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Climatic Control and Energy Conservation through Landscape Design

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INTRODUCTION

Buildings consume significant large amount of energy for cooling, heating, ventilation and lighting in buildings to create desirable thermal comfort conditions. Increasing consumption of energy has led to environmental pollution resulting in global warming and ozone layer depletion and subsequently having climate change. Hence to reduce the emission of greenhouse gases, caused by fossil fuels to power the operational energy requirement of the buildings has stimulated the interest towards adoption of climatic control and energy conservation measure through landscape design. In warm and tropical climates excess solar gain results in high cooling energy consumption. The use of landscape materials to moderate effects of adverse climates is not a new concept, but is receiving considerable attention in view of current emphasis on energy conservation.

The goal of energy-conserving landscaping is to regulate energy flows from the sun and wind.[1] Landscape design is a part of the wider design process, allowing interaction between the building orientation, building design, site conditions, and proposed landscape development. Climate responsive landscape design can be one of the important factors for energy conservation in buildings.

Proper landscaping reduces direct sun from putting and heating up building surfaces. It prevents mirrored light-weight carrying heat into a building from the bottom or alternative surfaces. Landscaping creates completely different flow of air patterns and might be accustomed direct or divert the wind well by inflicting a pressure distinction to boot, the shade created by trees and therefore the result of grass and scrubs cut back air temperatures abutting the building and supply phase transition cooling. Properly designed roof gardens help to reduce heat loads in a building. A study shows that the ambient air under a tree adjacent to the wall is about 2–2.5 °C lower than that for unshaded areas, which reduces heat gain by conduction.[2]

Correctly placed shade trees, windbreaks, and ground plantings can reduce heating and cooling costs by an estimated 25–30%, with some estimates as high as 50%.[3] Sustainable landscape design is part of green building, and ideally it should be designed at the same time as a green building, so that energy and material flow from one set of systems can be used in the other.

Another reason is that the building and landscape designs can complement each other, as in the landscape shading the building or the building sheltering an area of the landscape. In this paper, different strategies how landscape design can be integrated with housing design to modify summer and winter temperatures, improve comfort and save energy especially in tropical climate such as in India are discussed.

INTEGRATING LANDSCAPE WITH THE BUILDING DESIGN

Too typically the landscape is not thought-about till once a building is completed. Landscape style ideally is an element of the broader style method, permitting interaction between the building orientation, building style, web site conditions, and projected landscape development. This presents the simplest chance for maximizing the landscape advantages to the house and its occupants. Once the required performance characteristics of the projected landscape are known, a neighborhood horticulturalist or nursery is also consulted concerning appropriate plant species that meet the wants, i.e. tall and deciduous trees; low and dense bushes, ground cowl, etc. (see Figure one and Table one for a guide to plant selection).

SITE AND MICROCLIMATE ANALYSIS

While there are broad climate zones throughout the country, each site will have its own microclimate and conditions that will influence the house design and landscape development. A well-oriented and well-designed home admits low-angle winter sun, rejects overhead summer sun, and minimizes the cooling effect of winter winds. In the northern hemisphere, it is usually best to align the home's long axis in an east-west direction.

The home's longest wall with the foremost window space ought to face south or southeast. The home's north-facing and west-facing walls ought to have fewer windows as a result of these walls typically face winter's prevailing winds. North-facing windows receive very little direct daylight. A website and microclimate analysis provides data to help the designer to choose on the simplest placement of the building on the positioning, and to spot what sorts of landscape protection are required. The analysis need not be more complex than an annotated diagram. The analysis should consider:

1. Site size, topography, slope, soil and drainage
2. Prevailing seasonal winds, temperature and humidity
3. Relationship to sun and shade patterns in summer and winter
4. Existing vegetation and any special features
5. Location of other buildings and fences;
6. Location of vehicular and pedestrian access
7. Views
8. Any legal setbacks and building restrictions
9. Adjacent site conditions

DESIGN RESPONSE

Concept plans for the site can be developed working with the design brief and site analysis. The site analysis will help to determine the best location for plants and the best contribution they can make. For example, should a windbreak be used to give protection from unpleasant winds and where should it be located? Are there large areas of glass to be protected from glare? Are there large areas of paving that have to be shaded? The brief may have identified the need for a paved courtyard besides the building. The site analysis might have concluded that unpleasant winter winds blow across the courtyard from the south-west, and that reflected glare may be expected from the north-west during summer. The concept plans may indicate the location of a windbreak for winter wind protection and shade trees for glare control. The detailed plan would give the precise configuration of the planting barrier

SOLAR CONTROL THROUGH VEGETATION

Restricting solar penetration and modifying summer temperatures is a high priority in most climate zones.[4] Windows facing south, southwest and west needs protection from the hot summer sun. Plants should be placed in such a way so they do not form a barrier when direct rays of the sun are needed for warmth in winter but to provide shade from the intense heat of the sun in summer. For example, a tree shading a window can reduce a room's temperature by up to 10 °C.

Summer Shading

Shading is that the most efficient thanks to scale back star heat gain and cut air-conditioning value. Shading and evapotranspiration (the method by that a plant actively moves and unharness water vapor) from trees will scale back close air temperatures the maximum amount as 5 °C differing types of plants (trees, shrubs, vines) are often selected on the idea of their growth habit (tall, low, dense, light-weight permeable) to supply the specified degree of shading for numerous window orientations and things. The following points should be considered for summer shading:

1. Tree arrangements that provide shade in summer may be detrimental in the winter if they block solar heating. Deciduous trees and shrubs provide summer shade yet allow winter access. The best locations for deciduous trees are on the south and the southwest side of a building. When these trees drop their leaves in the winter, sunlight can reach inside to help in heating the interior of the building. Leafless deciduous trees may reduce the amount of sunlight reaching the home by more than one-third. However, the winter sun is typically less than 45° above the horizon, so shading will be largely from tree trunks. For this reason, plant only those trees needed for summer shade along the southern edge of the home. Prune the lower trunk to allow maximum solar heating of walls and roof in winter.
2. The suggested thanks to offer shade is to plant deciduous trees in associate arc encompassing the house on the east, southeast, south, southwest and west sides. Plant shade trees supported their mature height so that they are properly spaced and supply desired shade. Location conjointly depends on the form of the tree crown, the position of the sun, the peak of the roof or walls, fascinating views from windows, aesthetic attractiveness of the general landscape, and presence overhead wires and underground pipes.
3. Trees with serious foliage square measure terribly effective in obstructing the sun's rays and casting a dense shadow. Dense shade is cooler than filtered daylight. High branching cover trees will be wont to shade the roof, walls and windows.
4. Trees with lightweight foliage, like eucalyptus, Gleditsia triacanthos and birch, filter the daylight and manufacture a mottled shade.
5. Evergreen trees on the south and west sides afford the simplest protection from the setting summer sun and cold winter winds.
6. Vertical shading is best for east and west walls and windows in summer, to safeguard from intense sun at low angles, e.g., screening by dense shrubs, trees, deciduous vines supported on a frame, shrubs used together with trees.
7. Shading and insulation for walls are provided by plants that adhere to the wall, like ivy, or by plants supported by the wall, like bush.
8. Horizontal shading is best for south-facing windows, e.g., deciduous vines (which lose foliage inside the winter) like ornamental grape or wisteria are adult over a framing for summer shading.

Winter Sun Penetration

The following points should be considered to have more of solar access in winter:

1. Deciduous trees and plants should be placed particularly to the south of the building, to allow the access of winter sun to south windows.
2. Tall, low-branching evergreen trees should be kept at sufficient distance from south-facing windows to avoid overshadowing in winter.
3. Where evergreen trees are used for shading the home, they should have branches high enough to permit the entry of as much sunlight as possible in winter.

WIND CONTROL

The other important climatic element to be controlled by landscaping is the wind. Research conducted on the Great Plains has shown that up to 25% energy savings for heating is possible from windbreaks. Trees and shrubs can be selected and positioned to moderate the cold penetrating winter winds, particularly on large or exposed sites, and can also assist in capturing cool summer breezes.

Windbreaks

A windbreak is an obstruction perpendicular to wind flow that alters the wind direction. The wind moves over and around the obstruction. The objective of windbreak design is to achieve enough height to create protection for the desired distance on the leeward side of the windbreak (Figure 1). Design and composition of the windbreak depend on the space available and the species and size of trees. Where area is proscribed, one row of evergreens is adequate. However, up to 5 rows of many evergreen species is more practical. Spacing in one-, two- and three-row windbreaks ought to be 6 feet between trees. Think about the mature form of the tree once developing a landscape set up for a hedgerow. Most windbreaks can also serve alternative functions they supply a visible screen for privacy once they reach 5–6 feet high to style a hedgerow; the subsequent criteria ought to be considered:

1. Windbreaks area unit handiest once settled at 90° to the direction of the wind.
2. A vertical, somewhat pervious hedgerow with 50–60% density is mostly more practical than a solid one, like a wall, which might produce turbulence.
3. A hedgerow ought to be four to 5 staggered rows wide if deciduous plants area unit elite. Earth mounds may also be used to deflect winds.
4. Wind velocity can be reduced on both the windward and leeward side of a windbreak.
5. Large dense shrubs can be used as windbreaks to the northeast to counter cold winter winds, and channel cooling summer breezes.
6. Planting can be utilized to promote natural ventilation by positioning to deflect airflow through the building.

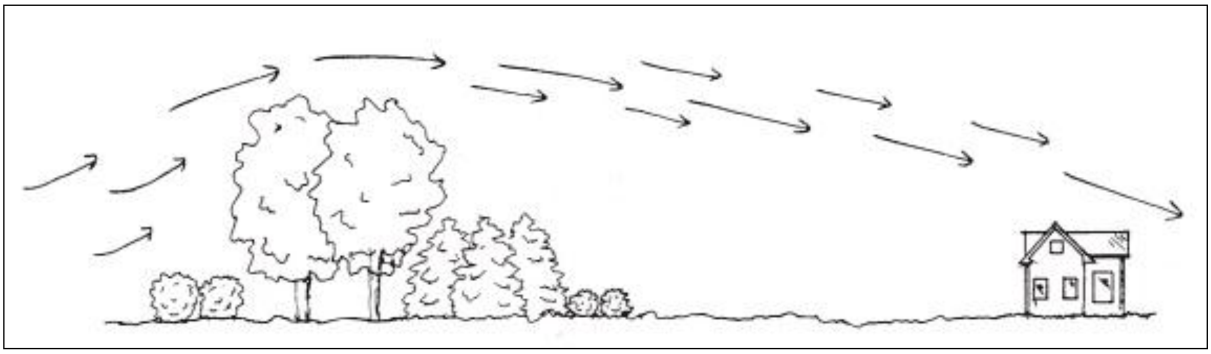

Fig. 1. *Wind Break Reduces the Speed of the Wind.*

Wind Channels

Windbreaks are designed to block wind; and are designed to guide its circulation. This is accomplished by deflecting wind currents into specified locations. The trees should be oriented in such a way so that the deflected wind is funneled into a desired area without decreasing the initial velocity.

Deciduous shade trees with dense canopies can be used to create wind channels. Low, dense shrubs placed underneath windows to the south of the shade tree would help circulate southerly breezes through the building.

The shrubs would deflect wind upward and increase its velocity while the shade tree would deflect the wind into the building. Careful positioning of windbreak planting can encourage the entry of desirable summer breezes (Figure 2). Low shrubs, lawn and ponds to the south will help cool hot summer winds.

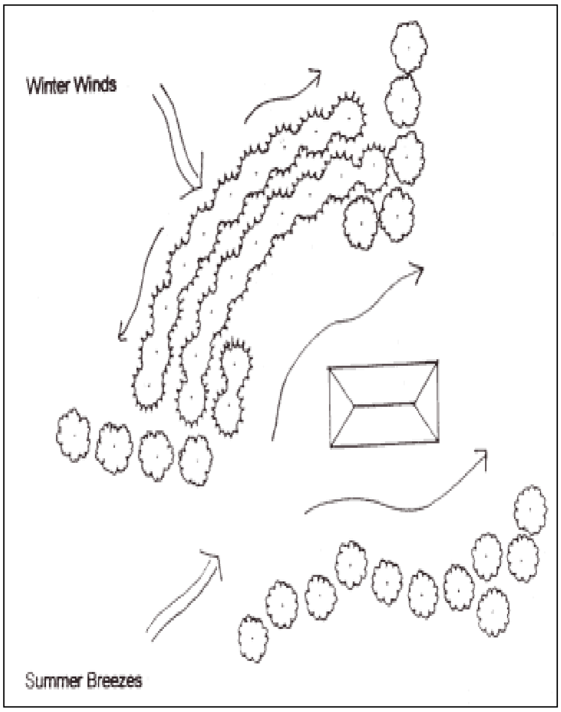

Fig. 2. *Shrubs can be used to Deflect Cold Winds and Channel Summer Breezes.*

REDUCING GLARE AND GROUND TEMPERATURE

Glare is produced when strong sunshine is reflected from a surface such as light-colored paving, walls, from water or a shiny object.

Lawns, ground cover and low-growing shrubs absorb more sunlight and re-radiate less heat than a paved surface. Ground cover planting not only reduces glare but also can lower the temperature near the ground by approximately 6°C through evapotranspiration (the loss of water from the soil by evaporation and by the transpiration of the plants).

In summer, the temperature above a ground cover is 10 to 15 degrees cooler than a heat absorbent material such as asphalt or a reflective material such as light colored gravel or rock. To reduce glare following points should be taken into consideration:

1. Low-growing shrubs, ground cowl or grass ought to be planted to soak up mirrored glare. Shade massive areas of paving with trees, pergolas or trellis
2. Avoid massive areas of paving close to the house to cut back mirrored glare and ground temperature, particularly south facing windows.
3. Shade massive areas of paving with trees, pergolas and planting.

WATER AS A LANDSCAPING ELEMENT FOR PASSIVE COOLING

Water has profound impact on climate control, especially in the utilization of solar radiation and energy conservation. Water stores large percentage of insolation striking the water surface and a small percentage is radiated off.

At the same time, while a small percentage of the solar energy strikes the land surface a large percentage of the same energy is radiated back into the atmosphere.

Hence breezes are formed. Breeze flows from the water body towards the shore or land during the day and vice versa at night. This natural airflow pattern may be utilized and controlled for natural ventilation and energy conservation. The leeward side of the water body will always be cooler since the wind is cooled as it moves across the surface of the water body. Therefore, it is necessary that areas or activities, which need to be naturally cool, should be located on leeward side of the water bodies and functions or areas, which need extra heat or warmth, on the windward side of the water body.[5]

CONCLUSION

The landscape design can be used as an integral part of energy management in buildings. Sustainable landscape design is simply an integrated approach aiming to create landscapes that conserve resources and energy, whose plants are adapted to the site's ecology. The different landscape design techniques are needed for shaping the landscaped spaces, which increases thermal comfort and reduce energy consumption. Incorporation of such techniques would certainly reduce our dependency on artificial means for thermal comfort and minimize the environmental problems due to excessive consumption of energy and other natural resources.

The language of climate responsive design is universal; however its usage and vocabulary must address local conditions of climate, economy, and the environmental aspect. The landscape design principle and selections of plant for energy conservation especially for the tropical climate such as in India is given in Figure 3 and Table 1.

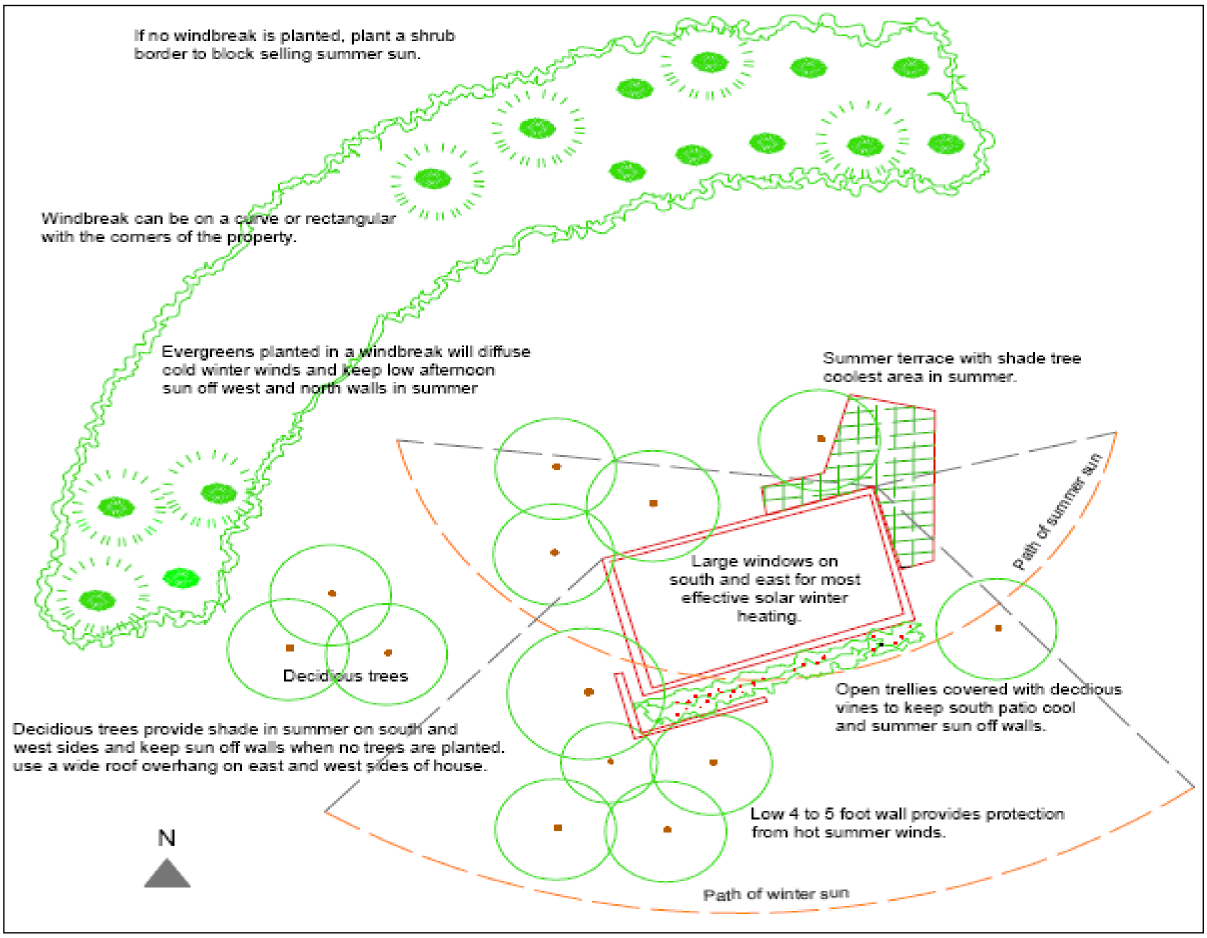

Fig. 3. *Plant Arrangement for Energy Efficiency.*

Table 1. *Selection of Plants.*[6]

S. No.	Botanical name	Common names	Height. (m)	Spread (m)	Type	Uses
1.	*Alstonia scholario*	Satni, Devils tree	15–22	7–13	Evergreen Maturity 10–20	Deep shade-parks and roads
2.	*Anthocephaluscadamba*	Kadamb	15–22	12–16	Evergreen Maturity 8–10	Deep shade-parks and roads
3.	*Azadirachta indica*	Neem	12–20	15–22	Deciduous Maturity 8–12 years	Excellent shade tree, good for shelter belts
4.	*Bauhiniapurpurea*	Khairwal, Kolar, Koilari	9–12	10–14	Deciduous Maturity 8–12 years	Avenues
5.	*Bauhiniavariegata*	Kachnar, Orchid tree	9–14	9–13	Deciduous Maturity 8–12 years	Avenues, pathways
6.	*Bombaxmalabaricum*	Simal, Indian silk cotton tree	15–25	12–22	Deciduous Maturity 20–30	Shade tree for parks, gardens and highways
7.	*Callistemonlanceolatus*	Bottle Brush	5–8	4–5	Evergreen Maturity 5–8	Ornamental, used in parks for landscape
8.	*Casia fistula*	Amaltas, Indian laburnum	10–14	9–14	Deciduous Maturity 5–8 years	Ornamental, roadside
9.	*Casuarinaequisetifolia*	Jangli Sasu, Beef Wood	15–22	9–13	Evergreen Maturity 6–8 years	Ornamental, thin light shade
10.	*Dalbergia sissoo*	Sisam, Shisham	12–17	12–19	Deciduous Maturity 10–15 years	Road side shade tree
11.	*Delonix regia*	Gulmohar	10–16	15–20	Deciduous Maturity 5–8 years	Roads, lawns and gardens
12.	*Ficus infectoria*	Pilkhan, White fig tree	12–23	18–25	Deciduous Maturity 8–12 years	Parks, lawns, for road side
13.	*Ficus religiosa*	Pipal, Sacred fig.	12–19	15–25	Deciduous Maturity 6–8 years	Good shade tree
14.	*Grevillea robusta*	Silver Oak, silk Oak tree	15–22	6–9	Evergreen Maturity 8–10 years	Windbreak and shade tree
15.	*Hibiscus*	Bola, Beli	9–16	12–19	Evergreen Life 50–60 years	Acts as a wind break
16.	*Mangifera indica*	Mango tree	15–122	12–19	Evergreen Maturity 6–10 years	Fruit tree, deep shade
17.	*Morus indica*	Shehtut, Mulberry	7–10	6–9	Deciduous Maturity 5–8 years	Ornamental, fruit tree for shade
18	*Polyalthia longifolia*	Ashok	10–20	6–10	Evergreen Maturity 5–9 years	Ornamental, deep shade
19.	*Tamarindus indica*	Imli	12–20	12–20	Deciduous Maturity 8–12 years	Withstand dust and insects, deep shade
20.	*Terminalia arjuna*	Arjun	15–24	10–18	Deciduous Maturity 5–8 years	Excellent shade tree

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BIOGRAPHY

Dr. Mohammad Arif Kamal is an architect, involved into teaching and research in Architecture. Presently he is working at Dept. of Architecture, Aligarh Muslim University, Aligarh. An alumnus of IIT Roorkee, his area of research is Sustainable architecture, Environmental Design, Climate Responsive Architecture and Traditional Architecture. He has published various papers in international journals and conferences and 5 book chapters. He is Editorial Board member of many International Journals and Conferences and also panel member of many National and International associations / Professional bodies. He is also an Adjunct Faculty at Shushant School of Art and Architecture, Ansal University, India. He has edited four books related to Energy Efficient or Sustainable Building Materials published by Trans Tech Publications, Switzerland.