— study min 2 examples for each
15 marks. B.Arch 2017 degree exam.

Design With Plants

Mohammad Shaheer

X. I How to select the right plants for the design.

I. BASIC CONSIDERATIONS

Introduction

Plant Materials are a very important component of landscape design. Planting design cannot be separated from landscape design and planning in practice, but its many facets, such as analysing the appearance of individual plants and exploring how plants can be used to fulfill various design requirements, can be suited in depth.

The effective use of plant material in landscape design requires the assimilation of an extensive body of data about plants, and its synthesis into a framework which is directly applicable to the process of designing with plants, including the following aspects :

- Ecology
- Botany
- Horticulture
- Aesthetic Values
- Growth and Survival
- Use of Plants in Design

Principles

Principles involved in developing a systematic approach to designing with plants :

Two major sets of factors influence the choice of Plant material : CC

- **Characteristics,** both botanical and physical of plant material
- Context in which 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.

The broadest level at which plant material can be classified in the physical sense, is by size. Plant material includes the smallest plants, such as ground cover, to large trees. A basic range can therefore be derived.

This basic classification can be elaborated further, to include various habits of growth within particular size classifications, flowering, foliage texture, species, etc. Differentiation between woody and herbaceous species, can also be made.

Information on plant material should be available in a systematic format to include: Definition, Significance and design implications of the following aspects :

(a) Nomenclature, Latin and common;

(b) Origin, family, native habitat;

(c) Growth characteristic form as a function of habit;

(d) Physical characteristics;

(e) Propagation and maintenance;

(g) Uses in landscape design.

Maintenance requirements are an integral component of design with plants - their influence on approaches adopted towards choosing plants in a range of situations, varying from the regional to the domestic, needs to be considered.

The above aspects are discussed in detail in the following sections.

Vegetation Types (1)

Vegetation types : Evergreen and deciduous

Functional implication: Particular types may be preferred in specific situations e.g.

Evergreen trees for

- places requiring shade throughout the year
- strong visual screening
- part of windbreak or shelter planting
- areas where leaf-litter is to be discouraged.

Deciduous trees for

- greater visual variety
- partial visual barrier
- areas where under-planning is to be encouraged (e.g. grass)
- emphasis on branching pattern and flowering
- areas where shade is not required throughout the year.

Growth Rate and Age of Vegetation (2)

Design with plants involves consideration of a fourth dimension, i.e. time. Thus, long term consequences of design decisions play an important role in the success or failure of designed landscapes.

The growth rate and life span of species is closely related. Generally, faster growing species have a shorter life.

Also, faster growing species generally have sparser foliage, e.g. Eucalyptus, Leucaena, etc. Thus, growth rate of vegetation can effect the physical appearance of the particular species and can also determine its suitability or otherwise for various design purposes.

Fast growing species would generally be appropriate in situations where:

- quick effects are required - for instance in wind-breaks and shelter belts
- immediate results with regard to stabilisation of soil, etc., are necessary
- 'nurse' plants to protect slower growing sensitive species are necessary.

Usually, slower growing and longer lasting trees are to be preferred for sustained environmental benefits in situations such as roadside planting, campuses, townships and other public landscapes.

Examples

Very Fast Growing	Leucaena leucocephala
Fast	Eucalyptus, Gulmohar, Erythrina
Slow	Neem, Mimusops elengi, Ashok

Growth Habits of Various Kinds of Vegetation and their Form (3)

The overall physical form of a plant is usually the result of the foliage density and branching pattern. The latter is a direct expression of growth habit.

A number of classifications of tree by their overall form exist, but it is almost impossible to have a variety according to regional conditions.

The following differentiation into basic types may be useful:

a. Trees

1 Trees of fastigiate or columnar habit e.g.

Polyathia longifolia (Ashok) Casudrina equisitifolia Populus species (Poplar) Frevillea robusta (Silver oak).

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

2 Tall trees with broad canopy e.g.

Terminalia arjuna (Arjun)

Tamiarindus indica (Imli) Dalbergia sissoo (Sheesham)

The canopy shape does not fit into any specific gometrical category.

3 Trees of spreading habit.

Pithecolobium saman (Rain Tree)

Delonix regia (Gulmohar)

Lagerstromia flosreginae (Pride of India)

Acacia planifrons.

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

4 Trees of weeping habit.

Callistemon lanceolatus (Bottle brush)

Salix babylonica (weeping willow)

The above classification is helpful in choosing various combination of the above types to achieve particular functional or visual objectives.

b. Shrubs

Basic growth habit and form :

1 Shrubs with exposed stem e.g,

Thevetia nerifolia, Tabernaemontana species

2 Shrubs of bushy habit e.g.,

Murraya, Oleander

3 Shrubs of spreading habit, (ground cover e.g., Lantana sellowiana

4 Shrubs with arching foliage on long shoots e.g., Jasminum, Allamanda Bougainvillea.

c Climbers

Climbers (a) self supporting (by tendrils or roots)

(b) needing external support

Self-supporting e.g. Tecoma grandiflora

Syngonium

Antigonon

Bignonia

Shrubs which can be trained on support, e.g.

Jasminum (chameli);

Bougainvillea,

Vernonia (curtain creeper)

Asparagus.

Foliage Charactersitics of Plant Material

Visual effects imparted by vegetation, eg. the perceived visual textures of plants forms depend on:

Leaf size

Leaf texture

Leaf and foliage colour

Foliage density and distribution

The textural appearance of a plant is the result of the play of light and shade on the foliage. Plants with larger leaves generally appear bolder in texture than smaller leaves plants as the areas of light and shade are larger and therefore more clearly differentiated.

An important consideration is the way in which particular kinds of vegetation are perceived. Tree masses are usually seen from greater distance than shrub areas; foliage texture of different distinctive kinds of trees growing together has to be markedly distinctive for individual species to be recognisably apparent. In shurb areas subtle differences in foliage texture may suffice for creating the required visual effect.

Examples of plants with large leaves and bold foliage texture:

Alstonia scholaris

Plumeria acutifolia

Plerospermum acerifolium

Smaller leaves, fine-textured foliage:

Jacaranda mimosaefolia

Parkinsonia aculeata

Neem

Delonix regia

Leaf shape can also determine the appearance of the foliage of the plant, as for instance

Polyalthia longifolia	Long narrow leaves
Callistemon	Narrow leaves giving a feathery appearance

Acacia auriculaeformis

Salix

Leaf colour : Most trees in India have foliage in varying shades of green with variations in colour at the time of leaf fall and at the period when the tree is newly in leaf, when the leaves are fresh and much lighter in colour.

Examples :

Trees

Lagerstroemia	Leaves acquire reddish tinge before falling
Chenar	Leaves become golden
Ashok, Gulmohar, Erythrina etc.	Leaves turn yellow before falling
Ficus Spp. Mango	Young leaves have reddish tinge

Shrubs

Hamelia has leaves with reddish tinge at the bottom of the leaf.

There are a great variety of shrubs whose leaves are a colour other than green, or variegated e.g., Acalypha; Dracaena, leaf bracts of Bougainvillea, euphorbia pulcherrima, etc. Colour variations in shurb foliage can be used effectively in designing with plants, to achieve a number of visual effects.

Leaf texture: Physical texture has an important bearing on the appearance of plants and also their value in landscape design. Rough textured leaves collect dust, and they may not look aesthetically pleasing at all times of the year Glabrous, or smooth textured leaves may repel dust and plants may therefore appear fresher and greener (e.g. Polyalthia spp., Thevetia spp.)

Plants with large, rough-textured leave are most susceptible to changes in appearance due to dusty environments e.g., Cassia fistula, Plerospemum, etc.

Flowering Characteristics of Plant Material

Important considerations while classifying plan material according to their flowering characteristic are:

1. Season
2. Density and distribution of flowerers on the plant
3. Botanical characteristics of flowers - e.g. single, in cluster, etc.
4. Colour
5. Presence or absence of foliage during flowering period.

For the purpose of understanding the visual effect of flowers, tree species can be divided into two types:

1. Those on which flowers appear in profusion and therefore have a very strong visual impact, e.g., Gulmohar, Cassia fistula, Laegerstoemia flos reginae.
2. Those on which flowers are less profuse, or perhaps last for a shorter period and visual impact is more subtle, e.g. Thespesia, Baulinia, etc.

An additional consideration when choosing shrubs for their flowering quality is the visual appearance of the floweres themselves, as shrubs are usually seen from quite close.

Distinctive flowers are those of

Hibisus
Thevetia
Beleperone
Ipomea palmala
Jasminum
Tabernaemoniana etc.

The olfactory characteristics, i.e., odour, of flowerers can be an added benefit of flowering plants. Flowers with distinctive scent include those of Har-Singar (Nyctanthes), Chameli (Jasminum), Rat Ki Rani (Cestrum species).

Flowering characteristics of plant material can be classified as follows:

Flower colour	Botanical characteristics of Flowers	Season Duration	Visual Speci impact ies

Growth Requirement of Plant Material

Information about growth requirements of plant material applicable in landscape design pertains to the ability of particular plants to survive in specific environmental situations. These environmental conditions may arise from a number of aspects:

Soil Conditions

Availability and quality of water

Availability of sunlight

Quality of air

Capacity of plants to grow in cultivated situations is related to the environmental conditions obtaining in their natural habitat.

Soil

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 (e.g. sandy) and Heavy (e.g. clayey) soils, and their structure.

Chemical properties pertain to presence or absence of nutrients and salts. Soil pH, Alkaline or Acid Soils.

A preliminary soil analysis is essential for implementing effective planting schemes.

Water

Certain plants have the capacity to survive in extreme conditions arising from the availability or otherwise of mositure in the air as well as the soil, as in either or water logged conditions.

Information about water requirements of various plant materials should include the humidity and rainfall characteristics of their natural habitat, as this would give an indication of their water requirements in a cultivated situations. The level of the water table has crucial bearing on this aspect

Sunlight

Most cultivated plants can be classified according to their sunlight requirements as follows:

- Plants which thrive only in full sunlight e.g.

  Lantana

  Bougainvillea

  Tecoma stans

  Even partial shade may affect their flowering.

- Plants which can grow in partial sunlight and partial shade;

  Crassula spp. Tradescantia zebrina pendula, Pilea nuscosa, Asparagus spp

- Plants which require predominantly shaded conditions

  Croton, Setcresia

- Plants which do best in complete shade

  Dieffenbachia, Draceana spp. and other indoor plants.

Air Pollution

Growth can be affected by chemical pollutants such as sulphur dioxide or physical pollutants like dust which tends to clog up the surface area of leaves. Certain plants have the ability to withstand pollution e.g.:

Polyalthia

Gulmohar

Acacia species

Oleander

Thevetia

II. MAINTENANCE AND PROPAGATION

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.

Maintenance needs and practices in any given situation arise out of the inter-relationship between the growth requirements of plant material chosen and the environmental conditions existing on site.

Likely degree of maintenance can be assessed by considering

- Scale of the scheme
- Financial and manpower resources
- Availability of manures
- Future intensity of use
- Environmental conditions

In small scale such as gardens or small parks the natural environmental conditions can be changed and maintained in this changed state by management practices such as irrigation and management practices and application of fertilisers. The choice of plant species is therefore not very strictly limited by the existing environmental conditions. On larger scale schemes, such as very large parks, campuses and townships, this kind of intensive maintenance is not possible, and any planting scheme which does not take this into account is likely to fail. The process of choosing plants must therefore respond to the existing environmental conditions: in such cases the choice of plant material is restricted by these conditions and suitable species are limited.

The type of treatment adopted also serves as a guide to the degree of maintenance required:

Low Maintenance	- The lowest degree of maintenance is usually possible in areas treated with native species of trees only.
	- A slightly higher degree is necessary where native shurb are also used, as these may require pruning
Medium	- Areas treated with a mixture of native and exotic trees
	- Exotic shurbs and trees
High	- Exotic shrubs, ground cover
	- Lawns, and maintained grass areas
	- Annual flowers, special schemes such as rose gardens etc.

Propagation

In large scale schemes, maintenance costs can sometimes be reduced by choosing plants which are easily propagated.

II X Function of Design with Plant

Types of propagation by seed, and by vegetative means:

- Stem cuttings
- Heel cuttings
- Leaf cuttings
- Gootying
- By root division
- Layering

III. FUNCTIONAL ASPECTS OF DESIGN WITH PLANTS

Plant material in landscape design can be used to :

(i) Improve existing environmental conditions with respect to
Soil
Drainage
Microclimate
Air and noise pollution

(ii) Create a designed physical environment through the organisation of open space.

(iii) Interpret and express the contemporary understanding of the man-nature relationship i.e. design with plants on an ecological rather than horticultural basis.

Whereas the first two of the above aspects are easily understood, the third aspect involves the development of what may be called an ecological philosophy towards designing with plants.

As already indicated, two sets of factors influence the choice of plant material in landscape design. One set relates to information about the plant material itself, and the other, to the situation for which a planting proposal has to be made.

The first set of factors determines the suitability of plant material from the point of view of:

(a) Growth requirements of plant material

(b) Physical characteristics of the plant material

The second set of factors pertain to the context in which the plant materials has to be used. Considerations of scale (i.e. regional, local, or very small scale situations), the existing environmental conditions, and functions which the plant material has to fulfill are important here. Also to be considered is the level of maintenance which is likely to be kept up. On very large sites this is very important.

The factors determining choice of plant materials may be summarised as follows:

1. *Environmental conditions* existing on site. These include climate, soil characteristics, water table, etc.
2. Functions which plant material has to fulfill in specific situations on a given site. These may be either *environmental functions* (pertaining to improvement of soil conditions, modification or microclimate etc) or design functions relating to creating spaces, enclosure, framing views, providing visual relief, etc.
3. *Physical characteristics* and growth requirements of plant material. The former include foliage density, foliage texture, leaf size and shape, flower colour, rooting characteristics, etc. The latter include moisture requirements, whether the plant grows in sunny or shade conditions etc.

The process designing with plants on a given site consists basically of:

1. The identification of different situations (zones) within the scheme with regard to:
   (a) Conditions existing in particular zones, (i.e. soil moisture, etc.)
   (b) Functions to be fulfilled by landscape treatment.
2. Decisions regarding what form the proposed planting should taken so as to fulfill the above requirements, taking into account the physical characteristics that the plant material chosen should have.
3. Plant material can then be chosen on the basis of the above consideration, i.e. conditions, functions, form, physical characteristics, growth requirements for different zones.

The Process may be tabulated as follows :

Zones	Characteristics	Functions	Form	Species chose	Remarks
A					
B					

Plant material used in landscape design can be broadly classified as :

Trees:	Large	e.g. Tamarind
	Medium	e.g. Neem
	Small	e.g. Indian Laburnum
Shurbs :	Tall	e.g. Bougainvillea
	Low	e.g. Galphimia glauca

Gound cover (very low shurbs less than a 30 cm high e.g. *Asparagus. Wedelia.*

Functions of Plant material include

Trees

Protecting soil	Enclosure
Modifying microclimate	Direction
Shade	Framing views
Shelter	Screening
Habitat	Visual relief
Noise	Ornamental

Shrubs

The functions are very similar to those listed above. Shrubs can be used together with trees to reinforce ~~fulfilled~~ fulfilled by the tree planting e.g. noise barriers, shelterbelts, enclosure etc. Other forms in which shrubs are used:

Hedges	-	Require regular maintenance
Shrubbery	-	where plants are allowed to retain their natural shape; they therefore require little maintenance.

Shrub planting can also be used (together with trees) to relate building to site, by providing visual interruptions in the rectilinear lines of the building.

Shrubs provide barriers, which can either be visual physical (hedges). Barriers may be required in a range of situations, e.g. they may be only for defining space, or they may be required for security and are therefore necessarily impenetrable.

Ground Cover

Ground cover plants are those which naturally grow to a very low height. Some of the uses to which they can be put are:

i. Stablising soil on steep slopes such as embankments

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

iii. For providing variety in surface treatment

iv. Contrast with paving materials, e.g. to soften rigid lines of paving

v. As a subtle means of demarcating space, as for instance in places where tall plants would be visually intrusive

vi. In combination with other plants to provide contrast or harmony in form.

Climbers

Certain climbers because of their spreading habit can also be used as ground cover (e.g. asparagus) Climbers are useful on pergolas, and for shading exposed walls from direct sunlight. They can also be used for stablising soil on embankments (e.g. *Ficus stipulate, Ipomea biloba*).

On sites where a high degree of security makes fencing necessary, climbers and spreading plants like Bougainvillea, can be used to camouflage the fence, similarly, they can be trained on boundary walls.

IV. PROTECTION OF TREES ON SITES UNDERGOING DEVELOPMENT

The following points illustrate a few ways in which the development of a site can affect the existing landscape of the area :

(a) Development of a site involving the removal of a number of trees is likely to affect the microclimate. Tall buildings affect wind movement causing turbulence in their vicinity, and affecting the growth of vegetation in the adjacent zones.

(b) Development is usually accompanied by an increase in the non-porous surfaces (e.g. roads, paving roofs etc.) on a given site. Run-off from the site is therefore, increased affecting the local drainage pattern of the surrounding area.

(c) Building construction involves the use of heavy machinery: a large portion of the soil around the building is compacted and disturbed. Compact soil being less porous, water logging may occur. This would affect existing vegetation.

(d) Increased activity in the vicinity of developed areas leads to the vacation of those areas by their original inhabitants e.g. birds etc. who have to find other habitats.

Before development occurs, the vegetation on a site should be identified and priorities for its conservation allo-

cated, so that it is protected during construction and after it as well.

The successful preservation of trees depends on:

(1) Taking them into account when designing e.g. ensuring that new buildings do not interfere with any existing trees which are worth preserving

(2) Strict control over contractor's operations, deployment of plant and machinery during construction.

(3) Maintenance after, to rectify any damage caused during construction.

It takes a long time for a tree to mature, a fine tree cannot be replaced easily.

The following is a guideline for the protection of trees:

At the Design Stage

1. Established trees will have adapted themselves to local soils, ground water and should these conditions be changed, the trees could be affected and they may die. If the design involves considerable changes in level of the ground, the ground level around the trees should be kept constant. The ground should not be lowered within the spread of the branches; the root system within this area is required to support the growth and stability of the tree.
2. Building should not be sited closer than 5m. from the trunk of the tree. Otherwise foundations will interfere with the root system or vice-versa.
3. Any young tree on the site should be identified and transplanted, if possible, within the site.

During Construction

1. Compaction of soil around tree must be avoided;
2. Materials should not be stored within root spread;
3. Spillage of fluids should not take place in the vicinity of trees;
4. Protective barricades should be erected;
5. Branches should be trimmed corresponding to reduction in the root system;
6. Soil around trees should be cultivated;
7. Site should be properly drained to prevent water logging of roots in wet periods;
8. Roots more than 75 mm thick should not be cut
9. Not more than 40% of roots should be removed
10. Ensure that water table is not lowered or raised i the vicinity of the tree, due to excavation o raising of ground level.

V. PLANTING FOR SHELTER AND SOIL CONSERVATION

The use of vegetation for controlling wind is widel recognised as an effective way of conserving soil and reduc ing erosion by wind. Wind currents also influence extreme of temperature and humidity and may create comfortabl conditions respective to the climate in a particular are: Examples of this are the server hot wind in the North-India summer, and the cool breezes of the monsoon. In temperat climates, cold winter winds can create very uncomfortabl conditions. Vegetation may therefore also be used for mod fying the microclimate, by obstructing, guiding, deflectin or filtering wind currents.

Vegetation areas designed to fulfill these general fun tions are usually classified as windbreaks and shelterbelt The term windbreak refers to protective plating around garden or orchard. Windbreaks may also provide shade f buildings or cattlepens, and they have an aesthetic value i areas which do not have much existing vegetation cove Windbreaks generally consist of a single or double row trees. The term shelterbelt refers to extensive barriers trees protecting fields. To be effective shelterbelts requi a much more careful layout then simple windbreak Shelterbelts usually consist of several rows of trees. Speci are chosen with particular regard to their physical a growth characteristics, and their effectiveness in achievi the desired results. Both windbreaks and shelterbelts ha a considerable visual impact in the landscape in which th are situated. they therefore need to be designed so that th make a positive visual and aesthic contribution to th environment.

Benefits

Windbreaks and shelterbelts are very important f agriculture under arid and semi-arid conditions; they al fulfill essential microclimatic functions in urban and ru environments. Benefits accruing from plantation of shelt planting can be listed as follows (Sitaram Rao 1979, Lelo 1955):

1. Reduction in wind velocity resulting in the arr of movements of sand and soil particles

2. Prevention of soil erosion.
3. Modification of micro-climate;

   Change in air temperature are moderated;
4. Protection of crops from being blown down by high winds.
5. Protection of livestock.
6. Reduction in evaporation of soil moisture. Increase in soil moisture content varies from 3 to 7.8%. Water loss due to evaporation is lessened. This is estimated to increase production by 15%.
7. Increase in soil moisture due to greater dewfall in sheltered areas has been found to be 200 per cent higher than on exposed ground. Heaviest dew-fall is over a distance of 2-3 times the height of the shleterbelt.
8. Beneficial effect on growth of plants: At higher wind velocities the stomatal apertures are decreased; as photo-synthesis depends upon Carbon Dioxide intake through these apertures, growth of plant may be affected if it is not protected from high winds.
9. Extensive shelterbelts can also be used to augment the supply of fuel in rural areas.
10. 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 within 10 times the height of the tree belt, on the leeward side.

Wind Erosion

As already mentioned, some of the basic functions of windbreaks and shelterbelts in arid and semiarid areas are to conserve soil, improve productivity, and reduce erosion by wind. The latter is a natural Phenomenon in arid lands having very little rainfall (125mm-250mm) 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. To understand the techniques used for the control of wind erosion it is important to know how eroding action by wind occurs:

Factors which influence the degree and kind of wind erosion are as follows (Rama Rao 1974).

Features of wind	Speed, direction, Temperature, humidity, burden carried
Character of surface	Rough or smooth plant cover, obstruction, temperature.
Topography	Flat, undulating broken.
Character of soil	Texture, organic matter, moisture content.

At ordinary wind velocities, 93% of the windborne soil is carried less then 30 cm above the ground and only traces of large windborne particles are carried above 1 m . However, the very finest particles rise to very great heights and remains suspended for long periods of time. It can be seen therefore, that to reduce wind erosion, reduction in the surface velocity of wind is essential.

Eroded soil fractions are carried by wind in three types of movement.

Surface creep	Rolling, sliding along surface,
Saltation	Jumping and bouncing,
Suspension	Floating in air-stream

The proportion of the three types of movement varies greatly with different soils. Generally movement by jumping and bouncing is predominant accompanied by movement of particles by suspension and surface creep.

Techniques

The principal method of reducing surface velocity of wind, upon which depends the abrasive and transportation capacity of wind, is by vegetation measures (Rama Rao 1974)

Vegetation methods are found to be most effective in the form of wind breaks and shelterbelts. In aerodynamic terms, these provide protection as follows (Konda Reddy 1979):

i. Sheltered zone on the leeward side extends to approximately 15-30 times the height of the belt
ii. A dense belt provides greater shelter immediately to leeward but the sheltered area is not as extensive as when a more permeable zone of vegetation is provided.
iii. Porosity is important in the effectiveness of shelterbelt and proper selection of free species is necessary. Porosity near ground level is desirable.
iv. 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 effect greater reduction in wind velocity.

Protection obtained varies in relation to height (H) of shelterbelts (FAO 1957).

distance	H	-	wind reduced by 90%
distance	2H	-	wind reduced by 75%
distance	5H	-	wind reduced by 50%
distance	10H	-	wind reduced by 20%

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

Profiles

A belt which rises and falls abruptly on windward and leeward sides is said to be more effective. Smaller trees and shrubs should occupy the inter-spaces between the tall trees. Some authorities (Rama Rao 1974) maintain that a triangular section of shelterbelt planting is more effective.

The depth of the shelterbelt should be approximately ten times its height. This is, however, only a thumb rule. Much lesser widths of 20 m - 30 m have also been found to be useful in particular situations; 15 m should be considered as a minimum width.

Apart from factors such as climate, soil, fast rate of growth, one of the more significant considerations in choosing species for shelter planting is the possibility of a particular species serving the dual role of wood-production (for fuel, fodder) as well as shelter.

Spacing of Plants in Windbreaks and Shelterbelts

Windbreaks : Usually consist of a single or double row of trees planted at .7 to 1.5 m according to species. Normally , one year old trees are used (Leloup 1955). If tractor is used for cultivation then 3 m to 4 m should be distance between rows. Otherwise the distance between rows can be 2 m - 2.5 m. Spaces suggested for various Indian situations: Casuarina equisetifolia. Tamarix articulata.. Eucalyptus is not recommended because of the strong competition exerted by the spreading root system. Usually, evergreens are preferred, but deciduous trees such as Poplar and Dalbergia sissoo can also be used.

Since the roots of tree extend for some distance beyond the rows in which they are planted, fruit trees and garden crops should not be grown closer than 4 to 5 meters to the windbreak. Trees with long roots are not suited for windbreaks as their roots compete with the crops they are supposed to protect.

The most common layout where shelter planting is part of an extensive planned programme, is that of tree belts arranged in a chessboard pattern, each field being protected from every side. This pattern gives full protection to all the fields, provided that the right distance between the fields has been chosen. Efficient protection is achieved if belts are separated by a distance of not more than 20 times the height of the trees.

A considerable mixture of species is recommended so as to compensate for different rates of growth and also to achieve variety in the form of crowns. However, under arid conditions the choice of species is limited.

Within shelter belts, close spacing of tree is the general practice. The recommended spacing for shrubs is 1 m, and for tree such as Casuarina and Silver Oak 2.5 m Spacing between rows should be 2.3 m - 3 m. to enable mechanised cultivation. Five rows of tree and shrubs are considered necessary for protection. A soil improving crop of legumes may be grown between the rows during the first years, in order to foster the growth of the belt.

Management

Shelterbelts should be regarded as living groups of trees to be managed in perpetuity. Thinnings are limited to a strict minimum. Cutting is done individually by single tree selection method.

Continuous cultivation may be required in areas with scanty rainfall.

If individual trees do not survive then they should be replaced immediately so that no gaps remain in the vegetation belt. The shelterbelt should be protected from cattle, either by fencing or other means, especially in the early stages.

Examples

The following examples, from India and abroad illustrate experiences of use, function, techniques in planting of shelter vegetation in various situations:

1. Without giving the tag "Shelterbelts", the Forest Department in Andhra Pradesh has been planting Casuarina all along the coast from Vishakhapatnam to Nellore since 1920. Eucalyptus and cashew plantation on leeward side of the casuarina belt, since 1958, provided reinforcement necessary and supplied demand of fuel and small timber.

2. Shelter planting on a massive scale was done on the Eastern bank of the Hazari between 1946-53 to prevent sand drift from the wide sandbed of the river and protect fields and villages from being overrun by moving sand and dunes. Prosopis was used as the land was arid, with clayey soil. These shelterbelts are worked on a simple coppice system to provide feed for cattle and small timber to local population.

3. In arid districts of Andhra Pradesh shelterbelt planting is being done along river Penna in Anatapur and Cuddapah and along river Cheyyer - with species : Dalbergia sissoo, Eucalyptus, Tecomma, and the results have been satisfactory.

4. Coastal Shelter Planting: Storms and tempests hitting the coast lift sands from ridges and dunes and blow them on land resulting in sand drift which covers several thousands of hectares of coastal land. In the cyclone of 1977, areas which were planted with Casuarina shelter planting suffered comparatively less.

In nature the species which grow on sands and bind soil, stabilising drifting sand are as follows :

Spinifex squarrosus

Cyperus rotundus

Pandanus odoritissima

Calamus species grows wherever water collects in sheltered niches on leeward side of the ridge or embankment.

Forest department have planted Casuarina, Cashew and Acacia auriculeformis at Srikurmam (1974). This has proved successful in stemming sand drift.

The Forest Department have also raised 30 Km. long shelterbelt of Casuarina interspersed with Acacia auriculaeformis planted at 1.5 × 1.5 cm c/c in 70 rows, in the same area.

It has been suggested that planting *Casuarina* at 1.5 × 1.5 m may not permit permeability. Probably an interval of 2 m in the rows along the coast line and 3 m between the rows may ensure permealibility and growing space for the shelterbelt, incidentally reducing costs per unit area.

Construction of an effective palisade of Pandanus odoratissima at the commencement of planting, and growing Ipomea pescarpae or Impomea biloba on the windward side to bind the sand and fix the dunes would constitute the preliminary operations.

5. In Tamilnadu the percentage of forest area is less than 16% as against the optimum requirement of 33.1/3% for balanced development of a region. Social forestry is therefore being implemented to increase the forest area under the following heads.

Afforestation,

Avenue and shelter planting,

It is proposed to afforest village waste lands, foreshores, barren hillocks to the extent of 1000 hcts. annually. The major species chosen for avenue planting is Tamarind, as this is also remunerative.

Other trees chosen for planting have been selected on the basis of their capacity to yield leaves suitable for manure:

Cassia siamea — *Thespesia populnea*

Delonix alata — *Glyricida maculata*

These are useful on farmsteads as they supplement the requirement for organic fertiliser.

6. The following vegetation species have been found to be effective in immobilising the soil (Central Soil Conservation Board, Jodhpur)

Tree	*Tecoma undulata*
	Prosopic spicigera
	Prosopis juliflora
	Azadirachta indica
Grasses	*Cenchrus cliaris*
	Pennisetum cenchoides
	Elionurus hirsutus
	Cenchrus bilflorus
	Panicum antidotale
	Dicanthium annulatum

Vegetation protection and erosion control of gullies is offered by the following species (Dehradun 1977):

Pueraria thunbergiana

P. Phasaeloloides

These are planted on borders of gulies and cover the area very quickly.

7. In Egypt Casuarina is planted around farmlands to protect the farms from sand drift and to provide fuel and timber. In the Sudan Eucalyptus

camaldunesis and Neem are planted according to available soil both for shelter and income.

8. There has been a striking and continuous decrease in the average annual wind mileage received in the environment of the city of Canberra, Austrialia, over a period of 40 years. The decrease in the amount of wind received appears to be associated with the progressive growth of ornamental street trees and protective or commercial plantation. Also in wind protected areas in Australia the extent of deaths of shorn sheep is less than in unsheltered areas.

9. Conservation measures in China

(UNEP Booklet Series No. 1, pp 16-17, 1980)

In China shelterbelts are planted to protect farms from wind damage, and are found to be essential for the environment of sandy land, as they control wind erosion and protect crops.

Selection of Plants

Quick growing bushy and wind resistant plants are chosen. Poplar is preferred in sandy land, where conditions are favourable to it. Other Species.

Salix Massudana

Amorpha fruticosa are planted on both sides of forest belts.

Planting :

One year old seedlings are used.

Two-three years old seedling can also be used, where conditions are favourable. Large seedling reduce damage caused by livestock and accelerate protective effect of shelterbelt sooner than small seedlings.

It has been found in China that the following benefits accrue from the planting of shelterbelts.

i. Reducing sandstorms

ii. Recovering wastelands,

iii. Create favourable conditions for animal husbandry

iv. Eye, ear and lung diseases (Common in sandy areas) have been checked. Rate of "Trachome" has been reduced by 30%

Conclusions :

Shelterbelts should be regarded as living groups of trees to be managed in perpetuity. Their location can be related to local features such as public and private road networks, building, irrigation and water conservation works and methods and soil management practice (Contour bunding contour cultivation etc.)

Careful choice of site will provide maximum protection to adjacent farmlands and give shelter and shade to man and beast while travelling or at rest.

The application of the concept of shelterbelts to landscape planning and design can be effective in the creation of landscape structure of very large developments at the regional scale, or townships or campuses. Shelterbelts can also be established in association with, or instead of road side planning in rural areas. This itself would create a distinctive landscape pattern. The advantage of using native species in sheltef planting are :

- New development is merged into the existing landscape. The original character of the landscape is therefore not obtruded upon.
- The shelterbelt is a component of land management : previous waste or barren land is husbanded and conserved.
- Additional habitats for wildlife are brought into existence.

Species suitable for wind breaks

Dry & Arid regions

Albizzia lebbeck	*Casuarina equisetifolia*
Peltophorum ferrugineum	*Pongamia glabra*
Dalbergia sissoo	*Azadirachta indica*
Tamarix articulate	*Acacia planifrons*
Melia indica	*Acacia auriculaeformis*
Eugenia jambolana	*Tamarindus indica*
Ailanthus excesa	
	Mangifera indica
Artocarpus integrifolia	*Sesbania grandiflora*
Grevillea robusta	*Eucalyptus citridora*

Coastal Area

Anacardium occidentale	*Ailanthus malabarica*
A. auriculiformis	*C. equisetifolia*

P. glabra

Thespesia populnea

Callophyllum inopnyllum

Agave

Sesbania aegyptica

Sesbania aculeata

Glyricada maculata

Cassia auriculata

Vitex negundo

Dodonea viscosa

Thevetia

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 minimise the build-up of pollution levels in urban areas, by acting as pollution sinks.

Studies have estabilised that air pollution, smoke and sulphur dioxide leads to an exacerbation of chronic respiratory diseases and they are linked with morbidity from lung cancer, pnemonia, tuberculosis, chest disease in children, stomach cancer and cardio-vascular diseases. Lead from Vehicle exhausts may have an adverse effect on mental health of children asbestos from disintegrating clutch and brake linings has been considered as a causal factor in lung cancer.

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 photosynthesis, and they can also remove pollutant gases from the air.

Plants are very effective pollutant sinks:

- They are good absorbers of sulphur dioxide.
- It has been found that parks with trees have an SO_2 level 25% lower then city streets.
- Roadside hedges can reduce traffic generated airborne Lead by 40% on leeward side.
- Heavy roadside planting in the form of shelterbelts can result in a 60-80% reduction in airborne Lead.
- Complete dust interception (100%) can be achieved by a 30 m belt of trees. Even a single row of trees may bring about a 25% reduction in airborne particulates.

Pollution sink potential of 1 H2 of woodland

Vegetation	Pollutant	Qty. removed/year
Forest	So_2	0.29 tonnes
Forest	CO	2.2 tonnes
Fires	N-oxides	35 tonnes
Large trees	Dust	40-60 tonnes

Soil surface around plants is also a pollutant sink, which can absorb gaseous pollutants : SO_2, CO, N-oxides, Hydrocarbons.

Choosing Plants

There are three main criteria

(i) Tree, shrubs should have a dense foliage with a large surface area, because it is the leaves which absorb pollutants. Fine leaved trees are therefore preferred : Casuarina, Parkinsonia, Cassias, Peltophorum etc.

(ii) Evergreen trees are found to be more effective.

(iii) The species chosen must be resistant to pollutants, particularly in the early stages of their growth.

Though there are as yet a few detailed and specific studies listing plants for pollution control, conclusions can be derived from observation of condition of vegetation in the vicinity of pollution sources such as power stations, factories and roads. Studies (Rao 1965) on resistance to SO_2 indicate the following species, which are resistant:

Lilium sp. (Lily), *Thuja occidentalis* (Cedar), *Gardenia* sp. (Gardenia) *Citrus* sp. (Citrus), *Acacia arabica* (Babul) *Pithecolobium dulce* (Jangal jalebi), *Tamarindus indica* (imli), *Lennotis nepetifolia* (Bantulasi), *Ficus religiosa* (peepal), *Ficus bengalensis* (banyan tree), *Polyalthia longifolia* (Ashok tree), *Zizyphus sp.* (Ber), *Prosopis Juliflora, Rhus mysorensis, Dyospyros* sp.

Filtering of pollutants is most effective when plants are close to the source of pollution. In certain countries vegeta-

tion buffers are an integral part of development schemes (*e.g.* sanitary protection zones in Russia)

The design of shelterbelts against pollution is similar to those for protection from wind. They should be permeable to encourage air turbulence and mixing within the belt. There should be no large gaps. The profile should be rough and irregular and should present a tall, vertical leading edge to the wing. Spaces should be left within the shelterbelt to allow gravity settlement of particiles.

Applications

Air pollution shelterbelts can be used to protect sensitive land uses from air pollution. For instance school playgrounds, children' play area and residential estates close to major roads can be so protected. Shelterbelt protection can also be provided for hospitals, institutions etc., where the vegetation would also be a visual screen and a partial noise barrier. Vegetation can also be used where the existing means of pollution control have proved inadequate i.e. in the vicinity of industrial sites and powerstations.

REFERENCES

Madders, Martin and Lawrence, Margaret Air Pollution Control by vegetation buffer zones: Landscape Design. August, 1981.

Rao, Dr. D.N., Use of Plants as indicators and Monitors of Sulphur Dioxide Pollution Banaras Hindu University, 1965.

Tandy, Cliff, Handbook of Urban Landscape, The Architectural Press, London.

Marlow, Olwen, Outdoor Design, Cresby, Lockwood & Staples, London.

Konda Reddy, C.V; "Shelterbelts against Storms and Cyclones on the Coast" Indian Forester Oct. 1979, pp. 700-705.

Rama Rao, M.S.V.; Soil Conservation in India; ICAR 1974 pp.

LeLoup, Marcel, Tree Planting Practices for Arid Areas; FAO Foresty Development Paper No. 6. FAO Rome 1955, pp. 86-89.

FAO Tree Planting Practices in Tropical Asia: Rome 1957.

Rao Sitaram M.; Introduction to Social Forestry: Oxford and JBH Publishing Co. 1979, pp. 21-24.

Carpenter, Philip L : Walker, Theodore D. and Lanphear, Fredrick O.: Plants in the Landscape. W.H. Freeman & Co. San Francisco 1975; pp. 167-168.

Deneke, Fredric J. and Grey Genew : Urban Forestry, John Wiley, 1978.

Hall, N., Russell V.S. Hamilton C.D., Trees and Microclimate : Proceedings of the Canberra Symposium on Climatology and Microclimatology ; UNESCO 1958; pp. 259-263.