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Environmental control in architecture by landscape design

Nazire Papatya SEÇKİN
papatya.seckin@msgsu.edu.tr • Department of Architecture, Faculty of Architecture, Mimar Sinan Fine Arts University, Istanbul, Turkey

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Abstract

The landscape design is a significant component of effective building design. Landscape elements can provide such benefits to buildings as shielding them from the sun, protecting them against wind, facilitating passive cooling, and providing opportunities for natural ventilation. Furthermore, landscape elements can be useful to clean the air and water, absorb floodwaters, improve aesthetics, provide recreational amenities and develop ecological habitats for wildlife. The heating, cooling and lighting of a building are very much affected by the site and landscape in which the building is located. Plants are immensely useful in the heating, cooling and lighting of buildings. Landscaping that supports the heating, cooling, and lighting of buildings varies with the climate. The general logic for tree planting around a building includes shade trees on the east and west, wind breaks on the north, and open fields on the south-facing sides. In this connection, lawns should be used only when necessary. On the other hand, a vertical vine-covered trellis is very effective on east and west facades, while a horizontal trellis can be used on any orientation. Outdoor shading structures such as trellises and pergolas, can be used for providing shade and/or to control air movement. Other functional landscaping elements include allées, pleached allées and hedgerows. In short, the following sections discuss some of the critical concepts and topics necessary for understanding landscape design as it relates to sustainable building design.

Keywords
Landscape design, Building design, Landscape elements, Shading structures, Windbreaks.

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1. Introduction

The architectural design of a building has a tremendous effect on the heating, cooling and lighting of a building. In fact, when an architect starts to design the appearance of a building, he/she is simultaneously starting the design of the heating, cooling and lighting. In this connection, plants are also immensely useful in the heating, cooling and lighting of buildings. Although plants are very popular, they are usually used for their aesthetic rather than functional benefits. Ideally, along with their decorative function they could act as windbreaks in the winter, as shading devices and evaporative coolers in the summer, and as light filters all year long. Plants can also reduce erosion, noise, dust and other air pollution, the level of carbon dioxide, and increase the level of oxygen in the local air.

In that case, buildings can be combined into landscaping techniques that promote the heating, cooling and lighting of buildings. The shading from plants depends on the species, pruning, and maturity of the plants. The best shading devices are the deciduous plants, because they lose their leaves in response to temperature changes. Other advantages of deciduous plants include low cost, aesthetically pleasing quality, ability to reduce glare and ability to cool the air by evaporation from the leaves. On the other hand, the disadvantages of deciduous plants are slow growth, limited height and the possibility of disease destroying the plant. In general, the east, southeast and southwest sides of buildings are the best locations for deciduous plants. Unless carefully placed, deciduous plants on the south side of a building may do more harm in the winter than good in the summer. However, deciduous plants without their leaves still block a significant amount of sunlight.

Furthermore, if the roof has collectors for domestic hot water, pool heating, and /or heating, and/or photovoltaic, it should also not be shaded in the summer. Thus, on the south side of buildings, plants should usually be kept below the solar access boundary. If large plants already exist on the south side of a building in very hot climates with mild winters, it may not be appropriate to cut them down to improve the solar access. The summer shade from mature plants might be more valuable than the last energy from the sun. However, in most climates, the energy from the sun is too valuable not to use. Every square meter of the south façade and south-facing roof should be used to collect daylight, photovoltaic electricity, and hot water all year long and passive solar in the winter.

On the other hand, evergreen plants can be used on the east, west and north sides of a building. These plants are most appropriate for protecting against the cold winter winds. To provide continuous shade or to block heavy winds use evergreen trees or shrubs. The best windbreaks block wind, close to the ground by using trees and shrubs that have low crowns.

Through the proper location and selection of plants, well-designed landscaping can reduce winter heating and summer cooling costs of a building as much as 25 percent (Lechner, 2015). Plants can also improve the quality of daylight by filtering and diffusing the light and heal human health and performance.

A landscape design is often based on the mature size of plants, thus the growth rate is very important. Choosing a fast-growing plant is not always a good choice, because most fast-growing plants have poor strength. However, some vines can be the ideal fast-growing plant for landscaping. They are supported on a man-made structure such as a wall, a trellis, a pergola or a table network. These vines are very effective sun shading devices.

Proper use of trees, shrubs, vines and man-made structures can modify the climate around a building to reduce heat gains in summer and heat losses in winter. Plants can protect a building from winter winds and shade it from summer sun. Vegetation around a building can regulate solar radiation during different seasons of the year. Proper building design and landscaping control noise, air pollution, winter wind and summer sun.

The design of landscape elements such as trees, shrubs, vines and man-made structures is a significant component of effective building design.

Landscape elements can provide such benefits to buildings as shielding them from the sun, protecting them against wind, facilitating passive cooling, providing opportunities for natural ventilation, cleaning the air and water, improving aesthetics, and developing ecological habitats for wildlife.

2. Landscape concepts

Before discussing landscape design techniques, some general comments about plants are important. The selection of proper plant material requires knowledge of concepts such as growth habits, origin, species` adaptations, and plant biological processes. It is also important to have a comprehension of contextual topics, including local and global hydrologic systems, precipitation, seasonal temperature fluctuations, wind, and geography. Some of the critical concepts and topics necessary for understanding landscape design as it relates to proper building design are discussed as follows (Carpenter & Walker, 1998; Marsh, 2010; Vassigh at all, 2013).

Landscape plants are herbaceous plants and woody plants. Herbaceous plants do not produce woody stems and are known botanically as herbs. They may have an upright, prostrate, or viney growth habit. Woody plants can be classified as trees, shrubs, or woody vines. The distinction between trees and shrubs is not always apparent. Generally, trees are characterized by a single upright stem or trunk, whereas shrubs have several stems. In addition, trees usually are taller than shrubs. The distinctions, however, may be obscured by pruning, training, or environmental conditions.

Among woody plants, a major distinction is made between deciduous plants, and evergreen plants. Evergreen plants are classified as either broadleaved evergreens or needle evergreens. Conifers constitute the needle evergreen group.

Plants may also be classified on the basis their life span. Annual plants complete their life cycles in one growing season and must be planted anew each year. Biennial plants complete their life cycles in two growing seasons. Perennial plants grow year after year. Annuals and biennials are only herbaceous; perennials can be either herbaceous or woody. Some woody perennials are not totally hard in cold climates and act like herbaceous perennials.

There are a variety of characteristics by which to describe or classify plants and distinguish them from one another. Among these, growth habit, seasonal persistence, and ecological origin are particularly important with regard to sustainability.

2.1. Growth habitat

Growth habits define the shape or form of the plants and play a key role in both their aesthetic character and their function in the landscape. Based on growth habit, plants can be classified as trees, shrubs, groundcovers, or vines. The boundaries between these growth habit types are not always distinct, nor consistent. A plant species may fall into several categories depending upon the conditions of a particular site or its maintenance regime. Despite the shortcomings of this classification system, it is widely used in landscape design.

2.1.1. Trees

Trees are the largest plant elements used in landscape design. It can generally be defined as a plant which is taller than 3m. Trees measuring 3 to 6 m is height can be classified as `small trees`, trees 6 to 9 m can be considered as `medium trees`, and trees taller than 9 m can be considered as `large trees`.

2.1.2. Shrubs

Shrubs are relatively smaller plants than trees. They can be defined as being larger than 0.5 m, but less than 3 m in height.

2.1.3. Groundcovers

Groundcovers are low-level understory plants that are grown over and cover an area of ground, acting as a base layer in a planting design. A groundcover is utilized to provide protection from erosion and drought, and to improve the aesthetic appearance of a landscape by filling areas between large plants and trees. Plants used as groundcovers typically grow to less 0.5 m tall or are maintained at that height. In general, they reach 15-30 cm high.

2.1.4. Vines

A vine is a plant that spreads extensively along the ground, over the plants and objects, or up vertical surfaces. Vines are climbing and rambling plants. They are used on man-made structures such as a trellis, a pergola, a balcony to protect from summer sun the horizontal and vertical planes. Various vines can also be used for an effective erosion control.

2.2. Seasonal foliage persistence

The term seasonal foliage persistence describes plant species' annual retention of foliage, that is leaves or needles. Some plants periodically drop their foliage during a portion of the year, while other plants keep their foliage throughout the year. The differences between plant species' foliage retention patterns can have significant impact on their functionality in shielding sun and wind. Therefore, foliage persistence is an important consideration in the selection of plants on a site.

2.2.1. Deciduous plants

Deciduous plants are those which completely or significantly, shed their foliage during the winter or dry season, and remain bare for a period of time, followed by the growth of new leaves in the next growing season, typically spring. The shedding of leaves by deciduous plants allows them to avoid cold damage and to conserve more water during dry periods. During the process of leaf shedding, the leaves of the deciduous plants can merely dry up and drop off or they may display a wide array of colors before they are shed. Depending on the species, the leaves may turn a bright yellow, a dark burgundy, or one of a variety of tones.

2.2.2. Evergreen plants

Evergreen plants retain foliage throughout the year. However, some evergreen species grow leaves constantly during the same period that old leaves are simultaneously shed. All of these plants have special leaves that are resistant to cold and/or moisture loss. Evergreens may continue to photosynthesize during the winter or dry period. Depending on the species, foliage colors vary widely and include yellows, reds, purples and silvers.

2.3. Ecological origin

The ecological origin of a plant is typically considered to be the location from which a plant species originated. A plant that originates from the local ecology is called native or indigenous. A plant that is not from the local ecology is non-native.

Native plants are well adapted and integrated into their native ecologies, they tend to be supportive of these ecologies. These plants can be the food source for native insects and native birds. Using native species in a landscape also tends to consume fewer resources because the native plants typically don't require much maintenance or irrigation relative to non-natives. The use of non-native plants in a landscape design is unlikely to contribute to the native ecology and in some instances may hinder or cause damage to it.

3. Landscaping

Well-designed landscaping can make a significant difference in the amount of energy required to maintain a comfortable building. Proper use of trees, shrubs, vines and man-made structures can modify the climate around a building to reduce heat gains in summer and heat losses in winter. Plants can protect a building from winter winds and shade it from summer sun. In fact, heat exchange in a building occurs through three major processes as air infiltration, heat conduction and transmission of solar radiation (Walker & Newman, 2009).

The first heat exchange process in air infiltration is the passage of outside air through cracks around windows and doors or other openings in building walls or ceilings. Air pressure on surfaces that face the wind are subject to increased air pressure as wind velocity increases. Air enters the building through openings in these surfaces. In winter, heat losses due to air infiltration may represent up to half of the total heat losses on the windiest, coldest days. Properly placed plants can reduce air infiltration by reducing wind velocity near the building.

The second heat exchange process is heat conduction through materials from which the building is built. The amount of heat conduction depends on the insulating property of the building materials, thickness of materials, and the temperature difference between the inner and outer surfaces of the building. Landscaping can help control the temperature difference between the inner and outer surfaces of walls and ceilings, and thus reduce heat conduction. The outer surface temperature is controlled mainly by outside air temperature, wind velocity and solar radiation. In summer, trees and shrubs can reduce the amount of solar radiation reaching the outside surfaces of a building, and thus reduce heat conduction into the building. In the winter, solar heating can reduce the rate of heat loss by raising the outside temperature of walls. Blocking cold winter winds also reduces conductive heat loss.

The third process for heat exchange in a building is transmission of solar radition through windows. Large expanses of east or west-facing glass admit undesirable solar radiation in the summer. Large expanses of south-facing glass can help heat a building in winter. Vegetation around a building can regulate solar radiation during different seasons of the year. In fact, solar radiation has significant impact on building. The extent of this impact is dependent upon several factors, including building orientation, architectural form, materiality and landscape. The heating, cooling, and lighting of a building are very much affected by the site and landscape in which the building is located. Plants are immensely useful in the heating, cooling, and lighting of buildings. Through the proper location and selection of plants, well-designed landscaping can greatly reduce energy consumption of a building. Plants promote heating primarily by reducing infiltration and partly by creating air spaces next to buildings, which act as extra insulation. Shading of a building's surfaces during periods of the most intense solar radiation, particularly in hot climates and seasons, can be highly effective in reducing excessive thermal heat loads on the building.

The shade from tree is better than the shade from a man-made canopy because the tree does not heat up and reradiate down. This is the case because of the multiple layers that are ventilated and because the leaves stay cool by the transpiration of water from the leaves. Transpiration cools not only the plant but also the air in contact with the vegetation. Thus, the cooling load on a building surrounded by trees or grass will be smaller than on a building surrounded by asphalt or concrete. Trees are more effective than grass in providing comfort. Usually the best plants to use are native varieties that have adapted to the local climate, soil and pathogens. Thus, less water, fertilizer, and chemicals are needed for healthy plant growth. At night, trees work against natural cooling by blocking long-wave radiation. There will be more radiant cooling in an open field than under a canopy of trees.

Plants can also improve the quality of daylight entering through windows. Direct sunlight can be scattered and reduced in intensity, while the glare from the bright sky can be moderated by plants. Vines across the windows or trees farther away can have the same beneficial effect.

In recent years, vegetated green roofs have become very popular, but for reducing the cooling load on a building, vegetated green walls are often more effective. Plants are most helpful on the east and west walls, which are exposed mostly to the summer sun. The north wall needs the least shading, and the south wall's shading needs depend on the building type and climate. The plants can also help shade the east and west windows. Shading south windows with plants on buildings that need winter heat is a challenge because even deciduous plants shade a great deal.

On the other hand, the proper choice and positioning of plants can greatly improve the microclimate of a site. The selection of these plants is very important. In this connection, advice should be obtained from such sources as local nurseries, foresters, agriculturists and landscape architects.

3.1. Landscaping elements

Simple strategies utilizing landscape planting elements such as trees, shrubs, groundcovers or vines in key locations and in proper quantities can greatly reduce energy consumption. Appropriately utilized landscape elements and systems can deflect and diffuse sunlight or dissipate solar heat energy to moderate thermal loads and reduce requirements for mechanical cooling (Walker, 1991: Haque, et al., 2004: Kachadorian, 1997).

3.1.1. Shading created by plants

Shading of a building's surfaces during periods of the most intense solar radiation, particularly in hot climates and seasons, can be highly effective in reducing excessive thermal heat loads on the building. Important to the effectiveness of canopy shade is the proper location of trees and shrubs on a site. The most effective shading arrangement for reducing maximum air temperatures and hastening early evening cooling is by shading a building's roof and its southwest- and west-facing walls and windows. Shade the south-facing roof and wall surfaces that receive the most direct sunlight during midday when the sun is higher in the sky. Also, place plants to shade walls that face generally east or west. These walls receive direct sunlight in the morning and afternoon.

In landscaping, deciduous trees and shrubs can be used to block summer sunlight and also allow winter sunlight to reach the building (Figure 1). Planting tall trees with elevated branching structures, or trimming up branches, will also allow more winter sunlight to reach a building as the sun is crossing the sky at a lower angle. Shading other portions of a building and its adjacent site can also help to reduce ambient air temperatures around the building as well as indoor temperatures at some degree. Trees planted at distances too far to shade a particular building's façade surfaces away also help reduce the air and ground temperatures surrounding the building. Site planting can also help to diminish the light reflected toward a building from surrounding surfaces.

On the other hand, the locations of trees on a site, the impact of canopy shade on moderating heat load is significantly affected by other factors such as trees height and canopy spread. When trees are not available to shade the east, west, and north windows, high bushes or a vine-covered trellis or pergola can be used. A newly planted vine will provide shade much sooner than a newly planted tree. Pergolas without plants must be carefully designed if they are to provide effective shading. A vertical vine-covered trellis is very effective on east and west facades, while a horizontal trellis can be used on any orientation. Bushes can act as vertical fins to block the low sun on north façades. On east and west windows, only the bush on the north side should be used if winters are cold. Other functional landscaping elements include allées created by bushes or by trees (Figure 2).

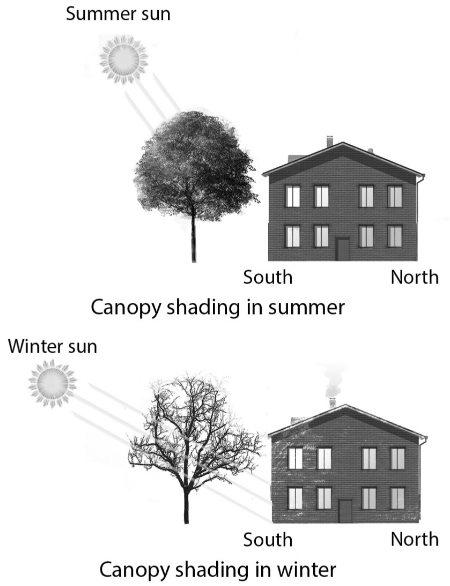

Figure 1. Effect of deciduous trees in summer and winter.

Figure 2. Allées for creating shade and/or controlling air movement.

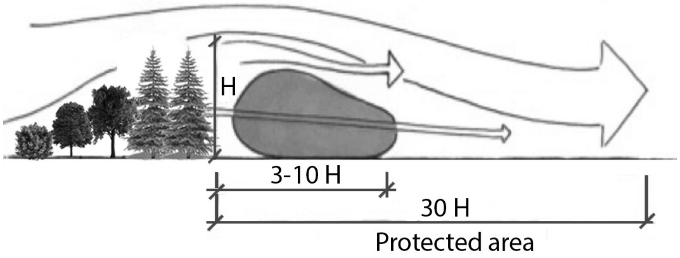

Figure 3. A windbreak can shield the building from prevailing winter winds.

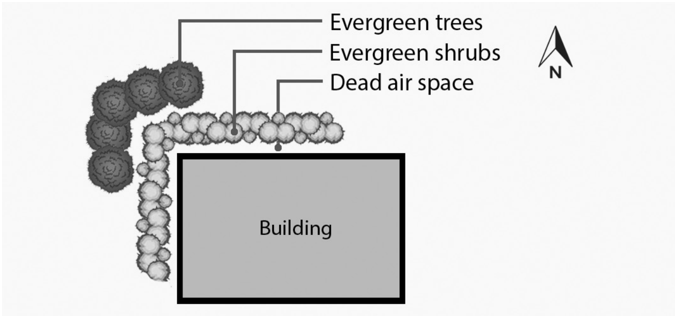

Figure 4. *Foundation plantings to create dead air space.*

3.1.2. Windbreaks

An important climatic element to be controlled by landscaping is the wind. Windbreaks can be effective in controlling wind and its impacts on buildings. These shelter belts are occurred from rows of trees and shrubs that are planted to reduce wind speed or redirect wind movement. In a cold climate, a properly located and effective windbreak can decrease air infiltration and heat loss by reducing wind velocity near the building. Plant species selected for a windbreak should be able to withstand the desiccating effects of winter winds. Evergreen species should constitute a significant portion of the windbreak composition because they retain wind-blocking mass in winter when it is most needed. An evergreen properly selected and placed can divert cold winds from the building and reduce heating costs. Distance from the building depends on the tree height. The optimum distance for reducing wind velocity is about one to three times the windbreak height. However, a windbreak can reduce winds up to a distance of 30 times the height of their tallest row, downwind (Figure 3). The effective distance of a windbreak is usually expressed in terms of a windbreak height multiplier, which is measured from the center of the outermost low of planting, downwind, along a line following wind direction. The higher the windbreak, the larger the wind shadow or protected area. Trees or shrubs in a windbreak should be closely spaced to provide a continuous barrier to winds.

Design and composition of the windbreak depend on the space available and the species and size of trees. Where space is limited a single row of evergreens is adequate. However, up to five rows of several evergreen species is more effective. Spacing in one-, two- and three-row windbreaks should be 1.80 m between trees. Consider the mature shape of the tree when developing a landscape plan for a windbreak (Walker&Newman, 2009). Evergreen planted close to the building can further reduce effects of wind. If allowed to develop into a thick hedge, spreading evergreens in front of the north and east wall provide additional insulation from the trapped dead air space they create (Figure 4).

In short, a one-row windbreak is composed of a single linear row of trees or shrubs. To be effective, the one-row windbreak should utilize densely planted evergreen that will retain their lower limbs and foliage. If deciduous trees are to be used, they should be densely planted and have narrow crowns.

Two-row and twin-row windbreaks are comprised of two linear rows of trees or shrubs. A two-row windbreak can be composed a single species, a set of two species or a mixture of species. To be effective, each row of the windbreak should be densely planted as is done in a one-row windbreak. A twin-row windbreak is composed of two rows of trees or shrubs, but planted adjacent to one another in an alternating pattern to form a single mass of planting. Planting should be of evergreen-type trees or shrubs.

Three-row windbreaks are comprised of three rows of trees or shrubs. The three rows should consist of at least one dense row of evergreen trees. The other rows can be deciduous or evergreen plantings. There can also be a frontline row of shrubs for catching snow if necessary. A three-row windbreak can have considerably more wildlife value than a single or double-row windbreak with its additional sheltered spaces and the possibility of a greater diversity of plant species.

The use of four or five rows in a windbreak can provide an even greater level of protection. Additional rows allow for greater flexibility in the design and in the diversity of species. One or two of the rows should consist of evergreen planting. The windbreak can also include one or more rows of deciduous plants and small shrubs for snow catch, if necessary.

3.1.3. Foundation plantings

Foundation plantings are a continuous line of evergreen along the length of the foundation and around the corners of a building, approximately 1.5 m out from the outer walls (Figure 4). They can be utilized to achieve considerable heating and cooling energy savings in a low-rise building or the lower levels of a taller building like windbreaks, foundation plantings are used to reduce wind speed around the building. However, they are also used to create a buffer of "dead air space" around the building with slower circulating air, which acts as an additional insulating layer.

In the development of an effective foundation planting scheme, the plants should never be allowed to grow much closer to the building than 1.5 m in order to be sufficiently effective. In addition, planting too close to a building can create problems with mildew, fungi, humidity, and insects.

3.2. Landscaping techniques

The following design cases show landscape strategies for solar, thermal and wind control and are based on climate types. These design solutions illustrate some general principles that can be a guide for applications elsewhere (Bertauski, 2009: Bainbridg & Haggarol, 2011: Lechner, 2015; Vassigh et al, 2013).

3.2.1. Temperate climate strategies

To best accommodate the climate conditions of temperate regions, it is necessary to consider more substantial seasonal variations. It is advantageous to maximize the warming effect of the sun in winter and maximize shade during the summer. Buildings should be protected away from winter winds. Summer breezes should be directed toward the buildings. A prototypical landscape design for temperate climate regions could include the use of high-canopy, high-branching deciduous trees on the east and west sides of the building (Figure 5). This would allow penetration by the warming rays of the low winter sun, but protect the building from the high summer sun with a full summer canopy. Low-branching evergreen tree clusters could be utilized to help block cold northwest or northeast winds during the winter. In addition, the use of dense evergreen shrubs on the north, west and east sides can form an insulating air space between the building and the planting, which would help to reduce heat loss during winter months. The windbreak on the north side of the building should be no further away than four times its height.

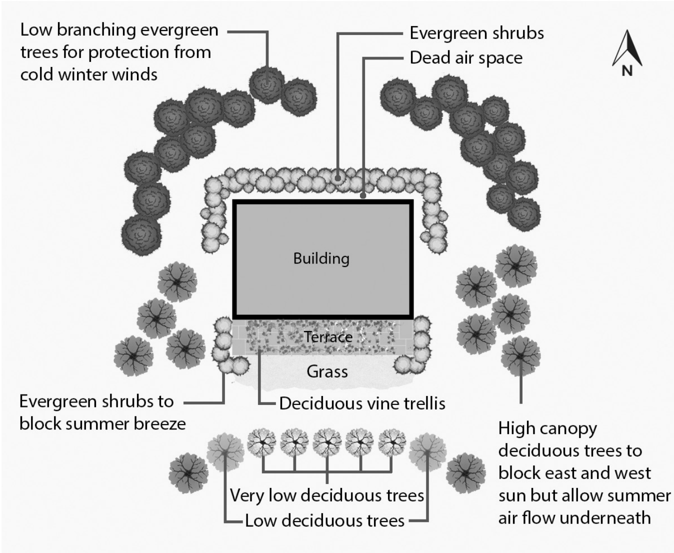

Figure 5. *Landscaping techniques for a temperate climate.*

Utilizing an overhead trellis adjacent to the southern façade of the building with deciduous vines can provide additional shade to the building and create a shaded outdoor space for use in the summer. The use of outdoor paving materials with light colors will lower heat absorption on the site and help maintain cooler air temperatures around the building in warmer weather periods. Contrary to their name, temperate climates are hot in the summer and cold in the winter.

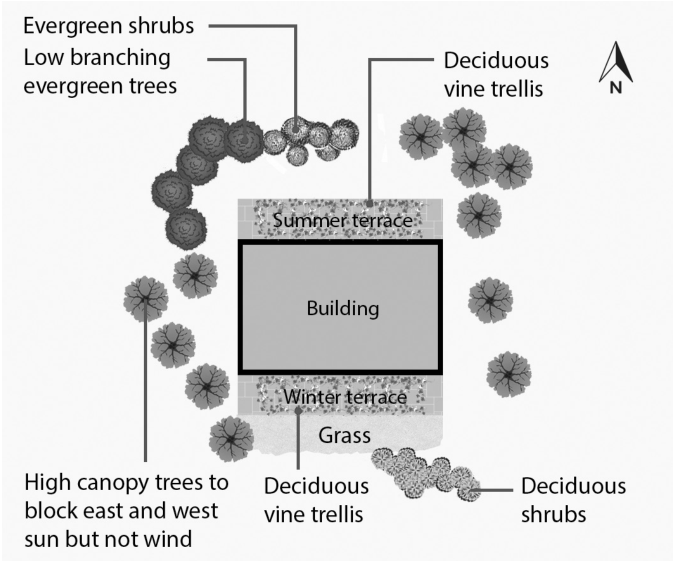

Figure 6. *Landscaping techniques for hot and humid climates.*

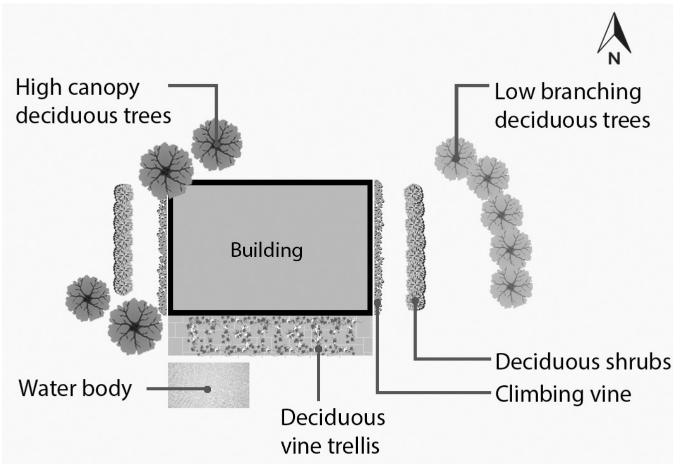

Figure 7. *Landscaping techniques for hot and dry climate.*

3.2.2. Hot and humid climate strategies

Maximizing shade throughout the year and encouraging air movement are the main objectives for a landscape design in a hot and humid zone. Plants that allow penetration of low-angle winter sun should provide shade to the building and outdoor living spaces whenever possible (Figure 6). Avoid locating planting beds close to the building if they require frequent watering. Should avoid forestation on the southern front, in the northern front. Significant shade structures such as wide trellises with deciduous vines on the north and south sides of a building can provide additional help for solar protection and form comfortable outdoor areas. Utilizing high-canopy deciduous trees on the east and west sides of the building can increase solar protection in the morning and afternoon, and allow air movement underneath the canopies. It is also important to keep low vegetation away from the building to allow breezes through and to prevent dampness. To maximize air movement, it is important to channel prevailing winds with wind channeling and deflection techniques. Light-colored paving materials around the building can help to reduce glare and heat absorption.

3.2.3. Hot and dry climate strategies

The key objective of landscape design in a hot and dry zone is to maximize shade, especially during the late morning and late afternoon hours. In this connection, north and south sides should avoid forestation, while the eastern and western directions, shrubs, vines have been placed on the walls and deciduous trees should be implemented. Locating shade trees to the east and west of the building can help to maximize shade. Also, due to the high altitude of the sun in the sky during hot summer months. It is advantageous to locate high-canopy deciduous trees immediately adjacent to the building to maximize shading of the roof. However, care should be given to closely monitor tree roots in order to avoid foundation damage when using this strategy (Figure 7). Additional shade trees or a trellis structure with vines on the southern side of the building can help prevent solar heating of the south walls.

Protecting the east and west sides of the building with climbing vines growing on vertical structures will help to reduce heat gain in the morning and afternoon as well as cooling the air immediately adjacent to the building through transpiration processes. In addition, adding water features is another useful landscape strategy to cool a building in a hot dry zone. Hot, dry winds channelized across a water body can produce a cooling effect for the building, and also deliver needed moisture, taking advantage of quick evaporation in the dry air.

With regard to site landscape, it is preferable to reduce the amount of paving and cover the ground with vegetation as much as water resources allow. This significantly reduces the potential for heat absorption by the paved surface and also reduces glare. In areas where paving is necessary, use of light-colored surface materials can help to reduce negative effects. In addition, courtyards and garden walls keep out the hot winds and conserve cool, moist air.

3.2.4. Very cold climate strategies

In very cold climate regions, it is very important to protect the building from northern winter winds. Dense windbreaks are used to protect the building from cold winter winds. If summer overheating is a problem, shade south and west windows and walls from the direct summer sun. The north façade is useful in very cold climate regions partly raised land application. Northern, eastern and western fronts in constantly evergreen shrubs and the low branches of trees should be preferred. In the southern wind breaker, low shrubs and grass should be applied. In southeast and southwest direction away from the building, deciduous trees should be used (Figure 8). Forming an earthen berm on the north and northwest sides of the building and planting dense rows of evergreen trees and shrubs will help to break the speed of the cold winter wind and create a trap for blowing snow. Additional dense evergreen shrubs adjacent to the northern sides of the building can help to create dead air space, providing insulation during both winter and summer months. Earth sheltering may also be an effective solution in very cold climates. If the building site is located on a south-facing slope that receives sufficient sunlight, an elevational earth sheltering design can be utilized effectively.

Using deciduous shrubs and trees on the south side of a building can provide some summer shading when needed, but admit low winter rays. In addition, deciduous, high-canopy trees on the east and west sides of a building will allow warm winter rays, provide summer shade, and promote summer breezes under their canopies. To further capture low winter sun and reflect its warmth to building interiors, a sunken terrace with a light-colored reflective material can be incorporated into the design on the southern side of the structure. Furthermore, darker paving materials may also be used on site to capture warmth and promote snowmelt.

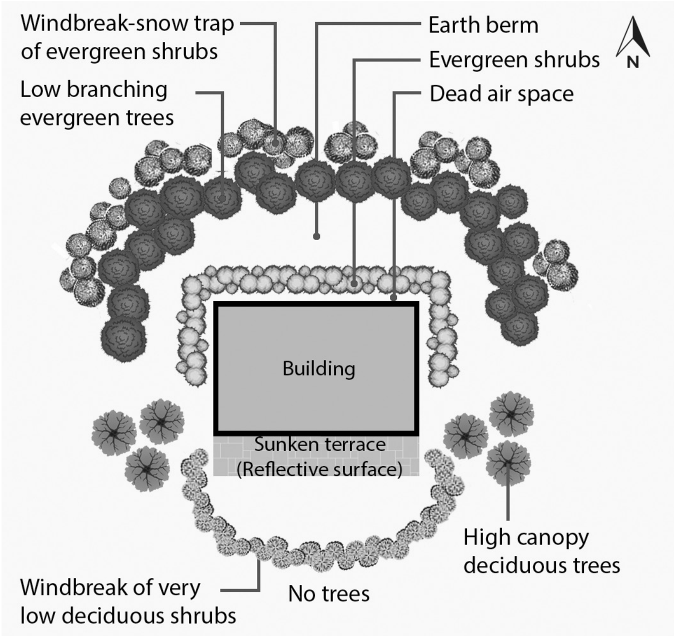

Figure 8. *Landscaping techniques for very cold climates.*

3.3. Vegetated surface systems

In recent years, planting on roofs and walls is one of the most innovative and rapidly developing fields in the world of the built environment. The use of green roofs is becoming more and more frequent, usually on new and innovative buildings. An idea and technology that started in the German-speaking countries of central Europe is rapidly spreading to the rest of the industrialized world, including the tropics. The use of living walls too is spreading, both the use of climbers and that of plants being grown vertically. The contemporary use of plants on roofs and walls is distinguished from previous uses by the integration of planting and its supporting structures with the construction of the buildings themselves. It is important to appreciate the distinction between older technologies of plant use and the new. Old-style roof gardens either restricted the planting to containers and planters or used a layer of ordinary soil spread onto a roof surface. Traditionally, roof terraces and roof gardens consisted of plants in containers which stood over

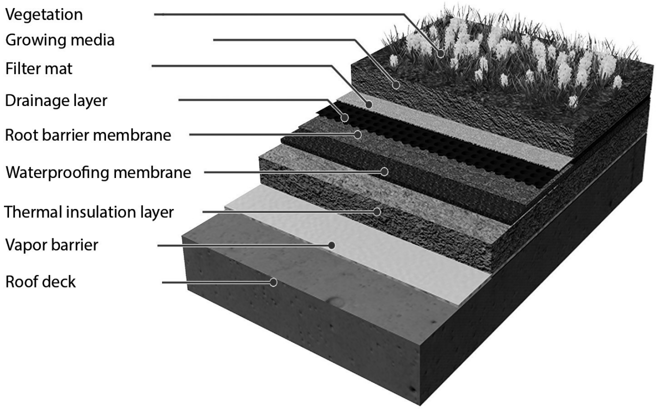

Figure 9. *Extensive green roof.*

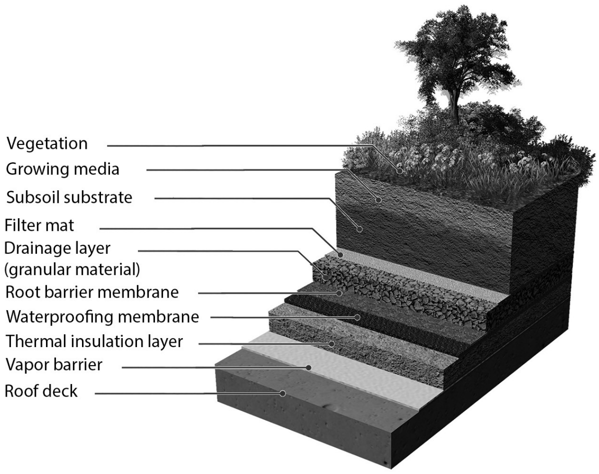

Figure 10. *Intensive green roof.*

paved surfaces (Dunnett and Kingsbury, 2008; Seckin et al, 2017). While new-style roof greening may incorporate substantial areas of hard surface and be accessible for recreation and other uses, plants and green dominate the roof area.

3.3.1. Green roofs

New-style roof greening recognizes three main approaches, extensive, intensive and semi-intensive. On a green roof, vegetation is planted in a growing medium laid over a waterproof membrane separating the system from the roof and the building below. A green roof may also contain additional layers to provide root barrier protection, irrigation, and drainage. The vegetation on a green roof can be composed of low groundcovers or may contain large trees and shrubs, depending upon the system`s construction (Weiler & Scholz-Barth, 2009: Snodgrass & Mclntyre, 2010). Green roof systems are defined as follows.

3.3.1.1. Extensive roof greening

Extensive is loosely used to describe a system that typically has a very shallow depth between 2 and 15 cm of soil or growing medium and is primarily used for its environmental benefits such as stormwater management, reducing the urban heat island effect and insulating properties. They can support relatively smaller-sized plant materials (Figure 9). Because of their limitations with plant material sizing, this green roof type is more commonly used where weight loads are a limiting factor, such as in cases involving conversions of existing conventional roofs. It is seldom irrigated; and it is not usually intended to be accessed directly for use as a garden or open space, though paved walkways and seating areas accommodate use as open space as well. Extensive roofs or living green roofs are generally much cheaper than intensive roofs, both in construction and maintenance.

3.3.1.2. Intensive roof greening

Intensive roof greening or landscape over structure is similar to the old-style roof gardens, where it is expected that people would use the area much as a conventional garden. Depending on the amount of vegetation, most of the same ecological and environmental benefits may be derived from the construction of landscapes over structures as from living green roofs. Where large weight loads can be accommodated, an intensive system can be utilized in which the growing medium exceeds 30 cm in depth (Figure 10).

Intensive roofs can support the whole range vegetation types, from trees and shrubs through to herbaceous planting and lawns. Substantial pools and water features are possible. Such roofs are usually intended to be accessible to people, and certainly need to look good.

3.3.1.3. Semi-intensive roof greening

Green roofs are seen as either extensive or intensive, but there is no reason why elements of both cannot be combined on the same roof. Extensive and intensive greening techniques can be combined on the same roof. There is great scope for using intensive and semi-intensive techniques on accessible roofs, combined perhaps with larger herbaceous and woody plant material in strategically placed containers or planters to create contemporary roof gardens that are much more sustainable than the roof gardens of the past.

In this context, the semi-intensive green roof has a great deal of potential for the creative extension of roof planting where the roof area is visible and intended for human use. Semi-intensive roofs use lightweight substrates and modern green-roof construction technologies (Figure 11). Substrate or growing medium depths are between 15-30 cm, which reduces the amount of extra loading that must be built into the roof construction.

Intensive and semi-intensive systems can accommodate larger plants species, including trees. In general, roofs with greater soil depth can better retain moisture and maintain more stable soil temperatures. On a green roof, evapotranspiration processes from plants absorb most solar radiation. This leads to cooler temperatures on the rooftop, reducing the heat load on the building. In addition the effects of evapotranspiration, the plants on a green roof offer a buffer for the building from incoming solar energy and also an irregular and diffusing surface for solar rays to strike.

3.3.2. Façade greening

One of the most unattractive features of much modern architecture is the presence of blank walls without windows or ornamentation. The idea of growing plants on a substrate attached to the surface of such walls is an attractive solution.

Façade greening is essentially a living cladding system for buildings. Climbers or in some cases trained shrubs, are used to cover the surface of a building. Traditionally, self-clinging climbers have been used, as they require no supporting network of wires or trellis. Modern façade greening, however, favours the use of climbers supported by steel cables or trellis.

Greening the wall of a building has potentially more effect on the building environment than roof greening, as the surface area of the walls of buildings is always greater than the area of the roof. For example, with high-rise buildings this can be as much as twenty times the roof area.

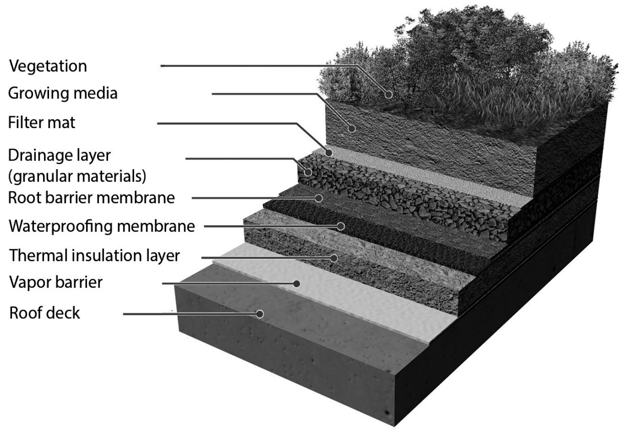

Figure 11. *Semi-intensive green roof.*

3.3.2.1. Vine-covered walls

For the vine-covered walls, vines may be grown on the ground level or in planters that can be attached to a building at elevated points to reach higher levels. In selecting the proper plant material for a vine covering, an understanding of the local climate plays a significant role. In cold climates, deciduous materials should be used on south-and east-facing walls, which will help in blocking sun in the summer and let sun through during the winter. In hot climates, evergreen vines should be used on the west and south walls. However, care should be taken in utilizing vine covering, as vines adhered directly to a wall can sometimes undermine the integrity of wall materials over time. Utilizing a trellis system can help to overcome this issue (Figure 12).

3.3.2.2. Living wall systems

Living walls are more complex than vine coverings, but they offer a level of increased design control and can be instituted more extensively and more selectively than vine coverings. Living walls are engineered systems, typically composed of many individual plants that are planted on a vertical support structure. They can be wall-mounted or freestanding systems. The support structure of the wall may contain plant-

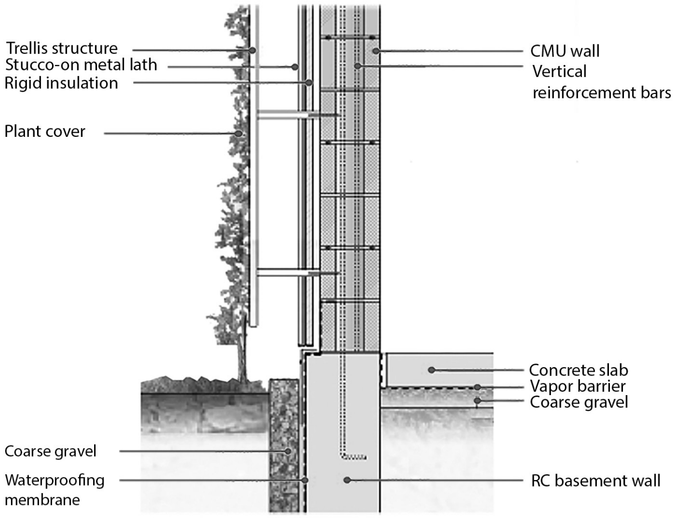

Figure 12. *Vine-covered wall.*

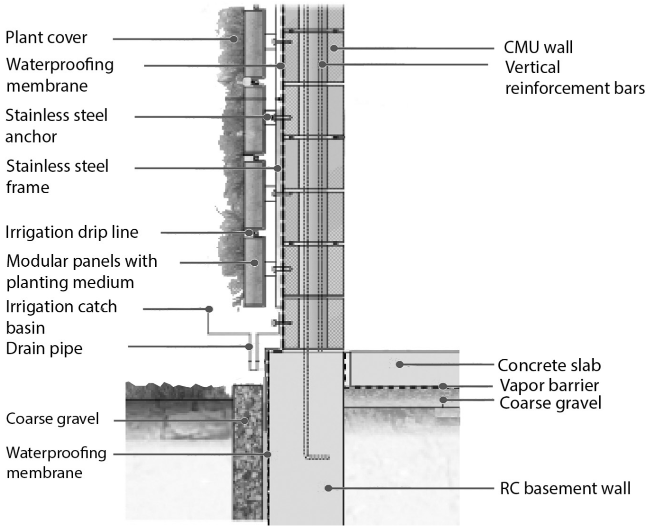

Figure 13. *Living wall.*

ing containers with a growing medium or fabric planter pockets that contain plants in a soilless hydroponic system (Figure 13). Hydroponic, the technology of growing plants without soil using balanced nutrient solutions to provide all the plant's food and water requirements, is the obvious solution in a situation where no water can be held for very long. Living walls also typically have an irrigation system. Hydroponic living wall systems are kept constantly moist through the irrigation system that provides all the requirements for successful growth of the plants. A living wall's vegetation can be composed of evergreen or deciduous plant species. However, the use of deciduous plants may expose the underlying structure of the living wall, which may not be desirable for aesthetic reasons.

4. Landscape irrigation

Water is an essential life element. Employing proper landscape design strategies plays a significant role in conserving water and reducing the demand on potable water supplies. The use of low-irrigation plant materials, efficient irrigation systems, and the expanded use of treated wastewater or harvested rainwater for irrigation can help to achieve significant reductions in water use.

The selection of plants materials is a significant component of developing a landscape design that is resource conscious and sustainable. Many plants used in man-made landscapes consume significant amounts of water to remain healthy. Turf lawns, in particular, can be large consumers of water resources and they also require a great amount of maintenance. Merely substituting a lawn with a properly chosen herbaceous plant cover can drastically reduce water use and maintenance in many instances. Large trees can also considerably reduce the irrigation needs of a landscape. But, the best strategy for reducing plant irrigation is to use native plants ideally suited to a site's conditions, including precipitation levels. In contrast, many non-native plant species may require significant amounts of irrigation and extra care to keep them alive and healthy.

Using appropriate technologies can easily improve water-use-efficiency in any irrigation system. There are two main irrigation systems that are commonly used to irrigate landscapes, namely sprinkler and drip irrigation (Figure 14). A sprinkler is a water emission device that throws water through the air with a predictable pattern and radius. There are two broad categories of sprinkler used in landscape as well as pop-up spray sprinklers and pop-up rotor sprinklers. Pop-up sprays are generally suitable for small-radius applications and small or irregular areas. Pop-up rotors are suitable for large-radius applications and larger areas of turf grass. Drip irrigation is commonly applied in landscape shrub beds, trees, and potted plants and the like and uses water emission devices called emitters, which have low flow rates. Emitters are available in single-outlet or multi-outlet models (Smith, 1997: Melby, 1995: Seckin, 2003, 2011 in press).

5. Conclusion

The architectural design and landscaping have a tremendous effect on the heating, cooling and lighting of a building. In that case, buildings can be combined into landscaping techniques. These techniques can reduce a building`s energy requirements during all four seasons, by blocking out the hot summer sun, encouraging warming solar radiation in winter, deflecting cold winter winds and channeling breezes for cooling in spring, summer and fall.

In reducing the amount of cooling energy required by a building, landscaping may be useful by directly shading the building with trees, shrubs or vines, shading the area around the building to lower the temperature of its surroundings, and using ground covers to reduce sunlight reflected into the building and lower the surrounding ground temperatures. In this connection, trees should not be planted closer than 3.0 m or 4.5 m from the building`s foundation. Shrubs are often a good alternative for shading walls and windows because they grow more quickly than trees and may be planted closer to the building since their root structures are less likely to cause damage. Vines may be trained to climb wire, trellis structures to provide localized shade in the summer. Be sure that there is adequate space between shrubs or vines and the building to allow air flow and help present mold or mildew formation on the wall. Vines grow quickly; make sure that they stay on their wire or trellis structure and do not move onto the building in order to avoid damage to the siding.

For solar systems to work effectively, they need to be unshaded between 9 a.m and 3 p.m solar time. Unfortunately, a tree extends into the solar access zone and causes shading depends upon the height of the tree and its distance from the solar collection surfaces. The overall energy needs of a building are better met by making sure the east and west sides are shaded during the summer. However, high branching deciduous trees make a good choice for these sides since they can both shade in summer and admit some winter solar gain.

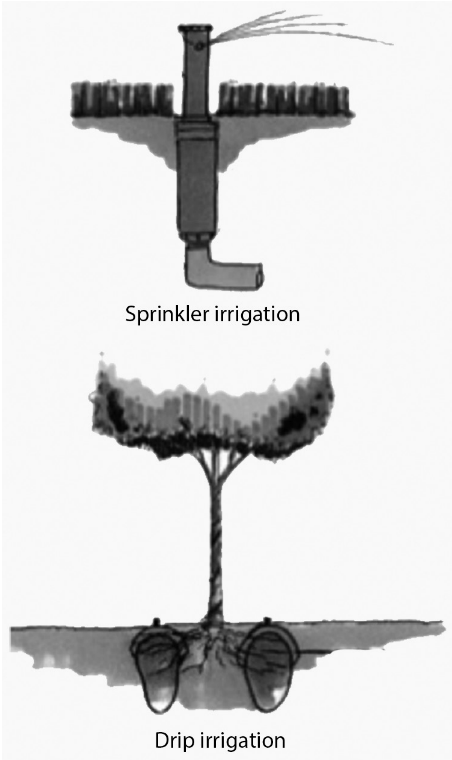

Figure 14. *Types of irrigation systems.*

Landscaping can also benefit a building in winter by decreasing infiltration. Since higher wind speeds mean higher infiltration rates, planting windbreaks to reduce the wind speeds approaching the building can lower its energy needs. Locate the windbreak on the windward side of the building in a way that it does not interfere with solar access. Use evergreen trees and shrubs for windbreaks on the windward side. If sunlight or a view is important, a combination of deciduous trees and shrubs may be used, but this will be less effective.

The windbreak should be dense, rather than solid, because solid windbreaks create turbulence behind them. The density of the windbreak should be maintained from the ground up without major gaps. A mixture of various shrubs and trees can help prevent these gaps. It is also a good idea to mix species within the windbreak to avoid the possibility of losing the entire windbreak to a disease which affects one species.

Landscaping may also be used to help cool a building by leaving an open channel between trees or hedges in the direction of summer winds to direct the breezes on and into the building. Unfortunately, channeling summer breezes for cooling is worthwhile only if the building`s personal tends to use natural cooling practices.

In short, in a strategic landscaping:

- Shade the east and west faces of the building, giving top priority to the west side, and giving priority to shading windows over shading walls.
- Avoid shading of surfaces to be used for solar collection.
- Shade the area surrounding the building.
- Cover bare ground with lawns or other ground covers rather than paving where possible.
- Plant to provide a channel for summer breezes, if natural ventilation is used, and if it doesn`t conflict with planting for a windbreak.

On the other hand, vegetated surface systems such as green roof, vine-covered wall and living wall are built on the façades and roofs of buildings to protect from solar heat in several ways. These systems can potentially offer an additional insulating layer to a building, helping to maintain the temperatures inside, and providing the effective environmental impact outside.

In addition to, well-designed landscaping has a significant role in conserving irrigation water. In this connection, he use of low-irrigation plant materials and efficient irrigation systems can help to achieve significant reductions in water use.

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