CHAPTER 3
ECOLOGICAL PLANNING FOR THE URBAN TREE COVER

3.1 INTRODUCTION

It has been widely established that the green-cover could improve the unfitting hostile urban environment to congenial fitting environment for the human survival. The newly emerging research knowledge on the urban green-spaces made us to realize ‘tree as both the ecological and cultural feature of the city’ (Sheladia 1998). However, Jim and Sophia (2003) in the Nanjing case study found that the tree cover improvement activity is missing the theoretical basis or holistic framework. In order to obtain the true ecological benefits of the green space, according to their study, the urban forest should be treated as a continuum and it should follow an integrated part of the planning system and the rational management. The interconnected network of green spaces can conserve the ecological functions and ecosystem values of the urban area that will provide the required benefits to the population. Therefore, Benedict and McMahon (2002), comparing the interconnected networks of the city’s green space with the urban infrastructure like, water supply and sewerage system, called the interconnected green-space as the ‘urban green infrastructure’. However, the green-cover network development process requires a broad-spectrum of attention, moving away from a piecemeal approach to overall package (Jim 2000). Ong (2003) insists for common strategies to integrate greenery within the urban system. That is, the urban green cover improvement activities require an appropriate planning system based on the ecological principles.
3.2 NEED FOR ECOLOGICAL PLANNING FOR THE URBAN TREE COVER

Man modifies the existing landscape pattern and processes either deliberately or inadvertently. Hence, future of the most landscapes is increasingly being determined by human activities, so as the quality of our living environment (Hobbs 1997). Therefore, understanding the landscape pattern and process is essential to restore the environment. For this end, the landscape ecology comes in handy to understand the structure of the biophysical environment, which defines the ecological process. Further, it explicates the dynamics of the ecological processes in time and space (Golley and Bellot 1991). Cook’s (2002) study in Phoenix Arizona found that implementing the ecological based planning approach has improved the environmental value of the urban open space system. Jim and Sophia (2003) is emphasizing on the ecological principle based landscape planning framework for the sustainable canopy cover.

Rookwood (1995) asserts that the landscape planning provides tools to maneuver changes in the landscape so as to bestow the sustainable future. And it is a process designed at broad scale to influence and control the physical characteristics of the landscape; have concern with the interaction of the natural and cultural systems. Landscape planning synthesis and transmit all the information, as diverse as politics and scientific research, commercial development and aesthetic theory for the defined objectives. Therefore, the landscape planning process should not be seen as means to achieve a final solution rather framework for decision making (Rookwood 1995). To ensure the landscape's sustainability, multiple and interdependent ecosystems functions within
the landscape should be carefully identified on the macro-level, meso-level and the micro-level, specifically at each intervene locations.

### 3.3 THE COMPONENTS OF THE LANDSCAPE ECOLOGICAL PLANNING

At any given location, *diversity*, *coherence* and *continuity* are the three basic aspects affecting the ecological services of a landscape (Kuipere1998). *Diversity* refers to the variety in landscape elements, landscape patterns, landscape units and landscape types, which reflects the topological relationships between the land use and the abiotic feature; it also includes the diversity of the ecosystems. *Coherence* reflects the chorological relationship between the landscape components that offers connectivity between landscapes. *Continuity* is the spatial arrangement of elements to enhance the persistence of the present and the proposed ecosystems. All these three elements are vital for the effective ecological functioning of the tree-cover in a landscape. Comprehending the ecological concept (i.e. structure and function of the landscape) that deals with these components are imperative for planning and management of landscapes (Doing 1997), so for the urban tree-cover planning.

### 3.4 SIGNIFICANCE OF THE ECOLOGICAL CONCEPT

The concept of ecological pattern i.e. structure-functions is widely used in numerous researches to examine various systems on this earth, including the urban forest. In the context of the urban forest, Rowntree (1995), defining structure is the array of static attributes of the urban forest, namely, spatial distribution of the species, biomass, size and age. Whereas he refers function as the dynamic operation of the urban forest,
i.e. how the vegetation interacts with other components and providing the services. In short the physical composition of the green-cover determines the horizontal and vertical processes. So, through recreating or reinstating the green structure according to the concept of ecological principle could restore the natural processes in the city. Subsequently it will improve the city’s environmental performance to bestow quality air, water, and physical comfort for human well being.

3.5 ACQUAINTANCE BETWEEN THE TREE COVER AND ECOLOGICAL SERVICES OF THE URBAN SYSTEM

The relationship between the tree-cover and the city’s natural processes are highly complex phenomena. However, understanding them is critical to evolve the planning framework to restore the tree’s services in the human landscape. ‘Conceptualization’ or ‘hypothesizing’ is a scientific method, which is widely adapted in researches to understand such complex system. Conceptualization of urban green system would reveal the ecological association between tree-cover and other elements. The three basic organizational frameworks which help to conceptualize and design the landscapes are scale, order and location (Lyle 1994). Significance of each one is described below:

3.5.1. Scale

Every landscape is a part of a larger system and at the same time it consists of smaller subsystems. **Scale** is about the relative size of the elements or landscape with reference to other elements or landscapes. In the urban green cover planning the ‘scale’ refers to the structural integration of the tree cover within the functional hierarchy of the landscape. That is, the green cover developed at higher level within the larger frame of reference, becomes a frame of reference for the smaller
landscapes in a hierarchical relationship (Figure 3.1). For instance, municipality fixes certain amount of the tree cover density at the neighborhood level, which determines the density and number of species at street and individual plot level. Subsequently, the street and plot level tree-covers are determined by the local factors such as, available space, the socio economic activity, and the local environmental condition.

3.5.2. Order

*Order* is the physical arrangement of elements and its interaction with other elements (Figure 3.2, Figure 3.3). In a landscape, *order* governs the innate functions of the landscape according to the local condition such as climate, landform and soil condition. Structure, function and location are the fundamental modes of order in a landscape. Among them, the landscape structure, i.e. spatial occurrence of elements in the landscape, controls most of the landscape functions. That is, a specific landscape configuration implies a specific landscape function such as, flow of water, wind, energy, animals and minerals (Forman and Godron 1986). Forman (1995) says that the landscape structure or form, which we see today, is produced by flow (function) of the past. He asserts that not only do flows create the structure but structure also determines flows. The structure-function relationship helps one to understand how the elements are fitting together in the landscape and producing the ecological services such as, flow of water, energy and material.

Change in the landscape structure alters the landscape function and vice versa (Turner 1989). The number of study on woodland also reveals the relationship between spatial pattern and natural processes. Flores et al (1998) says that the structure and functions are two sides of the coin. That is to say, occurrence of the plant community in a vacant plot and its
Figure 3.1 The two-way interrelationship between higher and lower level factors that determining the urban tree cover development.
change from being predominantly a grass land to being predominantly woodland, will change water and energy transfers between vegetation and the atmosphere; subsequently modifies the micro-climate (Flores et al 1998). Most of the urban green covers fail to restore the city’s ecological services due to heedlessness to this structure-function relationship. So, understanding the structure-function relationships enable us to make an effective green-cover for cities. For instance, knowledge about the physical arrangement of the plant and resulting benefits will help in question like ‘where and how to arrange the plant to reduce the surface solar radiation in the city?’ Luck et al. (2003), call this as ‘service providing unit’. In the context of the urban forest it may either refers to the number of trees / amount of a canopy cover / pattern of arrangement, which can produce the required services or, location at which the tree covers to be introduced. Forman (1995) observes three basic type of structural configuration in nature which influence the landscape processes. They are patch, corridor and matrix. Significance of each type of these is elaborated below:

![Image 1](https://example.com/image1.png)

**Figure 3.2** Topological relationships within the spatial unit.

![Image 2](https://example.com/image2.png)

**Figure 3.3** Chorological relationships between the spatial units.
3.5.2.1 Patches

It is a group of trees or a patch of vegetation (Figure 3.4) in the landscape. Basically it is a homogeneous, isolated, non-linear and prominent features, usually contrast to its surroundings. Physical attributes of patches such as, size, shape and types, widely differ in the landscape and significantly influence the landscape functions, biomass and species composition (Figure 3.5). Based on the form –function relationship, Forman (1995) draws attention to three types of patch shapes in the landscape, they are - 1. Convoluted forms enhancing the interaction with its surroundings, which can improve the natural process between the spatial units, for example, within the urban built milieu tortuous shape vegetation patches (Figure 3.6) counters the urban heat island effect through evaporation and also act like pollutant sink. 2. Network or labyrinthaline forms (Figure 3.7). -acts like a conduit system for the flow of natural processes. That is, the interconnected vegetation patches in the form of network improves the flow of water, energy, wind across the urban landscape. 3. Compact forms (Figure 3.8). -effective in conserving resources, it protects the internal resources and processes from the external forces. Patch of dense vegetations supports the biodiversity and enhances the ecologically sensitive processes. For instance, like a sponge, a forest patch absorbing the rain water and releasing it slowly, this reduces the heavy or sudden flooding (Forman 1995). Patches can be as large as a national park or as small as a single tree. But the locations and size of vegetation patches are critical for landscape function. The ecological value will vary according to the size of the vegetative patches (Forman 1995).
Some important ecological values of larger and small patches in the urban areas are:

Figure 3.4 Patch – group of vegetation. (Dramstad et al1996)

Figure 3.5 Physical attributes of patches such as size, shape and types are varying widely in nature. (Dramstad et al1996)

Figure 3.6 Convoluted shape patch (Dramstad et al1996)

Figure 3.7 Network or labyrinthine shape patch (Dramstad et al1996)

Figure 3.8 Compact shape patch. (Dramstad et al1996)

Figure 3.9 Corridors – linear vegetation patches (Dramstad et al1996)
a. Larger patches

Larger patches of vegetation protects the aquifers, interconnects the stream networks; sustains endanger population of most interior species, offers them the habitat and escape route. Example, the natural forests.

b. Small patches

Size of the small patches will vary from a single tree to a group of few trees. Whenever it is difficult to develop the large patches, small patches provide the supplemented ecological benefits as mentioned above. Microcosmically small patches provide some relief in the hot concrete urban surface. It supports uncommon species where large patches are missing, protects the scattered small habitat in the densely built up urban area. Example parks, group of vegetations in the plot, etc.

3.5.2.2 Corridors

It is linear shaped vegetation patches in the landscape (Figure 3.9). Streams, ridges and animal trails are some other corridor types exist in the landscape. Width and connectivity are the two structural attributes that influence the functions of the corridor. Width of the corridors varies from narrow strip to few kilometers wide. The width and presence of the internal elements (Figure 3.10) (stream, river, road, path, ditch etc) are the important spatial variables determine the functions of the corridor. The five major functions of the corridors are Habitat, conduit, filter or barrier, source and sink. Vegetation corridors contribute significantly to many goals of the human society, important amongst are 1. Offers biodiversity protection for a wide range of species and also function as dispersal route for them to re-colonization. 2. Contributes to the water resource management such as, flood control, sedimentation control and erosion; and cleans water through filtering runoff water.
3. Linear strip enhances agro-forestry production by acting as wind break, controlling soil erosion, providing wood product and preventing desertification. 4. Offers recreational facility which includes game management, wildlife conservation for nature enjoyment. 5. Enhances community and cultural cohesion and green belts give neighborhood identity (Forman 1995).

3.5.2.3 Matrix

The matrix is the most dominant structural characteristic of the landscape (Figure 3.12). Among patch, corridor and matrix features, matrix is the most extensive and most connected elements. Basically matrix differs from the patch in its relative size and configuration. Patches are isolated group of vegetation embedded in the landscape for example, parks in the densely built-up urban area, whereas matrix is the largest vegetation group intercepted / by other elements, for example, in the rural or suburban areas larger natural landscape is intercepted by an isolated building. Matrixes have larger homogeneous mass in its total area, enclosing other landscape features (such as patches, corridors). Being, most connected element of the landscape, matrix plays a major
role in determining the natural processes, that is flow of energy, materials, and species across the landscape.

### 3.5.3 Influence of the locational factor

Among the three elements of the ecosystem’s order, structural and functional characteristic of the vegetative cover rapidly vary locationaly (spatially) within the landscape. At the micro-level the locational factors determine the following characteristics of the green cover structure in the landscape. They are, diversity (type of species present), growth form (trees, shrubs, herbs, mosses), dominance (controlling species by virtue of size, numbers), relative abundance (relative proportions of different species) and tropic structure (food-web) (Lyle 1994). These characteristics of the green cover in turn affect the natural process in the landscape. That is, a close relationship between the green cover structure and the local processes determines the overall landscape processes. For example, relationship between the grass, wind pattern, wind speed and the topographic pattern generate the dune grass association and over the period it will evolve as a stabilized coastal forest. That eventually alters the movement of materials, energy, and species between the landscape spatial units. Briefly, understanding the structural and functional concepts of the tree cover and their relationship with locational factors are vital for restoring the stable and sustainable ecological services at the micro-level.
3.6. TREE-COVER BENEFITS ON THE SPATIAL AND THE TEMPORAL SCALE

Plants are the basis of life on earth as they perform numerous services in the biosphere. Each of these services may operate in different domain as shown in Table 3.1, namely local, regional, and global scale. For example, woodlands contribute to the climate regulation at the local, the regional and the global scales. Conversion of the forest to pasture or urban, modifies the local thermal balance and humidity level in the air; at larger scale, increases the temperature, decreases precipitation, and alters patterns of atmospheric circulation over the region as a whole (Vitousek 1994). Therefore, understanding the occurrence of the tree’s service at various spatial scales is vital for developing the appropriate conservation and management plan for different landscape levels. This will help us to answer the following type of questions, how much and where are the tree covers required to protect the aquifer recharging processes? How to distribute the tree cover patches in the urban built milieu to conserve the biodiversity? How to make the better connection between different tree cover patches to ease the flow of energy, material and species across the city? And where to plant the tree in the given plot
to gain maximum benefits? Apart from this spatial variation, trees services may operate at the temporal scale also.

Table 3.1 Trees services at various spatial scales.

<table>
<thead>
<tr>
<th>Services</th>
<th>Spatial scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purification of air</td>
<td>Local - Regional – Global</td>
</tr>
<tr>
<td>Flood mitigation</td>
<td>Local - Regional</td>
</tr>
<tr>
<td>Climatic stability</td>
<td>Local - Global</td>
</tr>
<tr>
<td>Purification of water</td>
<td>Local – regional</td>
</tr>
<tr>
<td>Soil protection</td>
<td>Local - Regional</td>
</tr>
<tr>
<td>Soil Fertility</td>
<td>Local</td>
</tr>
<tr>
<td>Aesthetic</td>
<td>Local – Regional</td>
</tr>
</tbody>
</table>

For example, upstream woodlands act like a sponge which stores the rain water during the storm and releasing it slowly afterwards, that keeps the downstream perennial. Besides, through their seasonal variation, trees significantly influence the micro-climate temporally, for instance, during the summer trees protect the urban surfaces through their shade from gaining the heat (Figure 3.13) and during the winter trees allow the surfaces to gain the heat through shedding their leaves (Figure 3.14). Hence studies for restoring the tree cover’s services in the urban area should be conducted at different spatial and temporal scale.

Figure 3.13 Winter time, trees allow sun light entering the building.  
Figure 3.14 Summer time, trees prevent the sun light entering the building.
3.7. THE METHODS TO INCREASE THE TREE-COVER BENEFIT IN THE CITIES.

Factors that influence the magnitude and variability of tree’s services can be understood in two ways. First, it is based on the amount of service provided by the tree cover (tree – centre approach), for instance, tree cover in one urban park size of 212 hectare is found to remove daily 48lbs particulates, 9 lbs of nitrogen dioxide, 6 lbs of sulfur dioxide and ½ lbs of carbon monoxide (Coder 1996). Secondly, it is based on the tree’s service as a whole, irrespective of the amount of tree cover that existed (service center approach). For example, McPherson et al (1997) in the Chicago urban forest climate project have found that the typical brick residence needs shade in their western side wall in order to reduce the annual air conditioning energy use by 2% to 7% and peak cooling demand by 2% to 6%. The choice between the tree -center approach and service-center approach should be based on the inventory at the local site condition. The tree-centered approach adapts the traditional tools of ecology to identify the environmental variables, which affects the distribution, abundance and persistence of trees. However, the tree-centereded approach has lots of limitation in the urban area due to various factors like scarcity of land, population density, and development pressure. And it is difficult to quantify the required amount of the tree cover in the ever growing city.

In the service-center approach, it is important to identify the environmental factors that influence the collective function of the tree’s service. For example, tree as an ameliorator of the urban air temperature through its evapo-transpiration function dependent on the availability of ground water. In the service center approach, factors that influence the tree’s service are given in the Table 3.2.
Table 3.2 Locational factors which influence the trees services.

<table>
<thead>
<tr>
<th>Trees functions</th>
<th>Locational factors</th>
<th>Soil</th>
<th>Ground water</th>
<th>Local temperature</th>
<th>wind</th>
<th>location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evapotranspiration</td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Infiltration</td>
<td></td>
<td>○</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>●</td>
</tr>
<tr>
<td>Sequestration</td>
<td></td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Interception</td>
<td></td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>●</td>
<td>○</td>
</tr>
<tr>
<td>Shade</td>
<td></td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>○</td>
<td>●</td>
</tr>
</tbody>
</table>

- Very high, ● - High, ○ - Medium, ○ - Less, ○ - Nil.

3.8. CONCLUSION

Improving the tree-cover is the natural means to ameliorate the air quality, the hydrological processes and the micro-climate of the urban area. Because of such awareness, the urban forests are emerging as an essential life supporting public infrastructure of the city. However, the two steps, which are vital for establishing these green cover infrastructure are, 1. understanding the existing local process and 2. identifying the potential of the land to support the tree cover that could restore the landscape process (flood control, ground water recharge, climatic amelioration etc). It could be achieved by understanding the order of the natural system. Order is the key organizational concept, which would guide us in the species selection, composition and their spatial distribution according to the local condition. Additionally, maintaining diversity, coherence and continuity could enhance the quality of the proposed green-cover. In this way, one can find a method to modify or expand the existing green cover system.