capita Surface Heat Radiation

Stored solar heat radiation from the urban surfaces is the primary cause of the urban heat island phenomenon. Urban heat island effects can be assessed in terms of surface solar radiation. The surface solar radiation (R_N) is the difference between the total incoming and outgoing radiation fluxes in the urban area [26]:

$$R_N = (1 - r)R - I_N$$

where r is albedo, the numerical value of the solar radiation reflective property of the surfaces. R is the total incoming solar radiation, I_N is the net long wave radiation and $(1 - r)R$ is the net short wave radiation. The value of albedo (r) for different land covers is inferred from Pielke R.A and Avissar R [27]. Accordingly, the functional relationships between land cover and surface radiation are constructed in the ArcGIS Spatial Analyst (Fig. 12.4).

Between the years 1997 and 2011, the city lost a considerable amount of green cover (Fig. 12.5), and the non-vegetative land covers increased as much as 88% in some of the wards. The R_N value is assessed for the two periods separately, and the change in the per capita R_N value is computed at ward level by comparing per capita difference at each ward. The comparison outcome indicates the surface radiation increase across the city; in some wards, it increased up to 100% from the year 1997 to 2011 (Fig. 12.6).

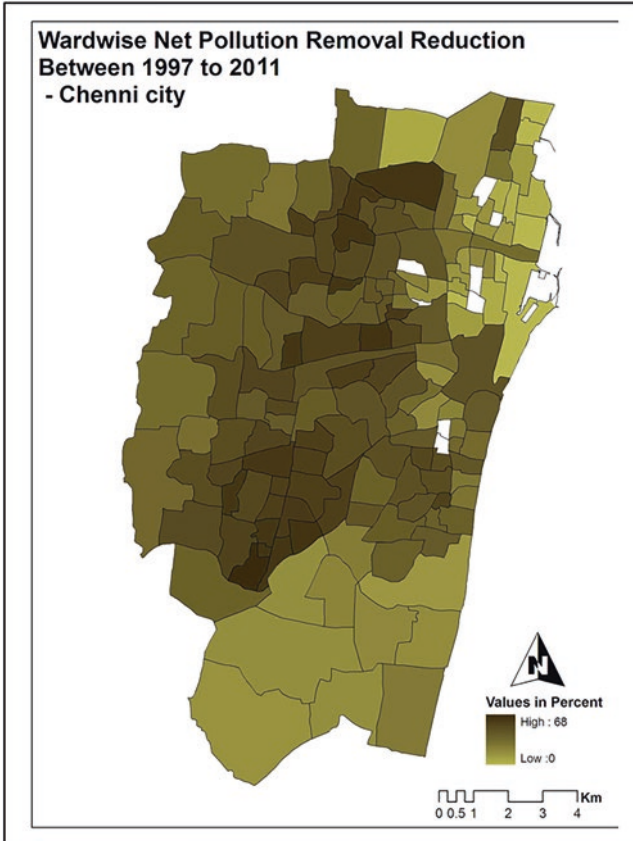


Fig. 12.3 Ward-wise pollution removal reductions by tree cover change

12.4.1.3 Changes in the Per Capita Urban Hydrological Process

Canopy interception of precipitation is a significant benefit from the trees to manage the stormwater floods and recharge the groundwater. Using the Technical Release 55 of the United States Department of Agriculture (USDA), functional relationships between land cover and the urban hydrological process are constructed in the ArcGIS Spatial Analyst (Fig. 12.7). Changes in the retention capacity, run-off volume and peak flow of Chennai city are estimated for 1997 and 2011.

The decline in the amount of green cover (Fig. 12.8) drastically reduced the water-holding capacity of the city's surface (Fig. 12.9). Thus, together with the augmented impermeable surface, increased the per capita peak flow and run-off up to 99% (Fig. 12.10). Reduced retention capacity of the land cover (Fig. 12.12) and the increased surface run-off almost stopped the groundwater recharging processes in the city. The groundwater level is gone down up to 10 m in 2011 compared to the year 1997 (source Chennai metro water and sewerage department).

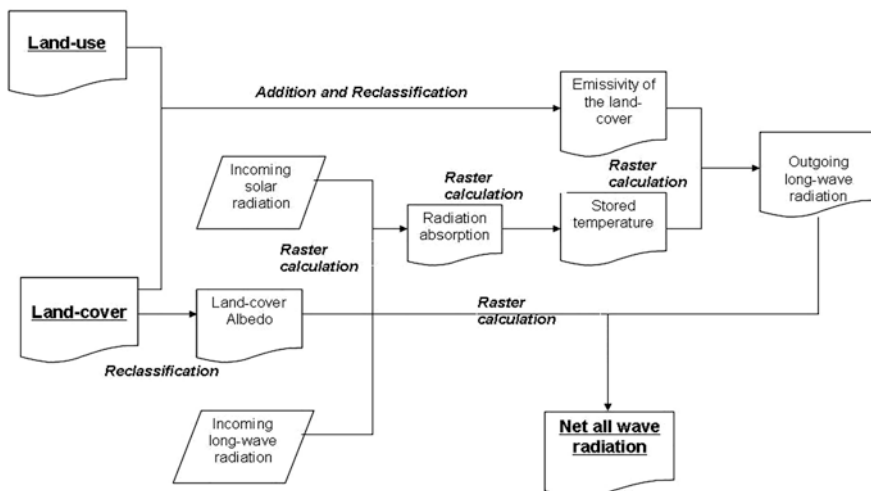


Fig. 12.4 Functional relationships between land cover and surface radiation

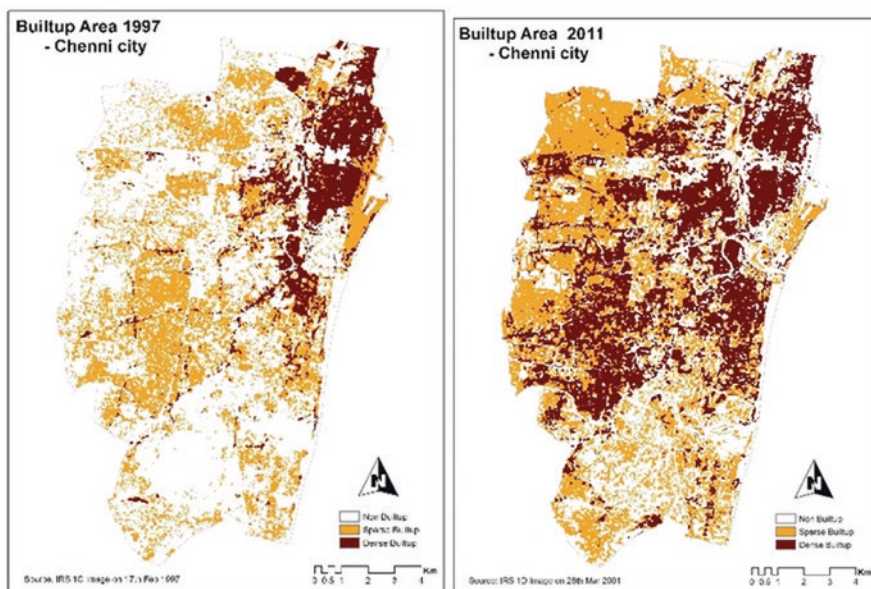


Fig. 12.5 Built-up area in 1997 and 2011

12.4.2 Identifying Scenarios of Chennai City

The natural processes are classified [28] into horizontal and vertical processes. Horizontal processes move across the landscape, such as surface water, groundwater, migration, wind erosion, water erosion, sedimentation and aerosol and gaseous

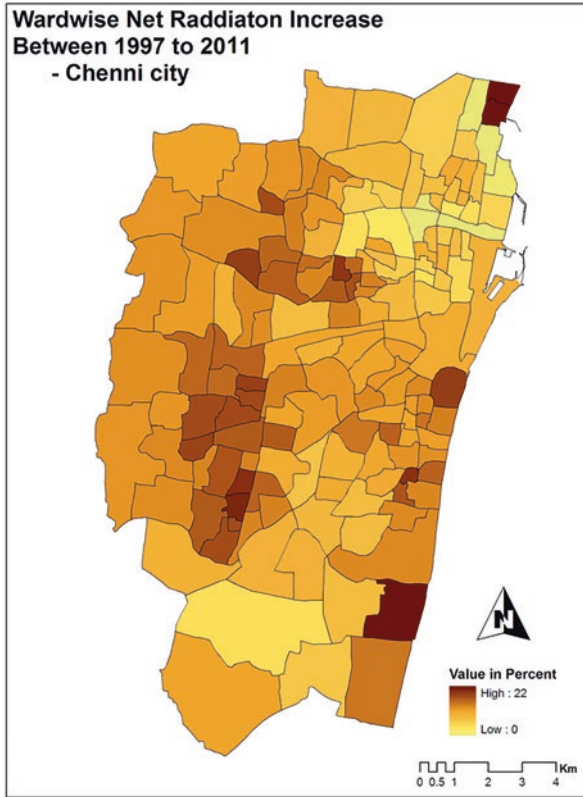


Fig. 12.6 Ward-wise net radiation increase between the years 1997 and 2011

movements. Succession, evapotranspiration, photosynthesis, nutrient uptakes and groundwater percolation are the vertical processes. Understanding the structure and function relationship would help to create appropriate spatial, strategic solutions to restore both the vertical and horizontal natural processes in the urban areas; and it is the way to build systematic solutions in the landscape planning to get ahead of problems in the landscapes [29].

Characteristics of urban ecosystems are not spatially uniform across the landscape. It is highly influenced by various local factors as well as socio-economic factors. It is indispensable to study those trends spatially to understand the scenario clearly, to make appropriate planning interventions. A spatial index was developed to understand the environmental scenario of Chennai city based on the environmental performance changes (Fig. 12.11) and the amount of green cover across the city. Index values are computed for each ward (the smallest administrative unit); the higher the index value, the better the scenario. The factors used to make the indexes were:

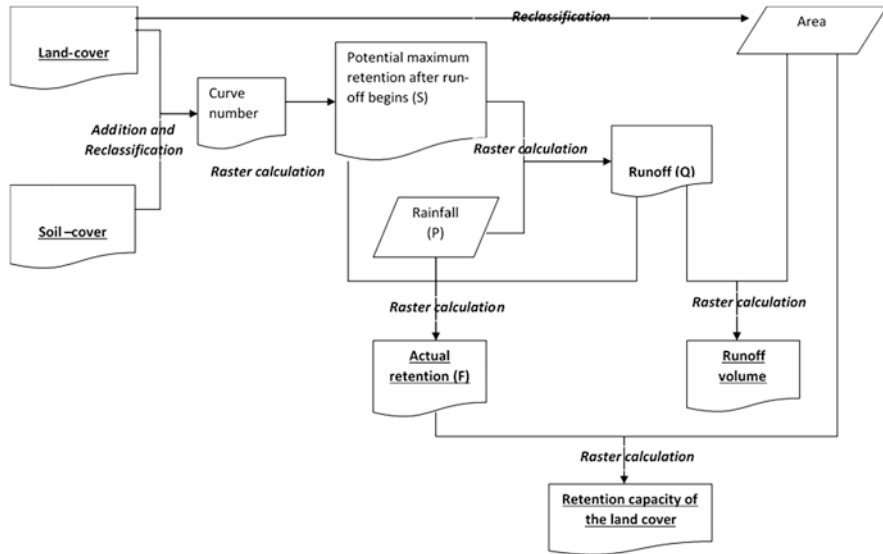


Fig. 12.7 Functional relationships between land cover and urban hydrological process

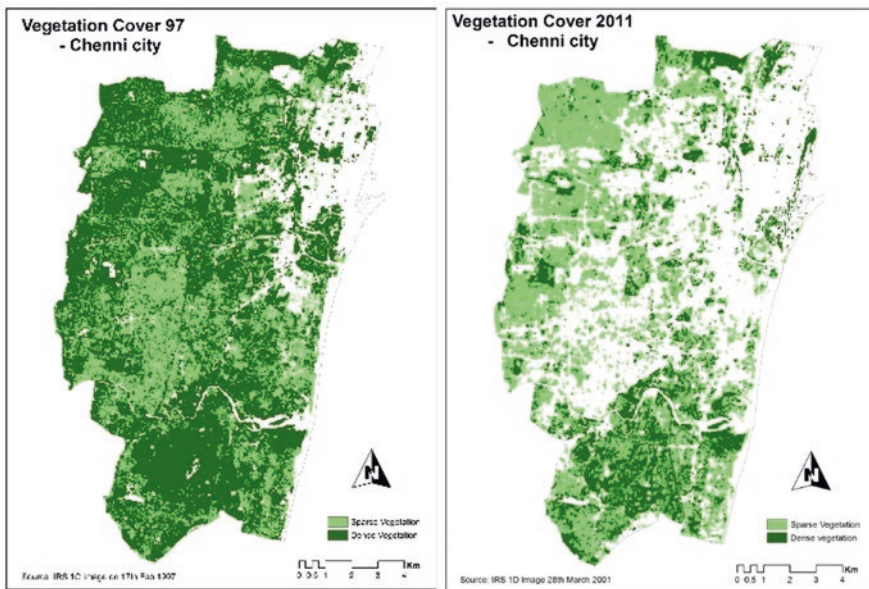


Fig. 12.8 Vegetative cover in 1997 and 2011

1. Area of green cover (GC).
2. Change in the per capita air purification services (AP).
3. Change in the per capita surface heat radiation (SHR).
4. Change in the per capita hydrological services (HS).

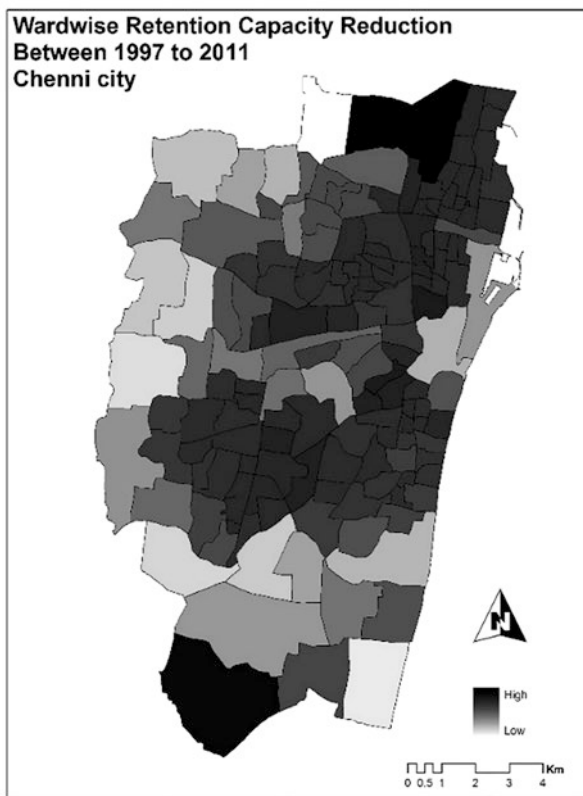


Fig. 12.9 Ward-wise retention capacity reduction between the years 1997 and 2011

Each of the above criteria is standardized to a scale of 0–100 (Fig. 12.12).

The spatial index (SI) derived by individual scores is combined through assigning weights for each of the criteria. More weightage is given to the ‘area of green cover’ criteria, and equal weightage is given to the other three criteria. That has been done using the following formula:

$$SI = (GC * 40\%) + (AP * 20\%) + (SHR * 20\%) + (HS * 20\%)$$

The weighted surface for the environmental scenario is derived through combining all the layers in the ArcGIS Spatial Analyst (Fig. 12.13). Further analysis shows that there is a strong correlation between per capita green cover change and environmental performance change (Fig. 12.14).

Using the natural classification method, the resulted layer is classified into zones representing best, very good, good, fair and worst scenarios in terms of available environmental services (Fig. 12.16).

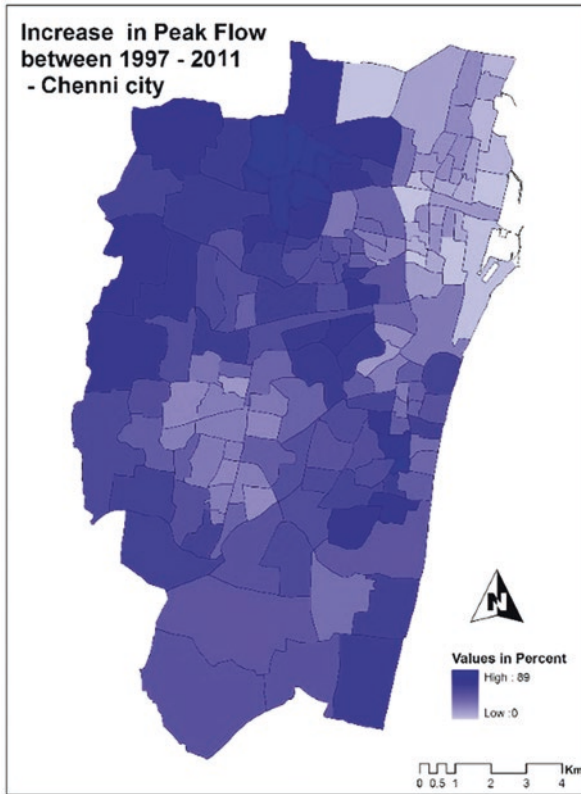


Fig. 12.10 Ward-wise increase in the peak flow between the years 1997 and 2011

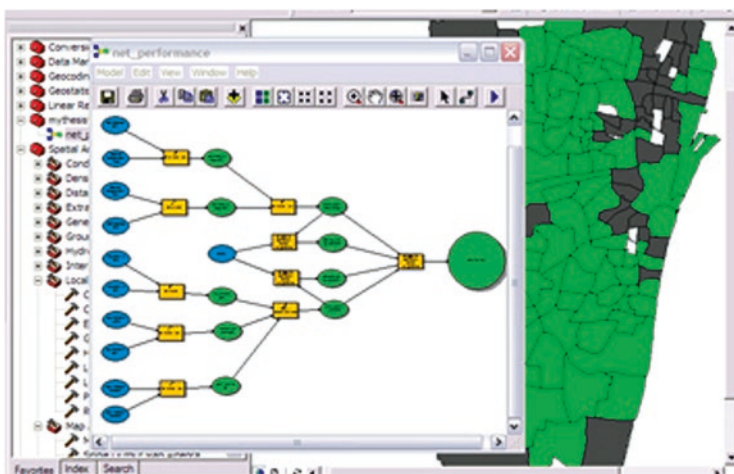


Fig. 12.11 GIS model in the model builder to assess the environmental performance of the city

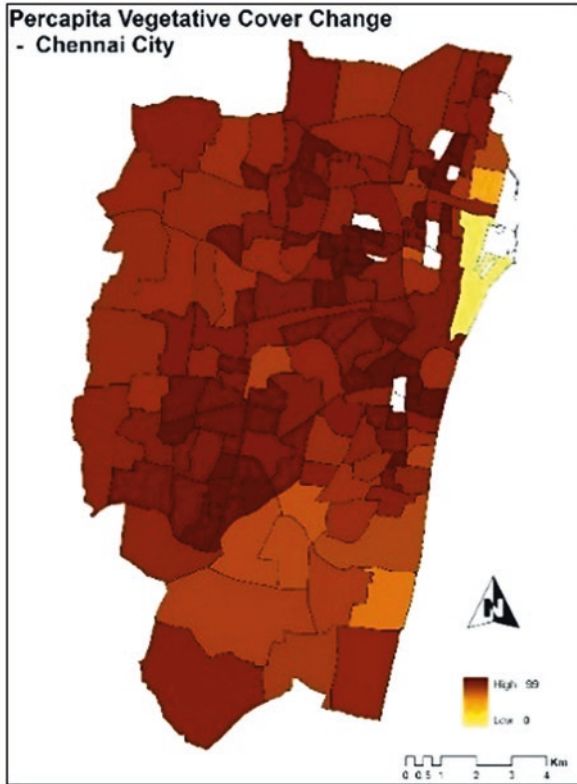


Fig. 12.12 Per capita vegetative cover change between the years 1997 and 2011

12.4.3 Environmental Scenario

Chennai city's environmental scenario is taken into consideration for the development of spatial strategies. Priorities for the green cover plan have been fixed according to its status (Fig. 12.15). The areas under the worst categories are characterized by heavy build-up areas with high-density populations, some with zero vegetative covers. The next fair area category has a significant amount of green spaces compared to the previous one, but they are highly fragmented. In the good zone, the area of vegetative cover is well balanced with build-up areas. The very good area covers more natural areas such as institutional open space and non-urban areas. The open spaces near the waterbody and reserved forest areas come under best zones. The landscape ecological planning concept has been adapted to identify the required spatial strategies for each of the zones.

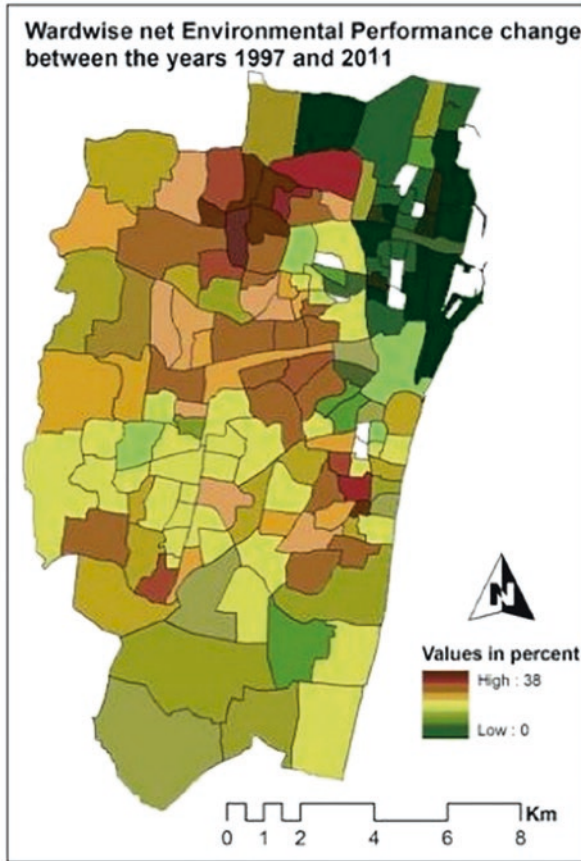


Fig. 12.13 Ward-wise net environmental performance change between the years 1997 and 2011

12.5 Developing Spatial Strategies

Trees contribute to the urban ecological services from the plot level to the region or city level [30–32]. There are three kinds of options considered in developing spatial strategies for Chennai’s green space restoration [33]. They are the following:

1. The portfolio effects or statistical averaging approach meets the required tree services through the random introduction/maintenance of trees within the available spaces of the built milieu.
2. Density compensation approach increases the density when there is a shortage in the required tree cover density to produce the essential services.
3. Functional compensation approach enhances the ‘individual tree’ efficiency, where space is the limitation to increasing greeneries’ density.

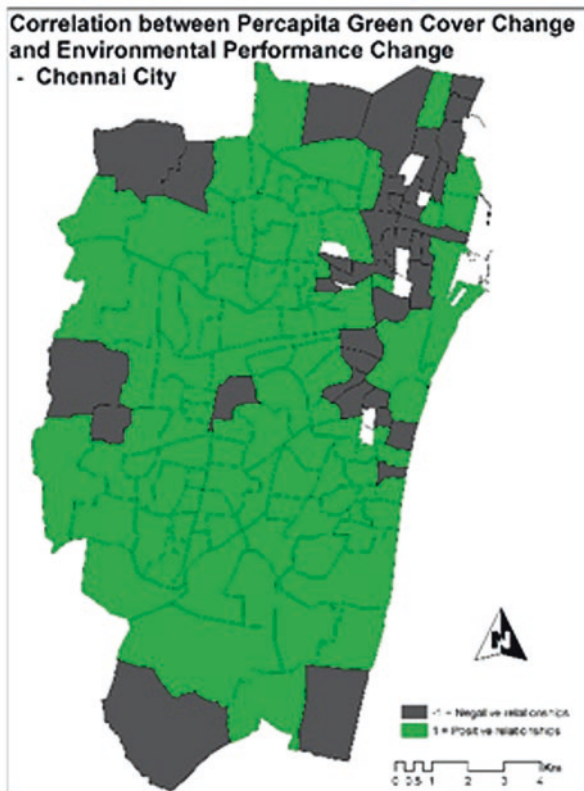


Fig. 12.14 Correlation between per capita green cover change and environmental performance change

Accordingly, this study developed four-level strategies for restoring the green cover plan from micro to macro level, namely, plot-level strategies, street-level strategies, neighbourhood-level strategies and city- or regional-level strategies (Fig. 12.15).

12.5.1 Plot-Level Strategies

The plot is the lowest level where the city's ecosystem gets modified first. Also, it is the smallest unit administered by the urban development authorities, whose size varies according to land use, socio-economic factors and other local development rules. The amount of natural area in a plot highly differs across the city according to the socio-economic pressure. Intensifying urbanization activity devours the greeneries in the plots, thus cumulatively reducing the city's environmental performance

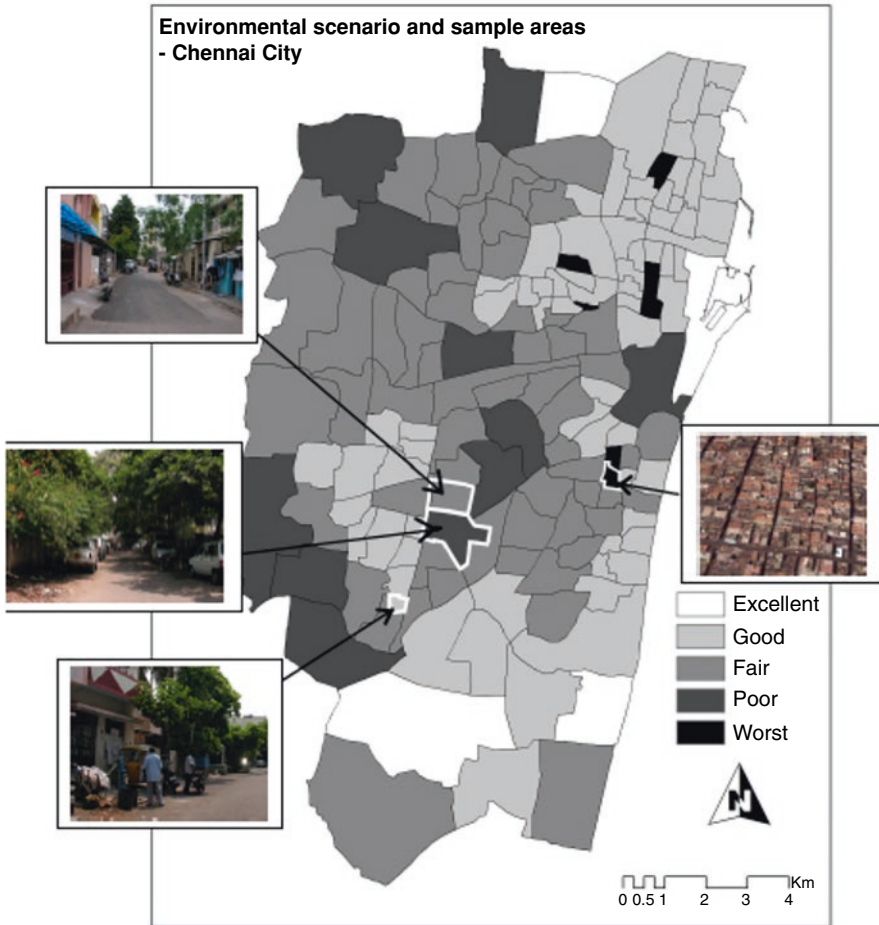


Fig. 12.15 Environmental scenario of Chennai and representing sample areas

at a higher level. For this reason, intervention to improve the city's ecological services should start at the plot level.

12.5.2 *Street-Level Strategies*

The study on avifaunal in an urban landscape [34] says that wooded streets (Fig. 12.16) potentially could function as corridors. A study on corridor quality and the demographics of a meta-population [35] found that any size of connection in the landscape is better than no connection at all. The critical three variables that determine a street as an ecological corridor are vegetative cover, vegetative structure and



Fig. 12.16 Tree-lined front setback area will function as wooded corridors for Chennai city

degree of its connectivity to the other natural areas [34]. Better ecological connectivity could be achieved in the urban street tree network using [36] the following guidelines:

1. Maintaining necessary width and connectivity is the primary condition for significant ecological functions such as habitat, conduit, filter, source and sink.
2. Reducing the contrast between the gap and corridor and reducing the gap between corridors according to the species movement.
3. Maintaining the similarity in vegetation type and structure between the corridors and patches.
4. Creating the stepping stone connectivity wherever the gap is wider, for example, placing islands or median vegetation in the broader roads.
5. Maintaining visual continuity between the successive stepping stones and green patches.

12.5.3 Neighbourhood-Level Strategies

Vegetation content is one of the significant factors that influences the urban microclimate [37]. The small scattered vegetated areas in the large matrix of the concrete surface could contribute to the urban ecological services better than larger ones [38].

The 'loose-fit' landscapes like waste lots, derelict gap sites, abundant sites, ruins and cemeteries are the potential sites to bring back the ecological process in the urban area [39]. Apart from those loose-fit landscapes, parks, community reserves and islands of road intersections, natural waterbodies are the few other potential spaces to increase the vegetated areas at the neighbourhood level.

12.5.4 Regional-Level Strategies

Large vegetation patches serve many major ecological roles that include protecting aquifers and interconnected stream networks and providing habitat for the local population and so on [38]. The larger vegetated landscape would bring back the natural environment into the city and safeguard the terrestrial and aquatic renewable resources. This sort of natural environment offers three amenity values to the urban population:

1. Option values – utility for individual who wants to visit or preserve it for future generation.
2. Existence value – utility derived from the mere knowledge of its existence.
3. Recreational value [40].
4. Though the importance of these landscapes is less tangible [41], keeping those landscapes is necessary to get the environmental benefits like soil erosion control, removal of air pollution, temperature modulation, provision of wildlife habitat, and so on [42].

In the urban green cover restoration, incorporating areas that offer realistic prospects for the development of phenomena of the ecological process that have regional or local significance would maximize the ecological process in the city. Those significant areas are major aquifers and groundwater systems, flood plains and low-lying areas, banks of the river channels and lakes, wetlands, public reserves like forest lands, etc. (Fig. 12.17).

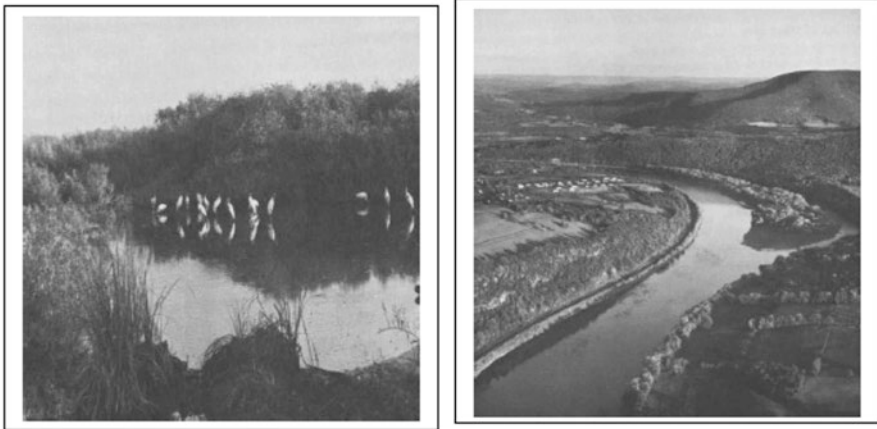


Fig. 12.17 Introducing tree cover around wetland, river corridors could protect the sensitive areas as well as improve the ecological services [43]

12.6 Landscape Planning for Urban Green Cover

Chennai city's four categories of environmental scenario best, good, fair and worst areas are considered for the green cover plan. The sites under the worst categories are characterized by heavy build-up areas with high-density populations, some with zero vegetative covers. Here, more priority has been given to increasing the green cover by identifying potential loose-fit sites such as vacant land and gap sites other than the open spaces. Other possible alternatives in these heavy build-up areas could be the vertical and roof gardens, where the vegetation functions the same way as it does at the ground level [44]. The next fair area category has a reasonable amount of green spaces compared to the previous one, but they are highly fragmented. The priority for these areas is identifying the additional space to increase.

The objective is not just to increase the greenery in the urban areas, instead establish/protect the required ecological process to enhance the city's environmental performance. With that focus, this paper tries to evolve a landscape plan for urban green cover using the above four strategies for the different environmental scenarios of Chennai city. The urban green cover plan for Chennai city has been carried out at three spatial scales. They are the following:

- City-level green cover plan – within the metropolitan boundary.
- Neighbourhood- or ward-level green cover plan.
- Street-level green cover plan.
- Plot-level green cover plan.

12.6.1 City-Level Green Cover Plan

Ian Mcharg [43] quoted that 'Planning that understands and properly values natural processes must start with identifying the processes at work in nature.' In the regional landscape planning, such identification should take account of significant natural areas that support the ecological process (aquifer, flood plains, etc.), quality and quantity of each of those areas, location and distribution of those areas in the urban fabrics and understanding their critical values in the urban ecosystem [45]. Identifying and protecting those areas that perform the ecological services is the crux for our future sustainability [46]. Urban developments are occurring without any compassion for the natural processes, which destroyed or altered most of the ecologically significant natural areas in the cities. In the green cover plan, the landscape planning approach has been adapted to identify the potential area to reinstate the natural services through the green cover.

In the first step, critical areas such as aquifer recharging area, banks of the water-bodies and wetlands are delineated within Chennai city; the existing natural vegetative areas are identified in the second step. In the third step, a weighted land use surface has been developed, by assigning weights based on the ownership, the

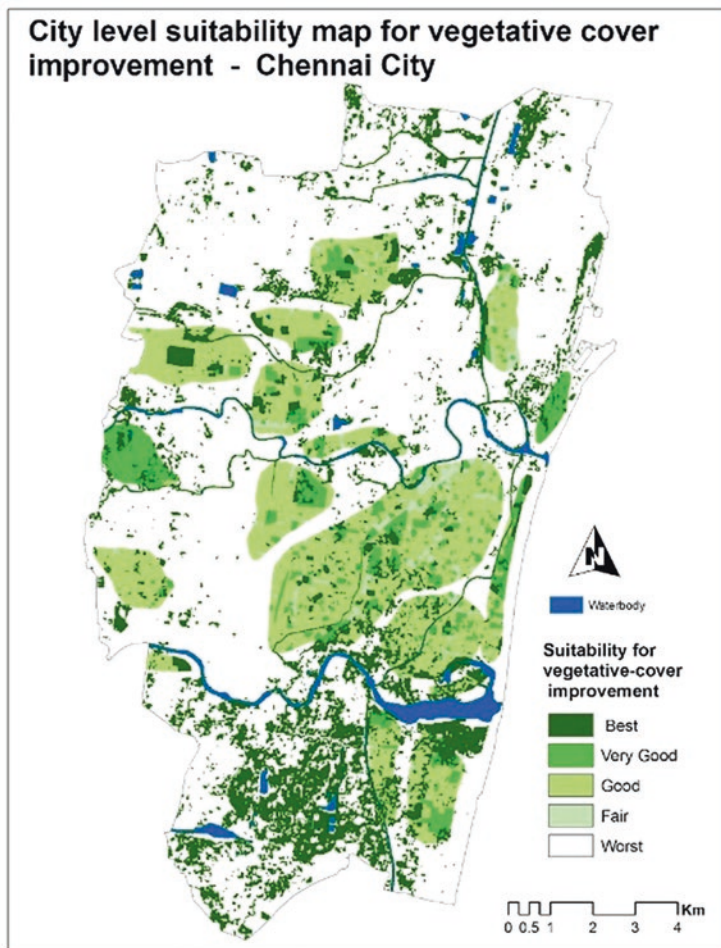


Fig. 12.18 City-level suitability map for green cover improvement

potential to accommodate the green space in terms of space, and the socio-economic activities (Fig. 12.18).

12.6.2 Neighbourhood- or Ward-Level Green Cover Plan

Based on the environmental scenario, the neighbourhood green plan has been developed. More priority has been given to increasing the green cover in the worst zone by identifying potential loose-fit sites such as vacant land and gap sites other than the open spaces. Other potential alternatives in these heavy build-up areas could be

the vertical and roof gardens, where the vegetation functions the same way as it does at the ground level [44]. The fair area category has highly fragmented green spaces in reasonable amounts compared to the previous one, but they are highly fragmented. The priorities for these areas are identifying the additional space to increase the green cover to improve the environmental performance and creating a green network to link the existing green spaces. In the good zone, the area of vegetative cover is well balanced with build-up areas, and here, the priority has been given to strengthen the existing green networks through establishing the new links. The reserved forest, the wetlands and the coastal vegetative areas fall in the best category, where the emphasis is given to protecting these areas from the development pressure.

In addition, priority is also given to establishing the connectivity among the green spaces to strengthen the urban ecosystem services. Based on the neighbourhood-level strategies, the potential area for the urban green cover network has been identified, as shown in Fig. 12.19.

12.6.3 Street-Level Green Cover Plan

Streets are highly functional areas in the urban landscape, imposing lots of spatial and site environmental constraints to incorporate the tree lines. Significant constraints are utility lines, street lights, signs, traffics, signals and building lines. Understanding the characteristics of roads would help integrate the tree lines effectively with the socio-economic activities [47].

Chennai city's street-side situation can be grouped into the following:

1. Pathway extending from road curbs to the building – mainly in the commercial areas.
2. Pathway with few trees extending from road curb to building a compound wall – institutional and industrial areas.
3. There is no well-defined pathway, with or without tree line along the roads, mainly in the residential areas.

Using the street-level strategies, five street-level solutions are proposed for Chennai city to establish ecological networks. They are the following:

- Establish the tree-lined networks along the roads.
- Minimize the corridor network gap either by introducing spreading-type species or introducing a stepping stone connection.
- Maintain the similarity between the corridors by introducing uniform vegetative structures and floristic characteristics.
- Keep up the visual continuity between the successive green patches and corridors.
- Introduce the intermediate tree line or stepping stone wherever the road's width is more.

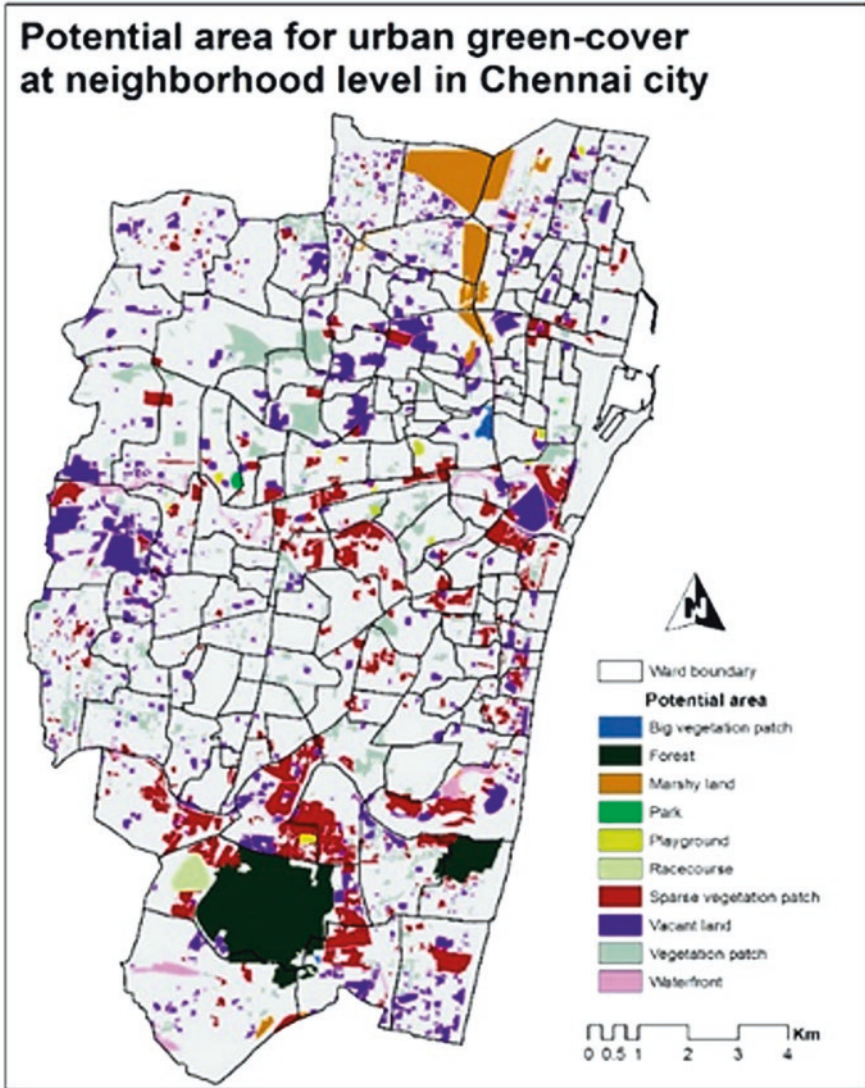


Fig. 12.19 Potential areas for green cover improvement at the ward level

Tree-lined corridors link the fragmented green patches. Also, reduce the adverse environmental effects of roads, and enhance the visual quality of urban roads.

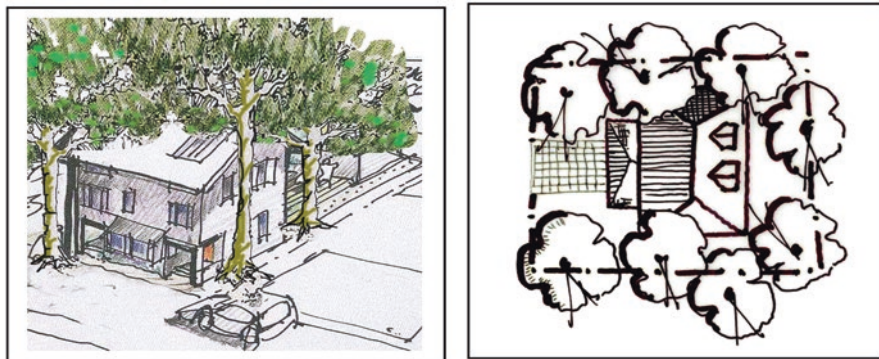


Fig. 12.20 Planting around the building improves energy efficiency of buildings as well as onsite natural process within the Chennai city

12.6.4 Plot-Level Plan

Trees in the plot modify the micro-level ecological process, including surface runoff, groundwater recharge and surface heat radiation [48, 49]. Understanding the morphology of built form and the local geophysical factors is most important, in order to integrate the vegetative covers at the plot level to capitalize on environmental benefits. The minimum plot size in Chennai city is 80–90 sqm, maximum plot coverage is 65–75% and setbacks from the plot line are 1.5–6 m concerning the abutting road's width. The morphology of the built form of Chennai city could be grouped under three categories. They are single buildings with setbacks, two or three buildings intercepted by open space and wall-to-wall constructed buildings with or without central courtyards. The potential areas to increase the green cover at plot level are the gap sites and the vacant lands, as shown in Fig. 12.20.

12.6.5 Urban Green Cover Restoration Plan for Chennai City

The sustainability of human survival requires sustainability at a finer scale too, apart from the biosphere scale [50]. For the ecologically sustainable world, Robert Costanza [51] stresses for an effective plan, based on efficient distribution and effective allocation of natural capital, with a deep understanding of the complex linkage between ecology and socio-economic system.

This paper has identified the potential way to integrate 'tree – the natural capital' [52] at various levels from the plot level to city level. Through combining all the four-level plans in the ArcGIS Spatial Analyst, this paper is proposing the urban green cover plan for the environmentally sustainable Chennai from the micro level to macro level as shown in Fig. 12.21.

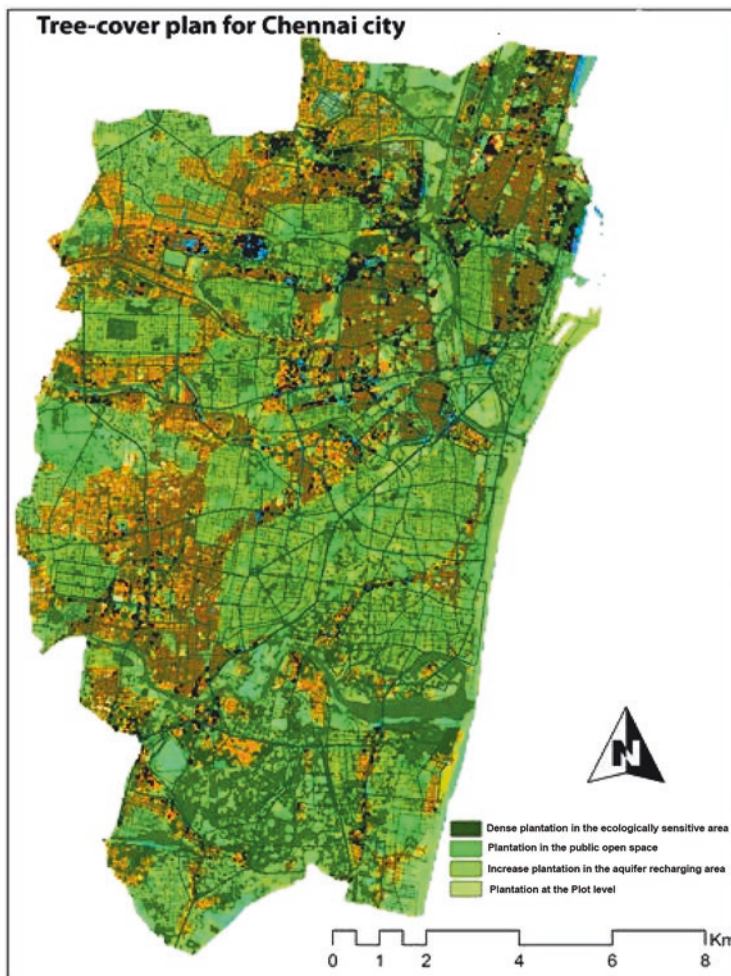


Fig. 12.21 Tree cover plan for Chennai city

12.7 Summary and Conclusion

Trees are one of the urban area's renewable or active natural capitals [52]; maintaining the optimum urban tree cover is a minimum prudent condition for assuring future sustainability and is increasingly evident from the numerical urban research. To establish the optimum urban green cover, this paper has developed comprehensive green cover planning strategies at four levels through employing patch, corridor and mosaic components of landscape ecology.

It considers the structure and function relationships of the landscape to establish the link between the fragmented natural areas and facilitate the natural process in the city, such as the flow or movement of energy, material and species across the

urban landscape. Based on these strategies, an urban green cover plan for Chennai city is developed.

The successful employment of ecological strategies in landscape planning requires a complete understanding of the scenario. To understand the scenario of Chennai city, an environmental performance analysis was carried out. The entire city was divided into four environmental performance zones, and their ecological objective was fixed separately. A comprehensive urban green cover plan is proposed for Chennai city by applying the four-level strategies according to the objectives.

However, this urban green cover plan for Chennai city is a conceptual one. A detailed study on design aspects at different levels is required to successfully implement this concept, including a selection of species and the establishment of management measures. Furthermore, to realize this dream, the planning and management of urban green cover should go hand in hand with the land use planning of Chennai city.

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