सत्यमेव जयते

CPWD

A Handbook of Landscape

Published by
Directorate General
Central Public Works Department

A Handbook of Landscape - A Guide

February, 2013.

Published By:
Directorate General
Central Public Works Department
101 A, Nirman Bhawan,
New Delhi – 110011.
Email: cpwd_dgw@nic.in

Prepared by:
Addl. Director General (Arch.),
CPWD, Nirman Bhawan,
New Delhi – 110011.
Email: adg-arch.cpwd@nic.in

Technical Advisory Team:
Smt. Sipra Mitra (Addl. Director General (Arch.)),
Smt. Indu G.Choudhary (Sr. Architect),
Sh.Sudhir K.Seem (Sr. Architect).

Support Team:
Sh. Biswajit Bose (Sr. Architect), Sh. P.S.Sodhi (Architect),
Sh. Anil Grover (Architect), Sh. S.S.Rawat (Architect),
Sh. Biswajit Roy (Architect), Sh. M. S. Sridhar (Architect),
Sh. Rajesh Singh (Astt. Architect).

Printed by:
Falcon Graphics,
M-2, A 42-44, Manushree Building,
Commercial Complex,
Dr. Mukherji Nagar, Delhi - 110009.
Email: falcon_graph@yahoo.co.in

A Handbook of Landscape

- A Guide

CPWD

Central Public Works Department

शहरी विकास एवं संसदीय कार्य मंत्री
भारत

MINISTER OF URBAN DEVELOPMENT
AND PARLIAMENTARY AFFAIRS
INDIA

MESSAGE

It is encouraging that CPWD is releasing "A Handbook of Landscape" on 26 February, 2013 at Vigyan Bhawan, New Delhi.

To prevent rapid growth from degrading the environment, there is a need to explore options that reduce energy consumption and create a pollution free environment. Professionals should make conscious efforts through utilization of landscape in planning and its implementation to achieve this.

The entire construction industry which is creating our infrastructure needs to adapt practices of energy and environmental efficiencies in order to make a visible change and arrest the depleting green cover in the cities. Landscape planning, a softscape design, is needed in the sustainable building movement to maintain a balance between the nature and built environment.

This handbook brings the basic concepts of Landscape design to the common person and makes available easily implementable methodologies. Architects and Engineers will have a much needed ready reckoner with this publication.

I congratulate the Central Public Works Department in bringing out this publication.

(Kamal Nath)

Foreword

सत्यमेव जयते

डॉ. सुधीर कृष्णा
Dr. Sudhir Krishna

Landscape is an integral part of sustainable development as it blends man's technology into the natural surroundings. It plays an active role in the preservation, improvement and enhancement of environment. As the urban cities are growing seamlessly, there is a need for solving the environmental issues which are created in the wake of rapid urbanization. A key to solving environmental crisis comes from the field of landscape architecture, a profession dealing with inter-dependence of environmental process and their use to achieve a harmonious balance between needs of rapid urbanization and environmental concern.

I compliment the Central Public Works Department in bringing out this handbook on landscape. It will go a long way in creating awareness about the importance of landscape and help professional in this field as an effective guide on landscape effects on property development and construction. This will also address the need for environmental concern and how they can be addressed to bring harmony with ecological balance to achieve sustainable urban development.

Sudhir Krishna
Secretary (UD)
Ministry of Urban Development
Government of India

About the Book

अशोक खुराना
Ashok Khurana

India is a country with diverse ecological and climatic regions ranging from mountains to valleys, dry lands to flood plains and from coastal belts to plateaus. A conscious effort to preserve and improve the environment and to train a new generation equipped by related education and training is needed. We are concerned over misuse of the environment and development that has lost its contact with nature. Those who plan for the future must understand natural resources and preservation methodologies. These being the basis of life are the pre-requisite for sustainable development. The demand for better resource planning and design is expanding.

Over the past several years, the Central Public Works Department (CPWD) has made significant efforts to move towards the creation of sustainable development and infrastructure blended with environment through the adaption of a multi-pronged approach. CPWD is a committed and conscious follower of NBC (National Building Code), MNRE (Ministry of New & Renewable Energy) and Ministry of Environment and Forest regulations on protection of the environment and energy conservation. The organization's voluntary efforts and commitments towards sustainability has now transformed into a mandatory and holistic approach.

Our Training institute at Ghaziabad, has been identified as a centre for excellence and is imparting training on all aspects of Green Buildings including Landscape Design to engineers and architects all over the country and facilitating dissemination of knowledge and technologies among experts in the field. The guide on landscape design for public spaces and buildings is another milestone in this journey. The individual impact of each building may be small, but the cumulative effects of integrating environment with the buildings through landscaped approach will be considerably large.

The hand book is simple and easy to adopt. The widespread dissemination has been planned to reach out to various players and will encourage its adoption across all climate zones, adding to our efforts in reducing environmental impact while meeting the needs of the people.

We look forward to your feedback and experiences on using this handbook.

Ashok Khurana
Director General
Central Public Works Department
Ministry of Urban Development

Acknowledgment

शिप्रा मित्रा
Sipra Mitra

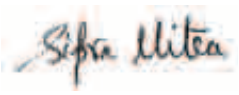
The idea to have a booklet namely “Handbook of Landscape”, which is needed for sustainable development, originated during discussions held with DG, CPWD, Shri Ashok Khurana based on the vision and approach of Hon'ble MoUD Shri Kamal Nath and Secretary, MoUD, Dr. Sudhir Krishna. The work on first edition of the booklet was started by Architecture Wing of CPWD in February 2013.

I would like to thank the Hon'ble MoUD Cabinet Minister Shri Kamal Nath for agreeing to release this booklet so that the “Handbook on Landscapes” may benefit the professionals, practitioners and the common man in this country. We are also thankful to the Secretary, MoUD, Dr. Sudhir Krishna for his vision, support and endorsement of the booklet for its widespread usage across the country. We are also thankful to Shri Ashok Khurana, Director General, CPWD, for his keen interest in studying the contents of the booklet, making significant contribution in a short span of time and ensuring its release from an appropriate forum so that the benefits of this booklet reach beyond CPWD.

I would also like to acknowledge the sincere efforts and hard work put in by the technical advisory team comprising Smt. Indu G. Choudhary, Senior Architect, Shri Sudhir K. Seem, Senior Architect and Shri P.S. Sodhi, Architect. The Team members closely interacted with each other and helped to bring out this booklet for use by not only professionals, but also the common man. I would also like to extend thanks to CPWD officials Shri Biswajit Bose Senior Architect, Shri Anil Grover, Architect, Shri S.S. Rawat Architect, M.S. Sridhar, Architect and Shri Rajesh Singh, Asstt. Architect for their active support.

Over and above, our thanks are due to all other individuals who helped to get this booklet published.

I wish that the book reaches the masses and fulfils the dream of building green across the country. Suggestions and modifications as well as rectification of errors and omissions may be sent to O/o ADG (Arch.), CPWD, Nirman Bhawan, New Delhi.



Sipra Mitra
Additional Director General (Architecture)
Central Public Works Department
Ministry of Urban Development

Content

A Handbook of Landscape

Chapter-1

Definitions

(Source : NBC)

1. **Avenue** : A wide road or pathway lined with trees on either side.
2. **Buffer** : The use of landscape to curtail view, sound or dust with plants or earth berms, wall, or any such element.
3. **Climber** (Creeper/Vine) : A non-supporting plant, woody or herbaceous, which clings to a wall, trellis or other structures as it grows upward.
4. **Columnar** : A slender, upright plant form.
5. **Egress** : A way out, or exit.
6. **Elevation** : A contour line or notation of relative altitude, useful in plotting existing or proposed feature.
7. **Exotic** : A plant that is not native to the area in which it is planted.
8. **Fencing** : A barrier of plant or construction material used to set off the boundary of an area and to restrict visual or physical passage in or out of it.
9. **Foliage** : The collective leaves of a plant or plants.
10. **Geo-textile** : Any permeable textile (natural or synthetic) used with foundation, soil, rock, earth or any other geotechnical engineering-related material as an integral part of a human made project, structure or system.
11. **Grade** : The slope or lay of the land as indicated by a related series of elevations.

11a **Natural Grade :** Grade consisting of contours of unmodified natural land form.

11b **Finished Grade :** Grade accomplished after landscape features are installed and completed as shown on plan as proposed contours.

12. **Gradient :** The degree of slope of a pipe invert or road or land surface. The gradient is a measure of the slope height as related to its base. The slope is expressed in terms of percentage or ratio.
13. **Grading** : The cutting and/or filling of earth to establish smooth finish contours for a landscape construction project. Grading facilitates good drainage and sculpts land to suit the intent of landscape design
14. **Grasses** : Plants that characteristically have joint stems, sheaths and narrow blades (leaves).
15. **Groundcover** : The planting material that forms a carpet of low height; these low-growing plants are usually installed as the final part of landscape construction.
16. **Hard Landscape** : Civil work component of landscape architecture such as pavement, walkways, roads, retaining walls, sculpture, street amenities, fountains and other built environment.

17. **Hardy Plant** : Plants that can withstand harsh temperature variations, pollution, dust, extreme soil conditions, and minimal water requirements and the likes. These plants have ability to remain dormant in such conditions and survive.
18. **Hedge** : Number of shrubs or trees (often similar species) planted closely together in a line. A hedge may be pruned to shape or allowed to grow to assume its natural shape.
19. **Herb** : An annual plant with a non-woody or fleshy structure. Certain herbs are highly useful for cooking or of high medicinal value.
20. **Ingress** : A way in, or entrance.
21. **Invert** : The low inside point of a pipe, culvert, or channel.
22. **Kerb** : A concrete or stone edging along a pathway or road often constructed with a channel to guide the flow of storm water and thereby serving dual purpose.
23. **Mound** : A small hill or bank of earth, developed as a characteristic feature in landscape.
24. **Native :** A plant indigenous to a particular locale.
25. **Planting** : Planting is the operation of transferring young plant from nursery to their permanent place in landscape.
26. **Screen** : A vegetative or constructed hedge or fence used to block wind, undesirable views, noise, glare and the like, as part of in landscape design; also known as 'screen planting' and 'buffer plantation'.
27. **Sediment** : The product of erosion processes; the solid material, both mineral and organic, that is in suspension, is being transported or has been moved from its site of origin by air, water, gravity or ice.
28. **Shrub** : A woody plant of low to medium height, deciduous or evergreen, generally having many stem.
29. **Soft Landscaping** : The natural elements in landscape design, such as plant materials and the soil itself.
30. **Spot Elevation** : In surveying and contour layout, an existing or proposed elevation noted as a dot on the plan.
31. **Street/Outdoor Furniture** : Items of furnishing in outdoor landscape.
32. **Swale** : A linear wide and shallow depression used to temporarily store, route or filter runoff. A swale may be grassed or lined.
33. **Topsoil :** The uppermost layer of the soil.
34. **Transplanting :** Moving a plant from its place of origin to another location.

    Transplanting is the process of bodily lifting of mature and large plants from their position to a new position.
35. **Tree :** A woody plant, generally taller than 2.00 m, with a well-distinguished trunk or trunks below the leaf crown.

35a. Deciduous Tree : Tree that sheds all its leaves in autumn or in dry season.

35b. Evergreen Tree : Tree that remains green for most part of the year and sheds leaves slowly throughout the year.

36. Tree Grate : A metal grille, installed at the base of a tree otherwise surrounded by pavement, that allows the free passage of air, water, and nutrients to the tree root, but does not interfere with the foot traffic.

37. Tree/Plant Guard : The protection constructed around a tree to deter vandalism and help to prevent damage. It could be made of metal, bamboo or concrete or the like.

38. GRIHA (Green Rating for Integrated Habitat Assessment) : The National Rating System will evaluate the environmental performance of a building holistically over its entire life cycle, thereby providing a definitive standard for what constitutes a 'green building'. The rating system based on accepted energy and environmental principles, will seek to strike a balance between established practices and emerging concepts both national and international.

(Source : GRIHA Manual Volume 1)

39. Green building : Buildings have major environmental impacts during their life. Resources such as ground cover, forests, water, and energy are dwindling to give way to buildings. Resource-intensive materials provide structure to a building and landscaping adds beauty to it, in turn using up water and pesticides to maintain it.

(Source : GRIHA Manual Volume 1)

40. Green Building Rating System : A green building rating system is an evaluation tool that measures environmental performance of a building through its life cycle. It usually comprises of a set of criteria covering various parameters related to design, construction and operation of a green building.

(Source : GRIHA Manual Volume 1)

Chapter – 2
Planting Design Consideration

(Source : NBC)

The following criteria shall be considered in planting design :

1. Plant Material
2. Soil conditions
3. Availability and quality of water
4. Availability of sunlight
5. Quality of air
6. Maintenance
7. Functional Aspects of Design with Plants
8. Planting for Shelter and Soil Conservation
9. Air Pollution Control by Plants

1. Plant Material

The major sets of factors that influence the choice of plant material are related to the characteristics, both botanical and physical of plant material and the context in which the plant material is to be used. The inter-relationship of these sets of factors is the basis for developing a sound approach to the process of designing with plants.

– **Physical and Botanical Characteristics of Plant Material**

The information on plant material should be available in a systematic format to include definition, significance and design implications of the following aspects :

(a) Nomenclature (botanical and trade-name);

(b) Origin, family and natural habitat;

(c) Growth characteristic and form as a function of habitat;

(d) Physical characteristics, for example bark, texture, foliage, etc.

(e) Propagation and maintenance; and

(f) Use in landscape design.

– **Vegetation Types (Evergreen and deciduous) :** Some examples of the functional implications of using evergreen and deciduous plant material for specific situations are :

(a) Evergreen trees for :

(i) Places requiring shade throughout the year,

(ii) Strong visual screening

(iii) Part of windbreak or shelter planting, and

(iv) Areas where leaf lifter is to be discouraged.

(b) Deciduous trees for :

(i) Greater visual variety,

(ii) Partial visual barrier,

(iii) Areas where under-planting is to be encouraged (for example grass),

(iv) Emphasis on branching and flowering pattern, and

(v) Areas where shade is not required throughout the year.

– **Growth Rate and Age of Vegetation :** Growth rate is directly related to the life span of tree and slower growing trees have a life span extending to hundreds of years. The fast growing trees to the exclusion of slower growing varieties is not recommended. Landscapes are developed to sustain future generations; slow growing long lived native trees shall be emphatically included in all major planting schemes.

– **Growth Habits of Various Kinds of Vegetation and Their Form :** The overall physical form of a plant is usually the result of the foliage density and branching pattern. It may also be expressed as the proportionate relations between height and canopy spread. The later is direct expression of growth habit. The following classification into basic types may be useful (Also Refer : Chapter on List of Trees)

(a) Trees of fastigited or columnar habit –

Examples of trees of this type are :

Casurina esquisitifolia (beet wood)

Grevilea robusta (Silver Oak)

Polyathia logifolia (Ashok)

Populus species (Poplar)

Though the branching pattern of each is different, the overall shape is similar

(b) Tall trees with canopy –

Examples of trees of this type are :

Dalbergia sissoo (Sheesham)

Tamarindus indica (Imli)

Terminalia arjuna (Arjun)

The canopy share does not fit into any specific geometrical category

(c) Trees of spreading habit –

Example of threes of this type are :

Delonix regia (Gulmohar)

Lagerstroemia flosreginae (pride of India)

Pithecolobium saman (Rain Tree)

Though these trees vary greatly in size, their basic form is similar

(d) Trees of weeping habit –

Examples of trees of this type are :

Callistemon lanceolatus (Bottle brush)

Salix babylonica (Weeping willow / Peking willow).

The above classification is helpful in choosing various combinations of the above types to achieve desired function and visual objectives.

2. Soil Conditions

Physical as well as chemical properties of the available soil are important. These may or may not be amenable to change; they would therefore affect the choice of plant material considerably. Physical properties include consideration of light (for example sandy) and heavy (for example clayey) soils, and their structure. Chemical properties pertain to the presence or absence of nutrients and salts; soil, alkalinity or acidity. A effective planting schemes.

3. Availability and Quality of Water

The water requirement may be derived by data of humidity and rainfall of plants natural habitat. The water table of the area where the plantation is to be done has a crucial bearing on the design with plants as well as a financial implication for reduced maintenance if planted appropriately.

4. Availability of Sunlight

The growth rate of plants are directly related to sunlight availability; such as plants that require (a) full sunlight, (b) partial sunlight, (c) predominantly shade, and (d) complete shade.

5. Quality of Air

Growth may be affected by chemical pollutants such as sulphur dioxide or physical pollution such as dust. Certain plants have the ability to withstand pollution, such plants are imperative for industrial areas, roads, highways, etc.

6. Maintenance

The success of a designed landscape depends upon the growth of vegetation over an extended period of time; therefore maintenance of landscape is also a design component.

7. Functional Aspects of Design with Plants

(a) Improve existing environmental conditions with respect to soil, drainage, microclimate, air pollution;

(b) Create a designed physical environment through the organization of open space; and

(c) Interpret and express the contemporary understanding of the man-nature relationship, that is, design with plants on an ecological rather than horticulture basis.

■ **Shrubs**

– The functions are similar to those o trees. Shrubs may be used together with trees to reinforce the functions, for example, noise barrier, shelter belts, enclosures, etc.

Other forms in which shrubs may be used are:

(a) Hedges : These require regular maintenance

(b) Shrubbery : Here plants are allowed to retain their natural shape; they therefore require little maintenance.

Shrubs provide barrier, which may either be visual or physical (hedges). Barriers may be required in a range of situations, for example they may be only for defining space, or they may be required for security and have to be, therefore, necessarily impenetrable.

- **Groundcover**

– Groundcover plants are those which naturally grow to a very low height. Some of the uses for which they may be used are:

(a) Stabilization soil on steep slopes such as embankments.

(b) As a low maintenance substitute for grass (where the surface is not to be used).

(c) For providing variety in surface treatment.

(d) Contrast with paving materials, for example to soften rigid lines of paving.

(e) As a subtle means of demarcating space, as for example, in places where tall plants would be visually intrusive.

(f) In combination with other plants to provide contrast or harmony in form.

- **Climbers :** Certain climbers because of their spreading habits may also be used as ground cover(for example Asparagus spp.) Climbers are useful for shading exposed walls from direct sunlight. They may also be used for stabilizing soil on embankments (for example, ficus stipulate, Ipomea biloba). On sites where a high degree of security makes fencing necessary, climbers and spreading plants like Bougainvillea species, may be trained on boundary wall.

8. Planting for Shelter and Soil Conservation

The use of vegetation for controlling wind is widely recognized as an effective way of conserving soil and reducing erosion by wind. Vegetation may therefore be used for modifying the microclimate, by obstructing, guiding, deflecting or filtering wind current.

Vegetation areas designed to fulfill these general functions are usually classified as windbreakers and shelterbelts. Windbreaker is grown protective planting around gardens and orchards. Windbreakers generally consist of single or double row of trees. Shelterbelt provides an extensive barrier of trees with several rows of trees. Plant species are chosen with particular regard to their physical and growth characteristics, and their effectiveness in achieving the desired results.

- **Function :** Windbreakers and shelterbelts fulfill essential microclimatic functions in rural and urban environments. Benefits accruing from plantation of shelter planting may be as follows :

(a) Reduction in wind velocity resulting in the arrest of movements of soil particles.

(b) Prevention of soil erosion.

(c) Modification of micro- climate; moderation of change in air temperature.

(d) Protection of crops from being blown by high winds.

(e) Reduction in evaporation of soil moisture. Increase in soil moisture content varies from 3 percent to 7.8 percent Water loss due to evaporation is lessened.

(f) Increase in soil moisture due to greater dew fall in sheltered areas has been found to be 200 percent higher than on exposed ground; heaviest dew fall is over a distance of 2 to 3 times the height of the shelterbelt.

(g) Beneficial effect on growth of plants that are affected by high winds.

(h) The zone of influence of shelterbelt on crop yield extends to a distance of 20 times the height of the belt, with the maximum effect being observed 10 times the height of the tree belt, on the leeward side.

- **Wind Erosion :** Some of the basic functions of windbreaks and shelterbelts in arid and semi- arid areas are to conserve soil and reduce erosion by wind. The latter is a natural phenomenon in and lands having very little rainfall (125 mm- 250 mm) and in areas adjoining a river, lake or sea. Wind erosion is a serious problem in areas where the ground is virtually bare and devoid of vegetation.
- **Techniques for control of wind erosion :** The principal method of reducing surface velocity of wind, upon which depends the abrasive and transportation capacity of wind, is by vegetation measures.

(a) Porosity is important in the effectiveness of shelterbelt and proper selection of tree species is necessary. Porosity near ground level is desirable.

(b) Effectiveness of shelter planting depends more on height and permeability than on width. The width influences the general microclimate but above a certain minimum width, it does not affect greater reduction in wind velocity.

Protection obtained varies in relation to height (H) of shelterbelts as given below :

Distance	Wind Reduced by (in percent)
H	90
2H	75
5H	50
10H	20

This indicates that it is better to have several windbreaks 5H to 6H apart rather than large forest stands with wide open spaces in between.

- **Species suitable for wind breaks are :**

(a) For Dry and Arid Regions

(i) Acacia auriculiformis (Australian Blackwood)

(ii) Ailanthus excelsa (Maharukh)

(iii) Albizia lebbeck (Siris)

(iv) Azadirachta indica (Neem)

(v) Casuarina equisetifolia (Beef- wood)

(vi) Dalbergia sissoo (Sheesham)

(vii) Eugenia Jambolana (Jamun)

(viii) Grevillea robusta (Silver oak)

(ix) Peltophorum ferrugineum (Cooper pod)

(x) Tamarindus indica (Imli)

(xi) Pongamia glabra (Indian beech)

(xii) Tamarix articulate (Tamarisk)

(b) For Coastal Area

(i) Anacardium occidentale (Cashew)

(ii) Ailanthus malabarica (Alston)

(iii) Cassuarina equisetifolia (Beef-wood)

(iv) Pongamia glabra (India beech)

(v) Sesbania aculeate (Sesban)

(vi) Thevetia Peruviana (Yellow oleander)

(vii) Thespesia populnea (Indian Tulip)

(viii) Vitex negundo (Sephali)

10. Air Pollution Control by Plants

Air pollution may be caused by areas or point sources such as cities, industrial areas, factories or by linear sources such as highways. Vegetation buffers can minimize the build-up of pollution levels in urban areas, by acting as pollution sinks.

- **Effect of Plants :** Plant leaves function as efficient gas exchange systems. Their internal structure allows rapid diffusion of water-soluble gases. These characteristics allow the plant to respire and photosynthesize, and they can also remove pollution from the air. Some of the beneficial results of plantations may be:

  (a) They are good absorbers of sulphur dioxide.

  (b) Parks with trees have an SO2 level lower than city streets.

  (c) Roadside hedges can reduce traffic generated air borne lead, on leeward side.

  (d) Heavy roadside planting in the form of shelterbelts can result in a reduction in airborne lead.

  (e) Complete dust interception can be achieved by a 30m belt of trees. Even a single row of trees may bring about 25% reduction in airborne particulate.

Chapter – 3

Role of Vegetation in Landscape Design

(P.S.Sodhi, M. Arch. (Landscape), Architect, CPWD)

With the advent of technology, the man is becoming isolated from nature day by day. The rapid urbanisation has resulted in diminishing the landscape features. The early culture of India is full of plant love, intimately concerned with the day to day life. With the increase in population and large scale Urban Development has taken a heavy toll on the green areas and has alienated the people from nature.

The trees play a vital role in a community's scenic beauty, the character of the local landscape and the overall quality of the environment. Despite their benefits, trees are disappearing faster than we think.

Just imagine what our streets and neighbourhoods would be like without trees!

Benefits of Planting and Protecting Trees

- **Environmental Value :** Trees provide a variety of environmental values, including screening of unpleasant odours, absorption of noise and reduction of pollution and temperatures in the cities as described below :

– **Air Quality :** Trees are an efficient and cost-effective way for a community to improve its air quality and reduce pollution. A mature tree absorbs between 120-240 pounds per year of small particles and gases, like carbon dioxide, which are released into the air by automobiles and industries. In addition, a single tree produces nearly three-quarters of the oxygen required for a person; and a canopy of trees in an urban environment can slash smog levels up to 6%.

– **Water Quality :** Trees help anchor soil and reduce storm water runoff, saving the high costs of drainage ditches, storm sewers, and other "engineered solutions" to storm water management. A street lined with 32' tall trees can reduce runoff by almost 327 gallons, allowing cities to install smaller and less expensive water management systems. Reducing runoff also decreases topsoil erosion and the amount of silt and other pollutants washed into streams, rivers and lakes.

- **Lower Heating and Cooling Costs :** Trees have demonstrated the ability to reduce heating and cooling costs and counteract the "heat island" effect in urban environments. Urban areas with little vegetation can experience temperatures of up to seven degrees higher than those with tree cover. This translates into significantly higher energy costs to cool buildings. Properly planted trees can cut heating and cooling costs by as much as 12 % and reduce overall power demand.

- **Reduced Noise Pollution :** Noise pollution is an often overlooked problem. Excessive or unwanted sound has negative physical and psychological effects. Noise can come from many sources, especially roads and highways. Trees can play an important role in deadening unwanted noise. Sound waves are absorbed by a tree's leaves, branches, and twigs. Studies suggest that belts of trees 100' wide and 45' long can cut highway noise to half.

- **Ecological Value :** Plants provide significant values to all sectors of natural environment in cities. The loss of vegetation cover adversely affects the soil, Air & Water balance.

– One of the major values of plants is improving of urban soil conditions. Urban soils are often buried beneath the sidewalks, streets and buildings. However, a significant portion in many urban areas remain exposed to environmental conditions which helps in improving urban soil conditions by building the Soil with roof system, by checking the loss of surface particles, by increasing the organic material contents in soil and retaining the water for longer period, to increase the ground water table. Soil benefits from trees, as their far-reaching roots hold the soil in place, preventing erosion. Trees improve soil quality as their leaf litter makes perfect compost. Some trees, for example acacias, have bacteria living in their roots. The bacteria convert nitrogen from the air into nitrates, which the tree can use to grow and reproduce, whilst the soil is also enriched.

– Plants also help to control the extreme fluctuation in temperature and reduction of pollution level in urban atmosphere. Plants have a useful effect upon the climate e.g. a comparison of the temperature difference in summer, between a planted area of urban landscape and built-up central area is likely to be 2-3°C lower with a 5% increase in relative humidity.

– During the process of photosynthesis all green plants take in carbon dioxide and give off oxygen. Primitive plants were responsible for converting the poisonous atmosphere of early Earth into an oxygen-rich atmosphere that supports animal life. Trees help to maintain low levels of carbon dioxide, thereby reducing the greenhouse effect which threatens to make the Earth uncomfortably warm.

– Trees provide nest sites for birds. The leafy branches make good hiding places and are difficult for most predators to reach - even non-breeding birds roost in trees at night.

- **Health Value :** There is mounting evidence that stress and noise have an impact on our physical and psychological health. Trees and vegetation can affect our mood and help relieve stress.

- **Economic Value :** Trees are a major economic asset to a community, building a positive community image which is a key factor in attracting residents, businesses, and visitors alike. The attractively tree-lined public areas are more desirable than those areas without trees. The landscaped areas enjoy higher occupancy and rental/lease rates than identical properties that lack landscaping.

- **Shelter :** The shade of trees is welcomed by man and beast alike, providing essential shelter in the hottest climates. Trees are often used as windbreaks to shelter sensitive crops.

- **Aesthetic Value :** Trees provide a variety of aesthetic values and accentuate the architectural design of buildings. For all their values to which a price tag can be attached, trees have one more contribution to make: their beauty and variety of form. Some species are tall and thin, others flat-topped and spreading, leaves come in every shape and size, flowers and fruits are frequently decorative. These qualities make trees ideal for beautifying gardens, cities, and even industrial estates.

  Planting is much more than a cosmetic treatment to be applied to in different or insensitive architecture and engineering etc. It plays a major role in integrating structure into

environment, providing a setting and reducing their visual intrusions within the functional requirement of any single area. Plants are growing, ever changing, interacting organism and plant communities are in a constan state of flux. Plants, whether trees, shrubs, climbers, groundcovers have to be placed at suitable location so that the desired purpose is served.

The efficient and successful choice of plants should be made on the basis of their design characteristics :

1. **Functional & Structural Characteristics :** Plants in combination and individually, create space beneath, between & sometimes within the bulk of their canopies. Plants create landscape structure, which both defines spaces and serves the required function.

   Trees, in the city are living building material used to establish spatial boundaries. They create spatial rhythms to heighten the experience of moving through the outdoor spaces, its ability to shelter, screen or shade, density of roof growth which will determine its ability to bind the soil and protect against erosion. Plants also provide a fitting environment for human activities while avoiding damage to ecology of the landscape.

2. **Visual & Other Sensory :** Plants offer an enormous wealth of aesthetic characteristics, the appearance of their laves, twigs, bark, flower & fruit, the fragrance of flower and aromatic foliage, the physical texture of bark & leaves even the sound of laves when stirred by the wind or beaten by the rain.

3. **Plant Growth Habit & Cultural Requirement :** There is enormous diversity of size, habit foliage & other characteristics among the range of species; that helps to determine the habitat & ecological niche. In the first place, planting design can help us make the best use of our environment. Secondly, it helps to restore the balance between people, nature and in some extent to the wild life and finally it offers many opportunities for enjoyment of aesthetic delights.

4. **Plants and Their Uses :** Plants are positive design elements in any environment and they can enhance the environment, if used with proper understanding

- **Trees (basic planting) :** This relates to the contemporary requirement in landscape design for mass planting of large groups, woodlands, which with the topography or land form, produce the large scale spatial arrangement of the landscape. The species selected for this group should be hardy, vigorous in growth, indigenous for ecological reasons and exotics which have become established as part of local scene.

  e.g.- Acacia auriculiformis, Lagerstroemia flos reginae (pride of india), Pterospermum acerifolium (kanak champa), Alstonia scholaris, Putranjiva roxburghii (jalpitri), Azardirachata indica (neem), Dalbergia sissoo (sheesham) etc.

- **Trees (special effects) :** Trees in this section should include those sufficiently individualistic, spectacular or strong in character to occupy the isolated positions, either because of these qualities or because they do not mix easily in visual sense with other trees.

  e.g.- Ficus bengalensis (banyan tree), Cassia fistula (amaltas), Bombax malabaricum (silk cotton tree), Cassia nodosa (pink javanica), Jacaranda mimosaefolia (neeli gulmohar). Chrosia speciosa, Mimusops elengi (mulsari) Callistemon lanceolatus (bottle brush) etc.

- **Trees (barriers) :** Barriers formed with plants are needed in landscape for screening the unpleasant views, for dividing up the landscape into spaces, for providing shelter from wind, for protection against pollution, for defining boundaries and for assisting in the creation of beautiful landscape.

  e.g.- Casuarina equisetifolia, Grevllea robusta (silver oak), Ficus benjamina, Polyalthia longifolia (ashok), Putranjiva roxburghii, Schleichera trijuga (kusum), Golden bamboo etc.

- **Shrubs (basic planting) :** The use of shrubs in the mass as a basic constituent of the planting of Landscapes. It should have the qualities of hardiness, vigorous growth with a greater emphasis on evergreen plants.

  e.g.- varieties of Acalypha, Bougainvillea, Cassia biflora, Cassia alata, Duranta, Ficus panda, Euphorbia, Thevetia, Taberneamontana (chandni), Palms such as areca, china, phoenix, rhapis etc.

- **Shrubs (special effects) :** Similar principles of selection apply to this as for trees (special effects), but at the same time it should be noted down that a number of shrubs planted together can produce special effects specially at the time of flowering.

  e.g. – Caesalpinia pulcherrima (peacock flower), Calliandra haematocephala, Poinsettia, Mussaenda, Justicia, Ixora, Bamboo-buddha valley, Franciscea latifolia (yesterday, today and tomorrow), etc.

- **Shrubs (barriers) :** Impenetrability is essential unless the barrier is for visual purpose, thus the twigs or thorns are considered as an advantage. Other things to consider are the ability of the plant to accept pruning, either to control growth or to produce topiary effects.

  e.g. – Bouganvillea, Duranta plumieri, Duranta plumieri varigata, Duranta goldeana, Murraya etc.

- **Shrubs (edging) :** To outline the flower beds or other kinds of plants and to create line effects.

  e.g. – Duranta goldeana etc.

Chapter – 4

Selection of Plant Material for Landscape

(Sudhir Kamal Seem, M. Arch. (Landscape), Senior Architect, CPWD)

The success of landscape design with plants depends on how to choose the appropriate plants for a particular situation. Thoughtful selection of the trees, shrubs, climbers, bulbs, foliage plants, grass, groundcover and aquatic plants transform the barren landscape into meaningful landscape. Efforts should be made to select an appropriate plant material for the given situation based on the following criteria :

(i) Habit (ii) Colour (iii) Season of flowering

(iv) Form (v) Rate of growth and Environmental considerations.

1. Trees

The selection of trees should be based on season, size, form, situational preferences of surroundings and artifacts.

1.1 Flower Colour

- **White :** *Alstonia scholaris, Baiiasea minor, Magnolia pterocarpa Milingtonia horternsis and plumeria acurmnaata.*
- **Yellow :** *Cassia fistula, Bauhinia tomentosa, Saraca indica, Peltophorum pterocarpum and Tabebuia spectabilis.*
- **Red :** *Bombax ceiba, Amberstia nobilis, Cassia marginata*
- **Scarlet :** *Barningtonia monandra, Cassia pavarnica Crennigena, Kelnbovia hospita.*
- **Purple :**

  Lagerstroemia speciosa, Bauhinia purpurea, Melia azadirach, Pachira, rosea and Tabebuia rosea.
- **Orange, Red, Crimson, Scarlet :** *Butea monosperma, Colvia racemosa and spathpdea campanulata.*
- **Blue, Mauve, Violet :**

  Jacarpanda aquisatifolia, Guaicum officinale, Millenia avaliolia and Solanum grandugkirum

Alstonia scholaris

Cassia fistula

Bombax ceiba

Lagerstroemia speciosa

Butea monosperma

Jacaranda

Barningtonia monandra

- **Greenish Yellow :** *Monodora grandiflora.Casealpnia,*
- **Creamy White or Yellow :** *Michelia champaca, Madhuca Indica, Magnolia grandiflora, and Terminalia Arjuna.*

Monodora grandiflora

Micheia champaca

1.2 Season of blooming

- **Ever blooming :** *Callisetermon lanceolatus, Mimusops elengi, Plumenia acuminata and Thespesia populnea.*
- **Winter blooming :** *Bauhinia purpurea, Butea monrosperama. Monodora grandiflora*
- **Spring blooming :** *Tabebuia, Amheristia niobilis, Bombax ceiba, Jacaranda, Saraca indica, Spathodea*
- **Summer Blooming :** *Erithrina indica, Cassia, Jacaranda, Lagerstroemia spp.*
- **Rainy season Blooming :** *Plumeria alba, Anthocephelus cadamba, Barringtonia raccemosa, Casia Marginata, P. rubra, Covillea raccemosa.*

Callisetermon lanccelatus

Bauhinia purpurea

Tabebuia

Erinthrina Indica

Plumeria alba

1.3 Range of Tree sizes

Albizia lebbek

Cassia fistula

Peltophorum

Ficus bengalensis

- **Dwarf trees (3 to 5m tall) :** *Albizia lebbek, Bisantha, Bixca orellana, Brownera grande eps, Crodia sebestena. Wevthrnia blackein Parkinsonia acuminata, Plumeria rubra.*
- **Medium size (6 to 10m tall) :** *Caesalpinia, Lagerstromia throreli, Melia azadirach, Plumeria accmnata, Saraca Inidica, Tabeulia spectabilis.*

- **Tall tress (more than110 m tall) :** *Peltophorum roxburghii, Bombax malabaricum, Cassia monisia, Chorisia speciosa, Jacaranda, Millingtonia hortensis, and spatholea campanulata.*
- **Giant trees :** *Ficus bengalensis, Bombax ceiba, Colvillea racemosa,*

1.4 Growth Habit of Trees

- **Oval :** These plants are suitable for frame or screen.

  Populus alba, Albizzia julibrissin, Crataeqs cerusoalli Cornus sp., Betula pendula Cassia fistula

Populus alba

- **Vase shaped :** They can be used above the large shrubs or small trees.

  Melia azadirach, Plumeria acutifolia. P.alba. P.obtusa, Saraca Indica. Almus Americana.

- **Pyramidal :** It can be used as an accent plant.

  Pinus roxburghii, Araucaria cooki. Thuja compacta, Quercus palustris, Stercula foedtida, Polyalthia longifolia.

Melia azadarach

- **Round :** These plants can be used in the lawn as specimen.

  Plumeria alba,Chorisia speciosa Mimusops elengi. Morus rubra, Quercus.

- **Columnar :** They frame the views and structure in the landscape setting. *Juniperus chinensis, Betula pendula, Quercus robustaj Eucalyptus robusta, polyelthia pendula.*

Pinus roxburghii

- **Weeping :** It can be used as a focal point.

  Salix Babylonica, S. alba. Putranjiva roxburghii, callistemon lanceolatus Tecomelia.

- **Round to spreading :** These plants mass well to create grove effect. *Dalbergia sisso, Dillenia Indica, Ficus glomerata, Thespesia populnea.*

Plumeria alba.

- **Fan shaped** : They can be used as a focal point.

  Cycus revoluta, Borassus fladellifer, Oredoxa regia.

1.5 Trees with scented flowers : *Anthocephilus cadamba, Alstonia scholaris, Cananqium odoratum Michelia champaca, Mimusops*

Salix Babylonica

Dalbergia sisso

Cycus revolute

Juniperus chinernsis

elengi, Dillenia indica, Gardenia latifolia, Custravia augusta, Magnolia grandiflora, Nyctanthes arbortristis.

1.6 Wind Resistant trees : *Eugenia jambolana, Caesalpinia pulcharima, Peltophorum pterocarpum.*

1.7 Salt Resistant trees : *Azadirachta Indica, Acacia sp., Butea monosperma, Azadirachta. Indica, Bassia Latifolia, Eucalyptus citriodora, Phonix dactylofera and Phyllanthus emblica.*

1.8 Drought Resistant : *Butea monosperm, Acacia sp., Albizzia lebbek. Casuaria equisetifolia. Crataeva religiosa. Tecomelia.*

1.9 Wet Land trees : *Nyctanthes arbortristis, Dillenia Indica, Michelia champaca, Saraca Indica, Thespesia populnea, Salyx Babylonica, Ecualyptus eostata, Guaicum officinalis.*

1.10 Fast Growing Trees : *Pongamia glabra, Sesbania grandiflora, Cananqium odoratum, Erithrina Indica, Thespesia populnnea, Populus sp., Salix sp,. Euclyptus sp., Thuja compacta.*

1.11 Shade givers : *Pteropsperum acerifolium, Albizzia lebbek, Pelptophorum, Michelia champaca, Anthocephalus cadamba, Dalbergia sisso,. Glyricidia Maculata accer sp., Cornus florida.*

1.12 Trees tolerant to Dust and Smoke : *Acacia auriculiformis, Alstonia soholaris, Butea monosperma, Ficus Benjamina, F. benghalensis, Madhuca Indica, Pongamia glabra, Ficus religiosa, Terminalia Arjuna, Albizzia llebbek, Bombax ceiba.*

1.13 Trees for Noise Reduction : *Terminalia Arjuna, Alstonia scholaris, Azadirachta Indica, Butea Monosperma, Mangifer Indica, Madhuca Indica, Juniperus chinesis, Eucalyptus Citradora, Kigelia pinnata*

Anthocephilus cadamba

Eugenia jambolana

Azadirachta indica

Butea monosperm

Nyctanthes arbortristis

Pteropsperum acerifolium

Acacia auriculiformis

Terminalia Arjuna.

Pongamia glabra

Chapter – 5

Plants and Indoor Air Quality

(P.S.Sodhi, M. Arch. (Landscape), Architect, CPWD)

Indoor Air quality plays an important role in the work performance and the health of the users. With the passage of time the indoor levels of pollutants increases, sometimes much higher than the outdoor levels. To mitigate these effects a study was undertaken by IIT, TERI and learning's from NASA that there are number of common green plants, with which we can grow all the fresh air we need indoors to keep us healthy. Common indoor plants may provide a valuable weapon in the fight against rising levels of indoor air pollution & are very useful in absorbing potentially harmful gases and cleaning the air inside modern buildings and provide a natural way of helping combat **"Sick building syndrome".**

The most common three air quality improving plants are **Areca palm**, **Mother-in-Law's Tongue and Money Plant**.

Areca palm is a plant which removes CO_2 and converts it into oxygen. We need four shoulder-high plants per person, and in terms of plant care, we need to wipe the leaves every day in Delhi.

Mother-in-law's Tongue is again a common plant. We call it a bedroom plant, because it converts CO_2 into oxygen at night. One requires about 6-8 such waist high plants per person in the bedroom.

Money plant is a very common plant; preferably grows in hyrdoponics. It is excellent plant for removing Formaldehyde and other VOC's (volatile chemicals) in the air.

The indoor plants most effective in removing Formaldehyde, Benzene and Carbon Monoxide from the air are:

1. Bamboo Palm - Chamaedorea Seifritzii

2.	Chinese Evergreen	-	Aglaonema Modestum
3.	English Ivy	-	Hedera helix
4.	Gerbera Daisy	-	Gerbera Jamesonii
5.	Janet Craig	-	Dracaena “Janet Craig”
6.	Marginata	-	Dracaena Marginata
7.	Mass cane/Corn Plant	-	Dracaena Massangeana
8.	Mother-in-Law’s Tongue	-	Sansevieria Laurentii
9.	Pot Mum	-	Chrysanthemum morifolium
10.	Peace Lily	-	Spathiphyllum
11.	Warneckii	-	Dracaena “Warneckii”

All the above mentioned indoor plants can be used to improve the indoor air quality.

Chapter- 6

Process of Planting and Transplanting of Trees

(Sudhir Kamal Seem, M. Arch. (Landscape), Senior Architect, CPWD)

Planting

Definition

- Planting is the operation of transferring young plant from nursery to their permanent place in landscape.

Steps Involved in Planting

Site Condition

- The conditions of the planting site are as important as the plant. Soil type and drainage, available water and sunlight, exposure to dying winds, and other factors must be considered.
- Attempting to match the requirements of the plant to the site increase the survivability, performance, and longevity of the plant selected.

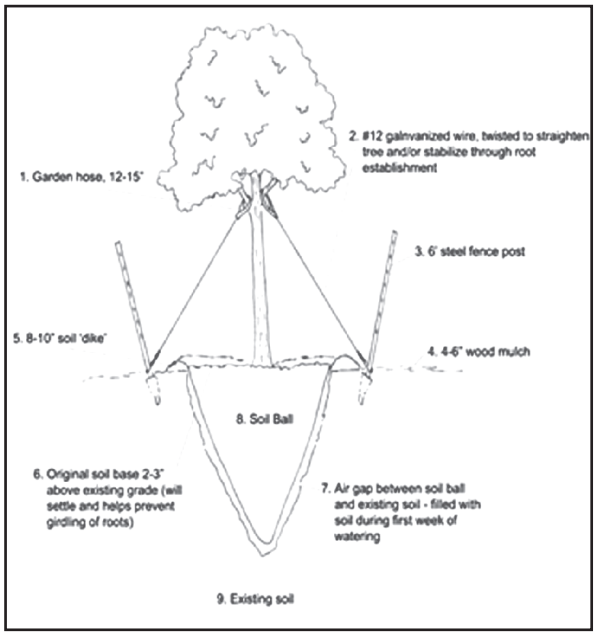


Fig:http://www.sustland.umn.edu/implement/treespade.htm

Soil Texture

- The first step in assessing the condition of the planting site is to examine the soil. Whether the soil is sandy and well drained, or is it moist with some organic material, or is it heavy dlay and therefore, wet and perhaps compacted.
- Construction practices such as cutting and filling, installation of underground utilities, and backfilling against foundations can create great diversity in soil structure. This variability can change drastically with depth and between planting locations on the same property- investigate each planting site.
- Soil texture and drainage are closely related. Sandy soils usually are very well drained, have large pore spaces, and poor water- holding capabilities. They are usually associated with dry conditions.
- Conversely, clayed soils have much smaller pore spaces, are poorly drained, and can suffocate plant roots. The pore spaces in soil are very important to plant growth because the oxygen that occupies them is essential to healthy roots. A tree planted in poorly drained soil will be slow to establish, lack vigor, and often will slowly die.

Drainage

- Because plant roots require both moisture and oxygen for growth, soil drainage should be checked before planting. A poorly drained soil, high in moisture but low in oxygen, prevents both proper root development and growth of beneficial soil micro-organisms that are responsible for decomposing organic matter and releasing plant nutrients.

- To test for soil drainage, dig a hole 18 inches deep, fill it with water, and let it stand overnight. If the water has not drained by morning, there is a draining problem. (Do not leave the drainage in this matter after heavy rainfall or before the ground has thawed in the spring).
- If soil drainage is inadequate, species that are tolerant of poorly drained soils may be planted, or soil drainage may be improved. This can be done in two ways. If a hard pan is present (a compacted, impermeable layer of soil) with an underlying layer of well – drained soil, a hole can be dug down to the permeable layer to provide drainage for the planting hole.
- If the soil is poorly drained and there is no well-drained layer below, a tile system can be laid. However, this is expensive and requires the assistance of a professional for proper design. Simply adding gravel to the bottom of the planting hole will further decrease oxygen availability to the root system.
- Compaction of the soil by vehicles or people can reduce pore space and restrict water infiltration, as well as cause physical damage to roots of existing trees. In compacted soil, oxygen is depleted, carbon dioxide accumulates, and root penetration is reduced. This is detrimental to root growth. Aerating the soil will help correct the problem.
- Soil pH is a measure of the acidity or alkalinity of a soil. A pH below 7 (7 is neutral) would indicate an acidic soil, and a pH above 7 indicates an alkaline soil. Many plants have an optimal range of pH. Most trees thrive on a pH between 5.5 and 6.5. Soil pH is raised by calcium carbonate or lime. Plant species that will tolerate a high pH should be considered for areas with buried concrete, near foundations, or sidewalks etc.
- Before a plant is planted on a particular site, a soil test should be conducted to determine possible pH problems or nutrient deficiencies.

Water

- The correct amount of water for plants is essential. Selected plants that are tolerant of excess water for low areas where water may be standing or very close to the surface, or where a heavy clay soil exists. Standing water or a high water table means low oxygen content in the soil. Therefore, trees and shrubs that can tolerate excessive moisture are often better suited to these poor sites.

Sunlight

- Although some plants can tolerate low light conditions, most require full sun to maintain their vigor and attain their full potential. Some plants may require some protective shade to prevent leaf scorch and desiccation.

Location

- The location of the planting site in relation to other trees and objects such as buildings, fences, etc. will have a considerable influence on temperature and moisture conditions around the tree. Prevailing westerly winds have a drying effect on non-protected sites. The south side of a building will be much warmer and drier than the north side. The warming effect of the sun on a cold winter day can cause injury to the bark and may cause the tree trunk to split. For evergreens, this warming can cause water loss and growth activity resulting in needle damage when the temperature is again lowered Plant hardiness can be greatly affected by the amount of protection provided by individual microclimates.

Planting Season

The season for planting will depend upon the following factors:

1. Adequate amount of rainfall.
2. Presence of moisture in the air.

- Mass planting should never be done in summer. A local level planting can be done in summer, provided proper irrigation is available.
- Plants growing in areas having composite climate should be shifted to the new site prior to the monsoon, preferably in the month of July in northern parts of India.
- When there is doubt of water logging, planting should be carried out at the end of rainy season.
- Salix babylonica, Salix monosperma, Dalbergia sissoo, Calestamon lanceolatus, Terminalia arjuna etc. can be planted in waterlogged area.
- In Punjab, planting is done in February when dormancy stage is crossed.
- Roses must be planted in the beginning of winter i.e. September.
- General planting should be carried out between February and April. March is comfortable for plants as temperature is neither of the two extremes and the soil temperature during this period is steady with adequate moisture content.

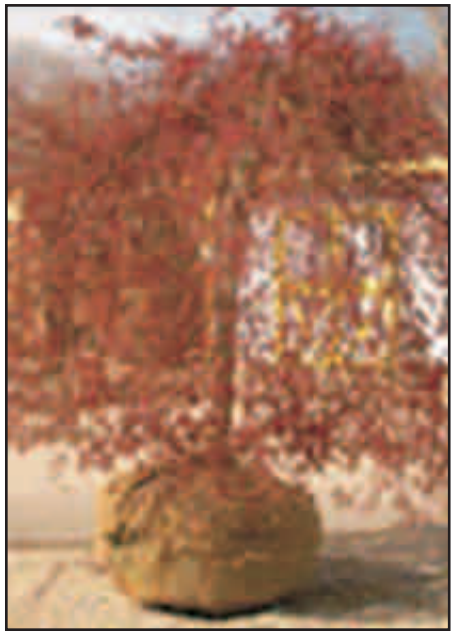
Planting Procedure

Preparation of Pit

- Pit should be prepared two months prior to planting to help the soil expose to the scorching sun.
- Tree pit should be 1.2mX1.2mX1.2m. The pit should be properly dug as per specification. Poor digging with improper base dimension would lead to the undernourished growth of the plant.
- While excavating, remove the top soil to a depth of 6" to 9" and keep it aside. Topsoil undergoes change in fertility status in the span of two months (between December and February)
- If the subsoil is poor in terms of water holding capacity etc., it must be treated with 3 parts of manure + 2 parts of sweet earth + 1 part of sand(3:2:1). This will improve the drainage conditions and also enhance the acquired fertility of the soil.
- Manure might generate heat after water is added. Hence, precaution must be taken to protect the plants. Also one third of compost manure is added at the time of refilling.
- After refilling, soil is consolidated by watering. Soil should be allowed to get dried up by exposing it to the sun.

Planting the sapling

- Prior to planting of the sapling, there is a need for the introduced sapling to get acclimatized to the new environment. If possible such saplings should first be procured in nursery beds.
- Preparation of hole: Hole is prepared in the soil large enough to take the roots of the sapling with a layer of sand underneath.
- Wrapping of roots: The roots of the sapling when lifted from nursery are wrapped with good earth, such that the evapo-transpiration is checked and the moisture content is maintained.
- Damaged roots and shoots are to be cut off to prevent evapo-transpiration from shoots and roots.



Plants from Nursery are always Balled and Barlaped

Staking

- Staking is done to protect the tree from bending and toppling due to the wind pressure. The staking thus helps in helping the tree sapling to hold vertically and achieve the desired form.
- The hole is then filled up with fine soil and firmly pressed down so that the roots are exposed. The soil is then consolidated property to avoid unnecessary settling or exposing of the roots.

Watering

- Watering must be done every third day for a young plant sapling to survive. The site can be divided into three zones and each zone can be watered one day. Watering done should be copious.
- Surface soil should be cultivated regularly to open up the soil so that proper aeration of the soil takes place.
- When subsoil drainage is poor, due to presence of clay or clay pan, it will result in damage of the roots. Hence brickbats with stone cover and dry leaves are laid in the pit to a depth of 4" to 8"
- White ants may occur if manure quantity is high. Hence, it is necessary to keep the manure quantity to the minimum.

Planting of Shrubs

- There are two ways of shrubs plantation, either individual or group planting.
- For individual plantation, the distance from centre to centre is usually 0.6m X 0.6m X 0.6m, but can very as per the requirement of the type of shrub.

- 6" of topsoil is removed and kept aside before trenching is carried out.
- Trenching is to be carried out in the entire area taken by the shrub bed. The depth of trench is between 25cm to 40cm.
- All weeds and roots, stones etc. are removed.
- 10cm of well rotted sable manure should be supplied to the bed and spread and mixed with 30cm of soil.
- The surface is to be roughly dressed and irrigated thoroughly. The soil is then firmly consolidated.
- When subsoil drainage is poor, the soil in the pit is to be replaced with good soil with 10cm manure.

Transplanting

Definition

- Transplanting is the process of bodily lifting of mature and large plants from their position to a new position.

Considerations for Transplanting

- Before transplantation a woody plant, evaluate whether or not the tree or shrub is likely to be a successful transplant.
- Prune the crown of the tree to a third and roots to a minimum such that it can be transported
- Plants which are already in advanced stages of decline are especially likely to succumb to transplantation stress.
- Often a young nursery-grown plant will resume growth sooner than an older transplanted tree or shrub and will provide more long-term benefits in the new planting location.
- Shrubs have better transplant tolerance than trees, deciduous plants better than evergreens, shallow rooted species better than deep rooted species, and younger plants better than older plants.

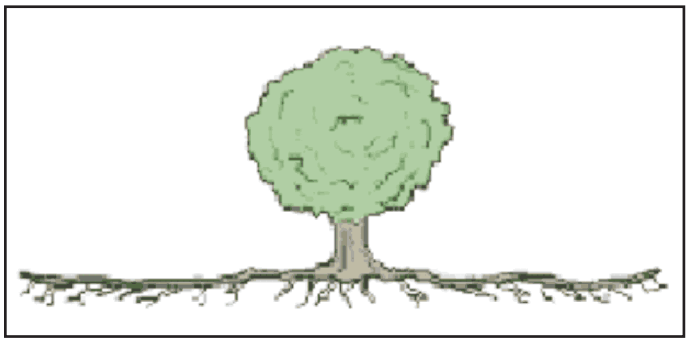


Fig : Root pruning of tree

- When deciding whether or not to transplant a tree or shrub, or to start over with a young plant, the following considerations are necessary:
  - (a) Species transplantation tolerance,
  - (b) Condition of the plant,
  - (c) Season to transplant,
  - (d) New planting site conditions,
  - (e) The Equipment needed and
  - (f) Follow up care

Season of Transplanting

- Transplanting is done when there is enough moisture in the soil. Hence, monsoon is the right time as there is enough moisture in the soil
- Some species may survive transplanting any time during the year when the ground is not frozen, but woody plants are preferably moved in the spring after the ground thaws and before the buds on the tree or shrubs begin to swell.
- They may also be moved in the fall after leaf drop but before the ground freezes. Fall planting should take place soon after leaf drop, providing time for new water absorbing roots to develop before the soil freezes.
- Since evergreens are especially prone to winter browning if planting is delayed until shortly before the ground freezes in the fall, they should be moved late in the summer to early fall.
- Wood plants that are transplanted in late spring and early summer, when shoot growth is at its peak, tend to show the greatest transplant injury.

Site Selection

- There are great differences in the environmental requirements for each tree and shrub species. Only transplant a tree or shrub where light, moisture, soil pH, and wind exposure are appropriate for the particular species.
- All plants require space for root and crown development; therefore, consider mature plant size when planting trees and shrubs.
- Soil characteristics are often limiting factors for woody plant survival in a given area. Sometime the soil is inappropriate for tree growth and will require improved drainage or amendments before trees and /or shrubs are planted at the given location. A soil test should be completed in areas where soil quality is questionable.

Transplanting Procedure

- Plant should be bodily lifted with as many roots as possible and taken to the new position immediately. Ball of earth surrounding the root should be also be lifted.
- Cover the root ball with damp material which will retain moisture (burlap, peat moss, canvas, plastic, etc.) until planting.
- Plastic should only be used in shaded areas for less than a day or heat injury and/ or root suffocation may occur.
- When a tree or shrub is stored, it should be protected from direct sunlight, winds, and temperature extremes. If any woody plants cannot be planted for more than a week, their roots should be covered with a match or moist soil and the plants should be placed in a shades area.
- In all cases root systems should be allowed to dry out. Dry roots can severely decrease the potential for transplant success.
- Roots should not be injured. It must be cut so that the amount of water absorbed in the new site can be checked. There is a change in the environment, thus more amount of water might create problems.
- If the earth breaks away from the root area, it must be smeared with clay, cowdung and water.

- The entire plant is then placed within the pit and fine soil can be added. Finally good soil will cover up the root. The replanting is to be done to the same depth as was at the old location.
- Broken limbs should be removed and leaf area to be removed and leaf area to be reduced to check evapo-transpiration. At the same time branches have to be cut back.

Staking

Trees should be protected from bending due to wind by stakes. Stakes also help in transpiration of water.

- Care should be taken that clay is not brought into the new site. Thus, roots should always be washed before replanting.
- Transplanting is done when there is enough moisture in the soil. Hence, monsoon is the right time as enough moisture exists in the soil. September is the ideal month for carrying out the process of transplanting.
- Cold, moist and cloudy weather is the best for transplanting. The evenings are better suited for the purpose as plants refresh themselves in cool night.
- Soft-wooded plants are better transplanted than hardwood plants.

Watering

After transplanting, copious watering is done. Copious watering procedure has to be clearly mentioned.

Post Planting Care

Watering

- Too much or too little water after transplanting is a major cause of tree or shrub loss. The site should be thoroughly watered immediately after planting.
- Thereafter, the soil must be regularly monitored to prevent drying out.
- If rainfall is inadequate, the soil around the plant's roots should be deeply watered approximately every 10 -14 days.
- If unsure if the soil is drying, dig down 3 to 4" next to the plant. Wet soil at that depth verifies watering is not needed at that time.

Mulch

- Mulches help conserve moisture, moderate soil temperature and control weeds around trees and shrubs.
- They are placed on the soil surface over the tree or shrub root system. Either organic or inorganic mulches may be used.
- Organic mulches may be composed of bark or wood chips, straw, partially decomposed leaves or other materials.
- They should be applied 3 to 4" deep. Maintain a 4 to 6" mulch-free area adjacent to the woody stems.

- Inorganic mulches include crushed rock, woven fabric, and other materials. Should plastic mulches may impede or prevent root development because they do not allow air or moisture to move into or out of the soil from above?
- Occasionally, when soil is poorly drained, mulch should not be used.

Fertilizer

- For the first few years, woody plants rarely need nutrients beyond those naturally occurring in the soil. No fertilizer or manure should be mixed with the fill soil, as this could cause root damage.
- If transplants appear to need fertilizer during the first few years, a totally soluble complete fertilizer should be applied.

Pruning

- Pruning may be required when transplanting trees or shrubs. The amount of pruning depends on the size of the root ball and plant canopy, health of the plant, and the species transplanted.
- Insect infested stems or those infected with disease should be removed during transplanting.
- Any broken stems should be removed as well.
- Additional pruning of shrubs may be required to balance the leaf area with the reduced size of the root system, but further pruning of deciduous trees should be postponed for at least one year after transplanting.
- Pruning of conifers should be limited to diseased, insect, and broken limbs. If additional pruning of conifers is necessary, it should be limited to one-year-old wood whenever possible.
- Late season plantings may require additional pruning since the plants have less time to become established before winter than those planted earlier in the season.

Mechanical Support

- Mechanical support for trees may be necessary when the tree is tall, slow to recover, heavily foliaged, or planted in a sandy site.
- Most small trees and shrubs do not require staking or other support and will develop strong trunks faster if allowed to move freely with the wind.
- For trees that do require mechanical support, staking may be used. Two stakes can be placed opposite of each other and the tree anchored to the stakes with a nonabrasive material, such as a soft, board, fabric strap.
- Any support provided to a tree should be removed as soon as the tree can stand alone, usually after the first growing season. The sooner the support is removed, the faster the tree will become stronger.

Root ball sizes for Deciduous Trees: Small Trees

Height (up to 6 feet)	Minimum Diameter Ball	Depth
2 feet	12 inches	9 inches
3 feet	14 inches	11 inches
4 feet	16 inches	12 inches
5 feet	18 inches	14 inches

Root ball size for Deciduous Shrubs

Height	Minimum Diameter Ball	Depth
12 inches	9 inches	7 inches
18 inches	10 inches	8 inches
2 feet	12 inches	9 inches
3 feet	14 inches	11 inches
4 feet	16 inches	12 inches
5 feet	18 inches	14 inches
6 feet	20 inches	14 inches
7 feet	22 inches	15 inches

Root ball sizes for Evergreens

Spreading, Semi-spreading and Globe (or dwarf) Types (broad leaf and marrow leaf)

Spread	Minimum Diameter Ball	Depth
9 inches	8 inches	6 inches
12 inches	10 inches	8 inches
18 inches	12 inches	9 inches
2 feet	14 inches	11 inches
$2^{1/2}$ feet	16 inches	12 inches
3 feet	18 inches	14 inches
$3^{1/2}$ feet	21 inches	14 inches
4 feet	24 inches	16 inches

Cone and Upright Types (broadleaf and narrow leaf)

Spread	Minimum Diameter Ball	Depth
18 inches	12 inches	9 inches
2 feet	14 inches	11 inches
3 feet	16 inches	12 inches
4 feet	20 inches	14 inches
5 feet	22 inches	15 inches
6 feet	24 inches	16 inches
7 feet	27 inches	18 inches

Columnar Types (narrow leaf)

Spread	Minimum Diameter Ball	Depth
12 inches	10 inches	8 inches
2 feet	13 inches	10 inches
3 feet	14 inches	11 inches
4 feet	16 inches	12 inches
5feet	18 inches	14 inches

References :

i. Study Material distributed at M. Arch. (Landscape) SPA, New Delhi.

ii. http://landscaping.about.com/cs/shrubsbushes/ht/transplanting.htm

iii. http://www.sustland.umn.edu/implement/treespade.htm

iv. http://www.lowes.com/cd_Transplanting+Mature+Trees+and+Shrubs

v. American Standard for Nursery Stock

Chapter – 7

Landscaped Parking

(Biswajit Bose, Senior Architect & Biswajit Roy, M.Arch. (Landscape), Architect, CPWD)

Purpose

- To provide shade to the parked vehicles.
- To divide the parking bays physically, generally after 9 cars
- To absorb air pollution
- To reduce noise pollution
- To add softness and aesthetic quality to otherwise paved areas
- To reduce the heat generated from the paved surfaces.

Design Principles

- Parking can be arranged in small units informally set amongst existing mature trees, preferably with loosely defined parking bays paved with gravel or grass-concrete.
- Hedges and shrubs can be used to break up long lines of vehicles, and to provide windbreaks against dust and rubbish blowing across the area.
- Parking bays can be grouped on different levels, separated by embankments planted with low cover.
- The trees should be planted between raised curbs or in elevated boxes to avoid hazards like vehicles backing into them and tree roots poisoned if fuel run-off gets into the water supply.

Plantation Criteria and Plant Characteristics

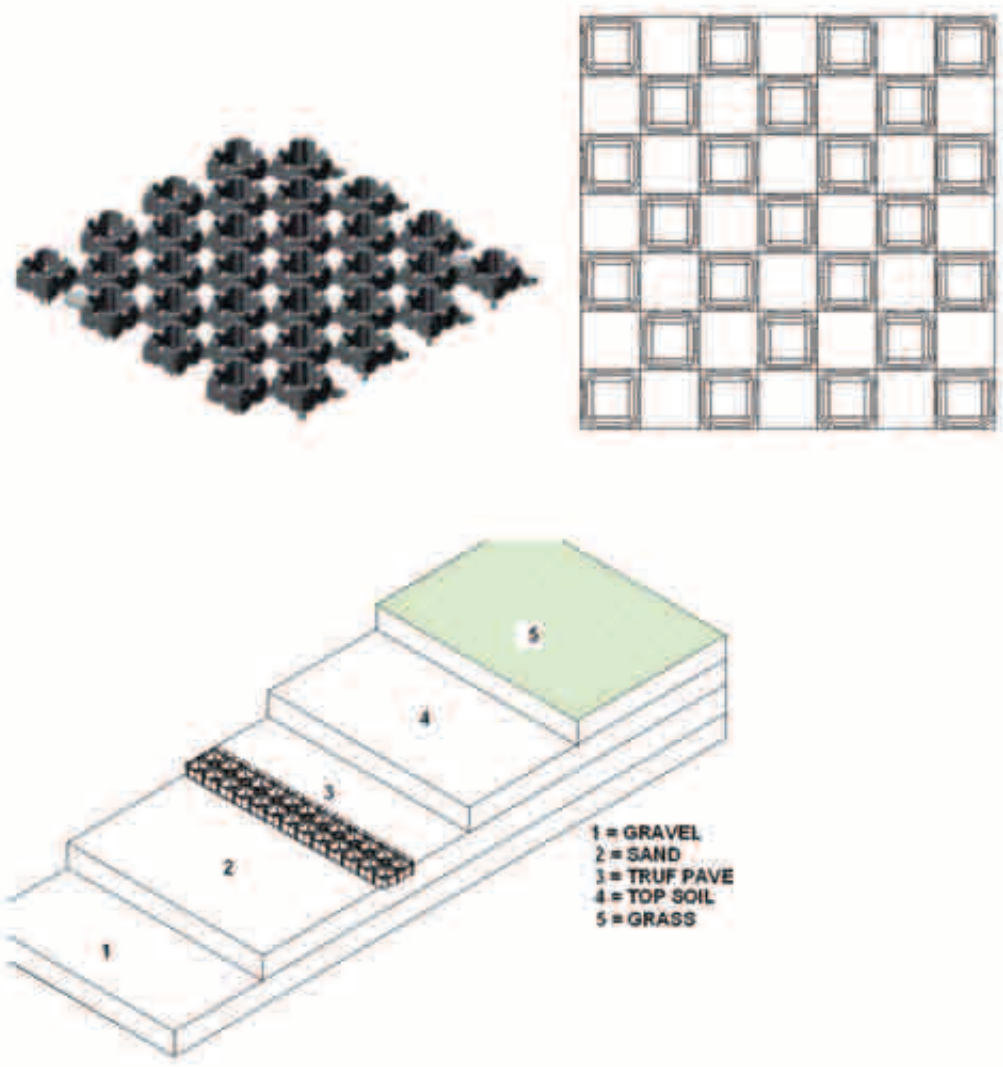
- The trees should be litter free.
- The trees should not be fruit bearing as fallen fruit can damage the surface of vehicles.
- The trees should be evergreen in nature so as to provide protection from sun rays causing discoloration of the painted surface of the vehicles.
- The plantation scheme should be efficient wherein required amount of shade can be achieved through minimum number of trees.
- The trees in parking areas should not be shallow-rooted or else the roots might come out on the paved surfaces.
- The trees should be fast-growing.
- The trees should cater to broad scale environmental aspects like being effective pollution sinks to absorb lead from vehicles etc.
- The trees should have dense foliage with large surface area and preferably fine-leaved trees to absorb pollutants.
- Cattle should not be able to feed on these trees.

Suggested Plant Material

- Ceiba pentandra
- Chorisia speciosa
- Cassia fistula
- Chukrassia tabularis
- Gmelina arborea

Turf Pave: A New Age Solution for Landscaped Parking

At the time of emerging demand for more and more car parking space in or around project premises and increased quantum of hard concrete and road to facilitate such parking, plastic Turf Pave has brought in some sense of sigh and relief.



Turf Pave

Turf Pave is a light weight robust plastic grid structure, specially designed to stabilise and support turf, grass or decorative gravels used for landscape. It provides an environment friendly and practical alternative to impermeable surfaces like concrete and asphalt.

Positioned under a grass landscape, Turf Pave distributes load from pedestrian and vehicular traffic to the base course below, minimizing grass and root compaction. The interconnected plastic cells allow roots to develop with minimal restriction, resulting in a durable and stable grass surface.

Characteristics

- Stabilize turf/ grass surfaces and protects soil against erosion.
- Pleasant alternative to asphalt and concrete surfaces.
- Enhances site appearance through green vegetation.
- Reduces need for storm water conveyances and treatment systems.
- Minimizes storm water run- off.
- Slope stabilization and erosion control.
- High water permeability.
- Distributes vehicle weight. Depending up on the manufacture, high compressive strength can withstand load up to 200T/Sq.m.
- Rapid installation with minimal trained manpower and tools.
- Off site preassembling of modules.

Application

- Vehicle parking lots.
- Sports complexes.
- Street shoulder parking on unstable ground.
- River banks and canals for soil stabilization on slopes.

Climatic Strength

- Rot and insect resistant.
- Ozone resistant.
- Solar UV resistant.
- Corrosion resistant.

Environmental impact

- Recycling potential.
- Renewability.
- Warranty up to 20 years (varies from product to product)
- Light weight.
- Manufactured from 100% recycled plastics.

Installation Procedures

- Excavate and/ or level the area.
- Install drainage systems and utility lines in the sub grade, as required.
- Lay and compact sand gravel to provide support for estimated weight bearing load.
- Position turf pave cell modules on compacted sand and gravel base.
- Cover turf pave with recommended sand soil mix for turf establishment.
- Apply recommended moisture, water retention agents and fertilizers.
- Place rolled turf or hydro- seed onto the filled turf pave modules.

Many international and local manufacturers are now producing Turf Pave. The users need to check the quality beforehand for the best results. The CPWD first used Turf Pave in the Jawaharlal Nehru Bhawan Project in New Delhi. After seeing its performance the product is now being used in the other CPWD projects.

Description of the Item	Rate (Rs.)	Unit
Providing and laying 500x500x40mm thick Turf Paver (Turf Pave XD) on 150mm thick sub grade of compacted bed of 20mm thick nominal size stone aggregate and base course with filling with 150mm thick Jamuna sand including spreading, well ramming, consolidating and Finishing smooth etc, complete as per direction of the Engineer -in -charge	1582.00	Sqm

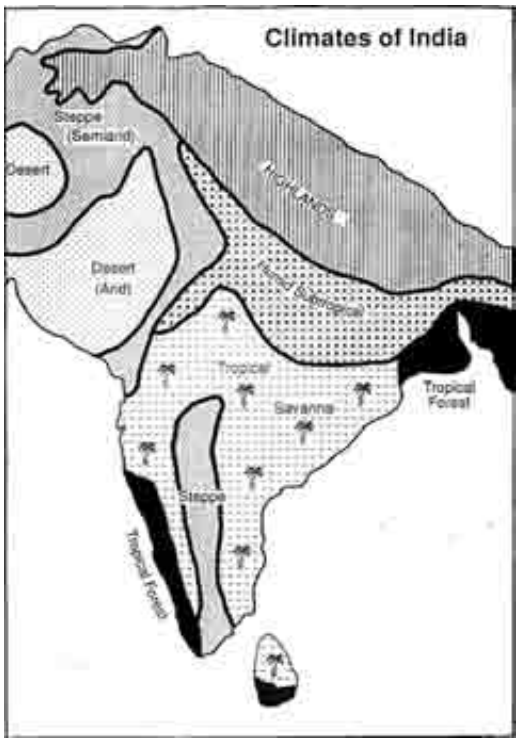
Chapter – 8
Climate and Vegetation

(Text Source : mnre.gov.in)

Urban Climate

The climate of any place depends on many natural and manmade factors like: Location, Altitude, Latitude, settings with respect to land profile, location of water bodies, lakes, rivers or ocean in the surroundings, rate of rainfall or precipitation, sun shine, wind direction, and speed of winds, type, size, location and intensity of vegetation and buildings or structures.

The air temperatures in densely built urban areas are often higher than the temperatures of the surrounding countryside. The term “urban heat island” refers to increased surface temperatures in some pockets of a city, caused by an ever changing microclimate. The difference between the maximum city temperature (measured at the city centre) and the surrounding countryside is the urban heat-island intensity.



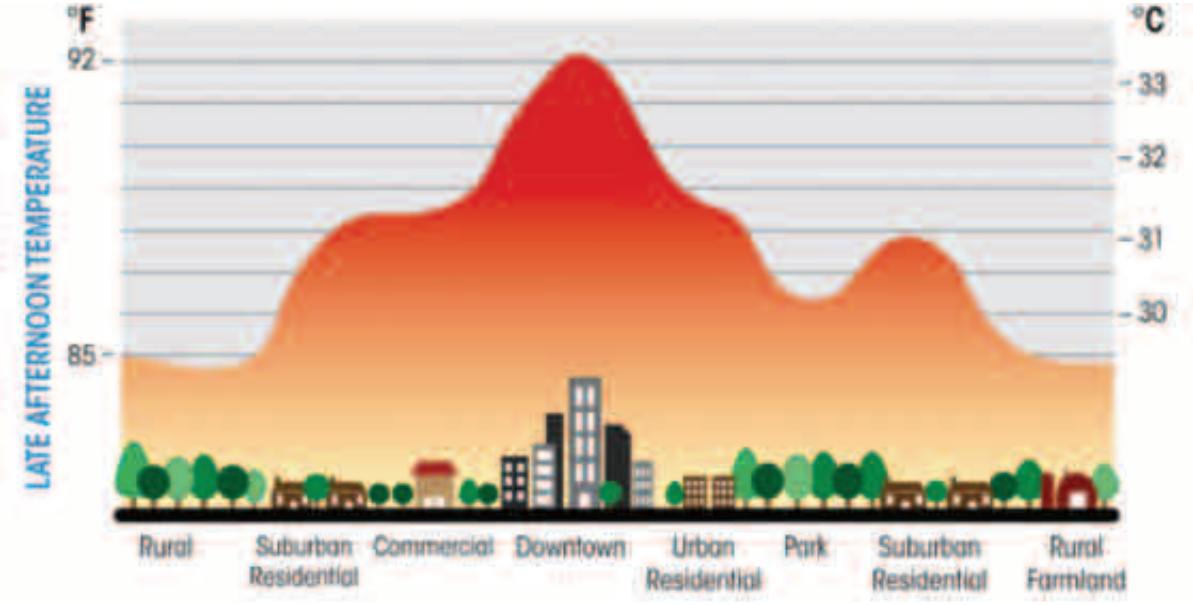
An urban heat island study was carried out in Pune, Mumbai, Kolkata, Delhi, Vishakapatnam, Vijayawada, Bhopal and Chennai by MNRE Govt. of India. It is seen that, among the cities listed above, the heat island intensity is greatest in Pune (about 10°C) and lowest in Vishakhapatnam (about 0.6°C).

Heat Island Intensities in Some Indian Cities

Station Heat	Island Intensity (°C)
New Delhi	6.0
Bhopal	6.5
Kolkata	4.0
Mumbai	9.5
Pune	10.0
Vishakhapatnam	0.6
Vijayawada	2.0
Chennai	4.0

In the metropolitan cities of Mumbai, New Delhi, Chennai and Kolkata, the corresponding values are 9.5, 6.0, 4.0 and 4.0°C respectively. The density of the built environment and the extent of tree cover or vegetation primarily affect the heat-island intensity. Pollution and heat due to vehicular traffic, industrialisation and human activities are other contributing factors.

Normally, the central business district (CBD) or the centre of a city experiences higher temperature than the other parts. This is because the CBD mainly consists of concrete buildings and asphalted roads, which heat up very quickly due to radiation from the sun. Most of this heat is stored and released very slowly sometimes even up to the night.



The phenomenon does not allow the daily minimum temperature to become too low. Though it may be a welcome phenomenon in cold regions during winters, it makes life unbearable for people in the hot regions. Thus, in tropical climates, the provision of sufficient ventilation and spacing between buildings is required to allow the cumulated heat to escape to the atmosphere easily. Street patterns and urban blocks can be oriented and sized to incorporate concerns of light, sun, and shade according to the dictates of the climate.

For example, the densely built areas produce, store and retain more heat than low-density areas. Thus, the temperature differential between urban areas and the surrounding countryside increases as the surrounding areas cool at night. As a result, cooler air from the surrounding countryside flows towards the centre. This kind of circulation is more pronounced on calm summer nights and can be utilised to flush dense areas of heat and pollutants.

To achieve cool air movement, a belt of undeveloped and preferably vegetated land at the perimeter of the city, can be provided to serve as a cool air source. Radial street patterns can also be designed for facilitating movement of air from less dense to more dense areas.

A system of linear greenways or boulevards converging towards the city centre will help to maintain the movement of cool air. Provided the soil is adequately moist, a single isolated tree may transpire up to400 litres of water per day. This transpiration together with the shading of solar radiation creates a cooler environment around the tree.

On a hot summer day, the temperature can drop significantly under trees due to cool breezes produced by convective currents and by shading from direct sunlight. Planted areas can be as much as 5-8°C cooler than built-up areas due to a combination of evapo-transpiration, reflection, shading, and storage of cold. Local wind patterns are created when the warm air over a dense built up area rises, and is replaced by cooler air from vegetated areas. Having many evenly distributed small open spaces will produce a greater cooling effect than a few large parks.

Studies suggest that for a city with a population of about one million, 10-20% of the city area should be covered by vegetation for effectively lowering local temperatures. As the vegetation cover in the city increases from 20 to 50%, the minimum air temperature decreases by 3-4°C and the maximum temperature decreases by about 5°C

The heat released from combustion of fuels and from human activities, adds to the ambient temperature of the city. Air pollution, caused mainly by emissions from vehicles and industries, reduces the long wave radiation back to the sky thereby making the nights are warmer. Global solar radiation during daytime is also reduced due to increased scattering and absorption by polluted air (this can be up to 10-20% in industrial cities).

Pollution also affects visibility, rainfall and cloud cover. Effective land use to decongest cities, and the provision of proper vegetation would mitigate the effects of pollution. It is also important to use cleaner fuels and more efficient vehicles.

Meteorological studies and remote sensing by satellites can be used to ascertain drastic changes in the climate,

land use and tree cover patterns. Remote sensing can also be used to map hot and cool areas across a city by using GIS tools (Geographical Information System). Such mapping can help to reduce unplanned growth of a city, in preparing a proper land use plan, and to identify future vulnerable areas (those devoid of natural vegetation, parks and water bodies). These measures would certainly help in reducing urban heat island intensity.

Microclimate

The conditions for transfer of energy through the building fabric and for determining the thermal response of people are local and site-specific. These conditions are generally grouped under the term of 'microclimate', which includes wind, radiation, temperature, and humidity experienced around a building. A building by its very presence will change the microclimate by causing a bluff obstruction to the wind flow, and by casting shadows on the ground and on other buildings. A designer has to predict this variation and appropriately account for its effect in the design. The microclimate of a site is affected by the following factors:

- Landform
- Vegetation
- Water bodies
- Street width and orientation
- Open spaces and built-form

An understanding of these factors greatly helps in the preparation of the site layout plan. For example, in a hot and dry climate, the building needs to be located close to a water body. The water body helps in increasing the humidity and lowering the temperature by evaporative cooling.

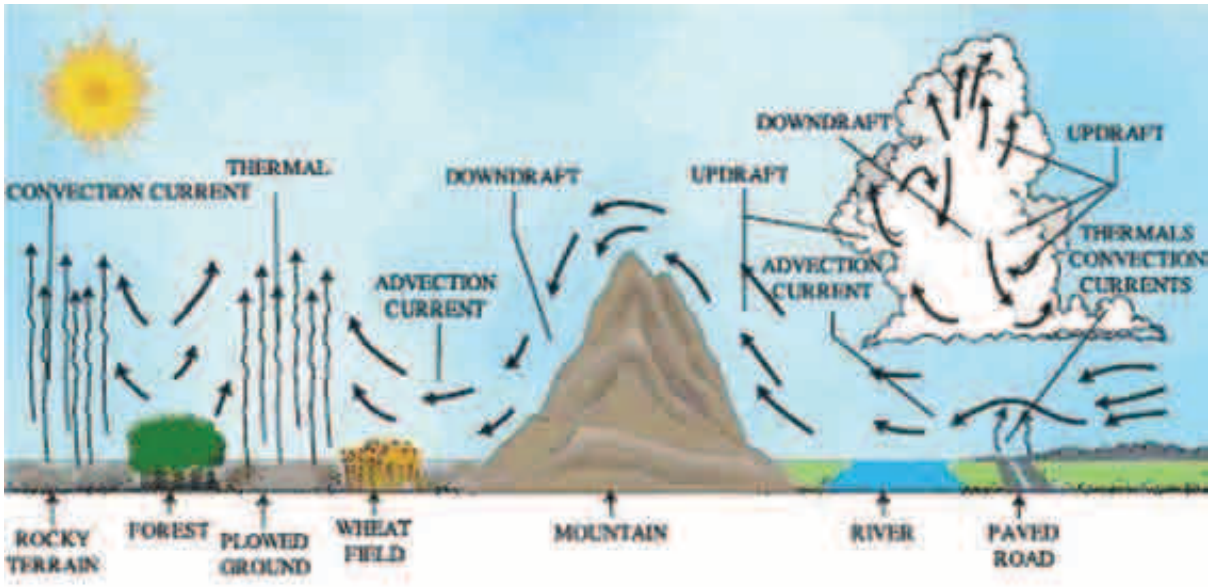
Landform

Landform represents the topography of a site. It may be flat, undulating or sloping. Major landforms affecting a site are mountains, valleys and plains. Depending on the macroclimate

and season, some locations within a particular landform experience a better microclimate than others.

In valleys, the hot air (being lighter) rises while cooler air having higher density, settles into the depressions, resulting in a lower temperature at the bottom. Upward currents form on sunny slopes in the morning. By night, the airflow reverses because cold ground surfaces cool the surrounding air, making it heavier and causing it to flow down the valley. Moreover, the wind flow is higher along the direction of the valley than across it due to unrestricted movement.

On mountain slopes, the air speed increases as it moves up the windward side, reaching



a maximum at the rest and a minimum on the leeward side. The difference in air speed is caused due to the low pressure area developed on the leeward side.

Temperature also varies with elevation. The cooling rate is about 0.8°C for every 100m of elevation. Air moving down the slope will thus be cooler than the air it replaces lower down, and vice versa. Further, the orientation of the slope also plays a part in determining the amount of solar radiation incident on the site.

For example a south-facing slope will get more exposure than a north-facing one in the northern hemisphere. Studies conducted in Mardin, Turkey showed that building groups located on a south facing slope in the city needed approximately 50% less heat to maintain the same indoor temperature as buildings located on the plain land. Careful positioning of a building with respect to landform can thus help in achieving comfort.

Vegetation

Vegetation plays an important role in changing the climate of a city; it is also effective in controlling the microclimate. Plants, shrubs and trees cool the environment when they absorb radiation for photosynthesis. They are useful in shading a particular part of the structure and ground for reducing the heat gain and reflected radiation. By releasing moisture, they help raise the humidity level. Vegetation also creates different air flow patterns by causing minor pressure differences, and thus can be used to direct or divert the prevailing wind advantage.

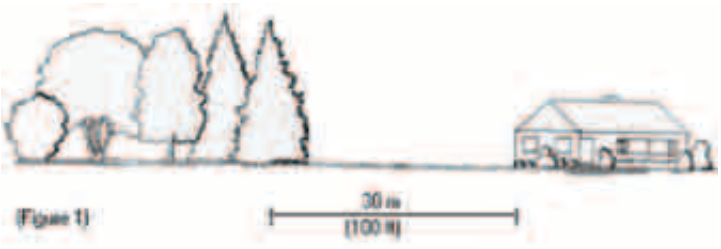
Based on the requirement of a climate, an appropriate type of tree can be selected. Planting deciduous trees such as mulberry to shade east and west walls would prove beneficial in hot and dry zones.

In summer, they provide shade from intense morning and evening sun, reduce glare, as well as cut off hot breezes. On the other hand, deciduous trees shed their leaves in winter and allow solar radiation to heat the building. The cooling effect of vegetation in hot and dry climates comes predominantly from evaporation, while in hot humid climates the shading effect is more significant.

Trees can be used as windbreaks to protect both buildings and outer areas such as lawns and patios from both hot and cold winds. The velocity reduction behind the windbreak depends on their height, density, cross- sectional shape, width, and length, the first two being the most important factors.

When the wind does not blow perpendicular to the windbreak, the sheltered area is decreased. The rate of infiltration in buildings is proportional to the wind pressure. Therefore, it is more important to design windbreaks for maximum wind speed reduction in extreme climates, than to attempt to maximize the distance over which the windbreak is effective.

In cold climates, windbreaks can reduce the heat loss in buildings by reducing wind flow over the buildings, thereby reducing convection and infiltration losses. A single-row of high density trees in the form of a windbreak can reduce infiltration in a residence by about 60% when planted about four tree heights from the building. This corresponds to about 15% reduction in energy costs. Thus, trees can be effectively used to control the microclimate. The data for various trees found in India are presented in the Table :



Properties of Some Indian Trees

S. No	Botanical Name	Common Name English	Height (m)	Spread (m)	Rate of Growth	Root System	Drought Resistance	Foliage
1	Eugenia jambolana	Jamun	12.2 to 13.7	9.1 to 10.7	Medium	Medium	Medium	BLE
2	Azadiracta indica	Margosa	13.7 to 15.2	10.7 to 12.2	Fast	Medium	Good	BLE
3	Mimusops elengi	Bulletwood tree	12.2 to 13.7	10.7 to 12.2	Slow	Large	Good	BLE
4	Peltrophorum ferrigeum	Copper pod tree	13.7 to 15.2	10.7 to 12.2	Fast	Small	Good	BLE
5	Tamarindus indica	Tamarind	10.7 to 12.2	9.1 to 10.7	Slow	Medium	Medium	BLE
6	Pithecellobium dulce	Goras	12.2 to 13.7	9.1 to 10.7	Slow	Large	Medium	BLE
7	Samanea saman	Raintree	10.7 to 12.2	9.1 to 10.7	Fast	Medium	Medium	BLE
8	Bauhinia variegate	Variegated bauhinia	6.1 to 9.1	7.6 to 9.1	Fast	Small	Medium	D
9	Cassia fistula	Indian laburnum	7.6 to 10.7	6.1 to 9.1	Fast	Small	Very Good	D
10	Cassia javanica	Pink cassia	7.6 to 9.1	9.1 to 10.7	Medium	Medium	Good	D
11	Cordia sebestena	Cordia	4.6 to 6.1	4.6 to 5.5	Medium	Small	Good	D
12	Delonix regia	Royal poincana	7.6 to 9.1	7.6 to 8.5	Fast	Large	Medium	E
13	Erythrina indica	Indian coral tree	7.6 to 9.1	4.6 to 6.1	Fast	Small	Good	D
14	Gliricidia maculate	Madra tree	6.1 to 7.6	4.6 to 6.1	Fast	Small	Poor	BLE
15	Largerstroemia spriosa	Pride of India	7.6 to 9.1	6.1 to 7.6	Fast	Medium	Very good	BLE
16	Morus indica	Mulberry	9.1 to 10.7	7.6 to 8.5	Medium	Medium	Medium	D
17	Plumeria alba	White frangipani	4.6 to 6.1	4.6 to 5.5	Fast	Small	Medium	D
18	Pogamia glabra	Pongam	4.6 to 6.1	4.6 to 6.1	Fast	Small	Medium	D
19	Psidium guyava	Guava	6.1 to 7.6	5.5 to 6.1	Fast	Medium	Medium	BLE
20	Morrga oleifera	Drumstick tree	9.1 to 10.7	7.6 to 9.1	Fast	Small	Medium	BLE
21	Pustrajiva roxburghil	Lucky bean tree	7.6 to 9.1	4.6 to 6.1	Slow	Small	Medium	BLE
22	Tecoma undulata	Wary leaved Tecoma	6.1 to 7.6	4.6 to 5.5	Fast	Small	Very good	BLE
23	Thespesia populnea	Portia tree	7.6 to 9.1	7.6 to 9.1	Fast	Small	Medium	BLE
24	Thevitai peruviana	Yellow oleander	4.6 to 5.5	3.0 to 4.6	Fast	Small	Medium	D
25	Nesium Oleander	Oleander	4.6 to 5.5	3.0 to 4.6	Fast	Medium	Good	D
26	Zapota	Zapota	6.1 to 7.6	7.6 to 9.1	Fast	Medium	Good	BLE

BLE = Broad Leaf Evergreen, D = Deciduous, E = Evergreen

Water Bodies

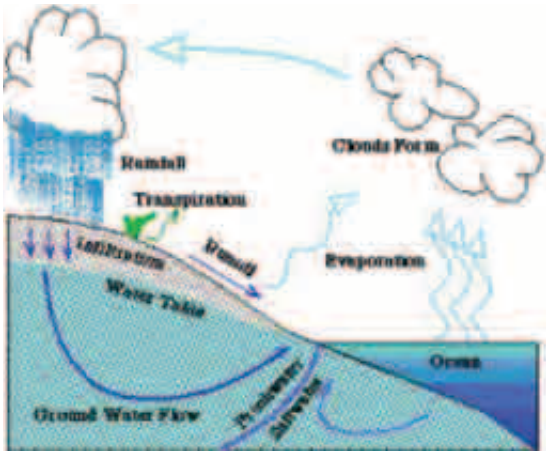
Water bodies can be in the form of sea, lake, river, pond or mountains. Since water has a relatively high latent heat of vaporisation, it absorbs a large amount of heat from the surrounding air for evaporation.

The cooled air can then be introduced in the building. Evaporation of water also raises the humidity level. This is particularly useful in hot and dry climates. Since water has a high specific heat, it provides an ideal medium for storage of heat that can be used for heating purposes.

Large water bodies tend to reduce the difference between day and night temperatures because they act as heat sinks. Thus, sites near oceans and large lakes have less temperature variation between day and night, as well as between summer and winter as compared to inland sites. Also, the maximum temperature in summer is lower near water than on inland sites.

The wind flow pattern at a site is influenced by the presence of a large water body in the following way. Wind flow is generated due to the difference in the heat storing capacity of water and land, and the consequent temperature differentials. During the day, the land heats up faster than the water, causing the air over the land to rise and be replaced by cool air from water. Hence the breeze blows towards the land from water during the day and in the reverse direction at night.

Evaporative cooling can help to maintain comfort in buildings in hot and dry climate. This feature was successfully adopted in vernacular architecture. For example, the Deegh palace in Bharatpur is surrounded by a water garden to cool the neighborhood. Other examples include the Taj Mahal at Agra and the palace at Mandu. The evaporation rate of water in such an open space depends on the surface area of the water, the relative humidity of the air, and the water temperature.



Street Width and Orientation

The amount of direct radiation received by a building and the street in an urban area is determined by the street width and its orientation.

The buildings on one side of the street tend to cast a shadow on the street on the opposite building, by blocking the sun's radiation. Thus the width of the street can be relatively narrow or wide depending upon whether the solar radiation is desirable or not. For instance in Jaisalmer (hot and dry climate), most of the streets are narrow with buildings shading each other to reduce the solar radiation, and consequently the street temperature and heat gain of buildings. It is seen that street temperatures in Jaisalmer can be up to 2.5°C lower than the ambient air temperatures due to mutual shading of buildings. At high latitudes in the northern hemisphere, the solar radiation is predominantly from the south; hence wider east-west streets give better winter solar access.

The orientation of the street is also useful for controlling airflow. Air movement in streets can be either an asset or a liability, depending on season and climate. The streets can be oriented parallel to prevailing wind direction for free airflow in warm climates.

Smaller streets or pedestrian walkways may have number of turns (zigzags) to modulate wind speed. Wind is desirable in streets of hot climates to cool people and remove excess heat from the streets. It can also help in cross ventilation of buildings.

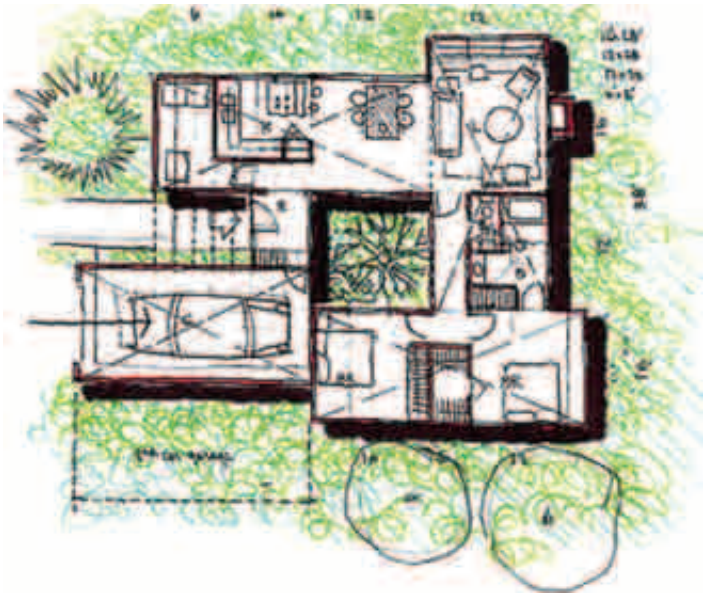
This is important in humid climates, and at night in arid climates. In cold regions, wind increases heat losses of buildings due to infiltration. For restricting or avoiding wind in cold regions, the streets may be oriented at an angle or normal to the prevailing wind direction. For regular organisations of buildings in an urban area, tall buildings on narrow streets yield the most wind protection, while shorter buildings on wider streets promote more air movement. When major streets are parallel to winds, the primary factors affecting the wind velocity are the width of streets and the frontal area (height and width) of windward building faces.

Open Spaces and Built-form

The form of a building and the open spaces in its neighbourhood affect the radiation falling on the building's surface and the airflow in and around it. Open spaces such as courtyards can be designed such that solar radiation incident on them during daytime can be reflected on to building façades for augmenting solar heat.

This is desirable in cold climates, and it is possible if the surface finish of the courtyard is reflective in nature. Inside a courtyard, wind conditions are primarily dependent on the proportion between building height and courtyard width in the section along the wind flow line.

The courtyards can also be designed to act as heat sinks. Grass and other vegetation in a courtyard can provide cooling due to evaporation and shading. Water sprayed on the courtyards would cause cooling effect due to evaporation. Consequently, the air temperature in the courtyard can be much lower compared to street or outdoor air temperatures in a hot and dry climate.



The air in open spaces shaded by surrounding buildings would be cooler and can be used to facilitate proper ventilation and promote heat loss through building envelope. Built forms can be so oriented that buildings cause mutual shading and thus reduce heat gain. For ensuring unobstructed airflow, taller structures can be planned towards the rear side of a building complex.

Chapter – 9
Green Building Environment & Landscape

(Indu G. Choudhary, M. Arch. (Urban Design) Senior Architect)

We need to acknowledge the basic reality that the building industry on one hand uses 40% of total energy, 42% of water and 50% of raw materials; and on the other hand it is responsible for 50% air pollution, 42% green house gases, 50% water pollution, 48% solid waste and 50% CFC (chlorofluorocarbons). There is no denying the fact that human habitat is an essential part of a civil society but at the cost of nature. The natural resources are limited and depleting very fast. Thus we must enforce measures of sustainability and live in harmony with nature. The fundamentals of the sustainable design approach are reducing the requirement, consumption and wastage of the resources; selecting ecologically sustainable materials, reusing and recycling them. We may also utilize renewable energy sources and generate energy on site.

The awareness, knowledge and implementation of sustainable planning and design techniques among professionals & users are needs of the hour. Conscious efforts need to be made in this direction by all concerned while designing buildings and open spaces for the users in urban as well as rural areas. The Green building design approach has gained momentum among professionals through sincere efforts made by the various government and non-government agencies in India and innumerous initiatives and steps taken by them in this direction in the last decade.

The depleting greencover in the cities shall be arrested through conscious application of environmental and landscape process and techniques while undertaking various development projects. Thus the landscaped approach shall be carried in a holistic manner by adding the green cover and preserving the existing vegetation to maintain a balance between natural and built environment. The landscape design has to be responsive to the local climatic conditions for its survival and sustainability.

It is important for the professionals to collect and analyse the site with respect to orientation, climatic conditions, soil, water & hydrology, wind direction, existing vegetation and slopes etc. The design intervention involves preserving and protecting landscape during construction, soil conservation, including existing site features, reducing hardscape/ hard paving on site, reducing landscape water requirement, optimizing building design to reduce conventional energy demand, waste water treatment, water recycling and reusing (including rainwater), storage and disposal of waste, resource recovery from waste and reducing outdoor noise levels and innovative use of new materials.

CPWD has recognized the above and takes pride in following the green building design approach and if implementation in all its projects. CPWD has also published a guide on **“integrated green design for urban and rural buildings in hot-dry climatic zone”.** The exhaustive information on sustainable development, green building environment and rating systems etc. is available on web sites of the various government and non government agencies.

Chapter - 10

Landscape Design - Imperial Delhi

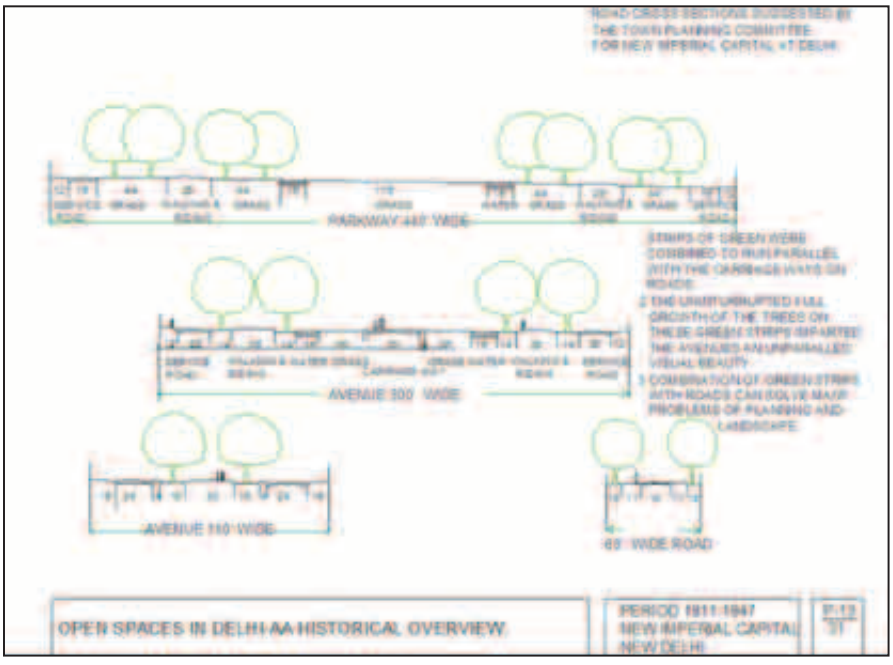
(S.S. Rawat, Architect, CPWD)

Imperial Delhi is known for its tree lined avenues. Captain George Swinton, Chairman of the Town Planning Committee, referring to the creation of Imperial Delhi reported in 1913:

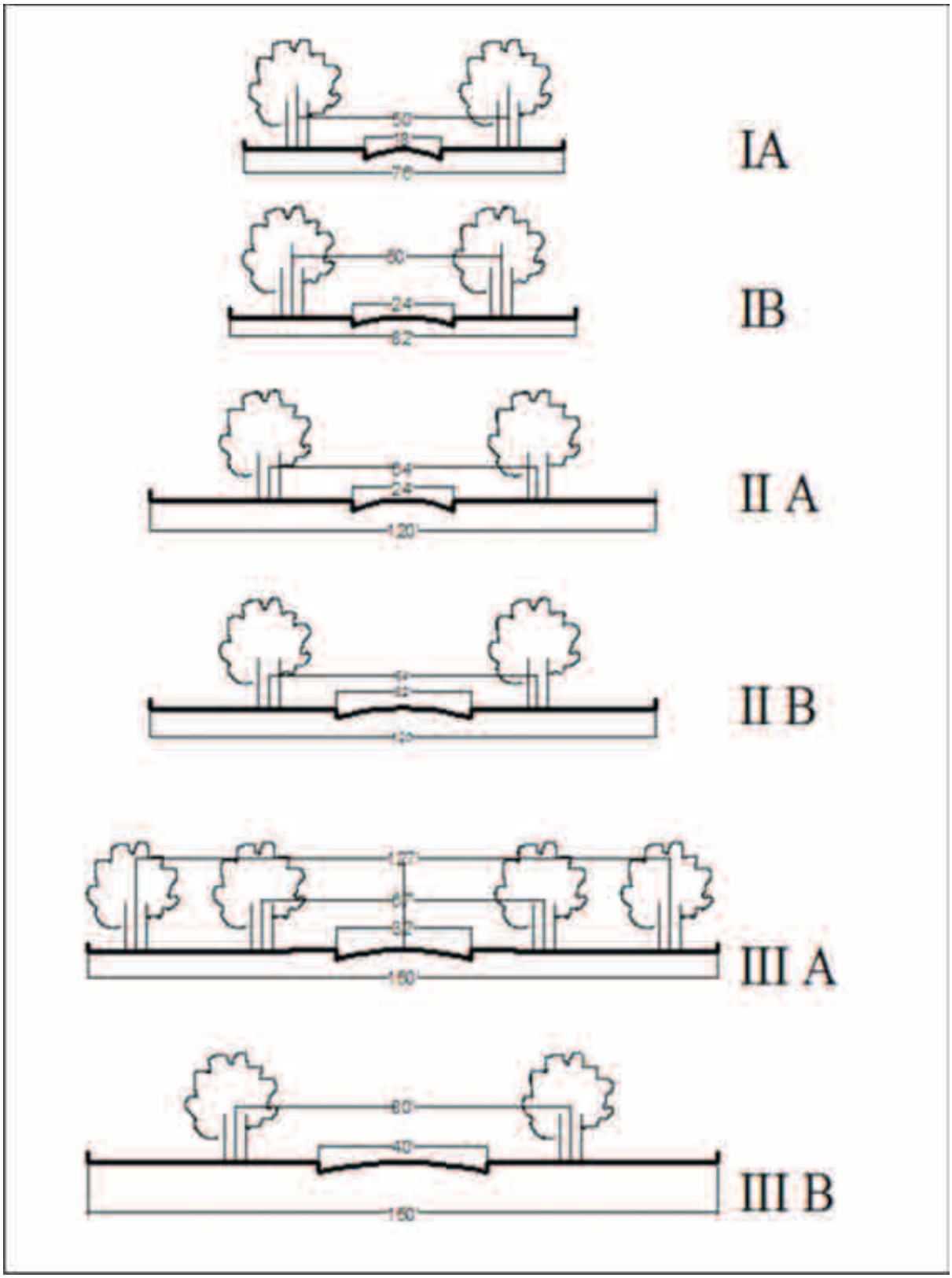
Trees will be everywhere, in every garden however small it may be, and along the sides of every roadway, and Imperial Delhi will be in the main a sea of foliage. It may be called a city, but it is going to be quite different from any city that the world has known.

The brief to the Architects was to retain one-third area as green space. The garden city concept was chosen as the planners felt a crowded city was not the answer to any metropolis.

Extending from the Central Vista is the hexagonal road pattern, which spreads north and south of Rajpath distributing traffic on shady avenues lined with regular plantation of indigenous trees. An important feature of the planning was the presence of major public green open areas on three sides of the Lutyen Bungalow Zone (LBZ). These are the Delhi Ridge on the west adjoining the Presidents Estate; the connected green of Nehru Park, the Race Course and the Delhi Gymkhana Club, Safdarjang Airport, Safdarjang Tomb, and the almost contiguous Lodi Garden on the south; the Delhi Golf Club on the south-east, and on the eastern side across the LBZ boundary along Mathura Road is the large green expanse of the Zoological Garden, with the Purana Qila at one end and Humayun Tomb at the other. This resource of green areas is the most valuable asset, not only of the LBZ but of the entire city of Delhi, because of the fresh air and natural beauty that the green areas represented. New Delhi is probably the only city in the world where the centre of the city is 4 degrees Celsius cooler than the peripheral areas. The bungalows are spread over just 1.8% of entire Delhi's area but these very green spaces contribute immensely to the ecology of the city.



Planning for the Avenues. The various flowering and evergreen trees were used along different roads. Only one type of tree was used in one road.

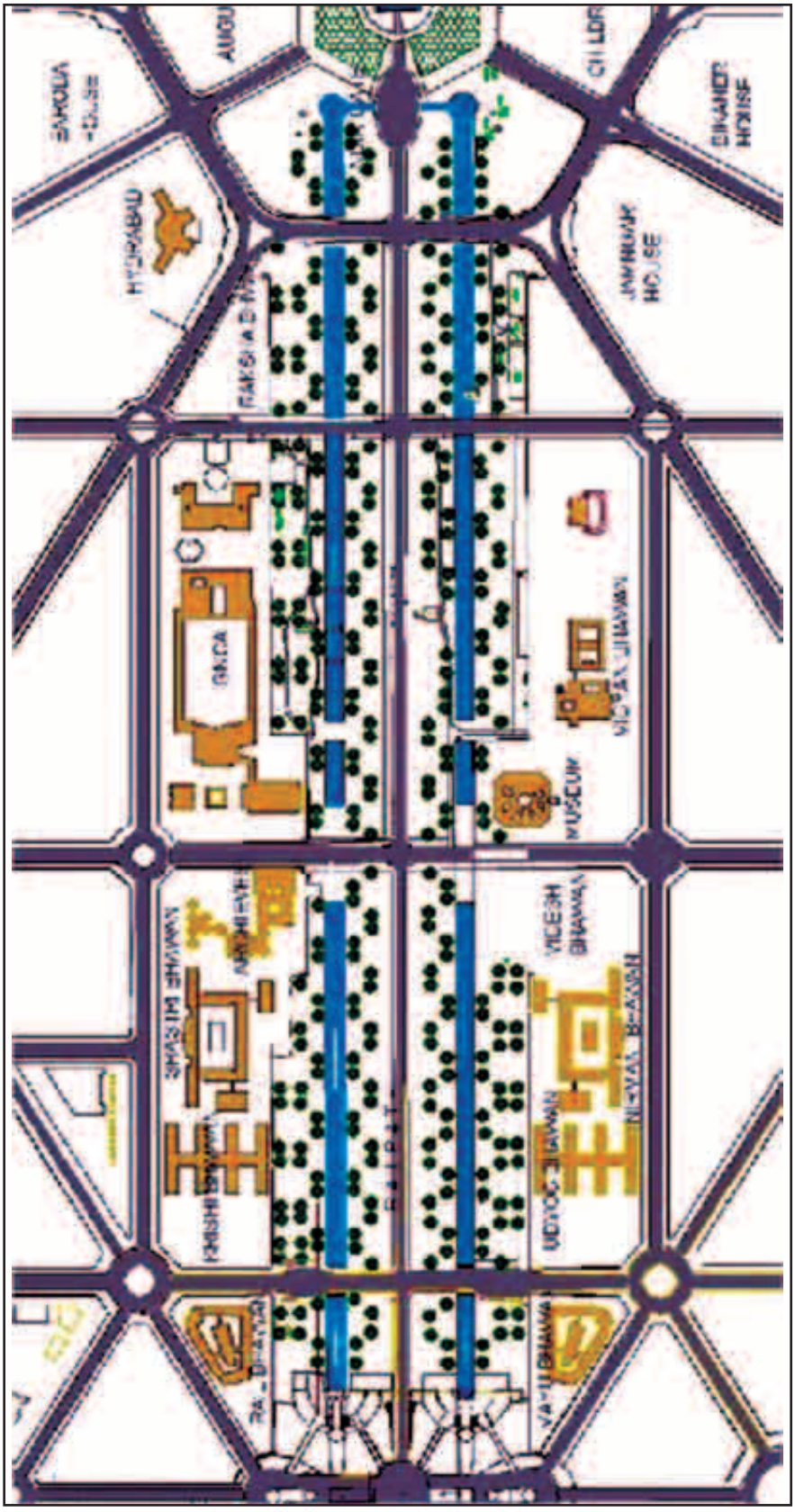


Road Sections along Various Avenues

List of Major Avenue Trees in NDMC Area

(Source: NDMC Website)

1.	Terminalia (Arjun)	arjuna	Janpath, Park Street, Mother Teresa (Mixed), BKS Marg
2.	Azadirachta (Neem)	indica	Aurangzeb, Shahjahan, Prithviraj, Aurbindo, Tees January, Safdarjung, Kamal Attaturk, KG, Rafi, Talkatora Road, Lodi, Sansad Marg, Pandara Road, Jai Singh, Jantar Mantar, GRG.
3.	Tamarindus (Imli)	indica	Tilak Marg, Akbar Road, Teen Murti Marg
4.	Syzygium (Jamun)	cumini	Ashoka, Rajpath, Sunehri Bagh, Tughlaq, Motilal Nehru, Feroze Shah, Raisina, Rajaji, Tyagraj, Kushak , Talkatora Road, Tolstoy, Mahadeva Road
5.	Kygelia (Kygelia)	pinnata	Purana Quila Road, Babur
6.	Ficus (Pilkhan)	infectoria	Krishna Menon Marg, Dr. Zakir Husain, Bhagwan Das Road, Blawant Rai Mehta Lane, Nyaya, Niti Marg, Dalhousie, Bhagwan Das Road, Satya Marg, Church Road.
7.	Ficus (Pipal)	religiosa	Mother Teresa Road, Panchsheel Marg, Sardar Patel, Mandir Marg, KG, Africa Avenue
8.	Terminalia (Baheda)	belerica	Dr. Rajendra Prasad Road, Barakhamba Road.
9.	Manilkara (Khirni)	hexandra	Maulana Azad Road, Mansingh Road(Part)
10.	Bombax (Semal)	ceiba	Niti Marg, Nyaya Marg
11.	Ailanthus (Maharukh)	excelsa	Copernicus Marg
12.	Madhuca (Mahua)	indica	Rajesh Pilot Marg (South end Road)
13.	Pterygota (Buddha's Coconut)	alata	Bishambhar Das Marg
14.	Gmelina arborea (Gamari)		B - Avenue, Sarojini Nagar
15.	Alstonia scholaris (Saptaparni)		Vinay Marg, Kautilya Marg, Kitchner Road, Safdar Hashmi, Tansen, RK Ashram Marg
16.	Ficus tseila		Malcha Marg Market
17.	Cassia (Amaltas)	fistula	Chandragupta Marg, Amrita Shergill, Humayun Road
18.	Ficus benghalensis (Bargad)		Teen Murti Road(Part)
19.	Hardwickia (Anjan)	binata	Pandara Road
20.	Moulsari		San Martin
21.	Large Mixed Gulmohar, Lagerstroemia thorelli, Polyalthea longifolia		South Avenue, North avenue,

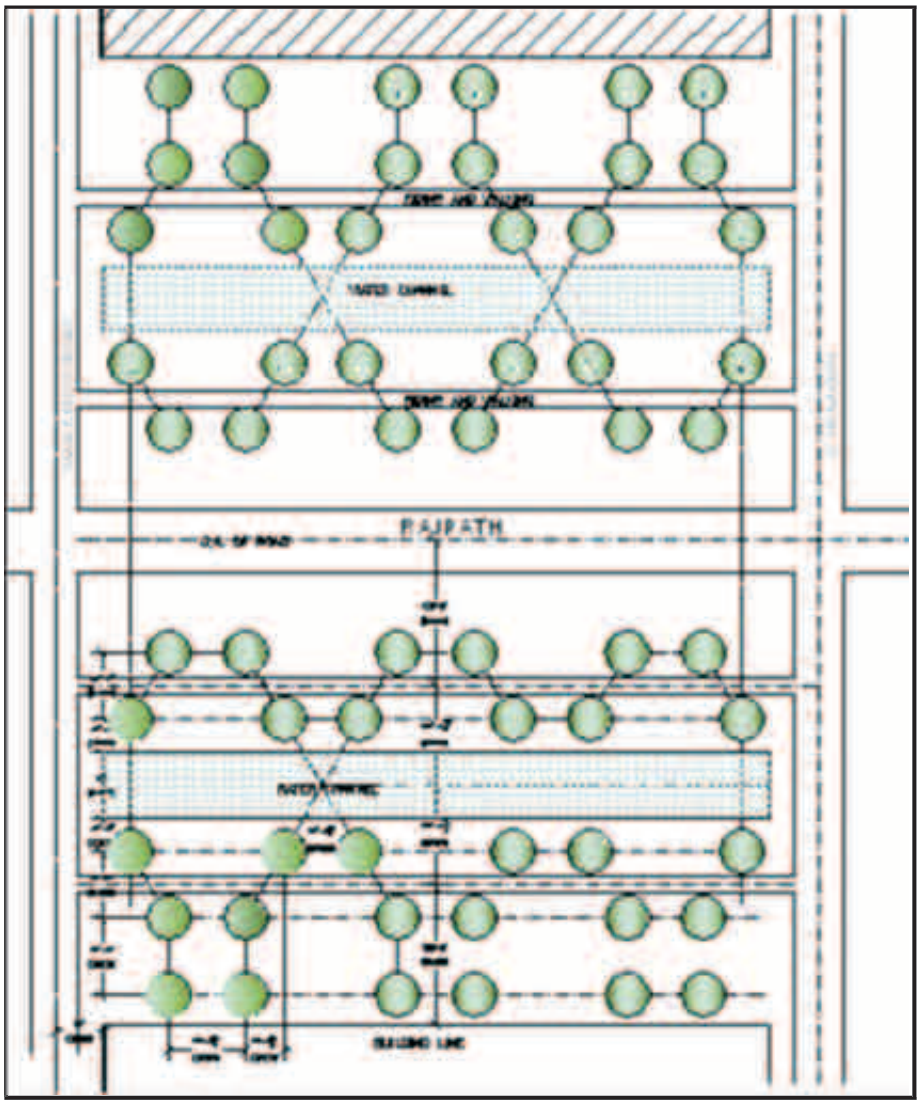


Planting Plan superimposed with Existing Buildings

View of Central Vista from Chhatri in C- Hexagon

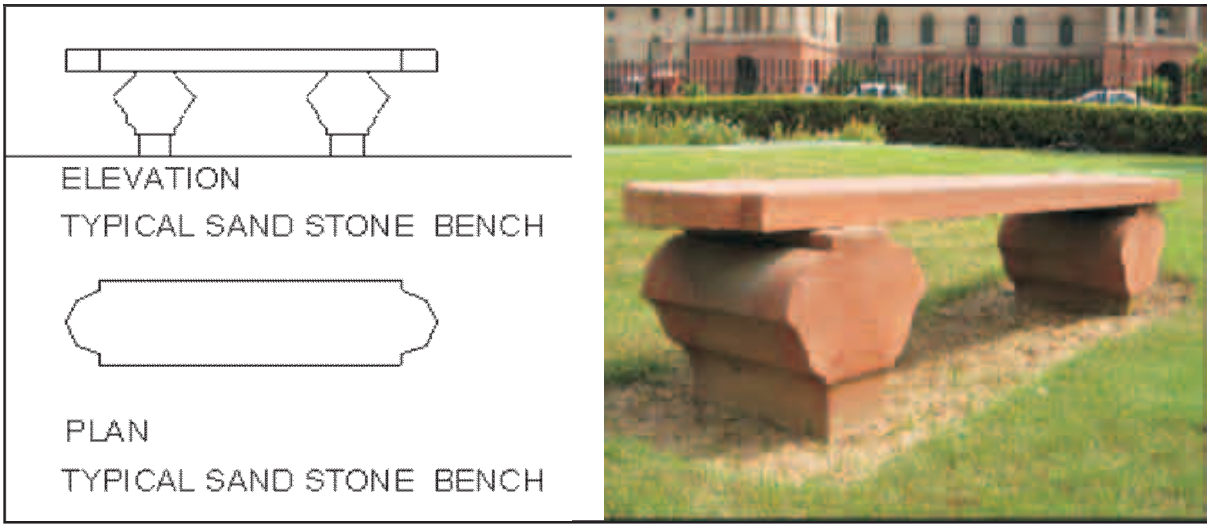
View of Central Vista from Air looking West (Source Architecture of Edwin Lutynes - Vol – 2)

View of Jamun Trees planted along Rajpath (Source Architecture of Edwin Lutyens - Vol – 2)



Original Planting Pattern between Man Singh Road and C- Hexagon

Lamp Posts



A Bench in Central Vista

Existing partially underground toilets/ drinking water points in Central Vista.

Chapter – 11

Landscape Design Concept-1

Paryavaran Bhawan, Aliganj, Jorbagh, New Delhi

(P.S.Sodhi, M. Arch. (Landscape), Architect, CPWD)

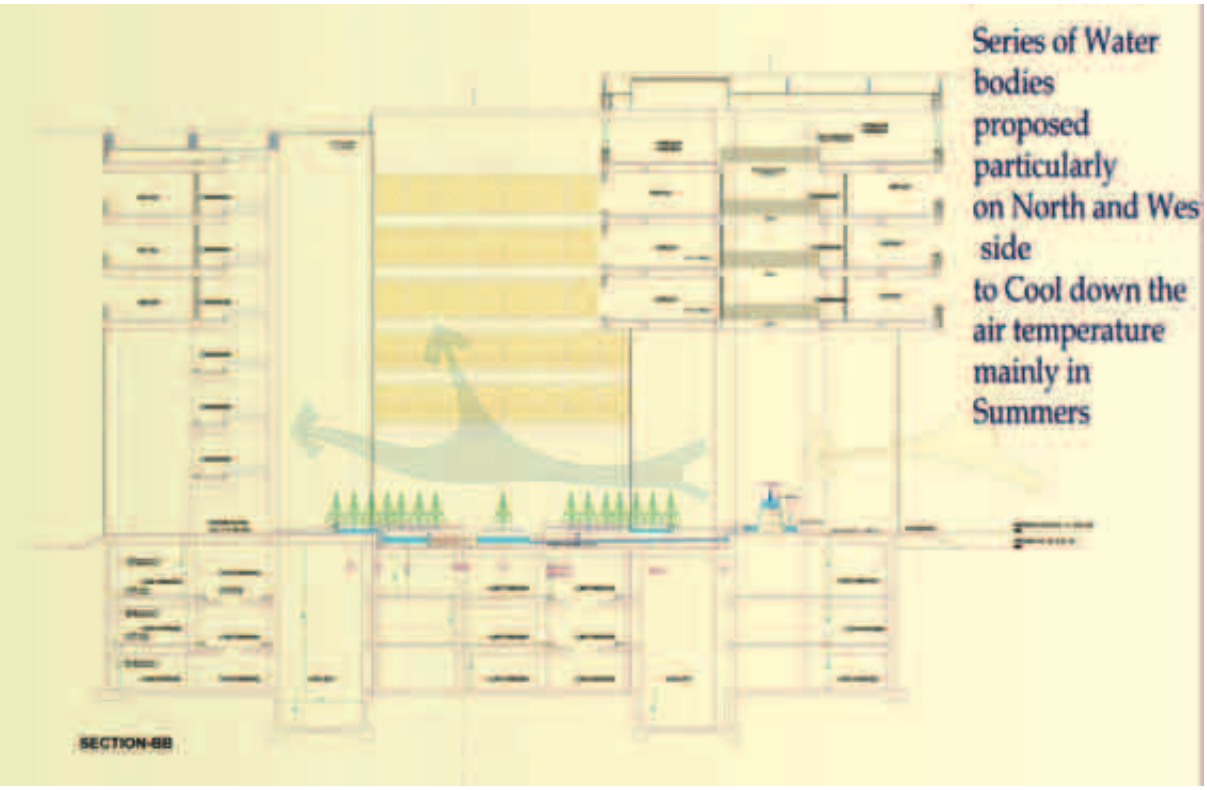
Landscape Design Concept

Ministry of Environment & Forest is the nodal agency for planning, promotion, co-ordination & overseeing the implementation of country's overall environmental and forest policies and programs.

Indian subcontinent is one of the most fascinating ecological and geographical regions in the world. It offers enormous diversity in topography, natural resources and climate as well. In landscape design proposal for Paryavaran Bhawan, we tried to represent the overall geographic regions of country; where each one has its own natural, ecological value of India.

These regions will be represented in the form of plant material, rocks, artifacts and pictorial representation in & around proposed building. The proposed plant material selection is based on MoEF's guidelines for different agro-climatic zones, judicious mix of biodiversity value and

aesthetics. The tree components in Paryavaran Bhawan complex will represent the indigenous flora of the country depending on adaptability to Delhi's climate.



Role of Biodiversity in the Design Development

Design for Biodiversity promotes the ecological function of a built structure and environs in its local context. This requires not only the consideration of how a built structure can minimise any adverse impact upon the local ecology, but also a consideration of whether the built structure or its landscaped environment can deliver any wider ecological benefits or enhancements. Considering this approach designing for biodiversity has been undertaken in a sympathetic manner in this project so that it can fulfill not only the requirement of Green Building but also offer a number of other benefits to user and public visiting the ministry. The main considerations undertaken for landscape design are:

- Demonstrating social and environmental responsibility;
- To recognise the importance of environmental agenda by integrating environmentally sensitive approaches into project development;
- To meet LEED & GRIHA requirements for getting Platinum and Five Star rating for proposed building;
- Financial savings compared with a traditional landscaping approach;
- To provide users and occupiers of buildings a diverse landscape;
- To educate visitors about the environmental benefits provided by reduced storm-water run-off, shading, insulation or 'natural air-conditioning' etc.

The task for demonstrating the entire biodiversity of the India in such a small area is difficult but the aim is to show the commitment of ministry towards environment and forests. One of the main aim objectives of this project is to get highest rating of LEED and GRIHA to make this building a role model for Green Building.

Green Building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from siting to design, construction, operation, maintenance, renovation, and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort.

Although new technologies are constantly being developed to complement current practices in creating greener structures, the common objective is that green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by:

- Efficiently using energy, water, and other resources
- Protecting occupant health and improving employee productivity
- Reducing waste, pollution and environmental degradation

Green building brings together a vast array of practices and techniques to reduce and ultimately eliminate the impacts of buildings on the environment and human health. It often emphasizes taking advantage of renewable resources, e.g., using sunlight through passive solar, active solar, and photovoltaic techniques and using plants and trees through green roofs, rain gardens, and for reduction of rainwater run-off. Many other techniques, such as using packed gravel or permeable concrete instead of conventional concrete or asphalt to enhance replenishment of ground water, are used as well.

Benefits of Green Building are:

Environmental Benefits

- Enhance and protect biodiversity and ecosystems
- Improve air and water quality
- Reduce waste streams
- Conserve and restore natural resources

Economic Benefits

- Reduce operating costs
- Create, expand, and shape markets for green product and services
- Improve occupant productivity
- Optimize life-cycle economic performance

Social Benefits

- Enhance occupant comfort and health
- Heighten aesthetic qualities
- Minimize strain on local infrastructure
- Improve overall quality of life

Landscape Design Approach

Central Courtyard

The thematic sections in the central courtyard area would include special plant groups such as Palms, Cycads and other tropical elements of high conservation value (e.g. Medicinal Ginger). Water bodies to be introduced as central feature in the court yard to soothe micro climate and to introduce sound effects.

Special attention will be given to the illumination of laid green areas with energy efficient lighting arrangements to create dramatic effects particularly in central courtyard and terrace garden

Terrace Garden

A sandwich space in-between gym & entertainment area at seventh floor will be designed to provide relief and to refresh. This is a vegetated surface on a roof, playing a part in slowing down rainwater runoff, helping to keep the building cool, ameliorating the 'urban heat island' effect, and contributing to the filtration of pollutants from the atmosphere.

Green Wall is used to describe a vegetated vertical surface particularly on the solid walls. This will provide an opportunity for wildlife in locations where conventional landscaping is impractical; providing visual amenity for the public. In addition to these; green walls can also help with rainfall attenuation, dust filtration, and reducing the urban heat island effect.

Horticulture

The proposed plants material suggested for this project has been taken after considering the diversity of plants. The suggested trees shrubs and ground covers are adaptable to the climatic conditions of the area. Since in Delhi the ground water level is low, hence the maximum care has been taken to plants the trees and shrubs which require minimum quantity of water and can survive in dry climatic conditions. Most of the trees & shrubs to be planted in the area have very good growth and are varied according to the climatic, soil conditions and the planting distance.

Most of the plants are Indian origin and can withstand to the adverse climatic conditions. Different trees have to be planted in the four different directions of the Paryavaran Bhawan i.e. North, East, South and West. Maximum care has been taken to select the tree species according to their suitable directions. On the terrace garden as well as in the internal courtyard species of Champa have been taken to give a beautiful look with its broad green leaves, white & creamy flowers.

Few selected plants such as Chinar, Rudrakash & Glacier Ivy suggested to give representation to the mountain areas are new to the Delhi climatic conditions and need special attention for their growth. Best efforts will be taken to make their survival in its new ecological condition.

Large spaces particularly below the trees grove are planted with ground covers to provide aesthetics, to hide the barren soil which otherwise can't be planted with grass or other shrubs control erosion of soil and to slow down the surface runoff effectively

As suggested by GRIHA & LEED, number of trees to be cut down will be replaced by new

trees planted in the ratio of 1:3 + 25% extra to gain one point

Deciduous trees are planted on the Southern and Western side to maximize the benefits of deciduous trees; this will help shade the lower parts of the building during the hottest months of the summer and when these trees drop their leaves, they allow sunlight to warm building during the winter.

Water collected from rainwater harvesting will be used for irrigation purposes to reduce municipal storm water runoff. To minimize the wastage of water drip irrigation systems (micro-irrigation systems) will be placed to deliver water directly to plants.

Composting occurs in nature and is a process that keeps organic nutrients cycling from soil to plants and back to the soil. Composting has many benefits, including: (1) Reducing municipal waste, (2) Improving soil moisture retention, (3) Boosting plants' immune systems, and (4) Reducing the need for chemical fertilizers. Organic waste from fruit peels, grass clipping, leaves, etc. is to be recycled and mixed into garden soil.

Chapter – 12

Landscape Design Concept - 2

Hostels for Central University of Rajasthan at District Ajmer.

(Sudhir Kamal Seem, M. Arch. (Landscape), Senior Architect, CPWD)

Introduction

The proposal is for construction of Scholars' Hostels of about 800 Students to be constructed on a piece of land measuring 218.33 hectares at Bandra Sindri, Ajmer district of Rajasthan. The land is situated on NH-8 about 90 kilometers from Jaipur.

The land is irregular in shape and is surrounded with agricultural fields without any type of buildings in around 2 km radius, and very little vegetation cover as the land was being used as grazing fields for the villages.

Site Features

The site is gently sloping in two directions with highest point in the centre and the gradient ranging between 1% - 2%. Highest point is 101.50 m, lowest point is 83.50 m.

The top soil is loose earth with exposed rocks at many areas and excavated ditches at some pockets. Thereby no top soil at places to 5-6 m soil cover at some places.

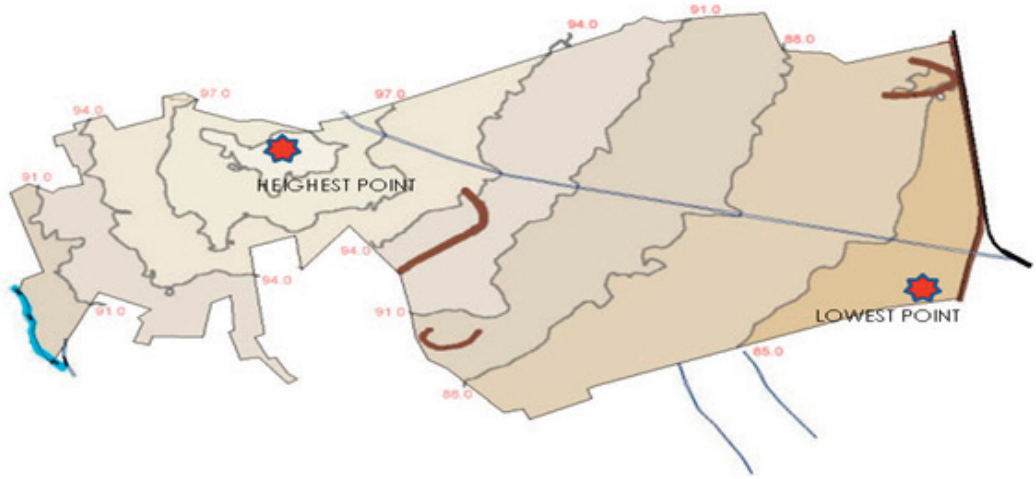
Excavated ditches in some parts on south west are found with over burden of excavated earth on some parts of the site. To be dealt with carefully with eco sensitive approach.

No prominent vegetation worth preservation. Vegetation at site is mainly of scrub (thorny bushes} xerophytic in nature. Green pockets are seen near recharge earthen bunds constructed at site

Proposal

It is proposed to construct 4 hostel blocks of 200 students each. The design has been evolved such that the buildings can be used as offices and class room/laboratories etc. For a short period of time and will be converted to hostels as and when required without much changes and extra expenditure.

Since the master plan of the university was not finalized it was proposed to use the approach of minimal intervention. The buildings were planned on one corner of the site using very small piece of land in order to have maximum flexibility for planning / design of master plan for entire site.



Topography

Gently sloping site- Gradient 1% - 2 % Highest point 101.5 m, Lowest point 83.5 m Generally loose earth with exposed rocks.

Excavated ditches in some parts on south west due to mining. Mining area to be dealt with carefully with eco-sensitive approach.

Wind flow and Vegetation

Wind direction in the region is mainly north westerly winds.

No prominent vegetation exist worth preservation

Vegetation on site is mainly thorny bushes xerophytic in nature.

Green pockets are found only near recharge structures.

A later study has shown that the site is part of a potential wind energy corridor therefore, half of the left part of the site has been reserved for wind mills.

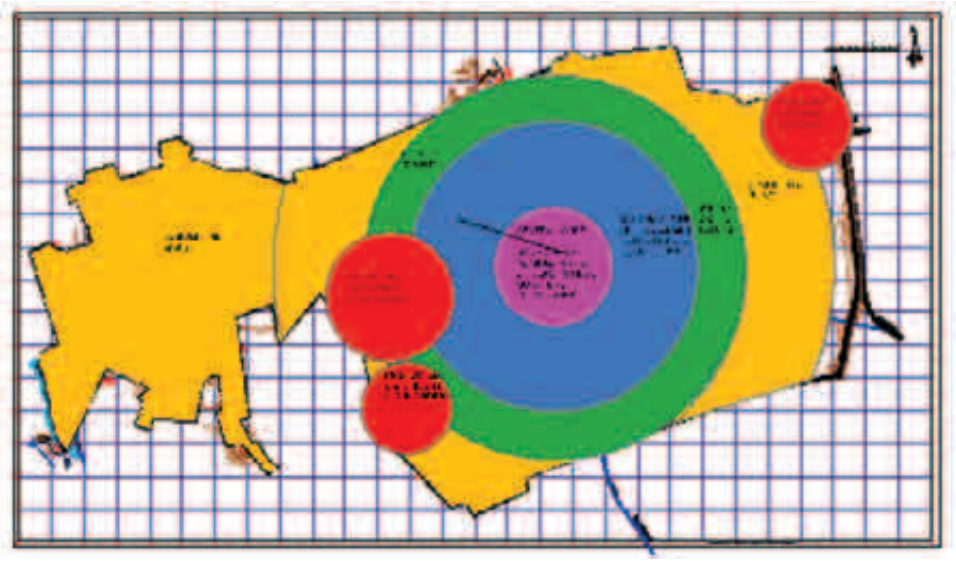
Hydrology

The storm water flow is mainly sheet flow in S-E and S-W from highest point. Three recharge earth bunds have been preserved and an additional bund has been created at the lowest point to contain Rain water runoff from site and recharge the aquifer.

Master Plan

A tentative master plan was prepared before the design of above buildings to justify the proposal.

Building Design



The proposal for providing comfort cooling (without refrigeration) in the Hostel buildings. Different options are given for the cooling for each of the Hostel buildings. Each Hostel building will have different air cooling system.

Design Goals for the Comfort Cooling System

- Low capital cost.
- Low operating cost.
- No use of Refrigerant.
- Maximum comfort by maintaining inside conditions below 30ºC
- Better Indoor Air Quality.

- Minimum Water Consumption.
- Use of geothermal energy.
- Minimize Environmental damage.
- Minimize Use of Energy.

Basis of Design

Outside Conditions	Summer	:	44°C DB ; 23.9°C WB
	Monsoon	:	35.0°C DB ; 28.3°C WB
	Winter	:	07.2°C DB ; 05.0°C WB
Outside Humidity	Summer	:	20%
	Monsoon	:	82%
	Winter	:	70%
Inside Conditions		:	To maintain the temperature in between 26°C- 30°C
Air Quantity	Approx.	:	15-20 Air changes/Hr and 10 ACPH for displacement ventilation
Occupancy		:	2 person/ Room
Fresh Air		:	Designed on 100% fresh air.
Equipment load		:	1.5 watts / sqft
Lighting load		:	1 watts / sqft

Option 1 : Hostel Building - 1

Earth Air Tunnel System with Evaporative Cooling

The heat will be rejected in two steps in this system.

The first stage of heat rejection will be inside the earth air tunnels.

The ambient air at 44 deg C will be brought down to 32-33 deg C.

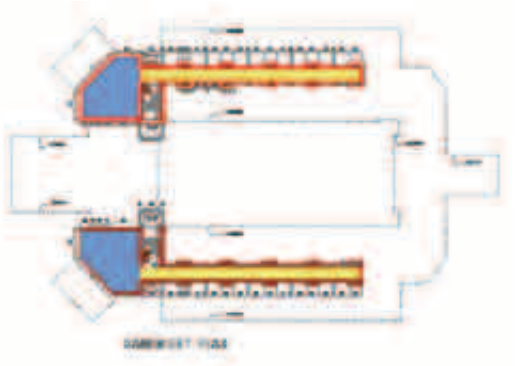
With the Earth Air Tunnel the air will be pre-cooled without adding any moisture to it.

There will be a special designed evaporative cooling unit after the Earth Air Tunnel.

The air coming from Earth Air Tunnel will be passed through the evaporative cooling unit which will bring down the temperature to 20-21 °C from 32 °C.

The cool air from the unit will then be passed into the rooms through insulated masonry vertical and horizontal ducts. The distribution

inside the rooms will be done through a special perforated Grilles at the floor level of each room.

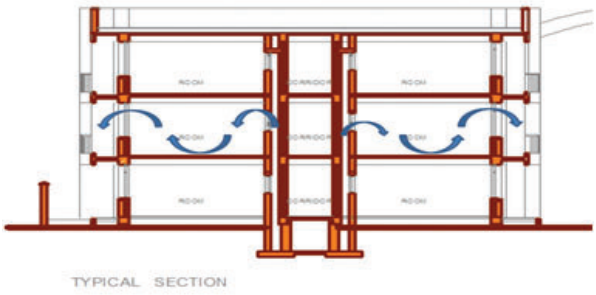


The exhaust air will be taken out through the grilles below the roof level of the Room.As the system is not based on mechanical exhaust the baffles needs to be placed after the exhaust grilles so that the exhaust air cannot be effected due to High atmospheric pressure outside the room.The temperature of 27-29 deg. centigrade will be maintained inside the room.The system is based on 100% fresh air supply to the hostel rooms.

Option2 : Hostel Building 2

Geothermal Boreholes with evaporative cooling

The system is based on 100% fresh air.



The heat from the ambient air will be rejected in two steps in this system.

The first stage of heat rejection will be done through the water in the pipes which is Inside the boreholes.

There will be a closed water loop inside the borehole.

The water from the geothermal boreholes will be pumped in the special designed AHU Coils where the heat rejection will take place.

The ambient air at 44 deg C will be cooled down to approx 35 deg C without adding Moisture it.

Evaporative cooling will be done in the second step inside the AHU.

The cool air from the unit will then be passed into the rooms through insulated G.I. vertical and horizontal ducts.

The distribution inside the rooms will be done through the grilles below the ceiling Level of each room.

The exhaust will be taken out from a lower level inside the room.

As the system is not based on mechanical exhaust the baffles needs to be placed after the exhaust grilles so that the exhaust air cannot be effected due to high atmospheric pressure outside the room.

The supply ducts will run on the ceiling level of the corridors on each floor.

The temperature of 27-29 degree centigrade will be maintained inside the room.

Option 3 : Hostel Building - 3

Two stage Evaporative cooling.

The first stage of two stage air washers will pre-cool the ambient air without adding any moisture to the air. The second stage of the two stage air cooling system will be the direct evaporative cooling. The first stage cooling is the alternative solution for the earth air tunnel system.The proposed two stage air cooling system is recommended because the region has hot and dry climate. The cool air will be taken through insulated G.I ducts to the rooms where the air will be exhausted out from the grilles. The temperature of 26-29 degree centigrade will be maintained at a certain air velocity inside the room which is quite comfortable. As the system is not based on mechanical exhaust the baffles needs to be placed. After the exhaust grills so that the exhaust air cannot be effected due to high atmospheric pressure outside the room.

Option 4 : Hostel Building – 4

Air cooling by wind towers with misting nozzles

This system will be based on 100% fresh air supply to the occupants. The concept of the system for the hostel building is that we will have a wind catcher which will bring the air from the fourth floor level to the ground floor level and in between the air will be cooled through the mist. There will be misting nozzles inside the wind tower through which the dry and warm ambient air will be passed. The temperature of the air will be brought down to 24–25 deg C with the addition of moisture in it from misting nozzles. This cool air will be supplied to the rooms with the help of the blowers in the AHU Room on ground floor through insulated G.I. ducts. The wind catcher will be made of masonry and it will be insulated.

Results

As the university was running in the rented premises about 25 Km from the site and was not able to get additional accommodation for running new courses it was decided to finish the buildings without installing the cooling systems as mentioned above. Only the features to be inbuilt in the structures were completed such as:

i. The Walls of the habitable spaces (HOSTEL ROOMS) were insulated with XPS Panels,

ii. The roof of the building was insulated with XPX foam,

iii. Stone frames for Doors were installed,

iv. UPVC window frames with double glass panes were installed.

v. Vertical shafts for earth Air Tunnel,

vi. Basement with Earth Air tunnel Shaft constructed under the corridor.

vii. Orientation of building is such that the habitable spaces are insulated by placing non-habitable spaces on east and west sides in order to reduce radiation.

viii. The shape of building is designed as/ best orientation.

Findings

It is found that a temperature difference of 5 ºC has been recorded in the insulated areas and non insulated areas.

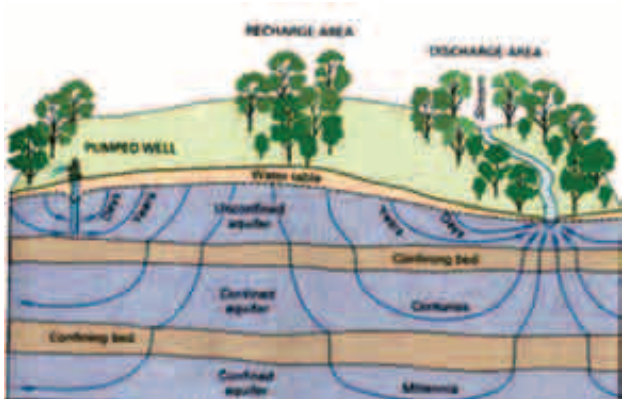
A temperature difference of 10-15 ºC has been recorded between inside and outside temperature.

Chapter – 13
Rainwater Harvesting
Selection of Appropriate Techniques

(Sudhir Kamal Seem, M. Arch. (Landscape), Senior Architect, CPWD)

What is Rainwater Harvesting?

The principle of collecting and using precipitation (rainwater) from a catchment surface is called rainwater harvesting. It takes few days to several centuries to replenish and recharge the rain water in the aquifers in ground.



There are two main techniques of rainwater harvestings:

- Storage of rainwater on surface for future use.
- Artificial Recharge to ground water.

Artificial Recharge to Ground Water

Artificial recharge to ground water is a process by which the ground water reservoir is augmented at a rate exceeding that obtaining under natural conditions or replenishment. Any man-made scheme or facility that adds water to an aquifer may be considered to be an artificial recharge system.

Components of a Rainwater Harvesting System

A rainwater harvesting system comprises of various stage components - transporting rainwater through pipes or drains, filtration, and storage in tanks for reuse or recharge. The common components of a rainwater harvesting are.

Pits

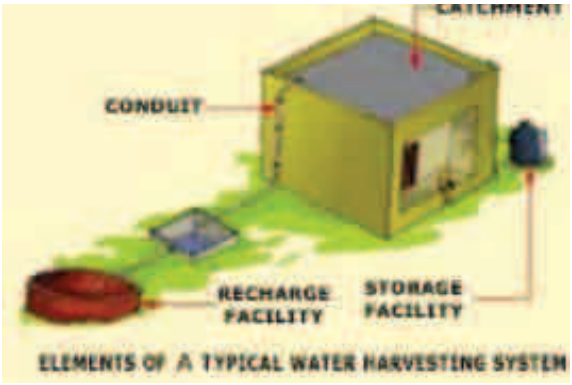
Recharge pits are constructed for recharging the shallow aquifer. These are constructed 1 to 2m, wide and to 3m. deep which are back filled with boulders, gravels, coarse sand.

Trenches

These are constructed when the permeable stream is available at shallow depth. Trench may be 0.5 to 1m. wide, 1 to 1.5m. deep and 10 to 20m. long depending up availability of water. These are back-filled with filter material.

Dug Wells

Existing dug wells may be utilized as recharge structure and water should pass through filter media before putting into dug well.



ELEMENTS OF A TYPICAL WATER HARVESTING SYSTEM

Hand Pumps

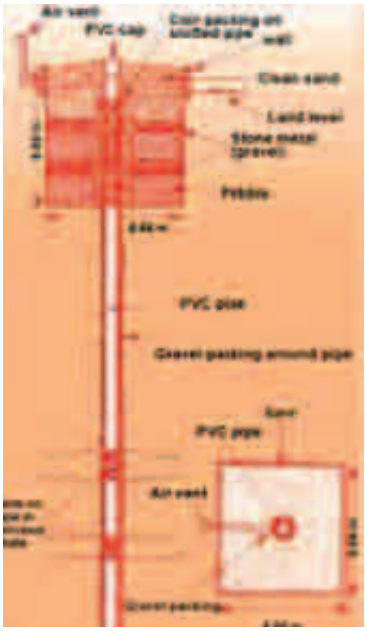
The existing hand pumps may be used for recharging the shallow/deep aquifers, if the availability of water is limited. Water should pass through filter media before diverting it into hand pumps.

Recharge Wells

Recharge wells of 100 to 300 mm. diameter are generally constructed for recharging the deeper aquifers and water is passed through filter media to avoid choking of recharge wells.

Recharge Shafts

For recharging the shallow aquifer which are located below clayey surface, recharge shafts of 0.5 to 3m. diameter and 10 to 15m. deep are constructed and back filled with boulders, gravels & coarse sand.



Lateral Shafts with Bore Wells

For recharging the upper as well as deeper aquifers lateral shafts (1.5 to 2m. wide & 10 to 30m. long depending upon availability of water with one or two bore wells) are constructed. The lateral shafts are back filled with boulders, gravels & coarse sand.

Spreading Techniques

When permeable strata start from top then this technique is used. Spread the water in streams/Nalas by making check dams, nala bunds, cement plugs, gabion structures or a percolation pond may be constructed.

" Since June 2001, the Ministry of Urban Affairs & Poverty Alleviation has made rainwater harvesting mandatory in all new buildings with a roof area of more than 100 sqm and in all plots with an area of more than 1000 sqm, that are being developed"

Selection of Appropriate Rain Water Recharge Structure for Different Areas in Delhi

Groundwater is one of the major sources for water supply in many parts of the country. In Delhi too ground water contributes to substantial quantity of supply. The groundwater is largely being utilized as a drinking water and for agriculture in a large area of the city because of the insufficiency of water from the River Yamuna.

Groundwater collects in the aquifers over thousands of years through infiltration and groundwater flow recharge. A particular amount of groundwater is replenished regularly through rainwater infiltration. Sustainable use of groundwater means withdrawal of groundwater at a rate at which it is replenished through recharge. Faster withdrawal rate would lead to fall in water table and finally depletion of groundwater.

The groundwater recharge areas need to be identified so that maximum recharge can be achieved. The recharge areas needs to conserved and preserved for the sustainable management of groundwater and to maintain the potential of the groundwater in Delhi. According to the Central Ground Water Board the recharge area identified is the northernmost part of the city. Areas, where the ponds already exist in the villages, the Najafgarh Lake and its surroundings and Delhi region between the northern ridges can also be used.

The city of Delhi comprises of four distinct physiographic units that influence and control the groundwater occurrence and movement in the city.

i. The ridge,
ii. Alluvial Plains,
iii. River Yamuna flood plains,
iv. Chattarpur Alluvial Plains.

Further the area is divided as per the soil strata and other physiological conditions:

Kohi

Area immediately south of Delhi that includes Ridge, Mehrauli, Toughlaqabad etc. the area is rocky and undulating in nature and is a limited source of groundwater which is confined to fractured planes and weathered zones of the ridge.

Khadar

The low lying area of plains that is liable to inundation during floods. It has light sandy soil.

Bangar

The area north of ridge is characterized by patches of saline efflorescence which is the result of composition of alluvium and gentle slopes of the land.

Dabar

The low lying basin situated west of ridge and consists of low ground or the basin scooped out by their westward drainage.

The Surface Geology, Groundwater Level and Water Quality of various parts of Delhi are shown on the table-1.

Techniques Suitable for Groundwater Recharge for Different Locations

A correct understanding of hydrology, geomorphology and geography of the area are important in successful implementation of any artificial recharge scheme. Recharge structures suitable for different area of the city are suggested on the basis of the following study.

References:

i. CGWC, Govt. of India.
ii. National Building Code
iii. Making Water Everybody's Business
iv. Jeyakumar; Rain water Harvest Manual
v. cleanwater@aquasure.nl

Table-1

Surface Geology and Water Quality

S.No	Area basin	Surface geology	Water level	Water quality	Recommendations
1	Kanjhawala	clay & Kankar formation exists upto a depth of 8m below ground level which is followed by layer of Kankar and silt which exists up to a depth of 24m bgl, which is followed by impermeable layer of clay and kankar from 24 to 42m bgl	fresh water is of limited depth only. The area is dominated by saline water aquifer. The amount of fresh water is decreasing due to extraction.	In Kankhawala the fresh water is of limited depth only. The area is dominated by saline water aquifer. The amount of fresh water is decreasing due to extraction	The intake capacity of recharge structures will be low in shallow water table condition.
2	Dwarka	clay and kankar formation exists in the top layer up to a depth of 4m below ground level. This layer of clay is followed by Kankar and silt up to a depth of 68m below ground level.	A comparative study of water level map of 1960 and 2002 shows in Dwarka the water level which was at 2 to 5m below ground level has gone down to 5 to 10 mts below ground water level.	In Dwarka the occurrence of fresh water in alluvium formation is up to a depth of 18mts. Below that level saline or brackish water occurs. The amount of fresh water is decreasing due to extraction.	The intake capacity of recharge structures will be low in shallow water table condition. Hence in Dwarka where the ground water level is below 10m rainwater harvesting can be taken up. The project was designed by CGWB.
3	Alipur	In the Alipur the first sand formation exists up to a depth of 12m below ground level(bgl), which is followed by layer of Kankar and silt which exists up to a depth of 16m bgl, which is followed by impermeable layer of clay and kankar from 16 to 20m below ground level. This clay layer is followed by layer of Kankar and silt up to 50m depth	A comparative study of water level map of 1960 and 2002 shows in Alipur the water level which was at 2 to 5m below ground level has gone down to 5 to 10 mts below ground water level	In Alipur the occurrence of fresh water in alluvium formation is up to a depth of 30m to 60m. Below that level saline or brackish water occurs. The amount of fresh water is decreasing due to extraction.	he intake capacity of recharge structures will be low in shallow water table condition. Hence in Alipur where the ground water level is below 10m rainwater harvesting can be taken up.

4	Central Ridge	In the Rastrapathi Bhavan the first Layer of clay and sand extends to depth of 3m, which is followed clay inter mixed with Kankar 8m below ground level. This is followed by layer of sand between 8 to 10m. This is followed by weathered and fractured quartzite, which extends up to 40m bgl. This is followed by partially fractured quartzite, which extends to greater depths.	A comparative study of water level map of 1960 and 2002 shows in Rastrapathi Bhavan the water level which was at 5 m bgl has gone down to 10 to 15 mts bgl.	In Rastrapathi Bhavan fresh water occurs at all depths	In this area the rainwater can be diverted to the weathered and fractured quartzite formations
		In the Lodi road area the first Layer of clay and kankar extends to depth of 8m bgl. This is followed by kankar and silt up to 20m, this layer is again underlain by clay and kankar up to 50m bgl.	A comparative study of water level map of 1960 and 2002 shows in Lodi road the water level which was at 5 to 10m below ground level has gone down to 10 to 15 mts below ground water level	In Lodi Road fresh water occurs in shallow zones.	In this area shallow recharge wells can be constructed. The non potable water from the subsurface formation can be used for non potable water.
	Vasant Kunj	In the Vasant Kunj area the first Layer of clay and kankar extends to depth of 12m bgl. This is followed by layer of kankar and silt from 12 to 25m below ground level. This is again underlain by layer of clay and kankar which extends even beyond 40m bgl	A comparative study of water level map of 1960 and 2002 shows in Vasant Kunj the water level which was at 5 to 10m below ground level has gone down to 20 to 30 mts below ground water level	In Vasant kunj fresh water occurs at all depths.	In this area the rainwater can be diverted to a depth of 15 to 20mts. By doing this the rainwater will undergo a natural filtration in the subsoil before it reaches the main aquifer. The recharge bore in the recharge well should be of 15 to 20mts bgl.
	Chattarpur Basin.	In the Hamdard area the first Layer of clay and kankar extends to depth of 8m bgl. This is followed by a layer of kankar and silt up to 20m, this is under lain by weathered and fractured quartzites.	A comparative study of water level map of 1960 and 2002 shows in Hamdard the water level which was at 20 to 30m below ground level has gone down to 30 to 45 mts below ground water level.	In Hamdard the fresh water occurs at all depths.	In this area the rainwater can be diverted to a depth of 20 to 25mts. By doing this the rainwater will undergo a natural filtration in the subsoil before it reaches the main aquifer. The recharge bore in the recharge well should be of 20 to 25mts bgl depth.

		In the Patparganj the first sand formation exists up to a depth of 20m below ground level (bgl), which is followed by impermeable layer of clay and kankar and silt which extends from depth of 20 to 28m bgl, which is followed by layer of kankar which extents up to 40m and below	comparative study of water level map of 1960 and 2002 shows in Patparganj the water level which was at 0 to 2m below ground level has gone down to 5 to 10 mts bgl	In Patparganj the occurrence of fresh water in alluvium formation is up to a depth of 30m to 60m. Below that level saline or brackish water occurs. The amount of fresh water is decreasing due to extraction.	The area falls in the flood plain of Yamuna, so the intake capacity of recharge structures will be low in shallow water table condition. Hence in Patparganj where the ground water level is below 10m rainwater harvesting can be taken up.

Table – 2

Suitable for Ground Water Recharge for Different Locations

Location	Suitable Structures	Examples
The Ridge Area Because of its quartzes formation and low top soil in some area have high rate of run-off and low percolation, it has a high fluctuation in water table due to high density development on and around it.	**Check Dam** Shall be constructed in the ridge area to reduce run-off and increase percolation in fractured parts of rock. Recharge Pits & shaft: these structures can also be adopted since surface is not porous hence no percolation possible.	**J.N.U. and IIT** Four Check Dams have been constructed in JNU and a rise of 4m to 13.5m has been recorded as per a study conducted in 2004.
Flood Plains of Yamuna The area being flood plains of the river have low water fluctuation but the quality of water is no good because of pollution in the river.	**Lateral Shafts** These are most suitable structures for the area because of • Shallow water table &. • Poor water quality.	**Shram Shakti Bhawan** Three lateral shafts with two injection wells have been constructed. An actual rise of 2m has been recorded in 2004.
Older Alluvial Plains The area on the west of ridge with the sand deposits and deposits of runoff from the ridge. The area being low lying and gently sloping to the west and south-west contains large amount of clay and windblown sand thereby increasing the porosity and low permeability.	**Injection Wells** Injection wells are most suitable for the area of Najafgarh and Alipur blocks. Water logging can be a problem if recharge pits are adopted since the area is low lying. Only deep recharge pits/wells are suitable.	**Link Road Dwarka** Recharge shafts have been proposed to be adopted along the road or recharge the underground aquifer.

Chattarpur Basin The area is an isolated basin that includes chatarpur and parts of Mehrauli.	**Recharge Shafts** can be used in this area since the area consists of isolated basin and sol with high porosity and low permeability. Check Dams can be proposed in some parts of Mehrauli Basin.	**Central Park, Vasant Vihar** Recharge wells in combination of trenches and abandoned wells have been used to recharge the rain water.

Chapter - 14

Garden Design and Selection of Plant Material

(Sudhir Kamal Seem, M. Arch. (Landscape), Senior Architect, CPWD)

Though there are many garden design rules, but no hard and fast rule as such. So there is always a scope to give your garden your own personal touch. The only person you really have to please is yourself. Often our gardens are created in a haphazard manner, with whatever plants are at hand or strike our fancy. There are some key elements that make a garden feel more cohesive. Things like repetition and focal points and colors that don't compete with one another are often easier in theory than in practice, following ideas can be considered and to be incorporated in the garden.

1. Garden Bones

Of all the garden design elements, garden bones are the hardest to incorporate after the fact. Like a building or a story, you need a solid structure before you start filling in the details. The garden where all the plants are of a similar size or height, the garden looks very monotonous. Small trees and shrubs are often used to provide the bones of a garden and evergreens are classic. It may not be possible to have a hedge of evergreens as a backdrop or border, but dwarf evergreens also look good.

2. Color

Most garden design advice begins with a discussion of color, texture and form. Color is arguably the most prominent factor in a garden design and often the first one considered. Color is what most gardeners are drawn to. We know what we like when we see it. Good garden design involves knowing how to combine colors so that the final product will be one we like. It is also a good point at times to combine colors like blue and yellow,that make their opposites appear more vibrant.

3. Focal Points

Ideally, a garden should not be able to be taken in one glance. It should be a leisurely discovery. An easy way to accomplish that is to include focal points in your garden. Focal points can be large plants, structures or ornaments and their function is to grab the eye's attention and

then direct to the surrounding plants. Don't think your garden is too small to have a focal point. Even containers need a focal point to anchor them.

4. Texture

Plants with different textures spot light the key attributes of each other. Somebody may love soft, billowy plants but an entire garden of them will look like a blur. One needs the contract of coarser leaves or wide, bold foliage. It's the contrast that gives your garden a crisper definition and keeps it from looking two dimensional. Luckily, texture is one of the easiest garden design elements to conquer.

5. Sound

Sound is probably not at the top of the list, when one thinks about things to include in the garden design. But sound is what breathes life into a garden. Whether it's the wind rustling plants, the sound of gravel crunching under foot, bird songs or trickling water, sound should be considered and planned for. It can be as easy as using plants with seeds for the birds or as complicated as a series of waterfalls.

Selection of Healthy Plant Material for Garden

At first glance, all the plants in the nursery look lush and glorious. Usually they are.

However there are times when a few quick checks can prevent us from bringing them home. It is always advised to take some time to look over the plants before it is purchased and introduced in the garden.

The following points must be kept in mind before selecting and purchasing plants :

1. **Quality of Nursery :** Take in an overview of the plant department. Look to see that the majority of the plants seem healthy and well cared for.

2. **Foliage:** Evaluate the condition of your specific plant. See that the leaves are green, shiny and lush. Steer clear of any plants that are wilting or yellowing. Stressed plants may or may not recover.

3. **Shape:** Consider the shape of the plant. It should be compact and full, with multiple stems. Taller sapling is often not better. It could mean the plant has been straining for light and has grown thin and spindly.

4. **Insects & Disease:** Inspect closely for signs of insects or disease. Check both sides of the leaves and the potting soil. Signs can include: blackened areas, holes, spots, mushy areas, stickiness and distortions.

5. **Root System:** Don't neglect the roots. If the plant is pot bound and the roots are growing out of the bottom, the plant may be stressed and take time to recover. If there aren't many roots and the plant lifts out very easily, it was probably recently repotted and could use more time to become garden worthy.

6. **Stem Damage:** If the plant has a thick or woody stem, make sure there are no cracks or scars. Even prior damage can weaken a plant.

7. **Weeds:** Weeds in the pot are competing with the plant for nutrients. They also signal some neglect on the part of the nursery staff.

8. **Root Ball:** When buying a balled and bur lapped tree or shrub, the root ball should feel solid. If it appears broken, there's a good chance the roots have had a chance to dry out and the plant will suffer.

9. **Buds & Flowers:** Plants in bud will transplant and thrive better than plants in flower.

10. **When All is Said and Done:** If you've just got to have it, go ahead and buy the plant. With a little pampering, it just may defy the odds.

11. **Orientation:** Note the orientation of the plant in the nursery and mark the same on the sapling before lifting from its original position. Plant the sapling as soon as possible in new location keeping the orientation of the plant same.

Containers and Pots for Gardens

Selecting Containers : Containers for Gardens can be almost anything: flower pots, pails, buckets, wire baskets, bushel baskets, wooden boxes, nursery flats, window planters, washtubs, strawberry pots, plastic bags, large food cans, or any number of other things. The containers should be selected keeping in mind the type of plant, it size, spread, foliage type, colour and requirements of sun and water etc.

Drainage: No matter what kind of container one chooses for the garden, it should have holes at the base or in the bottom to permit drainage of excess water.

Color Considerations : one should be very careful when using dark colored containers because they absorb heat which could possibly damage the plant roots. If you plan to use/ select dark colored pots, try painting them a lighter color or shading just the container, not the plants.

Size : The size of the container is important for larger plants. You can grow large plants in bigger containers; however they need to be provided with considerably more water.

Soil and Fertilizer

You can use soil in your container, but potting mixes are much better. Peat-based mixes, containing peat and vermiculite, are excellent. They are relatively sterile and pH adjusted. They also allow the plants to get enough air and water. Mixing in one part compost to two parts planting mix will improve fertility.

Using a slow release or complete organic fertilizer at planting will keep your plants fed for the whole growing season.

Watering

Pots and containers always require more frequent watering than plants in the ground. As the season progresses and your plants mature, their root system will expand and require even more water. Don't wait until you see the plants wilting. Check your containers daily to judge the need for water.

Wind

Wind can be a real hazard for any container grown plant. Try to place your containers so that they are not in an overly windy location. A breeze will provide nice air circulation and help prevent fungal diseases, but a strong wind can topple plants and containers and can also shred leaves and dislodge fruits/ flowers. If the garden is on a raised deck or a roof top, it may be necessary to provide some type of wind block.

Transplanting Trees and Shrubs

Transplanting trees and shrubs appears an easy task — deceptively so. Many transplants die due to improper removal or installation. But if you're about to give a facelift to a landscape design that has been neglected for years, then you will need to move existing plant matter, whether for relocation or for disposal. To do it successfully, you must take steps to improve the likelihood of survival.

Here's How

1. Location: Prior to transplanting, determine whether the tree or shrub likes sun or shade, and what its spacing and watering requirements are. For instance, don't locate a plant that craves water next to one that prefers dry conditions: their needs will be incompatible.

2. Dig the new hole before you dig up the tree or shrub. Once you dig up the plant, the longer its roots go without a home, the lower your chances for successful transplanting.

3. Estimate the width and depth of the root-ball by doing a bit of exploratory digging around the plant. The width of the new hole should be twice that of the root-ball. The depth should be kept a bit shallower, to avoid puddling and consequent rotting.

4. When you reach the bottom of the new hole, resist the temptation to break up the soil beneath. You would think that this would help the tree or shrub, allowing its roots to penetrate deeper. Instead, it could cause the tree or shrub to sink, inviting rot.

5. Dig out the tree or shrub selected for transplanting. But don't start digging right at the base of a mature tree or shrub. Rather, start digging about 3' out from the base, all along the

perimeter. Get a feel for where the main mass of roots lies. Also begin to judge what the weight will be of plant + roots + soil clinging to roots. You may need someone to help lift it!

6. The idea is to keep as much of the root-ball (roots + soil) intact as possible. But the larger the plant is, the chances of getting anything close to the entire root-ball will diminish — and you wouldn't be able to carry it anyhow! Usually you will have to cut through some roots on a mature plant (either with a sharp shovel or with pruners — make a good, clean cut).

7. Once you've removed enough soil from around the sides of the plant, you'll eventually be able to slip your shovel under it and begin to loosen the plant's grip on the soil below it. After it's loose, spread a tarp on the ground nearby and gently move the tree or shrub onto the tarp.

8. Using the tarp as a transporting medium, drag the tree or shrub over to the new hole step by step. Gently slide it into the hole, and get it straight. Shovel the excavated soil back into the hole. Tamp this soil down firmly and water it, to eliminate air pockets. The formation of air pockets could cause the tree or shrub to shift after transplanting.

9. Mound up the soil in a ring around the newly transplanted tree or shrub, forming a berm that will catch water like a basin. This will help you achieve your main objective from here on out — keeping the new transplant's roots well watered, until it becomes established.

10. Spread a 3" layer of landscape mulch around the new transplant. But keep it a few inches away from the base of the tree or shrub, to promote air circulation and so as not to invite rodents from nibbling on the trunk. Rodents become emboldened by the cover mulch provides.

11. Water: The first summer would be a difficult one for the plant to weather, unless it gets plenty of water. Watering is as essential as anything to success in shrub and tree transplanting.

Important Tips for Transplanting

1. When should you do your shrub and tree transplanting?

   For most trees and shrubs late winter or early spring are the best times for transplanting; fall would be the second best time. In summer it's not advisable. In the dead of winter it's almost impossible (in the North) — unless you've done all your digging ahead of time (before the ground freezes).

2. The time given for this transplanting project is 2 hours. However, that will depend greatly on the circumstances. To dig a mature tree or shrub out of rocky soil (especially in cramped quarters) is back-breaking work.

References :

Garden Design - Putting it all together, http://gardening.about.com/od/gardendesign/Garden_Design

Chapter - 15

Persian Garden

(Sudhir Kamal Seem, M. Arch. (Landscape), Senior Architect, CPWD)

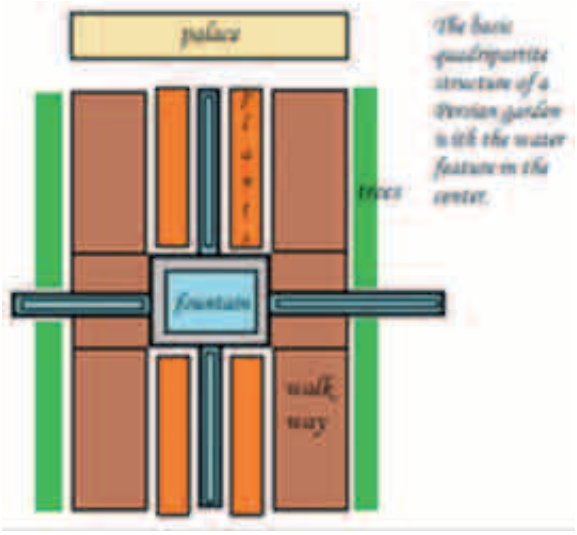
*The Avestan word pairidaça-, Old Persian *paridaida-, Median *paridaiza- (walled-around, i.e., a walled garden), was borrowed into Ancient Greek: parádeisos, then rendered into the Latin paradîsus, and from there entered into European languages, e.g., French paradis, German Paradies, and English paradise.*

From the earlier times the idea of an earthly **paradise** spread through Persian literature and to other cultures, both the Hellenistic gardens of the Seleucids and the Ptolemies in Alexandria.

"The god has actually defined paradise as Garden, and it is up to individual not only to aspire to it in the after-life, but also to try to create its image hare on earth"

It is with this theme in mind that the Persian gardens have been created as a model of orderly paradise, devised in the flat deserts of Persia. As greater part of Persia is arid, lacking water and vegetation. It is largely composed of elevated and level land with area of barren plain stretches as far as an eye can see, and for the most part of the year it is extremely hot.

The Persian gardens are enclosed, fertile and rich with fruits and flowers in contrast to the draught, heat and sun outside it has water, coolness and shade. It has order and tranquility, and it is place where one may sit shade and relax, enjoy the sound of birds, water flow and fragrance of flowers.

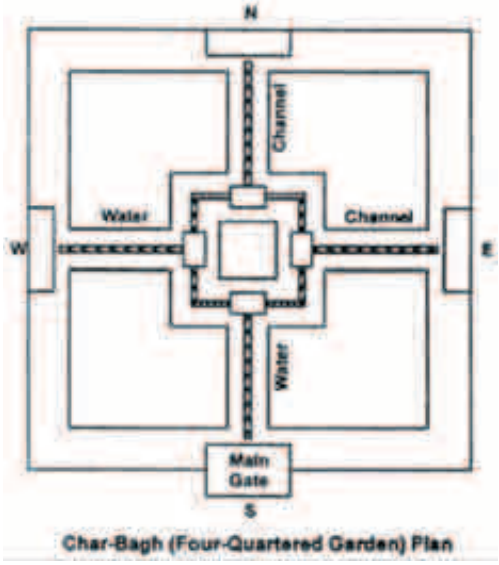


The tradition and style in the design of **Persian gardens**, has influenced the design of gardens from Andalusia to India and beyond. The Persian garden is an enclosed space (preferable a square) in its centre is a water source from which channels carrying water divide it into quarters. Each quarter is further divided into quarters and if the garden is large it is divided in further smaller quarters.

Taj Mahal is one of the largest Persian Garden interpretations in the world, from the era of the Mughal Empire in India. It has the elements of a **Persian Garden-** the Enclosure, the Quadrangles, Water channels, Groves of Trees and Plants, Pavilions, Boarders of pathways and lawns.

As the word expresses, such gardens would have been enclosed. The garden's purpose was, and is, to provide a place for protected

relaxation in a variety of manners: spiritual, and leisurely (such as meetings with friends), essentially a *paradise on earth*. The Common Iranian word for "enclosed space" was **pari-daiza-* (Avestan *pairi-daça-*), a term that was adopted by Christian mythology to describe the garden of Eden or Paradise on earth.



Char-Bagh (Four-Quartered Garden) Plan

The garden's construction may be formal (with an emphasis on structure) or casual (with an emphasis on nature), following several simple design rules.During the Arab occupation, the aesthetic aspect of the garden increased in importance, overtaking utility. During this time, aesthetic rules that govern the garden grew in importance.

An example of this is the *chahâr bâgh*, a form of garden that attempts to emulate Eden, with four rivers and four quadrants that represent the world. The design sometimes extends one axis longer than the cross-axis, and may feature water channels that run through each of the four gardens and connect to a central pool.

The invasion of Persia by the Mongols in the thirteenth century led to a new emphasis on highly ornate structure in the garden. The Mongol empire then carried a Persian garden tradition to other parts of their empire (notably India).

Use of Vegetation

Planting of trees and selection of species was carefully done in order to improve micro climate inside the gardens.

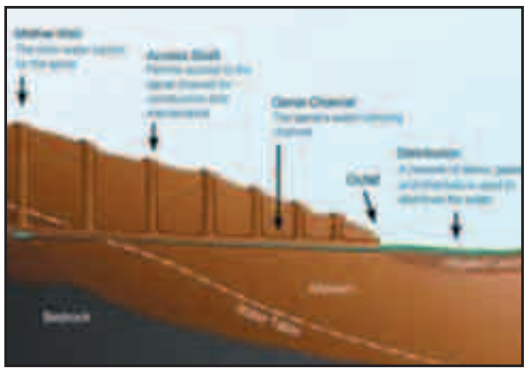
Elements of the Persian garden, such as the shade, the *jub*, and the courtyard style *hayât* in a public garden in Shiraz.

Sunlight and its effects were an important factor of structural design in Persian gardens. Textures and shapes were specifically chosen by architects to harness the light.

Iran's dry heat makes shade important in gardens, which would be nearly unusable without it. Trees and trellises largely feature as biotic shade; pavilions and walls are also structurally prominent in blocking the sun.

The heat also makes water important, both in the design and maintenance of the garden. Irrigation may be required, and may be provided via a form of underground tunnel called a *qanat*, that transports water from a local aquifer. Well-like structures then connect to the qanat, enabling the drawing of water. Alternatively, an animal-driven Persian well would draw water to the surface. Such wheel systems also moved water around surface water systems, such as those in the *chahar bâgh* style. Trees were often planted in a ditch called a *jub*, which prevented water evaporation and allowed the water quick access to the tree roots.

The Persian style often attempts to integrate indoors with outdoors through the connection of a surrounding garden with an inner courtyard. Designers often place architectural elements such as vaulted arches between the outer and interior areas to open up the divide between them.



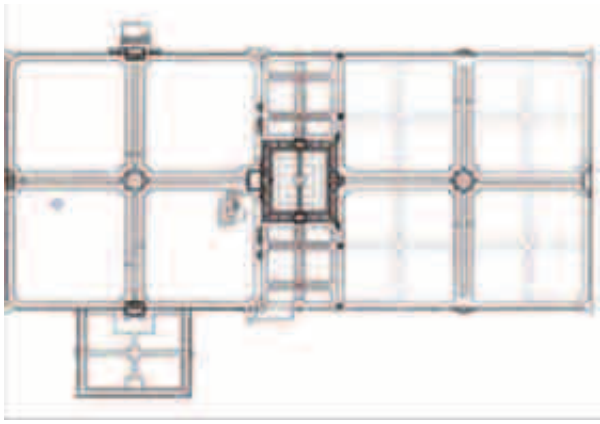
QANAT : WATER MANAGEMENT SYSTEM

Historical Descriptions

The oldest representational descriptions and illustrations of Persian gardens come from travelers who reached Iran from the west. These accounts include Ibn Battuta in the fourteenth century, Ruy Gonzáles de Clavijo in the fifteenth century and Engelbert Kaempfer in the seventeenth century. Battuta and Clavijo made only passing references to gardens and did not describe their design, but Kaempfer made careful drawings and converted them into detailed engravings after his return to Europe. They show chahar bâgh type gardens that featured an enclosing wall, rectangular pools, an internal network of canals, garden pavilions and lush planting. There are surviving examples of this garden type at Yazd (Dowlatabad) and at Kashan (Bâgh-e Fin). The location of the gardens Kaempfer illustrated in Isfahan can be identified.

Styles of Persian Gardens

The six primary styles of the Persian garden may be seen in the following table, which puts them in the context of their function and style. Gardens are not limited to a particular style, but often integrate different styles, or have areas with different functions and styles.



	Classical	Formal	Casual
Public	Hayât	Meidân	Park
Private	Hayât	Chahar Bâgh	Bâgh

Hayât

Publicly, it is a classical Persian layout with heavy emphasis on aesthetics over function. Man-made structures in the garden are particularly important, with arches and pools (which may be used to bathe). The ground is often covered in gravel flagged with stone. Plantings are typically

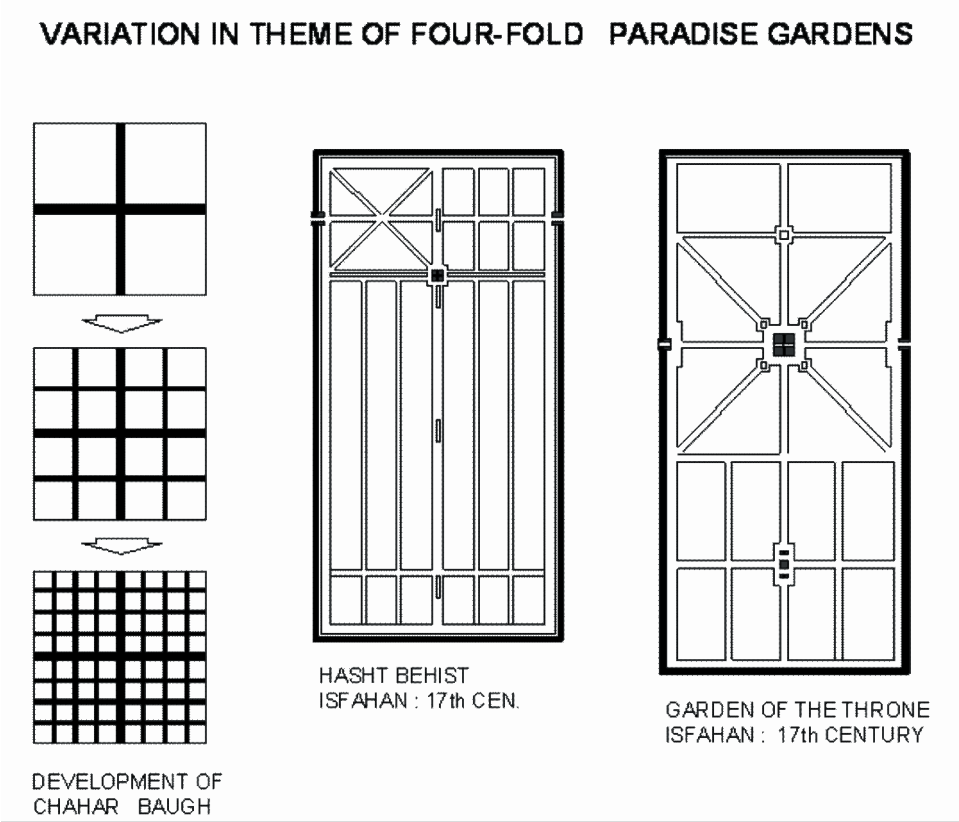
very simple - such as a line of trees, which also provide shade. Privately, these gardens are often pool-centred and, again, structural. The pool serves as a focus and source of humidity for the surrounding atmosphere. There are few plants, often due to the limited water available in urban areas.

Meidân

This is a public, formal garden that puts more emphasis on the biotic element than the *hayât* and that minimises structure. Plants range from trees, to shrubs, to bedding plants, to grasses. Again, there are elements such as a pool and gravel pathways which divide the lawn. When structures are used, they are often built, as in the case of pavilions, to provide shade.

Chahar Bâgh

These gardens are private and formal. The basic structure consists of four quadrants divided by waterways or pathways. Traditionally, the rich used such gardens in work-related functions (such as entertaining ambassadors). These gardens balance structure with greenery, with the plants often around the periphery of a pool and path based structure.



Park

Much like many other parks, the Persian park serves a casual public function with emphasis on plant life. They provide pathways and seating, but are otherwise usually limited in terms of structural elements. The purpose of such places is relaxation and socialisation.

Bâgh

Like the other casual garden, the park, *bâgh* emphasizes the natural and green aspect of the garden. Unlike the park it is a private area often affixed to houses and often consisting of lawns, trees, and ground plants. The waterways and pathways stand out less than in the more formal counterparts and are largely functional. The primary function of such areas is familial relaxation.

Concept of Persian Garden Carpet

Source: Victoria & Albert Museum

A Persian carpet of 17th or 18th century is a rectangle. Has a regular border of flowers and leaves and is followed by a wider one of trees- thin and pointed cypress- and shrubs. Each of these borders is enclosed by a thin band with an abstract pattern, suggestion boundary walls and paths. Within these boarders is the garden proper, divided into sections by four "river".

The four quarters are equal in size, each being divided into six squares. They contain alternately flower with flowers and chenar trees, of which four, the most prominent, grow outwards from the central floral design.

Both cypress on boundary and chenar have been planted to serve as the symbol of eternity and aesthetic importance. Cypress - eternity and earthly equivalent of LOTE tree. Chenar- is an earthly equivalent of TUBA tree, the great giver of shade as per KORAN. The central square and circle design is symbolic of perfection.

References :

i. Study material of SPA, M. Arch.(Landscape)

ii. Persian Gardens, Ankit Singhal.

iii. http://www.google.co.in/persian+gardens

iv. Victoria & Albert Museum.

Chapter - 16

English Gardens in India

Lodi Gardens, New Delhi - A Case Study

(Sudhir Kamal Seem, M. Arch. (Landscape), Senior Architect, CPWD)

New Delhi was designed by Edwin Lutyens and Herbert Baker as the new capital of British India. It is the last of the seven cities designed on the western plains of the river Yamuna in Delhi. Designed on the Garden city ideals of low density, openness and light, and contact with nature for all, the planning of New Delhi embraced the historic areas of Purana Qila and the tombs of the Lodi dynasty, the Mughal emperor Humayun and the tomb of Safdarjung.

As the building of new capital of India was in the making and was being made in classical style of architecture using Indian materials and construction practices the dominance of English style is still there. The influence of English garden can also be noted on the Lodi Garden.

Important features of English Garden

Set in the natural surroundings land in the European countries is rolling ground undulating landscape the English gardens/parks featured vast lawns, woods, and pieces of architecture, such as the classical mausoleum.

The Landscape Architects designed alleys into winding paths, built a gently turning stream, used the natural landscape features and slopes, and created a series of views and tableaus decorated with allegorical statues of Apollo, a wounded gladiator, a lion attacking a horse, and other subjects.

The gardens had “eye-catchers,” pieces of classical architecture, to decorate the landscape, and he made use of the “ha-ha,” a trench used to hide fences so the garden seemed to go into the far distance. The use of eye catchers was so important a part of these gardens that it almost became an essential element of the gardens.

Historical Background

Similar situation was found in the area known as the Bagh-I-Jud during the rule of the Lodi Sultanate Later on it formed a part of a larger necropolis of the Islamic rule in India, along with the Humayun’s Tomb and Safdarjung Tomb. In 1936, on completion of the layout of New Delhi, or Imperial Delhi as it was known then, the Lodi Tomb complex was designed as a park known as the Lady Willingdon Park, with native and exotic trees planted around the monuments.

Lodi Gardens: The Design Programme

In the design of the Lodi Gardens, Joseph Allen Stein teamed up with the landscape architecture firm of EDAW -Eckbo, Dean, Austin and Williams, from California. The programme was a part of an initiative of re-vitalization of the area known as the Lodi Estate on the edges of New Delhi. The Lodi Garden was designed as a part of the open space system of Lodi Estate, integrating the park and its historic structures with the new development at the fringe.

Design Features

Ëye Catchers

A picturesque garden, with the Monuments as eye -catchers. The two pictures given below show very striking similarities of using Monuments as Ëye Catchers"

Temple of Ancient Virtue at Stowe

Shish Gumbad in Lodi Garden

Use of vegetation as a Spatial

English Garden

Lodi Garden

Elements to Define Vistas and Linkages

- Planting features like the alleyé and clumps of vegetation to define and link the monuments.
- Use of vegetation in the horizontal and vertical planes in an asymmetric manner to highlight the monument-the eye catcher

- Mixing of vegetation species to generate effects of texture, impermeable backdrops and silhouette


- Use on natural, Man-made elements in landscape


- Winding paths are used to create different views along the path to make the garden picturesque.




Changes in the Planting Structure

Over the years, Lodi gardens have seen a variety of changes in the manner of use of plant material. This has created new dimensions in the interaction of the monuments with the landscapes, and the resultant visual perception. The Thuja orientalis shrubs were replaced by Roystonea regia (Royal palms), forming a square enclosure along the pedestrian paths around the entire monument. A clipped hedge of Ficus benjamina runs along the perimeter of the lawns of the monument.

Trees of Lodi Gardens

Today there are over a hundred varieties of trees in Lodi gardens. This is a partial list documenting the local, native and exotic species:

Acaia auriculiformis Vilayti babul

Acacia leucophloea Ronjh/ safed kikar

Ailanthus excelsa Maharukh/ uloo

Albizzia lebbeck siris

Albizzia procera Safed siris

Azadirachta indica neem

Bauhinia purpurea kachnar

Bauhinia racemosa kanchan

Butea monosperma Dhaak/ palash

Casaurina equisetifolia Vilayti jhau

Cassia fistula amaltas

Cassia siamea kassod

Callistemon lanceolatus *Bottle brush* Plumeria rubra/ alba champa

Chorisia speciosa Floss silk tree

Chukrasia tabularis chakarsi

Crateavea religiousa barna

Diospyros cordifolia bistendu

Ehretia canarensis Desi papri

Grevillea robusta Silver oak

Holoptelea integrifolia papri

Haplophragma adenophyllum

Lagerstroemia speciosa jarul

Madhuca latiflolia mahua

Magnolia grandiflora magnolia

Melia azederach bakain

Michelia champaca champa

Mimusops elengi Bakul/maulshri

Mimusops hexendra khirni

Morus indica shehtoot

Pithecolobium dulce Jangli jalebi

Polyalthia longifolia ashok

Prosopis cineraria jhand

Prosopis juliflora Vilayti kikar

Pterospermum acerifolium kanakchampa

Salvadora persica pilu

Eucalyptus citrodora safeda

Erythrina indica pangara

Anogeissus acuminata

Schleichera oleosa kusum

Taxodium distichum Bald cypress

References:

i. J.K. Maheshwari 1963)

ii. Shriganesh Ravindran, Landscape Research Work, M. Arch. SPA, New Delhi.

Chapter - 17

Organic Gardening Basics

(P.S.Sodhi, M. Arch. (Landscape), Architect, CPWD)

Organic gardening is not just about replacing harmful fertilizers and pesticides with natural alternatives. The art of organic gardening involves both theory and practice. The organic approach acknowledges the complexity of the natural world and aims to work within these systems.

What is Organic Gardening - The Basics for Gardening organically

The short answer is that organic gardening means not using synthetic products, including pesticides and fertilizers. Ideally, organic gardening replenishes the resources as it makes use of them. Like feeding depleted soil with composted plants, or planting legumes to add nitrogen to an area that had been planted with heavy feeder. The bigger picture involves working in cooperation with nature, viewing your garden as a small part of all the natural system.

What is meant by Organic Matter?

Organic matter is decaying plant and animal waste. It includes everything from compost, grass clipping, dried leaves and kitchen scraps to manures and fish heads. Organic matter is used as a soil amendment or conditioner. It can be worked into the soil of a new garden or used as a top dressing or mulch in an existing garden.

What's so Important about the Soil?

One of the basic tenants of organic gardening is to "Feed the soil and the soil will feed the plants". It's really common sense. Plants get water, air and nutrients from the soil. Clay soil is higher in nutrients than sand and hold water better. Sometimes it holds water too well and the plants can't get enough air. Sandy soil is well drained, but can use some amending to make it great garden soil. This is where organic matter comes into play. Adding organic matter improves any soil's texture as well as attracting soil organisms that create nutrients in the soil.

Soil

Conventional fertilizers are generally soluble, making their ingredients readily available. Organic gardening relies on soil-living creatures to make food available to plants.

Natural Pest Control

Organic gardening aims to attract natural pest controllers to your garden. Ladybeetles, birds and lizards all help to keep pests such as aphids, snails and insects in check in your garden. Other methods such as barriers and traps, disease and pest resistant plant varieties, and crop rotation also provide natural alternatives to pest control.

Managing Weeds

Weeds are a valuable composting resource but can also compete with other plants in your garden for food and water. Options such as hoeing (Godi), mulching or the use of solar heat are natural alternatives commonly used in an organic garden.

Environment

By minimising the impact on the environment organic gardening can help make a positive contribution to environmental sustainability. This means recycling and reusing, providing habitats for natural wildlife and the use of sustainable practices.

Diseases and Pests

Organic Gardening methods are great for protecting and nurturing your plants without having to resort to environmentally harmful practices. Organic gardening emphasises the balance between healthy soil, healthy plants and the health of your family and the wider community.

Organic gardeners work with natural systems to promote healthy gardens, with the ultimate goal of sustainability without the need for artificial chemicals or additives. Listed below are the main causes of disease and ill health in your garden.

General Growth Problems

Environmental factors can have profound effects on the overall health of your garden:

Water

Water shortages leave plants susceptible to disease and pest attack. Prolonged drought stunts plant growth and can alter the natural cycles of flowering etc.

Mineral Deficiencies

Minerals such as nitrogen, phosphorus, potassium and magnesium become unavailable to plants in extremely acidic soil and can lead to damaged leaf systems. Iron deficiency leaves plant leaves yellow in colour, however seemingly healthy. Well managed, biologically active, gardens utilizing compost and mulch tend to have only slightly acidic soils which promote healthy plant growth.

General good gardening

Many methods of organic control in the garden are simply examples of sound gardening practice.

Tip: Pests that are attracted to their host plant via smell can be confused by strong smelling companion plants e.g. inter-planting carrots with onions.

Garden Cleanliness

Carryover of pests and diseases from season to season can be prevented by good garden maintenance. A good compost heap can help kill of disease in older dead plants and methods such as winter digging can expose hibernating pests to predatory birds and ground insects.

Companion Planting

It is described as the growing of two or more different species of plant together for the benefit of one or both. For example many adult insects visit flowers for pollen and nectar and can be effective natural controllers of other unwanted pests.

Garden Cleanliness

Carry over of pests and diseases from season to season can be prevented by good garden maintenance. A good compost heap can help kill of disease in older dead plants and methods such as winter digging can expose hibernating pests to predatory birds and ground insects.

Companion Planting

It is described as the growing of two or more different species of plant together for the benefit of one or both. For example many adult insects visit flowers for pollen and nectar and can be effective natural controllers of other unwanted pests.

Using Natural Predators

A fundamental part of maintaining an organic garden is allowing the natural predators that exist in the wider environment to thrive. Many animals in the garden feed on pests. Ladybirds and their larvae are amongst the hardest workers, helping to control green fly as well as aphids. Mixing flowering plants with fruit and vegetables encourages predators such as parasitic wasps and hoverflies. It is important to recognise these natural predators and encourage their existence.

Barriers and Deterrents

Barriers around gardens certainly aren't new and have been in use for centuries. However the use of barriers etc to control insects and smaller pests are relatively new. Simple methods such as hanging shiny silver objects in the sunlight can confuse insects such as aphid which orient their flight patterns by sunlight. Medium mesh netting can also be effective in keeping out smaller birds etc from fruit growing areas of the garden.

Where prophylactics do not work, and pest populations reach proportions where economic loss is a surety, there are a number of non-chemical methods of pest control. These include, among others:

- Picking off the pest by hand (where the pest is a large caterpillar for example)
- Use of pheromone traps
- Use of light traps (for moths and other insects)
- Use of predator species (a point of debate)
- Growing trap crops (e.g. Mustard with cabbage; Maize around cotton)
- Use of microbial pesticides and biological agents like Heliothis, Spodoptera, Trichogramma, Trichoderma etc.
- Using easily-prepared natural pesticides

For preparing natural bio-pesticides, a number of plants can be used. Neem, ginger, chili, *vitex negundo* (Indian pivet tree), custard apple (the seeds), *pongamia pinnata* (pongam/karanj), asafoetida, turmeric, garlic, tobacco, sweet flag, *nux vomica*, tulsi and Persian lilac are among the many plants that are commonly used in pest control. Each pest requires a specific preparation.

Mulching is the use of organic materials (plastic mulch is expensive and non-biodegradable) to cover the soil, especially around plants to keep down evaporation and water loss, besides adding valuable nutrients to the soil as they decompose. Mulching is a regular process and

does require some labour and plenty of organic material, but has excellent effects, including encouraging the growth of soil fauna such as earthworms, preventing soil erosion to some extent and weed control.

Green manuring is an age-old practice prevalent since ancient times. Green manuring is beneficial in two ways - firstly it fixes nitrogen, and secondly the addition of biomass greatly helps in improving the soil texture and water holding capacity. Green leaf manuring can also be carried out if sufficient leguminous tree leaves are available.

How Do You Control Pests and Diseases without Chemicals?

Organic gardening doesn't mean you have to share your apples with the worms, but you will probably have less than pristine looking plants and produce. Since you are trying to garden in cooperation with nature, sometimes you have to accept the occasional pest in the garden. Your first line of defense should be vigilance. Inspect your plants regularly for signs of a problem and take action quickly. Keep in mind that not every insect is a foe and that action doesn't necessarily mean pesticide.

- There are many organic pesticides available, but first make certain that there is a problem and that you know what it is. You can live with a little damage. Some insects, like the 4-lined plant bug, do their damage and then move on for the season.
- Consider if you are having a pest problem because your plants are stressed and don't have the resources to defend themselves.
- Inter-planting and diversity will protect you from losing an entire crop to an infestation. Large swaths of a single plant are pretty, but are also a landing strip for interested insects.
- Many insects and larger animals are considered beneficial, preying on the insect pests. Reaching for the spray can every time you see a pest; you will be killing of the beneficial too. Lady bugs and parasitic wasps enjoy an aphid banquet. Birds will munch on grubs. Frogs, lizards and even snakes all contribute to the balance in your garden and prevent a pest population from becoming a problem.
- Barriers prevent problems. Floating row covers prevent moths from landing and laying eggs. Yellow sticky traps can easily catch dozens of flying pests. Foil collars around the base of plants will foil cut worms and many borers.
- There will probably come a time when you will need to apply a pesticide or lose your plants. Organic or natural pesticides can be very effective and are usually less toxic to wildlife, pets and humans than synthetic pesticides. Many organic controls can target specific problems, such as using Bacillus thuringiensis (Bt), a type of bacteria, that kills caterpillars, but not much else. Just be sure that you know what the problem is before you treat it and that you always follow the label instructions.

Chapter - 18

Ecotourism : Impact, Planning and Development

(P.S.Sodhi, M. Arch. (Landscape), Architect, CPWD)

Ecotourism means- **"Responsible travel to natural areas that conserves the environment and improves the well-being of local people".**

"Ecotourism" is a relatively new idea that has dramatically captured the attention of many people from a variety of backgrounds. It seems to be a catchall word that has different meaning to different persons. To some it means ecologically sound tourism; to others it is synonymous with nature tourism and other forms of alternative tourisms like responsible tourism, ethical tourism, and environmentally friendly or sustainable tourism. Despite the continued debate about what exactly eco tourism entails, it seems that it must be a force for sustaining natural resources.

Many view ecotourism as a viable way to protect the natural environment and create social and economic benefits for local communities. If we compare with other forms of alternate tourisms, basically it focuses on nature, local cultures, wilderness adventures and the uniqueness of the area. It is a responsible travelling to natural destinations where the flora, fauna, and cultural heritage are the primary attractions.

- Rainforests are becoming an attraction around the world which portrays the uniqueness of nature, like people going to see a 200-year-old Cactus in Arizona. But at the same time there is a risk that it can be damaged or cut down within no time. So the visitors are required to be sensitive enough to take care of the uniqueness of the site because their little carelessness can destroy it forever.
- On the other hand if an attraction is unique then it will attract more and more tourism. Like incase of General Sherman tree, the largest living thing on earth is one of the biggest attractions in California's Yosemite National park. It stands tall at 275 feet (84 meters) with a base diameter of 36'-6"(11 meters) having age of 2200 years approx.

Approximately 200 Year Old Saguaro Cactus in the Saguaro National Park in Arizona USA.

The eco-tourism is to preserve the natural resources since most of the popular eco-travel destinations have fragile eco-systems. It is important to maintain a careful balance between preservation and promotion – "sustainable development" to ensure the long-term health of both the ecosystems and tourism economics. It is need to make the entire travel industry more sensitive towards the environment and incorporates a strong commitment to nature and sense of social responsibility.

Origin of Ecotourism

The history of nature travel is traced back to Aristotle who is known to have traveled to the island of Lesbos (Greek island) in the Aegean Sea where he spent time studying marine creatures. Nature travel during the 19th Century became an essentially a quest for spectacular and unique scenery. This was also the time when the concept of national parks came into being.

In recent times, with the start of events such as Earth Day (1970) and the formation of United Nations Environment Programme (1972), the nature based tourism started taking shape of ecologically sensitive tourism. *Subsequently world summits such as the Rio Earth Summit (1992)* have helped to establish a worldwide concern for the impact of human activities on the natural environment. In 1983, Hector Ceballos-Lascurian, an enthusiast Architect of Mexico had evolved an idea in which travelling to relatively undisturbed natural areas with the specific objective of studying was mooted. In 1981, he first used the Spanish term ***"turisimo ecologica"*** to designate forms of ecological tourism. This term was later changed to **"ecoturisimo"** in 1983 and ultimately became **Ecotourism**.

The intention behind this idea was

- To encourage environmentally responsible travels and visitation to relatively undisturbed natural areas.
- To enjoy, study and appreciate nature and any accompanying cultural features that promote conservation.
- Be economically viable in order to attract financing and be sustainable.

Need for Ecotourism

Economic globalization has led to the rapid expansion of international tourism. Modern mass tourism has been earlier embraced by most of the governments in world as a "smokeless" (non-polluting) industry to increase employment and economic prosperity, especially in developing countries. But mass tourism development projects are often ridden with long-term negative impacts on the environment. It often promotes unsustainable production and consumption patterns in developing countries where appropriate technology for waste treatment and pollution abatement is often insufficient or entirely lacking.

It was observed that mass tourism has adverse effects on the environment, culture, and economics of the local communities. To overcome the further negative effects of mass tourism on environment, the necessity to have a new concept of tourism was felt, that could protect the fragile areas from deterioration, and preserve it for future generations. It was discovered in the form of Eco-tourism.

India

India is the seventh largest country in the world with a geographical area of 329 million hectares. It is situated in South Asia and is of sub continental dimension with a population of over one billion people. India is primarily an agricultural economy with a vast range of crops. The livelihood of over 60% of the population continues to be based on agriculture. The primary issue is one of poverty, with 320 million (32 Crore) people estimated to be below the poverty line.

India is one of the oldest civilizations with a kaleidoscopic variety of cultures, which makes for a rich cultural heritage. It has thousands of monuments and remains of many civilizations. The

peoples' lifestyles are varied e.g. Tribes of Bastar, Rann of Kucch, Banjaras etc. The Taj Mahal and 25 other World Heritage Properties and several National Heritage sites are in India. Hospitality for visitors is an ancient Indian tradition. The peoples' lifestyles are varied. Life is full of culture, fairs and festivals, art and handicrafts, classical dances, colour and spectacle. The country has an unparallel cultural diversity.

Indian subcontinent is one of the most fascinating ecological and geographical regions in the world. It offers enormous diversity in topography, natural resources, and climate as well. The mainland comprises of seven regions, viz. the great mountain zone, the plains of Ganges and Indus, the desert region, and southern peninsula etc. It includes the nearly rainless desert of Thar and the rainiest place on earth, Cherrapunjee, the hot, salty Rann of Kacch, and the permanently snowbound peaks of Himalayas.

India happens to be one of the 12-mega biodiversity countries in the world. The Western Ghats and Eastern Himalayan regions are among the 18 biodiversity "hot spots" in the world. India's biodiversity is rich, often unique and increasingly endangered. Consisting of 2% of the world's landmass, India possesses around 5% of the known living organisms on earth. It houses a wealth of various ecosystems, which are well protected and preserved.

Scope of Ecotourism in India

Tourism has proved to have both positive as well as negative impacts. In terms of positive impacts, it generates employment and revenue, whereas in terms of negative impacts, it contaminates indigenous culture, leads to degradation of environmentally fragile areas like mountains, hills, deserts and coastal regions.

In India, ecotourism can also become an instrument for sustainable human development also through poverty alleviation, environmental regeneration, job creation and that too, in the remotest areas of the country.

Most of the ecotourism sites of natural beauty and biodiversity value are located in the forest areas, and to promote wildlife preservation the Indian government has established 75 National Parks, 421 Wildlife Sanctuaries, apart from 7 Biosphere Reserves, which account for most of India's wildlife resources spread over an area of 14 million hectares. This covers 4.3% of the total geographical area of India.

Hence there is wide scope to practice ecotourism in India.

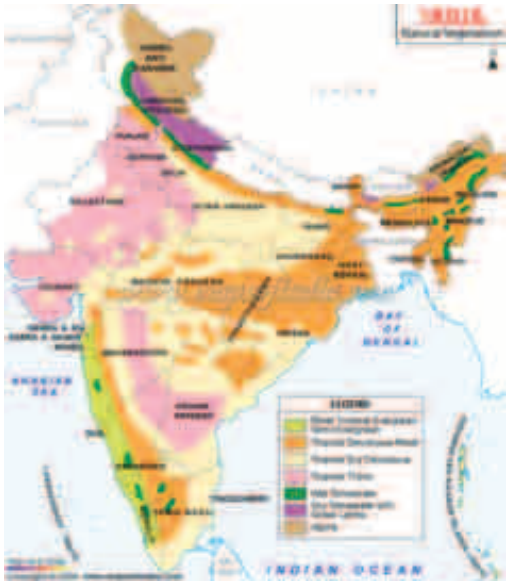
Chapter - 19
Forest and Vegetation Types of India

(Sudhir Kamal Seem, M.Arch. (Landscape), Senior Architect, CPWD)

Different Types of Forests of India

India has a diverse range of forests: from the rainforest of Kerala in the south to the alpine pastures of Ladakh in the north, from the deserts of Rajasthan in the west to the evergreen forests in the north-east. Climate, soil type, topography, and elevation are the main factors that determine the type of forest. Forests are classified according to their nature and composition, the type of climate in which they thrive, and its relationship with the surrounding environment.

Forests can be divided into six broad types, with a number of sub types.



Vegetation Types of India:

Located at tropical latitudes, the beautiful land of India is characterized by rainfall regimes and diverse temperature and climate. India's climate helps in the growth of forests in the country. However, in the past thousand years, various types of human activities have altered the climatic formations in the country to ala large extent.

Moist tropical	Montane sub tropical
Wet evergreen	Broad leaved
Semi-evergreen	Pine
Moist deciduous	Dry evergreen
Littoral and swamp	
Dry tropical	Montane temperate forests
Dry deciduous	Wet
Thorn	Moist
Dry evergreen	Dry
Sub alpine	Alpine

The natural vegetation in India primarily comprise of dry deciduous forests. Vegetation growing in correspondence with different environmental conditions is the natural vegetation of a particular place. Several major factors such as soil, topography, temperature and rainfall

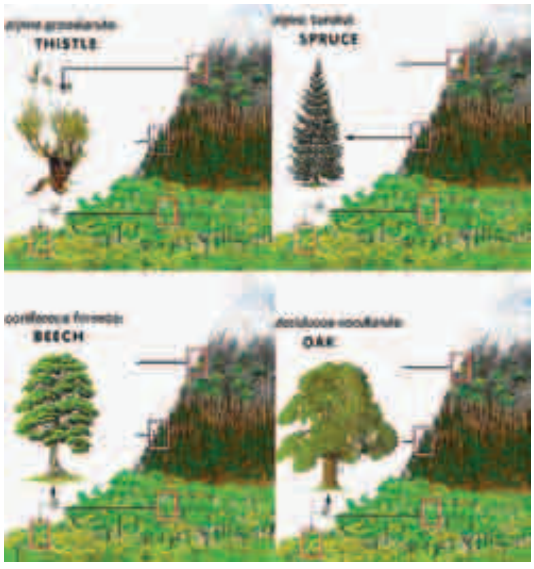
have influenced the natural vegetation of India to a large extent. Depending on the atmosphere, weather, position and other factors, there can be several classification of India's natural vegetation.

The many features that characterize the natural vegetation of India are:

- Tropical deciduous forests,
- Tropical rain forests,
- Alpine and tundra vegetation,
- Forests of Southern India,
- Himalayan vegetation,
- Desert region,
- Temperature forests and
- Grasslands.

A major role is played by the tropical rain forests, in the natural vegetation in India. These forests include the tropical semi-evergreen forests and the tropical evergreen forests. A place experiencing large amount of sunshine and rainfall have this type of forests. The trees found in these forests do not have any particular season to cast off their leaves since the area stays wet and warm all through the year.

The growth of the trees happens to be very briskly where the sublime height attained by the trees is 60m or more. The forests are also known as archetypal rain-forests. These type of regions are only concentrated to the plains of West Bengal and Orissa, the Western Ghats and North-eastern India. The varied species available in the region are huge and can be used commercially. Some of the functional trees found in the region consist of Mahogany, Rosewood and Ebony.



Alpine Vegetation: The Eastern slopes in the Western Ghats are home to the moist deciduous forests. These type of forests can also be located in northeast of India that is areas of Chhotanagpur Plateau, south Bihar, east Madhya Pradesh, and west Orissa They are also found in the north-eastern part of the peninsula i.e. in the region of

Chhotanagpur plateau, covering east Madhya Pradesh, south Bihar, the Shiwaliks in North India and west Orissa. The major trees in the region are Sal, Teak and Sandalwood. While Teak serves as an essential species in the region, Sal on the other happens to be an important tree found in the dry deciduous forests. Over the time, it has been noticed that the moist deciduous forests in India are being slowly replaced by the dry deciduous forests. The tress in this region unlike those found in the tropical rain forests, have a particular time for casting off leaves.

Alpine : **Moist**

Moist alpines are found all along the Himalayas and on the higher hills near the Myanmar border. It has a low scrub, dense evergreen forest, consisting mainly of rhododendron and birch. Mosses and ferns cover the ground in patches. This region receives heavy snowfall.


Alpine Vegetation

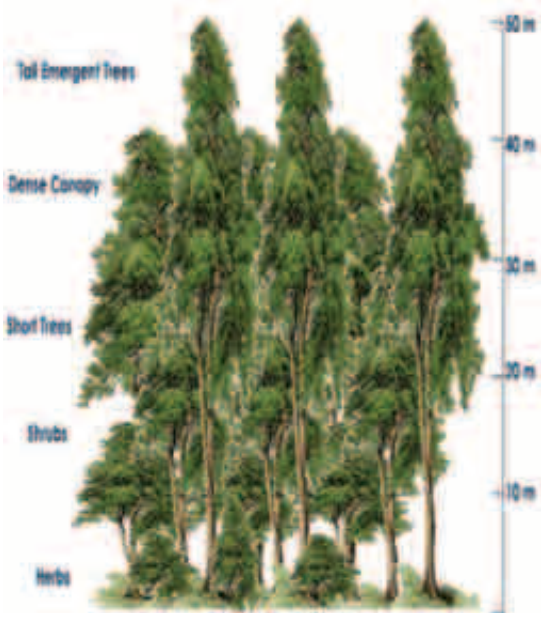
Dry

Dry alpines are found from about 3000 metres to about 4900 metres. Dwarf plants predominate, mainly the black juniper, the drooping juniper, honeysuckle, and willow.

Montane temperate forests

Wet

Wet montane temperate forests occur in the North and the South. In the North, it is found in the region to the east of Nepal into Arunachal Pradesh, at a height of 1800–3000 metres, receiving a minimum rainfall of 2000 mm. In the South, it is found in parts of the Niligiri Hills, the higher reaches of Kerala. The forests in the northern region are denser than in the South. This is because over time the original trees have been replaced by fast-growing varieties such as the eucalyptus. Rhododendrons and a variety of ground flora can be found here.



Stratification a Tropical Forest

In the North, there are three layers of forests: the higher layer has mainly coniferous, the middle layer has deciduous trees such as the oak and the lowest layer is covered by rhododendron and champa.

Moist

This type spreads from the Western Himalayas to the Eastern Himalayas. The trees found in the western section are broad-leaved oak, brown oak, walnut, rhododendron, etc. In the Eastern Himalayas, the rainfall is much heavier and therefore the vegetation is also more lush and dense. There are a large variety of broad-leaved trees, ferns, and bamboo. Coniferous

trees are also found here, some of the varieties being different from the ones found in the South.

Dry

This type is found mainly in Lahul, Kinnaur, Sikkim, and other parts of the Himalayas. There are predominantly coniferous trees that are not too tall, along with broad-leaved trees such as the oak, maple, and ash. At higher elevation, fir, juniper, deodar, and chilgoza can be found.

Sub alpine

Sub alpine forests extends from Kashmir to Arunachal Pradesh between 2900 to 3500 metres. In the Western Himalayas, the vegetation consists mainly of juniper, rhododendron, willow, and black currant. In the eastern parts, red fir, black juniper, birch, and larch are the common trees. Due to heavy rainfall and high humidity the timberline in this part is higher than that in the West. Rhododendron of many species covers the hills in these parts.

Montane sub tropical forests

Broad-leaved forests

Broad-leaved forests are found in the Eastern Himalayas and the Western Ghats, along the Silent Valley. There is a marked difference in the form of the vegetation in the two areas. In the Silent Valley, the poonspar, cinnamon, rhododendron, and fragrant grass are predominant. In the Eastern Himalayas, the flora has been badly affected by the shifting cultivation and forest fires. These wet forests consist mainly of evergreen trees with a sprinkling of deciduous here and there. There are oak, alder, chestnut, birch, and cherry trees. There are a large variety of orchids, bamboo and creepers.

Pine: Pine forests are found in the steep dry slopes of the Shivalik Hills, Western and Central Himalayas, Khasi, Naga, and Manipur Hills. The trees predominantly found in these areas are the chir, oak, rhododendron, and pine. In the lower regions sal, sandan, amla, and laburnum are found.

Dry evergreen

Dry evergreen forests normally have a prolonged hot and dry season and a cold winter. It generally has evergreen trees with shining leaves that have a varnished look. Some of the more common ones are the pomegranate, olive, and oleander. These forests are found in the Shivalik Hills and foothills of the Himalayas up to a height of 1000 metres.

Yet another kind of natural vegetation offered to India is by the **Thorn Forests and Scrub**. Found in dry places with an average annual rainfall below 70 cm, these forest sprawls over the

north western region of India, from Saurashtra in the south of the country to Punjab in the northern side. In the eastern part, the forests extend to the state of Madhya Pradesh, the south western part of Uttar Pradesh and the Bundelkhand plateau. Long roots, broadness and radial pattern are the most common features of the dispersed trees found in this region. The forests gradually die away to thorny bushes and scrubs, thereby consisting of the most classic vegetation of the deserts. Among the valuable species of plants found in this region, are kikar, babul, and coarse grasses.

Dry tropical forests: Dry deciduous forest: Dry deciduous forests are found throughout the northern part of the country except in the North-East. It is also found in Madhya Pradesh, Gujarat, Andhra Pradesh, Karnataka, and Tamil Nadu. The canopy of the trees does not normally exceed 25 metres. The common trees are the sal, a variety of acacia, and bamboo.

Thorn : This type is found in areas with black soil: North, West, Central, and South India. The trees do not grow beyond 10 metres. Spurge, caper, and cactus are typical of this region.

Dry evergreen : Dry evergreens are found along the Andhra Pradesh and Karnataka coast. It has mainly hard-leaved evergreen trees with fragrant flowers, along with a few deciduous trees.

Tropical deciduous forests: The forests are also known as deciduous, since the tress of the forests cast off the leaves for 6 to 8 weeks in the month of summer. With immense beauty and grandeur, these forests are also known as the monsoon forests. A natural cover is provided by this natural vegetation to the entire country, specially those areas that receive about having 200 and 75 cm of rainfall annually.

The forests stretch to Kerala, valleys of the Himalayas, eastern slopes of the Western Ghats, north eastern region of the peninsular plateau. The tropical deciduous forests are – effective, substantial, and less resistant towards fire. The forests can further be divided into dry and the moist deciduous forests.

A kind of vegetation is also found at the grasslands and temperate forests of India. Numerous types of plants can be traced at the Himalayas, varying with rising altitudes. Evergreen trees such as Chestnut, Oak, Maple etc are usually broad leaved and grow in altitudes between 1000m to 2000m. While the Coniferous trees such as Silver Fir, Deodar, Pine, Spruce etc, on the other hand, grow in altitudes between 1500m to 3000m. These trees

are generally found in the southern slopes of the Himalayan Region. The temperate grasslands are generally found in higher altitudes.

Moist tropical forests : Wet evergreen : Wet evergreen forests are found in the south along the Western Ghats and the Nicobar and Andaman Islands and all along the north-eastern region. It is characterized by tall, straight evergreen trees that have a buttressed trunk or root on three sides like a tripod that helps to keep a tree upright during a storm. These trees often rise to a great height before they open out like a cauliflower. The more common trees that are found here are the jackfruit, betel nut palm, jamun, mango, and hollock. The trees in this forest form a tier pattern: shrubs cover the layer closer to the ground, followed by the short structured trees and then the tall variety. Beautiful fern of various colours and different varieties of orchids grow on the trunks of the trees.

Semi-evergreen: Semi-evergreen forests are found in the Western Ghats, Andaman and Nicobar Islands, and the Eastern Himalayas. Such forests have a mixture of the wet evergreen trees and the moist deciduous tress. The forest is dense and is filled with a large variety of trees of both types.

Moist deciduous: Moist deciduous forests are found throughout India except in the western and the north-western regions. The trees have broad trunks, are tall and have branching trunks and roots to hold them firmly to the ground. Some of the taller trees shed their leaves in the dry season. There is a layer of shorter trees and evergreen shrubs in the undergrowth. These forests are dominated by sal and teak, along with mango, bamboo, and rosewood.

Littoral and swamp : Littoral and swamp forests are found along the Andaman and Nicobar Islands and the delta area of the Ganga and the Brahmaputra. It consists mainly of whistling pines, mangrove dates, palms, and bullet wood. They have roots that consist of soft tissue so that the plant can breathe in the water.

Alpine and tundra vegetation : The Alpine Vegetation grows at an altitude of over 3600 m. It has been noticed that with an increment in the altitude, the plants in the region show a stunted growth. Trees such as pine, silver fir, birch, juniper etc fall in this category of vegetation. An extensive use of the Alpine vegetation is made by the tribal people of Bakarwal and Gujjar. Vegetations such as lichen and mosses can also be found at high altitudes.

A major type of natural vegetation in India happens to be the Himalayan vegetation. The deep tropical forests located in the eastern part of India have differs sharply from coniferous and pine woodlands found in the western Himalayas. The natural cover changes with the change in the altitude. The evergreen forests usually having high alpine vegetation close to the snowline generally have temperate forests near the lower elevations. A plant called chir pine (Pinus roxburghii) exists in the northwest Himalayas, except Kashmir. Other plants such as oak, maple, chilgoza (pine nut), ash (Fraxinus xanthoxyloides), grow largely in the Inner

Himalayas. Deciduous trees, fern, shrubs and grass mainly cover the wet foothills of the Himalayas while the Brahmaputra Valley consists of tea plantations and rice fields.

The rain forests in South India contribute greatly to the natural vegetation in India. The most abundant rain forests are situated on the southwestern coast of Kerala. Here large number of coconut trees can be found canopying the lagoons, thereby leading to the development of a continuous stretch of rain forests in India. Some of the other parts in India where rain forests can be found are Arunachal Pradesh and the Andaman and Nicobar Islands. Further Teak, sandal and sisoo (Dalbergia sissoo) forests grow in the wet plateau of Karnataka plateau. The dry Telengana plateau located in the state of Andhra Pradesh comprises wild Indian date palm and thorny scrub.

When we are talking about the Natural vegetation in India, how can we forget the desert region in the country! The Thar Desert is a beautiful example of the vegetation in India. The trees in the Thar Desert are generally found to be stout, short and stunted by the sun. The popular trees in the region are reunjha (Acacia leucophloea), cacti, khejra (Prosopis spicigera), ak (Calotropis gigantea), kanju (Holoptelia integrifolia) etc.

Master Plan for Delhi 2021 has attempted to achieve environmentally sustainable development/ re-development considering the limitations of land and water with significantly improved quality of infrastructure. The main points related to environmentally sustainable development are elaborated below:

Green/Recreational Areas

Delhi has a much larger green cover than any of the other metropolitan city in the country, and could well be called “Green City”. The green recreational use constitutes 8,722 ha of land as per MPD 2001, which is around 19% of the total urban land area of 44,777 ha. This includes 1577 ha. Under the Northern, Central & South Central Ridge (the remaining area of the Ridge is in the rural area). The balance area under recreational/green use i.e.7145 ha. is in the form of District Parks, City Parks, Community Parks etc. comprising around the 15% of the total urban land area. In addition to this, a large chunk of green area is provided in the form of Neighbourhood Parks /Tot lots in the gross residential use zones, plantations / greens in large campuses like President’s Estates, JNU, IARI, Delhi University, plantations along drains and roadside plantations. In addition to above, two Bio-diversity parks are under development by the DDA.

In the Urban Extension the green cover is to be provided at the rate of 15% of the total land, excluding the Ridge/Regional Park. Out of this, some area shall be developed in the form of formal parks for the community and the rest shall be developed as woodlands and incidental greens for balancing the environment. This will be in addition to the development of specialized parks like Bio-Diversity Parks, plantation along the roads, drains, riverbanks etc.

Environment

Creation of a sustainable physical and social environment for improving quality of life is one of the major objectives of the plan. The almost unprecedented scale and speed of urbanization in Delhi has resulted in enormous pressures on the physical environment with a severe adverse impact in terms of pollution, and today Delhi is considered to be among the most polluted cities in the world.

The city’s environment can essentially be seen in terms of two components of urban management - the environment per se or the habitat, and services management. The pertains to the natural features and resources including : the elements of air and noise, water (Water bodies – rivers, lakes, drains and ponds and ground water) and land with reference to open spaces, green areas and other surface and sub-surface conditions. The latter is related to the built environment and includes the environmental infrastructure- water supply, sewerage, solid waste disposal and the transportation network.

In the above stated background the following three fold approach and strategy will need to be adopted:

(i) Management of Natural Recourses and the related environment infrastructure and services in a manner that would lead to optimization of use of natural resources, and reduction/ abatement or pollution.

(ii) Conservation and Development of the Natural features with a view to enhancing their environmental value; and

(iii) Development and preservation of open spaces, greens and landscape/ recreational areas.

A clear approach towards management of 4 types of wastes generated in Delhi, namely Solid Waste, Hazardous Waste, Bio-Medical Waste and Electronic Waste should be adopted. The approach should take into account the need for adopting the Clean Development Mechanism (CDM) and the awareness of the carbon credits that can be earned and encashed through a planned and organized mechanism, to be developed for this purpose.

The following critical areas from environmental point of view have been the focal points of the Master Plan of Delhi 2021:

- Special emphasis on conservation of the Ridge.
- Rejuvenation of River Yamuna through a number of measures including ensuring adequate flow in river by release of water by riparian states, refurbishment of trunk sewers, treatment of drains, sewering of unsewered area, treatment of industrials affluent, recycling of treated effluent and removal of coliforms at STPs.
- Provision of lung spaces/ recreational areas and green belt to the extent of 15 to 20% of land use.
- Multipurpose grounds: A special category for marriage/ public functions.
- The Master Plan 2021 stipulates that the land up to the depth of one peripheral village revenue boundary along the border of NCTD, wherever available, would be maintained as Green belt. 15-20 % of Land is distributed under Green/ Recreational land use.

Green Belt

The plan provides for agricultural land as Green Belt along the border of NCT of Delhi, in synergy with the provisions of Regional Plan 2021 of NCR. The belt extends from the NCTD boundary up to a depth of one peripheral revenue village boundary, wherever possible.

Bungalow Area

Lutyens' Bungalow Zone comprises of large size plots and has a very pleasant green environment. The essential character of wide avenues, large plots, extensive landscape and low rise development, has a heritage value which has to be conserved. Mix use high intensity development along MRTS corridor and de-densification of trees / reduction of green cover is not permitted at all. The strategy for development in this zone will be as per the approved plans and the LBZ guidelines, as may be issued by the Government of India from time to time. Civil lines also has Bungalow area of which the basic character has to be maintained.

Hierarchy of Urban Development- Provision of Open spaces

S.No.	Level	Facilities	No.	Land Area in Sqm	
				Per Unit	Total
1.	Housing Area Population 5,000	1.Totlot 2. Housing Area Park 3. Housing Area Playground 4.Aanganwari	20 1 1 1	125 5,000 5,000 200-300	2500 5,000 5,000 400-600
2.	Neighbourhood Population 10,000	1. Neighbourhood Park 2. Neighbourhood Play Area	1 1	10,000 5,000-10,000	10000 5,000-10,000
3.	Community Population 1,00,000	1.Community Park a) Park b)Multipurpose Park/ground	 1 1	 50,000 20,000	
4.	District Population 5,00,000	1.District Park a) Park b)Multipurpose Park/ground	 1 1	 2,50,000 40,000	
5.	Zonal/Sub City Population 10,00,000	1. City Park a) Park b)Multipurpose Park/ground	 1 1	 10,00,000 80,000	

Notes:

- The open space at the Neighbourhood level shall be provided @ 4.5 sqm. per person.
- Minimum size of Tot lot at cluster level shall be 125 sq.m.

- The location of Schools and Aanganwaris should be made in the lay out plan in cluster form to facilitate sharing of common parking space and playground.
- Rain water harvesting shall be an integral part of the storm water drainage plan at the time of sanction of layout plan for all plots.
- The natural drainage pattern is not to be disturbed.
- Dual pipe system of recycled water I recommended in new areas and redevelopment schemes.
- Dhalaos including facility of segregation of biodegradable and recyclable solid waste should be provided.
- Non-conventional sources i.e. solar energy etc. is recommended for public areas in all establishments.
- Suitable landscape plans for the neighbourhood shall be pre4pared, indicating in reasonable details, the landscape development of the parks and roadside plantation etc.

Infrastructure Requirement for layout at Residential Neighbourhood Level

Use Premises	No. of Units	As per standard norms (in LSC)	
		Unit Area(ha)	Total Land(ha)
Recreational (i) Totlot @ 0.50sqm/person		0.0125	0.5
(ii) Housing Area Park	2	0.5	1.0
(iii) Neighbourhood Park	1	1.0	1.0

Planning Norms, Standards for Recreational Areas/Parks at Sub-City Level

Sl. No.	Category	Planning Norms & Standards	
		Population/Unit(APPROX.)	Plot Area (Ha)
1	City Park	10 lakh	100
2	District Park	5 lakh	25
3	Community Park	1 lakh	5

Planning Norms, Standards for Recreational Areas/Parks at Neighbourhood Level

Sl. No.	Category	Planning Norms & Standards	
		Population/Unit (APPROX.)	Plot Area (Ha)
1	Neighbourhood Park	10000	1.0
2	Housing Area Park	5000	0.5
3	Tot lot at Housing Cluster Level	250	0.025

Planning Norms, Standards for Multipurpose Grounds

Sl. No.	Category	Planning Norms & Standards	
		Population/Unit (APPROX.)	Plot Area (Ha)
1	City Multipurpose Ground	10 lakh	8
2	District Multipurpose Ground	5 lakh	4
3	Community Multipurpose Ground	1 lakh	2

Other Controls:

1. Minimum 50% of total area shall be under Soft Parking and remaining 50% shall be utilized for activities.
2. Minimum 3% of the remaining area (excluding Soft Park area) shall be utilized for Electric Sub Station, Toilets, Security and other marriage related activities etc.
3. Multipurpose Ground can be sub-divided suitably with minimum of 0.5 ha of plot area to accommodate number of functions at one time.
4. Park Multipurpose Ground shall have provisions for rainwater harvesting.

Permission of Use Premises in Sub Use Zone

Sl. No.	Use Zone	Activities Permitted
1	Green Belt	Forest, Agriculture use, Vegetation belt, Dairy Forms, Piggery, Poultry farms, Farm house, Wild life sanctuary, Biodiversity Park, Veterinary Centre, Police Post, Fire Post, Smriti Van, Plant Nursery, Orchard, Area for water-harvesting, Floriculture farm, Open Playground, Agro Forestry, Amenity structureExisting village Abadis, already regularized Unauthorised colonies & already approved Motels may continue.
2	Regional Park	Ridge, Residential Flats (for watch & ward), Picnic Hut, Park, Shooting Range, Zoological Garden, Bird Sanctuary, Botanical Garden, Local Govt. Office (Maintenance), Open Air Theatre, Police Post, Fire Post, Orchard, Plant Nursery and Forest.Approved Farm Houses sanctioned prior to 01.08.90 may continue.
3	City Park	Aqua Park/water sport park, Arboretum, Botanical Garden, National Memorial (approved by Cabinet/Govt. of India), Amphitheatre, Open Playground, and Aquarium. Other activities same as permitted in District Park. 30% of the area shall be developed with plantation of native species
4	District Park	District Park, Theme Park, Recreational Club, National Memorial, Open-air food court, Children Park, Orchard, Plant Nursery, Area for water-harvesting, Archaeology Park, Specialized Park, Amusement Park, Children Traffic Park, Sports activity, Playground,

		Amenity structures.Restaurants in a District Park having an area above 25 Ha, subject to following :
		(a) Area of the restaurant plot shall not be more than 0.8 Ha or 1% of the District Park, whichever is less. (b) Restaurant plot shall have no physical segregation from the rest of the District Park area. (c) The building shall be a single storey structure with max. FAR of 5 and height not more than 4m. without any residential facility and to harmonize with the surroundings. (d) In case there is no parking lot in the vicinity, parking should be provided at a reasonable distance from the restaurant complex / green.e 30% of the area shall be developed as dense platform.
5	Community Park	Park, Children Park, Open- air food court, Playground etc.
6	Multipurpose Ground	Public meeting ground, Public address podium, Social functions, Soft drink and snack stalls etc.

Chapter - 21

List of Plant Material

Medicinal Trees

(Source: Chandigarh Botanical Garden)

Botanical name	Common name
Acacia catechu	Khair
Adina cordifolia	Haldu
Aegle marmelos	Bel
Albizzia lebbek	Siris
Alstonia scholaris	Sataparna
Artocarpus heterophyllus	Kathal
Artocarpus chaplasha	Barhal
Artocarpus lakoocha	Dheu
Artabotrys odoratisissimus	Hari champa
Anona squamosa	Sitaphal
Anogeissus latifolia	Chhal
Anogeissus pendula	Dhok
Anthocephlus cadamba	Kadam
Azadirachta indica	Neem
Bauhinia variegata	Kachnar
Boswellia serrata	Salai
Bombax ceiba	Red silk cotton tree
Butea frondosa	Dhak, Palas
Cassia fistula	Amaltas
Caesearia tomentosa	Chila
Cedrela toona	Tun
Cinnamomum camphora	Camphor tree
Cinnamum tamala	Tejpatta
Cordia dichotoma	Lasura
Cocculus laurifolius	Tilpara
Commiphora wightii	Guggulu
Crataeva adinsonii	Barna

Dalbergia sisoo	Shisham
Diospyros Montana	Kendu
Elaeocarpus ganitrus	Rudraksha
Emblica officinalis	Amla
Erythrina variegata	Indian coral tree
Eugenia cuspidate	Jamoa
Ficus bengalensis	Banyan tree
Ficus religiosa	Pipal
Ficus glomerata	Gular
Garcinia indica	Kokum
Ginkgo biloba	Ginkgo tree
Gmelina arborea	Gambar
Grewia asiatica	Phalsa
Holorhina antidysentrica	Kurchi
Kigelia pinnata	Balamkhira
Lannea coromandelica	Jhingan
Madhuca indica	Mahua
Mangifera indica	Mango
Mesua ferra	Nagkesar
Melia azedarach	Bakain
Mimusops elengi	Maulsiri
Mimusops hexandra	Khirni
Moringa oleifera	Sohanjana
Morus alba	Shahtoot
Murraya koenigii	Curry patta
Oroxylum indicum	Pharrai
Pterospermum acerifolium	Kanak champa
Pithecolobium dulce	Jungli jalebi
Pongamia pinnata	Karang
Prosopis spicigera	Khejri
Psidium guava	Amrood

Putranjiva roxburghii	Putranjeeva
Salvadora persica	Jal, Pilu
Saraca indica	Ashoka
Salix babylonica(water front)	Weeping willow
Santalum album	Sandalwood
Sapindus mukorossi	Ritha
Schleichera trijuga	Kusam
Shorea robusta	Sal
Sterculia urens	
Swietenia mahagony	Mahogany
Syzygium cumini	Jamun
Taxus baccata	Taxus
Tecomella undulata	Rohida tree
Tamarindus indica	Imli
Terminalia bellerica	Bahera
Terminalia chebula	Harar
Terminalia tomentosa	Sain
Terminalia Arjuna	Arjun
Terminalia myriocarpa	Hollock

ORNAMENTAL/FLOWERING TREES

(Source: Chandigarh Botanical Garden)

Botanical name	Common name
Acacia auriculiformis	Australian Kikar
Albizzia lebbek	Siris (Kokoo Tree)
Albizzia procera	Safed Siris
Artabotrys odoratissimus	Hari Champa
Barringtonia acutangula	Samudraphal
Bauhinia alba	Safed Kachnar
Bauhinia purpurea	Geranium tree/ Kachnar
Bauhinia tomentosa	Yellow Kachnar
Bauhinia variegata	Kachnar
Bauhinia blackiana	Kachnar
Bauhinia sulpharai	Kachnar
Bauhinia accuminata	Kachnar
Butea frondosa	Dhak, Flame of the Forests
Cassia fistula	Amaltas
Cassia javanica	java-ki-Rani
Cassia nodosa	Pink-mohur
Cassia renigera	Pink-Cassia
Cassia siamea	Kassod
Callistemon lanceolatus	Bottle Brush
Chorisia speciosa	Mexican-Silk Cotton tree
Delonix regia	Gulmohar
Erythrina indica	Indian Coral tree
Erythrina blackei	Shrub
Jacaranda mimosifolia	Nili Gulmohar
Koelreuteria apiculata	Koelreuteria
Lagerstroemia thorelli	Queen’s Flower

L.flos reginae	Pride of India
Millettia ovalifolia	Rosewood
Murraya paniculata	Satin Wood
Nyctanthes arboritis	Haar Shringhar
Peltophorum ferrugineum	Yellow Flame tree
Plumeria alba	Pagoda
Plumeria rubra	Pagoda
Robinia pseudoacacia	Black locust (Kashmiri Kikar)
Saraca asoka	Sita Ashok
Tecoma argentea	Tecoma tree
Tecomella undulata	Lahura
Terminalia myriocarpa	Hollock

Trees Suitable for Landscape

Source : TCPO

Sl. No.	Botanical /Name	Common/ English/ Hindi/ Local Name	Structure Height Spread	Shape	Physiognomy: Evergreen/ Deciduous/ Flowering/ Shady etc.	Climate and Soil	Areas Most suitable for Planting	Recommended use	Period taken from Planting to mature stage	Remarks	
1	2	3	4	5	6	7	8	9	10	11	
1	Abies Pindrow/ Silver fir.	Rai, To's Morinda	Very tall straight tree, upto 70m.	Cylindrical	Evergreen, Conifer Ornamental Foliage Tree	Temperature Climate Hilly Soil	High Hills, 2,500- 3,000 m.	Timber is light used for packing boxes for apples etc.	50 - 75 years	Grown in big pot, give side sucke	
2	Acacia Dealbata	Silver Wattle	Small tree, 12m, height	Spreading	Flowering Tree Deciduous leaves thin	Cold (No Snow)	Mid & Low Hills. Particularly, Nilgries.	Bark is excellent tanning material	Approx. 10-15 years	Blooms in Feb. to March & July , Aug. Native of Australia. Large scale plantation in Nilgiries	
3	Acacia Nilotica	Kikeri/ Babul	12-15 mts	Rounded	Evergreen	Dry & Sandy	Throughout the planis	Boundary Parks and Gardens.	Approx. 15 years	Indigenous Plant Drought resistan useful tanning material	
4	Acacia Auriculiformis	Asutralian Blackwood	10-12 mts	Rounded	Evergreen	Sub- Tropical	Dry to moist Locality Dressy well in North India, Ooty, Gujrat, Maharashtra.	Fuel- Tanning	Approx. 20 years	Bears yellow flowers Petals are enlarged look like leaves (Phyllode)	
5	Artocarpus Heterophyllus	Jack Fruit/ Kathal	10-15 mts	Rounded	Deciduous	Hot humid any Soil	Madhya Pradesh, S. India, Bengal	Large house compounds Orchards	15-30 years	Very fragrant at the time of floering Huge size fruits (10-20 kg.) appear on the main stem Eastern cooked on fresh when ripe.	
6	Aegle Marmelos	Bael	10-15 mts	Rounded	Deciduous	Hot& Dry	Throughout the planis and foot hills.	Fruits are eaten & Pulp made into cooling drinks.	10-20 years	Leafless in March, April, Scared trees caves offered in temples (Shiva)	

7 Aesculus Indica	Horse Chestnut/ Bankhor Pangar	15-20 mts	Rounded	Deciduous	Temperature shady ravine & hilly areas	High Hills, 2,000-2,500m.	High by ornamenti al when painted in group	20-30 years	Whitish Pink flowers, from May to July Fruits are being tested for hormonal alkaloids.	
8 Albizzia Lebbeck	Tree of Heavon/ Maharukh, Mahanim	12-15 mts	Rounded	Deciduous	Hot & Dry	Plains of India and Low Hills	Wood soft used in match industry	15-20 years	Seed propagates in Rainy season and bears creamy yellow flowers.	
9 Albizia Procera	Safed Siris/ Kanhar	Very tall 20-30 mts.	Deep oval Crowned trees.	Deciduous	Sub- Tropical Moist climate & well drained	Ambala , Karnal Kurukshetra Sub- Himalayan tract upto	Avenues, Parks and River fronts	10-15 years	Short leaves growing good for timber. Yellowish bark & coopery young foliage giving a excellent look also.	
10 Alstonia Scholaris	Chatim, Saptparni	Large Spreading 15-20 mts	Oblong	Evergreen & Ornamental	Throughout the plains with rainfall upto 1,500 mm.	Throughout the plains with rainfall upto 1,500 mm.	Avenues, Parks , River banks	20-30years	Bears creamish white flowers in October to December . Foliage Ornamental.	
11 Anthocephalus Chinensis	Kadamb	20-30 mts.	Oblong oval Crown	Evergreen		Throughout the plains & in sub-tropical areas.	Avenues, and Parks	8-10years	Indigenous, glossy leaves, scented ball-like flowers creamish white colour blooming from June to August Tall straight conifer Native of Australia.	
12 Araucaria Excelsa		15-20 mts	Pyramidal tree	Foliage Tree Evergreen.		Plains and low hills	Parks & buildings compoun ds	15-20years	Tall straight conifer Native of Australia.	
13 Azadirachta Indica	Nim Margosa	10-15 mts	Rounded	Deciduous		Throughout the hot & dry plains.	Avenues & Parks	10-15years	Naturalished through out India . Dislikes too much moisture , fine shade trees with Whitish Scented Flowers Highly Medicinal. Ornamental foliage very hardy.	
14 Bambusa Spp. (Bamboo of various species)	Bans	20' and 5"	Tall stait Single Stems	Deciduous		Plains & foothills	In clumps	5years	Ornamintal foliage very hardy.	

15	Madhuca Longifolia	Mhua	Large tree15-20 mts	Rounded.	do		Sub-Himalayan tracts & plains of U.P. M.P. etc.	Village plantations	20-30years	White flowers in March-April. Leafless in March handsome tree slow growing.	
16	Bauhinia Variegata	Baisakhi Lachnar	6-12 mts. 5-8 mts	Oval Spreading crown	Flowers very showy.		Plains to sub-tropical regions	Avenues, Parks and house compound	8-12years	Indigenous with good fodder value. Flowering from Feb. to April, with white pink colour fragrant flowers unopen buds eaten as vegetable	
17	Bauhinia Purpurea	Gulabi Kachnar	5-10 mts	do	Flowers showy.		Plains to sub-tropical regions with good rainfall	Avenues, Parks and Gardens.	8-12years	Indigenous, good fodder, compact tree with rosy purple flowers, Flowering in september- Nov.	
18	Bischofia Javanica	Pankain	15-18 mts.	Spreading crown. Umbrella like	Flowers is conspicuous good shade		Plains to sub-tropical areas close to running water	Avenue	10-15years	Foliage turns red before falling , wood is use ful looks ugly without leaves and burches of dull fruits hanging from branches.	
19	Bombax ceiba	Semul tree	Very large tree 15-25 m.	Stem clear to more than half the length crown oblong round	Flowers large, red-yellowish	Throughout the planis and sub-tropical regions.	Throughout Indian plains	Avenues, Parks	20-30 years	Red flowers in Feb., teafles in Dec. Jan. and Feb.. Floss obtained from fruits is used for stuffing pillows. Wood used in match and ply-wood industry.	
20	Bouca Burmanica	Miriam	Medium size		Evergreen		Andaman Island	Avenues			
21	Brownea Coccinea	-	Small medium	Spreading round	Semi deciduous	Moisture	Southern & Eastern India	Parks & Gardens	10-15 years	Bears and flowers	
22	Butea monosperma(B. frondesa)	Dhak	8-15 mts. 3 8 mts	Irregularly oval crown with thick	Deciduous	Tropical soil	Throughout the plains.	Avenues & Parks	15-20 Years	Indigenous tree, can stand in salinity and unde desert condition.	
23	Caesalpinia coriaria	Libi- Dibi	Medium size	Round and spreading	Evergreen.	Tropical	S. India, N,W. India & Bengali	Parks & Gardens	8-10 years	Foliage feature and graceful	
24	Chukrasia Tadularis	Chikrasi	15-20 mts	Rounded	Deciduous	Wet	High rainfall areas, Western., Ghats, Bengal etc.	Parks Avenues	30-40 years	Creamy white flowers during March April, Hardy Tre-excellent shade.	

25	Dhonida Speciosa	Mexicano Silk cotton tree	15-20mts 8-10 mts	Bottle shaple with green trunk	do	Moist tropical well drained rich loamy soils.	Throughout Haryana	Parks, Gardens, Avenues	15-20years	Exotic. Large priceless on the stems floss obtained for pods is used for stuffing.	
26	Cinnamomum Camphora	Camphor	15-20m	Rounded	Evergreen	Moist tropical well drained rich loamy soils	Plains and foot hills with good rainfal	Parks, Avenues	20-30 years	Exotic. Beautiful ornamental foliage camphor scent. Timber fragrant	
27	Callistemon Concolobus	Bottle Brush	3-6mts 3-5 mts	Ovalcrown with pendulous branches	do	Sub-Tropical well drained rich soil	Throughout Haryana	Avenues & Parks	5-8 years	Exotic hardly and fast growing tree, flowering in March and October	
28	Dasia Fistula	Amaltas Indians Laburnum	8-12m, 3-5m	Rounded	Deciduous	Sub-tropical climate	Throughout India	do	5-8 years	Indigenous , Hardy look attractive when blooms	
29	Dasia Javanica	Java Dasia.	10-15m	do	do	Tropicalt to Sub-tropical	Plains and foot hills	do	5-10 years	Bears large cluster of pink white flowers.	
30	Dasia Nodosa	Pink Dasia	10-15m	do	do	do	do	do	5-10 years	Bears beautiful clusters of deep pink white flowers in April-May.	
31	Dasia Rariglora	do	10-12 m	Spreading	do	Moist sub-tropical	Foothills	Parks & Gardens	10-12years	Flowers pink yellow Scented.	
32	Samea	Kasod	10-12 m	do	do	Tropical	Plains	Avenues & Parks	10-15years	Fast growing and looks handsome.	
33	Garuja Arborea.	Kumbamastis kumbhi	10-15mts & 10mts	Oval crown	Deciduous	Moist tropical climate rich well drained loamy soils	Throughout Haryana	do	5-10 years	Indigenous Tree. flowering in March-April with pink white colour. Red leaves appear in October	
34	Toona Ciliata	Tun	15-20mts	Rounded	do	Moist - Tropical Sub-tropical	Plain & Sub-Himalayan tracts	Avenues	10-15 years	Creamy white flowers quick growing and handy Timber useful	
35	Casuarina Equisetifolia	Beef wood	12-20mts & 10m	Paramydial	Partially Deciduous.	Light Sandy soil but can grow in all types od soil	Throughout hot areas and sea coast	Parks &Sea coast	5-6years	Exotic (Australia) graceful branches. Good fuel. Soil binder.	
36	Cochlospermum Religiosum	Yellow silk cotton tree	3-8mts 3-4mts	A small conical tree with thick branches	Deciduous Flowering Feb-March (Golden yellow)	Dry tropical climate light soil	do	do	3-4 years	Indigenous Soft wood tree.	
37	Colvillea Racemosa	do Cotton tree	10-12m	Rounded	Flowering Tree	Tropical and Sub-Tropical	Peninsular India and Bengal etc	Parks & Gardens	10-15years	Propagates on Rainy season, Bears flowers in April - May very showy	

38	Cryptomeria Japonica	Cryptomeria	20-25m	Columnar	do	Wet Temperate	High hills Darjeeling	Hill slopes	15-20years	Beautiful and use for interior decodration. Fast growin-conifer	
39	Conninghamia Lanceolata	Monkey puzzel	15-20m	do	Evergreen Foliage trees	Subitropical to tremperate	do	do	20-30years	Slow growing conifer	
40	Cupressus Sempervirens	Sanu	6-20 2-5m	Conical Tree	Evergreen	Tolerate heat but not extreme cold well drained deep soil	Throughout Haryana	Parks, buildings and street	10-15years	Exotic (W. Asia Too much of moisture & too rich soil promotes over growth of foliage and bending of branches.	
41	Dalbergia Sissoo	Sikisham	10-15m	Irregular	Deciduous	Tropical & Sub-tropical	Plains of N. India	Canal banks, highways	10-15years	Very hardy good for shade and wood	
42	Delonix Regia (Poinciana regia)	Gulmohar	10-15m	Umbrella crown tree	do	Moist warm climate , rich loamy soil	Througout hot plains	Avenues & Parks	5-8years	Eery showing flowers fern leaves.	
43	Dillenia Indica	Chalta	10-12m 6-8m	Rounded crown	do	Moist sub-tropical climate rich loamy soil	Throughout India in the plains and wet places	do	6-8years	Indigenous, Large size fruits are used for making pickle in Bengal.	
44	Rhododendron Arboreum	Burans, bras	8-15m	So	Evergreen	Temperate hills	Hills above 2,000m	Hill sides	10-15years	Abundent red flowers in spring very showy.	
45	Guaiacum Officinale	Treeof life	5-10m	Rounded	Deciduous	Moisture	Moist tropical	Bombay	20-30years	Blue slow growing Exotic.	
46	Erythrina Indica	Indian Coral tree, Dhaibhuk, Pangra	5-10m 4-6m	Open crown	do	Moist tropical climate rich loamy soils	Throughout Haryana	Parks , Hedges & Avenues.	2-4years	Indigenous , quick growing largely planted as shade and ornamental	
47	Erythrina Blakei	Small tree	3-5m	Irregular	Deciduous	Moisture	Chandigarh	Parks	5-10 years		
48	Eucalyptus Citriodora	Safeda	10-40m 3-2m	Majestically ever erract with straight trunk and smooth bush	Evergreen	Warm climate rich, moist & well drained soil.	Ambala , Karnal Kurukshetra , Jind, Sonepat and Rohtak	Parks & Avenues	5-10 years		
49	Descaspermum Paniculatum (Cuspidata)	Jamoh	10m 5m	Oblong	Evergreen	Warm climate rich, moist & well drained soil.	North India , Kerala and Nilgiri	Parks & Avenues	15 years	Dense foliage, Creamy white floweninf March April	

50	Ficus Benghal lensis	Banyan/or Banyan	20-30m	Majestically Umbrella shaped crown (Spreading)	Evergreen Shady	Sub-tropical climate light soil	Throughout plains forest tracts of India low hills & Haryana	Avenues & river fronts	10-20 years	Indigenous very shady. A crucial root develop into numerous trunk.		
51	Ficus Benjamina	Golden Fig	10-15m	Spreading	Evergreen	do	Plains & foothills of India	Avenues & Parks	15-20 years	It gives golden yellow figs in April and looks most beautiful		
52	Ficus Plastica	Rubber Tree	20m	do	do	do	Low and mid hills	do	20-30 years	Slow growing very shady tree.		
53	Ficus Racemosa (Ficus glomerata)	Gular	8-15 mts. 6 mts	Irregular rounded	do or Occasionally deciduous, shady	Moist tropical climate loamy soil.	Throughout Haryana	Parks & river fronts	8-12years	Indigenous		
54	Ficus-virescens(Ficus infectoria)	Pilkhan and Chilkan	10-20m & 12m	Umbrella Shaped	Deciduous shady	Sub-tropical climate thrives on any soil.	do.	Avenues and Parks	8-12years	Indigenous quick growing two varieties with narrow and broad leaves ocurit. copper coloured foliage in April beautiful shade and hardy trees. Leafless in March.		
55	Ficus Retusa	Chilkan	12m-12m	Spreading	Evergreen	Tropical to Sub-tropical	Chandigarh	Avenues and Parks	15-20years	Pale green in May Nice shady tree and very hardy.		
56	Ficus Religiosa	Peal	15-20m	Rounded Crown	Deciduous shady	Sub-tropical climate, thrives on any soil.	Throughout Haryana	do	8-12years	Indigenous, Scared the trees for Hindus Hardy and shady tree		
57	Grivillea Sepium	Small tree	10-12m	Rounded	Deciduous	Southern tropical	South India	Road Side	3-4years	Exotic (S. America) Quick growing crown as ornamental with arching branches and feathery foliage. Looks beautiful in bloom when its masses of pinkish purple of pale pink flowers.		
58	Grevillea Robusta	Silver Oak/Silky Oak	10-13 mts 3-10mts	Tall tree with upright spreading branches pyrimidalli	Evergreen	Mild climate well drained light soil	Throughout India	Road side Avenues and Parks	8-10years	Exotic (Australia) has invasive roots and brighter branches. Rapidly growing graceful silkery leaves.		

59	Heterophragma	Marair	12-15 mts	Oblong	Evergreen	Tropical	Throughout India	Road side Avenues and Parks	10-15years	Pale yellowish brown	
60	Pithecellobium dulce	Jangli Jalebi	5-15m	Rounded crown	Evergreen thorny tree	Tropical climate loamy soil.	do	Hedge Plants	3-5years	Exotic (American)	
61	Jacaranda mimosoi folia (Ovalifolia)	Nilo Gulmohar	10-15m	Rounded tree with fern like foliage	Deciduous for short period	Warm climate light fertile well drained soil.	do	Roadside, parks Building and compoun ds.	8-10years	Exotic (Brazil) susceptible to wind damage. Rapidly growing.	
62	Lagerstroemia	Pinneps	10-15m	Rounded	Flowering	Dry locality	do	Road side and Parks	10-15years	Indigenous	
63	Juniperus Sp.	Juniper	10-15m	do	Evergreen	Sub-tropical to temperate	High hills	do	15-20years	Many spices for different altitudes.	
64	Kigelia Pinnata	Sausage tree	10-15m	Spreading	Evergreen shady	Tropical climate loamy soil.	Eastern parts of India	Avenues & parks	10-15years	Exotic (Africa) Gourd like fruits, hanging from big cord-like stalk. Hardy & fast growing tree.	
65	Lagerstroemia Speciosa (Lagerstr oemia)	Jarul	5-15m 10m	do	Deciduous Evergreen	Moist sub-tropical climate rich alluvial soil	Plains & Subtropical	Gardens, Parks & compoun ds.	4-6years	Indigenous. Cultivated as an ornamental plant.	
66	Lyidice rhodostegia	Rose of China	-	-	-	-	Low hills	-	-	Rose purple flowers in January -February. Exotic (China)	
67	Magnolia grandiflora	Sarc Champa	5-10m	Symetrically spreading heavy rounded tree pyramidal	Evergreen	Moist tropical climate deep moist heavy well drained soil.	From plains to about 2,000 m altitude.	Parks Buildings compoun ds.	10-15years	Exotic (Very smart). Difficult to transplant unless roots are carefully balled.	
68	Michelia Champaca	Champa	15-20m	Tall tree	Evergreen shady	Moist sub-tropical climate rich well drained loamy soil	Throughout India	Avenues& parks & compoun d	8-10years	Indigenous . It bears white creamish flowers which are very fragrant.	
69	Millettia Ovalifolia	-	8-10m	Spreading	Evergreen	Tropical & Sub-tropical	Plains to about 1,000 m. altitude	Parks & Gardens	8-10years	Very attractive when in flower.	

70	Millingtonia hortensis	Aksha Neem/ Nim Chemeli/ Indian Cork tree	10-25m	Tall trees	Deciduous	Moist tropical climate rich alluvial soil	Plains to 1000m.	Avenues & parks	5-8years	Exotic (Burma) Liable to wind danger . Flowers delightfully, fragrent very graceful trees fast growing.	
71	Mimusops elengi	Maulsari	10-15m	Small to large spreading	Evergreen	Hot	Throughout the plains.	Parks & Gardens	15-20years	Fragant flowers, shady tree slow growing tree slow growing. Indigenous.	
72	Manikara Kauki	Khirni	10-15m	spreading	Evergreen	Tropical	Plains tp 1,000m	Parks & gardens Gardens/ temples	15-20years	Creamy white flowers March April very slow growing	
73	Manikara Littoralis	Pinle Mohua	30 mts. 4-8 mts. Girth	do	do	Moist tropical	Andaman Nicobar	Avenues	20-30 years	A large tree cultivated in some placed of India	
74	Morus Indica	Mulberry	10-15m	Rounded shape	Deciduous	Tropical to low temperate	Plains to about 1,000 m.	Canal banks.	5-10 years	Hardy tree. Leaves used for feeding silk work. Best timber for hockey sticks.	
75	Roystonea regia	Royal Palm	10-15m	Palm with both shaped trunk	Evergreen	Moist tropical climate rich alluvial soil	Throughout the plains opto 1,000m.	Avenues & Parks	6-8 years	Stems mooth and greayish white	
76	Pandanus and amanensis	-	5-12m	Simple	do	Moist to wet	Andaman Nicobar	Gardens	5-10years	Fast growing	
77	Peltophorum ferruginoum	Copper-pod/ yellow gold Mohar	10-15m	Rounded	Decidioous	Dry to Moist	Plains to 1000m.	Avenues & Parks	5-10years	Naturalished large tree with feathery leaves. Golden yellow flowers during summer and rainy season	
78	Pinus roxburghii	Cheel/ Chir	2-30m	Tall bare stem with plated corky bark	Evergreen	Sub-tropical	500-1, 500m in the hills.	Parks & hills slopes in groves	15-30 years	Long Needle like leaves very pretty	
79	Samanea Saman	Rain tree	15-20m	Wide spreading umbrella like	Semina Ever green Decidaous	Moist	West Bengal coast, South India	Avenues & Parks	15-30 years		
80	Platanus Orientalis	Chinar	10-20m 8-12m	Round spreading	Deciduous	500-200m	Foothills & to popular hills station	Good Avenues Tree & Parks	20-40 years	Patchy bark. Prefer Proximity to water Beautiful autum foliage colours from orange cooper red.	

81	Plumeria (rubra forma acuminata)	Temple tree pagoda tree (Gule- Chini)	4.8m	Spreading umbrella like	do	Tropical to sub-tropical climate loamy soil	Throughout plains to 1,000 m	Parks & compounds	4-6 years	Flowers very fragrant. Leafless from Dec. Feb good foliage highly brittle.
82	Pinociana Pulcherrima	Dwarf Gulmohar	3m	Up-spreading branches	Flowring throughout the years	Tropical climate rich well drained alluvial soil	Throughout Haryana	Parks & short Avenues	2-4 years	Orange-red flowers April-May very showering flower is good as hedge plant.
83	Polythia longifolia	Devdara Pendula	10-20m 3.6mts.	Pyramidal tall crown	Evergreen	Moist tropical alimate rich alluvial soil	Throughout India specially U.P., Bihar, Bengal, Haryana etc.	Avenues. Parks & compound	6-10 years	Indigenous to Srilanka. Highly ornamental foliage. Variety with pendulous short branches looks more attractive.
84	Pongamia Pinnata	Karanj	5-8 mts. 4.6mts.	Umbrella shaped crown	do	Tropical climate light soil	Throughout Haryana	Avenues & Parks	5-8 years	Indigenous Bengal fast growing.
85	Populus nigra	Popular	12-30 mts 3.5 mts	Normally columner up-rising tree with vertical branches	Deciduous	Fairly deep any type of soil	do	do	5-6 years	Exotic (West Asia) Tolerates heat and cold and wet & dry soils has various roots. Helpful in preserving soil conservation.
86	Prunus Puddum	Paja	10-15 mts. 15 20 mts	Rounded	do	Temperate	High Hills Mid hills.	Road side and Parks	10-15 years	Bears white flowers in November - January Propagated in rainy season.
87	Pterospermum Acerifolium	Kanak Champa	15-20 mts 5-8 mts	Rounded council	Evergreen Moderately shady	Tropical moist	Maharashtra Manipur, Bengal Assam	Gardens	15-20 years	Usually loose and straggly Sweetscented flowers, branches and large rounded leaves.
88	tranjiva roxburghii	Jiaputa Putijiva	5-10 mts. 5-8 mts	Spreading	Evergreen	Moist tropical climate rich alluvial soils	Ambala Kurukshetera and Karnal	Avenues & Parks compound	5-8 years	Indigenous.
89	Ravenala madgascariensis	Travellers tree	5-8 mts.	Fan-like leaves of banana type	do	Tropical dry	Hot plains	parks & house compounds	3-5 years	Leaves spread out like Japanese fan. Propagation during the rainy season.
90	Robinnia pseud-acacia	Bobinia	10-15 mts	Rounded	Deciduous	Temperate	Mid & High Hills.	Edges of fields and orchards in hills	8-10 years	Creamy white fragrant flowers spring summer very good solid binder. Good for honey collection. Propagated in rainy season.

91	Salix babylonica	Weeping/ Willow Majnu	5-12 mts	Round with spreading branches	do	Tropical to low temperate	Plains to 2,000m hills	Parks Gardens water ways	8-10 years	Droping branches which touch the ground, beautiful specimen near water ponds Propagated during rainy season.
92	Sapium sebiferum	Maidan tree/ Tar Charbi	10-15 mts	Rounded	do	Sub- tropical	Foot hills	In groups for autumn colour component	5-10 years	Artistic branches and red coloured autumn leaves changes the character of landscape
93	Saraca asoca (S. India)	Ashok	3-15 mts	Round with spreading branches	Evergreen	Moist tropical climate rich alluvial soil	Plains to 1,000m.	Parks, Avenues & component	15-30 years	Appear in cluster on the main steams. Very attractive when in flower
94	Schleichera trijuga (S. Deosi)	Ceylon Oak/ Kusum	15-20 mts	Rounded	Deciduous shady	Dry- moist tropical	do	Avenues	20-40 years	Leaves become red March - April and again in June - September- Heavy leaf shedding.
95	Solandra grandiflora	Potata tree/ Night shade tree	Small tree; 5m.	loose rounded	Semi- Deciduous	Dry to moist	Low hills area	Gardens	3-5 years	Large showy blue flowers and beautiful Prickly stem.
96	Spathodea campanu lata	Foundation tree	10-15m	Rounded	Semi -Evergreen	low hills area	Does well upto800m.	Avenues & Parks	8-10 years	Exotic . It is very common in S. India for scenic plantation in intestive ground it is one of the best tree.
97	Pongpia alara (sterculia alata)	Pinari	Very tall 25-30mts	Oblong	Semi-Deciduous	Moist tropical to sub tropical	Plains to 1,000 m.	Long avenues	10-20 years	Pale green foliage sheds leaves in April very ornamental and graceful tree. Very heavy leaf fall.
98	Swietenia mahagoni	Mahogony	15-20mts	Rounded	Evergreen	Tropical moist	Plains with average to good rainfall	Avenues & Parks	20-30 years	Handy tree. Good foliage and gives good shade. Timber very useful.
99	Tamarindus indica	Imli	10-25 mts	Oval to rounded crown large tree.	Never leaf less shady	Tropical climate& light soil	Throughth hot ster parts of India	do	8-12 years	Exotic Africa but completely naturalised in India. Fruit eaten, shady tree.

100	Tamaria articulata	Farash	5-12 mts	Up-right spreading baranches forming bushy erosion	Evergreen	Tolerates heart some degree cfd cold,soil very tolerant prefers light sandy soils	Desert and arid areas	Suitable for Hedges, wind breaks & erosion control	5-8years	Indigenous., Tree sheds blanch lets throughout the year. Branches used for making baskets. Good fuel.
101	Taxodium mucronatum	Mexican baldcyoress	15-25 mts	Spreading with dropping branches	Semi-decidous	Sub-tropical to temperate	Along canal banks marshy lands&high rainfall areas	..	10-15years	Exotic, from Mexico, Light durable and elastic timber., Fast, growing conifer, very long lived, resistent to disease. Foliage very graceful.
102	Tectona grandisi	Sagoon teak	10-20 mts	Rounded	Decidous	Tropical Dry climate	Tropical to sub tropical areas	Avenues	10-15years	Indigenous. Very important timber tree.
103	Terminalia arjuna	Arjun	15-25 mts	Oval rounded crown tall tree	do	Sub-tropical climate and moist alluvial soil	Throught the plains	Avenues & Parks	5-8years	Indigenous, one of the finest of Indian tree. Leaves broad and glosy green beds. White flowers in Nov. January, very hardy tree.Bark used in medicine as tonic.
104	Terminalia bertlirica	Bahera	51-20 mts	Tall rounded	do	Hot&Dry climate	Dry arid regions Throught the plains.	Large Avenues & Parks	15-30years	Leafless in May-June every shady fruit Bahera is used.
105	Terminalia catappa	Desi-baddam	Medium height	Pyramidal	do	Tropical coastal	Peninsular India	Avenues & Parks	10-20years	Good shady tree fruits in Indian medicine is sold as Badam Leaves change colour from to green.
106	Terminalia chebula	Harar	10-15 mts	Rounded	Decidous	Tropical to sub-tropical	Throught out plains	Avenues particularly in rural areas.	15-30years	..
107	Thespesia populnea	Pras pipal	5-12 mts	do	do	Likes high humidity	coastal Regicons of bengal india andamans	Avenues , Parks & Rly. Station	5-10years	Flowers large, Pale yellow

108	Thuja orientalis	Mayur pankhi	5-10 mts	Evergreen	Evergreen	Moist climate stands heat A good deal of cold.Well drained soil	Throught the plains low hills	Parks , Lawns and river front	10-15years	Exotic (N. China & Korea) No. of carieties are available Always prumed to keep a uniform shade slow growing.
109	Tilia cordata	Lime tree	10-15 mts	Decidous	Decidous	Hill stations above 1,500m	Mid high hills	Avenues	10-30years	Exotic. Beautiful and shady tree, Introduced in anali, Simla etc. seeds are attached to glider type wing for dispersal.
110	Trachycarpus for tunei	Wind mill palm	3-10mts 3-5 mts	Evergreen	Evergreen	Tropical climate and haigh moist well drained sandy loamy soils	Throughtout Haryana	Parks, Buildings and tree Plant	8-10years	Exotic (Burma, Japan) does not stand prolonged freezing. Moderate by growing tree.

Supplementary List of Trees

Source : TCPO

S. No.	Botanical Name/ Latin/ English	Common Indian Name/ Hindi/ Local	Structure Height Spreading (approx.)	Shape	Physiegnomy Evergreen Deciduous, Flowering, Shady, etc.	Climate and Soil	Area most suitable for Planting	Rounded use	Period taken from Planting to mature stage	Indigenous/ Exotic/ Remarks, if any
1	2	3	4	5	6	7	8	9	10	11
1.	Acar oblongum	Pangol	15 mts.	Tall	Deciduous	Sub-tropical	N. India upto 6,000 ft.	Rounded	30 years	Young foliage of beautiful colour. Indigenous.
2	Acrocapus fraxinifolius	Mandania	30 mts.	V Tall	do	Moist sub-tropical (West)	N. India upto 3,000 ft.	Parks & open land scape	20 years	Flowers attract lot of birds during spring Indigenous to East India.
3	Adenanthera microsperma		15 mts.	Rounded	do	Plains sub-tropical	N. India upto 3,000 ft.	Parks small avenues	20 years	Attarctive foliage Seeds red like Rattipods twisted. Indigenous.
4	Aesculus assamica	Dingri (Nep.)	15 mts.	do	Deciduous flowering	Moist sub-tropical (West)	N.W. to E. sub-troop	Parks & open scape	20 years	Attractive autumn foliage. Flowers very ornamental. Indigenous to E. India
5	Aescsuls indica	rankhor, Horse Chestnut	20 mts.	do	do	Temperate	N.W. to E. N. Temp.	Parks avenues	30 years	Flowers and foliage ornamental. Patchy bark. Indigenous
6	Agathis robusta	Kauri pine	20 mts.	Tall	Evergreen	Sub-tropical to temp.	N.W. to E. N. India	Parks, city avenues	30 years	Conifer with bread leaves. Self-pruning habit. Graceful. Exotic (Australia)
7	Araucaria bidwillii	Bunya-Bunya	20 mts.	do	do	Sub-ropical	N. India	Parks in groups	30 years	Very peculiar branching habit. Conifer Exotic.
8	Araucaria columnaris (A. Cookii)	Monkey puzzle	20 mts.	do	do	do	N. India	Parks	20 years	Graceful conifer columnar exotic

S. No.	Botanical Name/ Latin/ English	Common Indian Name/ Hindi/ Local	Structure Height Spreading (approx.)	Shape	Physiegnomy Evergreen Deciduous, Flowering, Shady, etc.	Climate and Soil	Area most suitable for Planting	Rounded use	Period taken from Planting to mature stage	Indigenous/ Exotic/ Remarks, if any
9	Araucaria cunninghamii	Hoop pine	30 mts.	do	do	do	N. India	Parks, gardens, avenues	20 years	Conifer, tall, straight Exotic
10	Bauhinia retusa	Semla	15 mts.	do	Deciduous	sub-topical upto 5,000	Sub-tropical N India	Parks, open lands cape, hill slopes	20 years	Pads about 1 ft. long, turning red maturity Useful gum is obtained from tree Exotic
11	Cassia glauca		8 mts.	do	do	do	Sub-tropical N India	Parks boundries	5 years	Ornamental, flowers yellow exotic
12	Cedrus deodara	Deodar	25 mts.	Conical	Evergreen	Temperate	N India		50 years	Conifer, Beautiful shape, Valuable timeber Very graceful tree Indigenous
13	Cupressus Cashmeriana		15-20 m.	Conical	Evergreen	Sub-topical temperate	N. India & hill stations upto 2,000 m.	Parks & approach roads, gardens	20 years	Gymnosperm Very shady tree indigenous
14	Cupressus funerbris	Weeping cypress	15-20 m.	do	do	Sub-topical temperate	N. India & hill stations upto 2,000 m.	Parks, gardens & approach roads	20 years	Drooping leaves gymnosperm Natu ralised
15	Diospyros embryopdulenris	Kala tendu	15 m.	do	Evergreen dense shady	Tropical to sub-tropical	N. India & hill stations upto 2,000 m.	Parks Marshy lands	20-30 years	Yound foliage deepred colour in spring season Indigenous
16	Eucalyptus camaldulenisis		40 m.	V Tall	Evergreen	do	Throughout India where rainfall 1,000 m. and above	Damaged by strong winds. Avenues gardens. Canal banks	10-20 years	Evergreen. Fast growing tree Exotic.

S. No.	Botanical Name/ Latin/ English	Common Indian Name/ Hindi/ Local	Structure Height Spreading (approx.)	Shape	Physiegnomy Evergreen Deciduous, Flowering, Shady, etc.	Climate and Soil	Area most suitable for Planting	Rounded use	Period taken from Planting to mature stage	Indigenous/ Exotic/ Remarks, if any
17	Eucalyptus deglupta	Bule-gum	40 m.	do	do	Hills upto 1500m. N. India 200m in S. India	Rainfall about 1,500 m. & above	Hill station	10-20 years	Useful oil of cucalyptus is distilled as cottage industry Suffers from snow damage. Exotic
18	Eucalyptus deglupta	Rainow Eucaly ptus	40 m.	do	do	Sub-tropical high rainfall	Most areas or places of high rainfall	Parks avenues	10-20 years	Useful timber, bark of different colours from green to red Exotic.
19	Eucalyptus ficifolia		10-15 m.	Small	do	Hills upto 1500m.	Cold places	Gardens. Parks	20 years	Flowers pink. Exotic
20	Eucalyptus teneticornis		40 m.	V Tall	do	Tropical & sub-tropical	Areaswith average to low rainfall	Canal, Baks,roadsides, farmlands as wind breaks.	10-15 years	Useful as fuel and raw material for paper Exotic.
21	Ginkgo biloba	Maiden hair tree	15-20 m.	Tall conical	Deciduous	Sub-tropical to temperate	Hill stations.	Gardems. Parks, College, compounds.	20-50 years	Tree of great academic importance Spectacular autumn colour of leaves. Living fossil tree. Exotic
22	Homalium tomentosum		30 m.	Oblong	do	Wet tropical	Dehradun, Haldwani, Nahan where rainfall is high above 1,500 m.	Gardens, Parks city avenues.	30 years	Bark white. Very attractive tree. East India & Burma
23	Koalreuteria apiculata	Chinese Golden rain tree	10 m.	Rounded	do	Sub-tropical temperate	Foot hills & upto 1,500 m.	Parks & Gardens.	10-20 years	Very attractive when in fruiting stage. Exotic.
24	Podocarpus gracilior		15 m.	Oblong to Conical	Evergreen	Cold	From 500-1,500 m.	City roads parks & botanical gardens.	25 years	Gymnosperm with very handsome sense foliage. Exotic

S. No.	Botanical Name/ Latin/ English	Common Indian Name/ Hindi/ Local	Structure Height Spreading (approx.)	Shape	Physiegnomy Evergreen Deciduous, Flowering, Shady, etc.	Climate and Soil	Area most suitable for Planting	Rounded use	Period taken from Planting to mature stage	Indigenous/ Exotic/ Remarks, if any
25	Populus (various) species	Sufeda	20 m.	Tall	Deciduous	Sub-tropical to temperate	300-2, 500 m.	Parks & hill stations	15 years	Fast growing Exotic Naturalised
26	Quercus incana	Hanj	15-20 m.	Rounded	Evergreen	Temperate	Hill above 1,200 m upto 2,500 m.	Barren hillsides, roadsides	30 years	Underside of the leaves is silvery, It looks attractive wind Indigenous.
27	Rhododendrom	ar-Burans	10 m.	Rounded	Evergreen	Temperate	Hills from 1,550-2500m.	Hillsides Parks and avenues.	20 years	Searlet flowers appears in spring very showy Indigenous.
28	Sapindus mukorossi	Ritha	20 m.	do	Dedicuous	Upto 4,000 sub-tropical	Foothills, upto 1,200 m.	Roadside Parks	20 years	Golden Yellow autumn colour leave are very attractive Indigenous.
29	Terminalia myriocarpa	Hollock	30 m.	V Tall tree of E. India	semi-deciduous to evergreen.	Teropical to Sub-tropical with high rainfall.	Upto 1,200 m in places of high rainfall.	Avenues Highways & Parks	30 years	Most striking tree when in flower and fruit during autumn Indigenous (East India)
30	Tabebuia argentea		12 m.	Rounded	Dedicuous	upto3,000	Planis to 1,000 m	Parks & Gardens	8 years	The whole tree gets covered with golden yellow flower in spring. Very striking Exotic.
31	Syzygim Cuminieugenia Jambolaina	Jaman	15 m. 10 m.	Rounded	Evergreen	Warm climate rich, moist and well drained soil	Low hills chandigarh	Avenues	15-20 years	Dense foliage, good shady tree.

Shrubs Suitable for Landscape

Source : TCPO

Sl. No.	Botanical / English Name	Common / Hindi /Local Name	Structure Height Spread	Shape	Physiognomy Evergreen Deciduous Flowering Shady, etc.	Climate & Soil	Areas most Suitable for Planting	Recommended use	Period taken from Planting to Mature stage/ season for Planting	Remarks
1	2	3	4	5	6	7	8	9	10	11
1	A butilon Sp.	Chinese Lantern	6-8'	-	-	-	Mid to High Hills	-	Propagated in spring & rainy season	From cutting & seeds. Flowers like ear drops a beautiful shrubs good pot plant, summer flowering.
2	Acalypha	Acalypha	2-4'	-	-	-	Mid to low Hills	-	Rainy Season	From cutting Requires sahde. Good pot plants some are veriegated summer flowering.
3	Acanthus	Acanthus	2-4'	-	-	-	do	-	do	From seeds and cutting . Many species , summer and rainy season. Blossming.
4	Acacia Sp.	Wattle	8-10'	-	-	-	do	-	do	From seeds and cutting . Many species give perfume Summer flowering.
5	Hibiscus	Hibiscus	6-6'	-	-	-	do	-	do	From seeds & cutting, gives profused red flowers all around the year.
6	Aerva Tomentosa	Aerun	1-1-1/2'	-	-	-	do	-	do	From seed and cutting. good pot shrubs.
7	Allamanda Sp.	Almand	6-8'	-	-	-	do	-	do	From cutting , dark polished green . Evergreen flowers.
8	Allthara rosea	Holy Hock	6-8'	-	-	-	propagated in Autumn	-	Propagated in Autumn	From seeds. Perineal varities to not grow well in low hills in rainy season.
9	Artabotrysuncinatus	Haronampa	8-10'	-	-	-	Rainy season	-	Rainy Season	From cutting/ flowers/ seeds. scented flowers. summer flowering.
10	Beloporone	Belopérone	2-4'	-	-	-	Low hills	-	Rainy Season	From cutting and seeds good pot plant . flowering all the year.

11	Bougainvillea	Boughainvillea	-	-	-	-	-	do	-	do	-	do	From cutting layers good as well can be trained as a shrub. Many varieties summer flowers.
12	Buddleja Sp.	Buddleja	4-8'	-	-	-	-	Low to High hills dependin g spices	-	-	-	do	From cutting and layers. Many species with variable habits, summer and rainy season flowering.
13	Buxus Sempervirens	Box	6-8'	-	-	Evergreen	-	Mid and High Hills	-	-	-	do	Side suckers, beautiful brote leaves in autumn evergreen shrub, autumn colouring of leaves (red)
14	Camellia	Camellia	2-4'	-	-	Evergreen	-	Mid and High Hills	-	-	-	Sow seeds winter cutting & longers rainy season.	From seed cutting. Like partical shade and good leaf summer flowering.
15	Congea	Box	4-6'	-	-	do	-	Low hills	-	-	-	Rainy Season	From seed like high humimidity also used for pitching. Large jumphet shaped flowers.
16	Catesobaea spinesa/ Cytisus sp.	Elly thron/Spanish broom	4-5'	-	-	-	-	Mid & Low Hills High Hills	-	-	-	do	Exotic (America) from cuttings and seeds good, soil binder and can be grown pour soil.
17	Citrus aurantium	Thatta Narenga	A large shrubs	-	-	Evergreen white flowers	Warm white flowers	Ambala, Karnal, Kurukshet ra.	-	-	4-6 years	Indigenous, suitable as hedge plant.	
18	Clerodendrum Spp.	-	4-5'	-	-	Deciduous	-	Mid & High Hills	-	-	Rainy Season	From seed suckers and cuttings flowers produced on new growth. May species Summer flowering.	
19	Coccoloba	Kankhajura	4-5'	-	-	-	-	Low & Lid Hills	-	-	do	From cutting, Love warm situation most beautiful pot plant.	
20	Codiacum/ Croton	Croton	1/1/2013	-	-	-	-	Low hills	-	-	-	From cuttings Love warm situation, most beautiful pot plant.	
21	Cestrum nocturnum	Rat ki Rani	6-8 ht. w 2-3	-	-	Evergreen flowering at night	-	Mid & Low Hills througho ut Haryana	Parks & Compoun ds	3-5 years Rainy season		Exotic(mexico) seed cuttings and layers very strongly seconded climber & shrub white flowers very fragrant.	

22	Crossandra Sp.	Crossandra	2-3'	-	-	-	Low hills	-	-	Flowering through out the year. From seed cutting flowers fragrant.
23	Dodnaca Viscosa	Sanatha/ Aliyar	A shrubs or small tree, vertical branches.	-	Evergreen	Dry Sub-tropical climate, can grow on pour soil.	Throughout Haryana	Hedge Plant	3-5 years	Indigenous, very shring leaves.
24	Duranta repens (Duranta Plumieri)	Duranta/ Neel Kanta	Large shrubs	More or less throny	Evergren flowering	Moist trop, climate rich loamy soil.	Ambala, Karnal, Kurukshetra.	Hedge Plant	3-5 years	Exotic (South America) from cuttings.
25	Euphrbia	Euphrbia	1 1/2 - 1/1/2	-	-	-	Low hills Area	-	June & July	From cuttings good for rockersies and pot plant flowering throughout the year.
26	Fuchsia Sp.	Fuchsia/ Dancing Lady	-	-	-	-	Mid & High Hills	-	Spring & Rainy Season	Flowering summer and rainy season from cuttings, good pot plant inlove shade.
27	Gardenia florida	Gandhraj	6-8'	-	-	-	Low Hill Area	-	Rainy Season	From cuttings rainy season flowering white scented flowers.
28	Haimelia patens	Haella	Large shrub	Spreading crown	Evergreen flowering reddish yellow	Tropical climate rich well drained soil	Throughout Haryana	Parks	3-4 years	Exotic (Tropical America) flowers and leaves whorls.
29	Hibiscus nutabilis	Gul-e-Ajaib	3-6 mts 2-3 mts	Large shrub or small tree	Deciduous flowering (light pink) in sept. to November	Warm climate rich, loamy soil.	Ambala, Karnal, Kurukshetra.	Parks & Hedges	3-4 years Rainy season	Exotic (China Japan) from cutting & many species for different elevators summer flowering.
30	Hibiscus rsa-sinensoss	China rose	-	Erect shrub	Evergreen Flowering throughout the year	do	Throughout Haryana	do	3-4 years	Exotic (China Japan) Several varieties with single and double flowers and colours.
31	Hrdranges	Hrdranges	2-4'	-	-	-	Mid & High Hills	-	Rainy Season	From cuttings many spices for different elecation and love shade.
32	Hypericum oblongifolim (H. ornuum)	Pahari Chameu Phionli	5-6'	-	-	do	do	-	do	Side suckers, and seeds grows wild in Simla and bears beautiful yellow flowers in summer.

33	Dixcra	Rukemani	2-6'				Low hills		do	From cuttings Many colours shade, loving summer flowering beautiful
34	Jasminum Sp.	Chameli	Small Shrub	Shurb	Evergreen flowering April-June (yellow).	Loamy rich soil sub-tropical climate light soil.	Low & high hills throughtout Haryana.	Parks & Compounds.	do	Indigenous from cutting gives jasminum Oil of Commerce, summer flowering fragrant flowers.
35	Jasminium sambac	Motva Mogra Chameli	3-4 mts.	More or less climbing.	Evergreen flowering April-June (White).	Sub-tropical climate & light soil.	throughtout Haryana.	do	2-3 years	Indigenous. Fragrant flowers.
36	Lagerst-roemina indica	Pride of India	3-5 mts.	Small shrub	Deciduous	Prefers deep loam soil.	do	Parks Buildings & Compounds.	5 years	Exotic (China) Tolerate heat and cold but not freezing and prefers. Leaves jurk warm red and golden before fall.
37	Ligustrum Sp.	Ligustrum	12-15'		Evergreen with beautiful foliga		Mid & High Hills.		Rainy Season	From seed and cuttings
38	Lonicervaregate	Variegated Honey suckle	1-11-2'				do		do	From cuttings beautiful pot plant.

39	Lawsonia inermis (Laliba)	Mehndi	16'		Deciduous		Low Mid Hills	Good for Hedging.	do	From seed and cuttings products of Mehandi of commerce. summer flowering.
40	Magnolia Sp.	Campa	8-5'		Evergreen		Mid & High Hills.		June, July	Tree of progress seed and layering. There are number of species famous for their fragrant spring and summer flowering.
41	Malpighia	Cesari Bush	10-12'				Mid Hills	Good for Hedging.	Rainy Season	From seed and Cuttings. Holy like leaves.
42	Montanoa bipinnatifida	Kaminiil Kamini	4 Ht.				Mid Hills		do	From cuttings. Flowers pink December Feb.
43	Murraya paniculata (Murraya Exotica)	Kaminiil Kamini	6-8'		Evergreen		Low Hills & Mid Hills.	Suitable for Gardens.	do	From seed and cuttings layings. Very fragrant flowers (White) can be trimmid of any shape.
44	Mussaenda Sp.	Kaminiil Kamini	4-6'			Deep soil & water.	Low & Mid Hills.		do	Laying or cuttings. rainy season blooming.
45	Myrtus communis	Belaiteel Mehndi	6'				Mid Hills		do	From seed laying cuttings flowers in March-April, leaves scented and red garlands bouquets.

46	Nandina domestica		2-4'				do		do	From seed and shrubs requires paracill shade in summer.
47	Nerium Sp.	Kaner	3-8'	Erect	Evergreen flowering (Red-white)	Sub-tropical climate & light alluvial soil.	Low & Mid Hills Throughout Haryana.	Parks & Hedge Plant	May-June 3-4 years	Indigenous. Porzonous from cuttings.
48	Myctanthes arbortristis	Harshinagar	6-8'		Deciduous		Low Hills.		Rainy Season	Seed and cutting flowers used for pujas, open at night and deep
49	Olea fragrans (Osmanthusfragrans)			Evergreen			do		do	Layin in shady place, flowering throughout the
50	Parkinsonia aculeata		5-10 mts.	An openly growing wide spreading shrun	Evergreen Flowring (yellow)	Tropicri deseratmospherey trivesm in dry shady soil	throughtout Haryana.	In parks used as hedge plant	3-5 years	Exotic (Tropical America) Tolerates alkali and drought but not prolonged freezing.
51	Phyllanthus niveus						Low & Mid Hills.		Rainy Season	From suckers cuttings small verigaated leawes with white pink rose purple colour.

52	Phyllanthus	Mock orange	5-6'				do		From cuttings layers. suckers in Feb-March grow in shady place prune soon after
53	Plumbago alba	Chitra Rose	2-2'			Mid Hills	do		From cuttings and suckers flowering in March-June P. Rosea is good for winter and colour of the leaves can be trimmed.
54	Euphorbia pulcherrima	Poinsettia	6'			Low & Mid Hills.	do		From cuttings can be good pot plant white flowers.
55	Pelargnium Sp.	Geranium	2-4'		Flowering	do	do		From suckers and cuttings good pot plant but needs winter projection gives geninium oil.
56	Portlandia grandiflora	Chinese Bashcher ry	4'			do	do		Cuttings and layers bears white flowering
57	Prinus Japonica	Flowering plum	4'			Low & Mid Hills.	do		Side suckers beautiful coloured leave flowering in summer.
58	Puuica Granatum	Mergrant e Anar			Diciduous	do	do		From cuttins varies with dwarfhanging white flowers are available in

59	Ricinus Communis	Caster oil plant/Re ndi	10-12'		Evergreen	Low Hills.		Spring and Rainy Season	Seeds, there is variety with purple branch leaves.
60	Russelia Macasa	rstmas Pride	2-3'			Low & Mid Hills.		Rainy	From cuttings can be grown in baskets. Leaves shade flowering throughout the
61	Russelia Gunoea	Coral plant.	4'					do	Good for hanging in baskets and ornamental heading grass like branching summer
62	Sanchezia Nobilis	Sanchezi a	4'			Low & Mid Hills		do	From cuttings yellow flowers with re-branches lowe shaded summer flowering.
63	Spirea Conyambosa	spiaea	4-6"			do		do	From side suckers good for hedging stands trimming summer flowering.
64	Stachytarphet a mutabilis	Tree Verbena	2-3'			Low & Mid Hills.		Rainy Season	From seed and cuttings. It bloom throughout the year verbina like colours flowers.
65	Streptosolenja mesoni (Browallia jamesonii)		5'		Evergreen	Mid & High Hills.		Rainy Season & spring	From cuttings. Bear bright orange flowers of great beauty.

66	Sambucus nigra				Deciduous		do		Rainy Season
67	Tabernaemontana Coronaria Erva--tamia coronaria	Chandni	6-8'				do		do
68	Tecoma Sp. T, grandiflora, T, Jasminoides. T	Tecoma	6-8'						do
69	Tecomella undulata	Pohira Tecomma tree	3-5 mts. 2-3 mts. (25'/15)	Shrub or small tree	Flowering (Plae yellow to deep ornage) March-Apr.		Sub-trop, arid climate light dry soil.	Parks & hedge plant	3-5 years
70	Thespesia Macrophylla	Thospesia	4-8'						Spring and Raniy Season
71	Thevetia Neriifolia	Pili-Kaner/Yellow Olender.	5-6' Large Rounded shrub or small tree.	Rounded	Evergreen flowering (yellow) Throughout the year.		Tropical climate rich alluvial soil		3-5 years Rainy Season

72	Thunbergia Erecta	Thurberg ia	Perennial Ssun flower	5-6'						do	From cuttings like cloxiona flowers peeping out of foliage flowers February-
73	Tithonia Diversifolia									do	From Seed or cuttings. Blooms from November to January.

Shrubs Suitable for Landscape (Supplementary List)

Source : TCPO

S. No.	Botanical English Name	Common / Hindi/ Local Name	Structure Height Spread in (Metres)	Shape	Evergreen Deciduous, Flowering, Shady, etc.	Climate and Soil	Area most suitable for Planting	Recommended use	Period taken from Planting to mature stage	Remarks
1	2	3	4	5	6	7	8	9	10	11
I.	Arundo donax	Nari	1 mts.	Multi branched					4-8 years	
2	Bambusa Sp.	Bamboo Bans	30 mts.	do	Evergreen				do	
3	Barleria Cristata			do	Flowering				do	
4	Bauhinia Acuminata			do	do				do	
5	Cestrum Alba	Din-ka Raja		do	do	Tropical Dry and domat			5-8 years	Indigenous
6	Daedalacanthus Nervesus			do	do				do	
7	Gossypium Sp.	Kaps		do	do				do	
8	Hamiltonia Suaveolens			do	do				do	
9	Jatropha Gossypifolia			do	Evergreen				do	Indigenous
10	Justicia Sp.			Thick leaves and Multi-branched	Flowering				do	
11	Thujacompacta	Mor Pankhi		Multi branched	Evergreen	Tropical Dry and domat			5-10 years	Indigenous

Creepers Suitable for Landscape

Source : TCPO

S. No.	Botanical English Name	Common / Hindi/ Local Name	Structure Height Spread in (Metres)	Shape	Evergreen Deciduous, Flowering, Shady, etc.	Climate and Soil	Area most suitable for Planting	Recommended use	Period taken from Planting to mature stage Method of prep./Season for Planting.	Remarks
1	2	3	4	5	6	7	8	9	10	11
1.	Adenocalymon Alliaccum				Evergreen	Grows well in sandy loamy soil	Low Hills		From layerings & cuttings-June - July.	Very beautiful climber.
2	Alfamanda cathertica	Allamanda					do		From seed in Rainy Season.	Heavy climber can be grown as a bush. Gives of various sizes in greal profusion in summer & Rainy Season.
3	Aatigonon Leptopus	antigonon			Deciduous		do		From seeds & Rainy Season	Plowers of pink, white carmine red etc.

Creepers Suitable for Landscape (Supplementary List)

Source : TCPO

S. No.	Botanical English Name	Common / Hindi/ Local Name	Structure Height Spread in (Metres)	Shape	Evergreen Deciduous, Flowering, Shady, etc.	Climate and Soil	Area most suitable for Planting	Recommended use	Period taken from Planting to mature stage	Remarks
1	2	3	4	5	6	7	8	9	10	11
1.	Argyreia Speciesa		As required		Flowering	Tropical Dry and domat			5-8 years	
2	Artabotrys Sp.	Kattli Champa	do		do	do			do	Indigenous.
3	Clerodendrum Splendens.		do		do	do			do	do
4	Echites caryphyllata (Aganesma caryophyllata)	Malti	do		do	do			do	do
5	Ipemoea.		do		do	do			do	do
6	Jasminum articulatuo	Joshi	do		do	do	do		do	
7	Perana Paniculata	Bridal Creeper	do		do	do			do	
8	Tecoma Radicars		do		do	do			do	

List of Other Plant Material Suitable for Landscape

Source : TCPO

S. No.	Botanical / English Name	Common / Hindi/Local Name	Structure Height Spreading (approx.)	Shape	Physiegnomy Evergreen Deciduous, Flowering, Shady, etc.	Climate and Soil	Area most suitable for Planting	Period taken from Planting to mature stage	Remarks
1	2	3	4	5	6	7	8	10	11
1.	Agaloma	-	About 1 mts	_	Flowering	_	-	1-2 Years	-
2	Agave	Hambans	-	_	_	_	Mid Hills Area	rainy season	Exotic (America) from seed & side suckers. It grows wild in sunny situation.
3	Alpina	-	about 1 mts	_	Evergreen	_	-	1-2 Years	-
4	Aspidistra	-	-do-	_	do	_	-	-do-	-
5	Aralia	-	-do-	_	Evergreen Flowering	_	-	-do-	-
6	Asparague Cooperi	-	-do-	Ornamental Leaves	Evergreen	_	-	-do-	-
7	Bryophyllum Sp.	Ajuba	1/2-1/2 mts.	Thick Leaves	do	Hot, Dry and sandy	-	1/2-1 Year	-
8	Cactus	-	1/2-1 mts	Thick Leaves	-	do	-	2-5 Years	-
9	Chlorophytum Sp.	-	About 1 mts	_	-	-	-	1-2 Years	-
10	Cordyline Sp.	-	-do-	_	Evergreen	-	-	-do-	-
11	Cruassula	Cruassula	-	_	do	-	Mid & High Hills	March-Aproll	From stem cutting. Does not grow in hot climate.
12	Crinum	-	About 1 mts	_	do	-	-	1-2 Years	-

S. No.	Botanical / English Name	Common / Hindi/Local Name	Structure Height Spreading (approx.)	Shape	Physiegnomy Evergreen Deciduous, Flowering, Shady, etc.	Climate and Soil	Area most suitable for Planting	Period taken from Planting to mature stage	Remarks
13	Croton Sp.	-	-	Ornamental Leaves	-	Shady Places	-	-do-	-
14	Dracaena	-	about 1 mts	Long green leaves	-	Shady Places	-	-do-	-
15	Echinopsis	Cactus	-	-	-	-	Low and Mid Hills	May-June	Large and wide cactus with pink flowers. Detatchable off sets.
16	Echinocactus	Cactus	-	-	-	-	d0-	May-June	Many spices with yellow pink flowers in March April. Detatched side plants.
17	Epiphylum	-do-	-	-	-	-	Mid & High Hills	rainy season	Detatchable off sets, Bears red, white or yellow flowers sensitive to Sun Shine.
18	Euphorbia	Euphorbia	-	-	-	-	d0-	rainy season	From stem cutting. Stems are glabular without leaves..
19	Hawerthia	Cactus	-	-	-	-	Mid & High Hills	rainy season	By off sets,attractive plants, short stems feathery leaves. Many species
20	Kalanchee	Kalanchee	-	-	-	-	d0-	-do-	From leaf cuttings, Many species resemble Bryphyclum red, white, yellow, orange. Flowers line sunny situations.

S.No.	Botanical / English Name	Common / Hindi/Local Name	Structure Height Spread (approx.)	Shape	Physiognomy Evergreen/ Deciduous, Flowering, Shady, etc.	Climatic and Soil	Area most suitable for Planting	Period (also from Planting to attaining this age)	Remarks
21	Mammillaria	Nipple Cactus	-	-	-	-	-	-do-	By dif. sets/Leafless cylindrical stems, Hairy top.
22	Opuntia Dillenii	Negihani	1/2 - 1 mts	Really Thick leaves	-	-	-	2-5 Years	-
23	Phyllocactus	Leaf Cactus	-	-	-	-	Low & High Hills	May-June	From leaves cuttings flowers from July to September.
24	Sapreneivum	Sapsanevi ra	-	-	-	-	Mid & High Hills	rainy season	From leaf cuttings flattened leaf flowers stems arise from the branches or various colours many species.

Central Public Works Department (CPWD)

In the service of the nation since 158 years

Under the Ministry of Urban Development, Government of India, CPWD provides single window services for all facets of the government built environment in India and abroad.

With its huge resource of skilled and competent engineers, architects and horticulturists, CPWD's strength is its country wide presence, with proven ability to undertake a whole range of complex constructions under difficult terrains. The department has the capacity to undertake construction varying from the smallest works in the remotest of places to mega projects in metro cities. These works include the construction and maintenance of government structures such as residential complexes, offices, schools, laboratories, hospitals, sport facilities, stadia, gymnasia, auditoria, storages, highways, flyovers, tunnels, bridges, jetties, airports, runways and border fencing. Intra-campus facilities such as water and electric supply, sewerage and treatment plants are also provided.

CPWD also performs other functions such as the custody of estates, valuation, rent assessment, technical advice to government, consultancy services, standardisation and benchmarking, State Ceremonies (Republic Day, Samadhis, etc.), processing of DPRs for development of urban infrastructure under JNNURM and works of other Ministries for centrally funded works. CPWD also assists in organising public and ceremonial functions, and upkeep of historical and important monuments and structures.

A Handbook of Landscape

CPWD also publishes various documents to help the construction industry. This publication is a further step forward in the department's commitment towards environment sustainability. It outlines the integration of landscape in architectural planning, taking into account the ecological environment. Professionals, practitioners and others will find this publication immensely useful in their day to day work.

Central Public Works Department
301-A, Nirman Bhawan, New Delhi 110 011.
Tel: 23062138; Fax: 23061774
Email: adg-arch.cpwd@nic.in

February, 2013.