

# **Control of Tropical Microclimates through Landscape Design: Concepts and Methods**

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## **Abstract**

The use of landscape design to moderate the microclimate is one of the tenets of design with climate.

## **1. Introduction**

Moderation of the microclimate through landscape design is one of the three pillars on which the concept of the natural house rests. The natural house is a hypothetical model that maximises the use of natural materials and passive technologies to produce a healthy and comfortable environment for man. The three components of this model are:

1. The use of landscaping, vegetation and water to moderate the microclimate of the house to produce a comfortable and healthy environment around the house.
2. The use of the building fabric and design to maintain the interior of the house within comfort limits irrespective of the external conditions.
3. The use of passive technologies for cooling, heating, ventilation and lighting to compensate for fluctuations and maintain the environment within comfort limits.

Although the three components overlap and complement each other, they form concentric envelopes which moderate the stress imposed by the climate on Man (Figure 1). The local climate varies during the day and from season to season, with the climatic variables often beyond the comfort limits. The climatic variables within the house should however be kept within comfort limits, and the usual fluctuations should not exceed these limits.

Figure 1. The natural house uses concentric envelopes to maintain a comfortable indoor environment independently of the local climate.

The first envelope, the landscape and vegetation, is the first line of defence and often the most effective in reducing temperatures through shading, regulating the humidity and improving ventilation. The next envelope is the building fabric, which combines with the building design, shape and orientation as well as design and location of openings to maintain a comfortable indoor environment. The passive technologies are often integrated into the building structure but they can be regulated to compensate when necessary for fluctuations in the environmental variables.

## 2. Concepts in Microclimate Control

While this paper concentrates on the use of landscaping for moderation of tropical microclimates, the concepts involved are common to deliberations on design with climate. Some of these concepts are discussed below.

### 2.1 The Microclimate

The microclimate is one of four generally recognised categories of climate based on spatial and time scales (Table 1). These categories are the global climate, the regional macroclimate, the topoclimate and the microclimate. The global climate, unlike the regional macroclimate, is largely independent of surface topography. At the next scale, the topoclimate or local climate, the effect of the topography and human activity play a very important role. The microclimate refers to a spatial scale of about 1 km horizontally and 100 m vertically. This is the space within which most buildings exist. The microclimate is affected by trees, buildings and wind flow patterns. Proper landscape design can therefore control the microclimate to a certain extent, thereby reducing the thermal load on the building and its occupants.

System	Approximate characteristic dimensions		
	Horizontal Scale	Vertical Scale	Time Scale
Global wind belts	2000km	3 to 10km	1 to 6 months
Macroclimate	500-1000km	1 to 10km	1 to 6 months
Topoclimate	1-10km	10 to 100m	1 to 24th
Microclimate	100m	10m	24th

Table 1. Spatial systems of climate.

### 2.1 Thermal Comfort

Comfort is a subjective sensation. It is that state of mind that expresses satisfaction with the thermal environment. Alternatively, it is that state of mind that does not express dissatisfaction with the thermal environment. It is equivalent to conditions in which human beings can sleep soundly and work comfortably and when there is a minimum demand on the thermo-regulatory mechanisms of the body. Outside comfort exists discomfort, which is characterised by the degree and duration of thermal stress. Comfort within dwellings is achieved partly by protecting buildings from heat gain during hot periods and by preventing heat loss during cold periods. When mechanical aids are employed for this purpose, they should only supplement passive methods (Ogunsote 1991).

### **2.3 Factors Affecting Thermal Comfort**

There are six major factors that determine comfort. They are ambient air temperature, humidity, radiation, air movement, intrinsic clothing and level of activity. The first four are factors of the thermal environment. Other factors that may have some effect on thermal comfort are age, sex, body shape, state of health, ethnic grouping, diet, sleep, colour of clothing, acclimatisation, availability of fresh air, transients, colour of a space enclosure and noise (Evans 1980). An indication of the relative importance of these other factors is the fact that when all the six major factors are within an acceptable and optimal range, about 70% of the population will be comfortable.

Control of the microclimate will involve manipulation of the four factors of the thermal environment to keep humans comfortable within the microclimate, irrespective of the variations in the topoclimate.

### **2.4 Comfort Limits**

The major factors that determine thermal comfort combine to create the sensation of comfort. Discomfort occurs not when one or more factors are outside the comfort limits, but when the combination of all the factors causes a shift outside the comfort limits. When all the other factors are within the comfort limits however, a shift outside the comfort limits of one factor will result in discomfort. The comfort limits for each of the four environmental factors that determine comfort are discussed below, with the assumption in each case that all the other factors are within comfort limits.

#### **Air Temperature**

The air temperature, that is the dry bulb temperature is a very important factor affecting thermal comfort. When temperatures are low, people feel cold and when they are high people feel hot. Comfort can approximately be achieved between 16 and 28 degrees Celsius.

#### **The Mean Radiant Temperature**

This refers usually to radiation to and from surfaces within an enclosure measured with the globe thermometer. The mean radiant temperature is calculated from the globe temperature using the air temperature and velocity. Comfort can be achieved if the globe temperature is between 16 and 28 degrees Celsius and if the difference between the mean radiant temperature and the dry bulb temperature is less than 5 degrees Celsius.

#### **Air Velocity**

Air movement is very effective in increasing heat loss from the body at high temperatures when sweating occurs. The air movement enhances the evaporation of sweat from the body thereby cooling down the body. Air velocity of up to 0.1 metre per second may lead to a feeling of stuffiness indoors. Air velocities of 0.1 to 1.0 m/s are comfortable indoors when air movement is required but above this level there is discomfort. Outdoors, wind speeds of up to 2.0 m/s can help achieve comfort, especially when the humidity is high. Wind speeds of over 5.0 m/s lead to considerable discomfort.

#### **The Relative Humidity**

When there is low humidity the air is very dry and sweating is more effective in cooling down the body. However, when the humidity is high the air is damp and clammy and sweating is no longer very effective in cooling down the body. Thermal comfort can be achieved when the relative humidity is between 20 and 90%.

## 2.5 Site Analysis

The main focus of site analysis is to discover the advantages and disadvantages of the site and how to take full advantage of the positive aspects and counteract negative effects. There are several analyses that can be carried out in site planning. **Physical site analysis** involves analysis of the type and depth of the soil and substructure for foundation design. Water bodies, underground streams, swampiness and drainage are analysed. The **infrastructural site analysis** covers existing buildings, roads, paths and all services including electricity, sewerage, water and telephone. The **ecological site analysis** deals with dominant plant and animal communities; their self-regulation and sensibility to change; mapping of ground cover and trees to be retained. The **cultural site analysis** involves studies of the resident population including group and individual identification with site, meanings attached to site, symbolic expression, hope, fears, wishes and preferences. **Aesthetic site analysis** is a study of the character of the site, vistas, viewpoints, smell and rhythm of visual sequences. **Acoustic site analysis** maps out the sources of noise and means of prevention. The **climatic site analysis** deals with the site climate.

## 2.6 The Site Climate

The site climate is the climate of the area to be developed and it is affected by the climatic variables, the ground cover and the topography. The climatic variables include temperature, wind speed and direction, humidity, rainfall, solar radiation, fog and dust-storms. The ground cover affects the flow of wind over the site and determines the amount of shade provided. The topography covers the slope, orientation and elevation of the site. It is important to determine the intensity of direct solar radiation and wind flow over the site.

## 2.7 Periodic Heat Flow

In climates with large diurnal temperature ranges the variations in temperature are clearly marked. There is a 24-hour cycle of increasing and decreasing temperatures with the minimum temperature around 6.00 am and the maximum around 2.00 pm. The fabric of the building absorbs and stores some of the heat during the day and releases this heat to the interior during the night. The variation of temperatures inside the building also has a fixed cycle but the peak occurs at a different time depending on the time lag. See Figure 2.

*Figure 2. Time lag and decrement factor.*

This tendency of materials to store heat is one of the reasons for the discomfort experienced in the early evenings when walls and ground surfaces that have received solar radiation during the day have temperatures above the air temperature.

## 2.8 The Greenhouse Effect

Short-wave radiation incident on glass is partly reflected, partly absorbed but mainly transmitted. This is because glass is “transparent” to short-wave radiation. Other materials, such as concrete or mud however absorb the larger portion of short-wave radiation. The absorbed energy causes a rise in their temperature and this energy is emitted in the form of long-wave radiation. Glass is “opaque” to long-wave radiation and if it encloses the emitter the heat is trapped within the enclosure. This leads to a rise in temperature within the enclosure known as the greenhouse effect. See Figure 3.

*Figure 3. The greenhouse effect.*

The greenhouse effect is used to keep buildings warm during the cold season by trapping the sun's energy and converting it to heat.

## **2.9 The Almond Tree Effect**

This refers to the modification of the microclimate produced by trees, which can be demonstrated using an almond tree as an example. The almond tree has big broad leaves and horizontal branches. The almond tree effect causes microclimate modification in several ways including reduction of the radiant temperature, lowering of air temperature, increase in air movement and modification of the vapour pressure (relative humidity).

The radiant temperature is reduced by the shade produced by the tree and differences in radiant temperatures of more than 20C have been recorded. The reduction in air temperature is also a result of the shade provided, although this reduction is much less than the reduction in radiant temperatures.

Tree leaves are arranged to catch as much of the sun as possible. In the process, they provide the best possible shade. This shading is however far superior to that provided by a roof or a wall. While a roof may provide full shading, the roof heats up in the process and hot air is trapped under the roof, causing discomfort. The roof also radiates heat, causing further discomfort. A tree on the other hand filters the radiation, with the upper leaves receiving most radiation, and therefore being the hottest. The leaves at the bottom receive less radiation and are much cooler. They therefore radiate less heat. The tree also allows cool air to rise through the leaves to the top of the tree; hot air is therefore never trapped under the tree.

The same applies when a tree is used to shade a surface, instead of a wall. A wall does not allow air to flow through it, and therefore air movement is inhibited when using a wall for shading. A tree on the other hand will allow a significant percentage of a horizontal air stream to flow through it, thereby improving air movement while providing full shading.

## **2.10 Effect of Altitude on Air Temperature**

There is a general fall in air temperature with altitude as a result of the expansion and subsequent cooling of air. This fall in temperature may be up to 1 degree Celsius for every 100-metre increase in altitude. Higher diurnal ranges and higher wind speeds are also recorded. See Table x.

*Table x. Variation in climate with increasing altitude*

This may be significant when designing on sites with very steep slopes, deep valleys or tall hills.

## **2.11 The Urban Heat Island**

Urban centres with large populations tend to create microclimates different from that of the surrounding region. The urban heat island is formed as a result of high concentrations of buildings, factories, structures, machines and human beings. This is manifested by higher temperatures as a result of modification of the reflective (albedo), absorptive, storage and emissive characteristics of surface components in cities (Adebayo 1991). According to Meffert (1981), urban heat islands are a result of:

1. Increased absorption of solar radiation by built mass and hard surfaces, due to their excessive storage capacity

2. Lack of vegetation that can cause cooling by utilising incoming energy for evapotranspiration.
3. Increased air pollution of different kinds, leading to additional heat absorption by the atmosphere.

This increase in the sol-air temperature leads not only to discomfort and reduced productivity but also to increased mortality (Tout 1978). According to Meffert (1981), reduction of the urban heat island can be achieved by replacing common urban fabric with more appropriate design elements, and in particular by:

1. Using suitable vegetation to provide ventilated shade and evapotranspiration for additional cooling.
2. Limit the area of hard surfaces to increase the time lag for precipitation run-off.
3. Apply low heat capacity materials for the outer skin of the structural fabric.
4. Avoid black-top surfaces such as tarred roads and roofs with felt.
5. Prevent air pollution.

### **2.12 Effect of Ground Cover and Topography on wind speed**

The wind speed is measured at a height of 10m in meteorological stations. This speed is significantly reduced at body height (1m). This decrease is more marked in wooded, suburban and urban areas as opposed to open areas. This is a result of the obstruction caused by trees, buildings and other elements of the topography. See Table x.

*Table x. Average reduction factors for wind in different locations.*

### **2.13 The Wind Shadow Effect**

The wind, on meeting an obstruction in its path, creates pressure on the windward part and suction on the leeward side. The area where this suction is effective represents the wind shadow of the obstruction. In the wind shadow, the direction of airflow is opposite to that of the wind direction. Buildings placed in the wind shadow of the obstruction will suffer from poor ventilation, except in special cases. Buildings are spaced at least six times their height to avoid this effect. See Figure x. Staggering has also been found to be effective.

*Figure x. Effect of neighbouring buildings on wind flow. (a) channelling of wind (b) interaction of low and high-rise buildings (c) wind flow around buildings.*

### **2.14 Condensation**

The amount of vapour air can hold depends on the air temperature. Warm air can hold more vapour than air at a lower temperature as is illustrated in Table x. When warm air is cooled therefore, there comes a time when the vapour in the air is sufficient to saturate the air mass. The vapour pressure at this temperature is called the saturation vapour pressure while the temperature is the **dew point** of air for the given vapour content. When the air is cooled further, it will no longer be able to hold some of the vapour and this excess vapour is converted to a liquid in a process called condensation.

*Table x. Saturation vapour pressure as a function of air temperature.*

There are two types of condensation - surface and interstitial condensation. **Surface condensation** occurs when air comes into contact with a surface at a temperature below its dew point. A layer of moisture is formed on the surface of the wall or roof as may be observed in some kitchens, bathrooms or rooms. This leads to damp interiors and mould growth. **Interstitial condensation** is condensation within walls or roofs. The use of trees, shrubs and climbers can effectively reduce the air temperature and lead to condensation and eventually mould growth. Reducing the amount of shade, reducing the vapour pressure and increasing the ventilation can solve this problem.

## **2.15 Ventilation**

Ventilation is the replacement of used inside air by outside air. Natural ventilation is ventilation achieved without mechanical aids, but by stack effect and wind pressure. Comfort cooling is the use of air movement for body cooling. Ventilation has three major functions - those of supply of fresh air, body cooling and structural cooling/heating. Body cooling by ventilation is achieved through the evaporation of sweat from the skin and increased heat loss from the skin by forced convection. The cooling effect is achieved by air velocity and not by low temperature.

## **2.16 The Stack Effect**

The stack effect refers to the movement of air as a result of differences in air pressure of two bodies of air at different temperatures. Thus when there is a significant difference in the temperature of air within and outside a building possessing appropriate air inlets and outlets, air movement results. If for example the temperature outside the building is lower than that inside, then cold air will enter through the lower inlet and warm air will rise and exit through the upper outlet. See Figure x.

*Figure x. Ventilation by stack effect.*

The rate of ventilation achieved is directly proportional to the area of the inlet, and the square root of the difference in temperature between inside and outside air, and the difference in height between the inlet and outlet. The rate of ventilation is also affected by the ratio of the area of outlet, to the area of inlet. This ratio determines the correction factor. Ventilation rate increases with increase in the ratio of the area of the outlet, to that of the inlet.

## **2.17 Glare**

Glare is a condition of vision caused by spatial or temporal contrasts in lighting or high levels of light. It is most commonly associated with direct sunlight entering a window (direct glare) but it can also be caused by sunlight reflected from external surfaces (indirect glare). We can distinguish two types of glare - disability glare and discomfort glare. **Disability glare** is glare that makes vision impossible due to extreme contrasts, as when there is an area of indistinct vision around a bright light. It does not necessarily cause discomfort and is rarely a problem in design. **Discomfort glare** is glare that causes discomfort, as distinct from reduction in vision caused by distractingly bright surfaces or sources of light. Discomfort glare should be avoided in building design.

While glare does not have thermal discomfort consequences, it is a source of discomfort and it is closely related to the climate (cloud cover and solar radiation). Vegetation has proven very effective in reducing glare.

### **3. The objectives of microclimate control through landscaping**

Landscaping can be used to control several aspects of the microclimate. The climatic variables that can be regulated include solar radiation (sol-air temperature), air temperature, wind speed and direction, relative humidity and glare.

#### **3.1 Sol-Air Temperature Control**

The use of ventilated shading provided by trees, shrubs and climbers for the control of radiant temperature, and reduction of air, ground and surface temperature is a primary objective of microclimate control through landscaping. Air temperature is measured in the shade (in a Stevenson's screen), whereas the globe temperature is measured without shade and it indicates the effect of solar radiation on air temperature. Ventilating shading reduces the amount of solar radiation reaching ground and wall surfaces, thereby reducing the sol-air temperature, which is an indication of the globe temperature. Climbers with or without trellis can be used to cover surfaces exposed to the sun.

#### **3.2 Air Temperature Control**

The air temperature control achieved through landscaping is a direct result of reduction in sol-air temperatures caused by ventilated shading. Ventilating shading is accompanied by evapotranspiration, a process whereby plants take water from the soil and lose the water by evaporation through the leaves. This causes cooling just like sweating causes cooling in humans, with the latent heat of evaporation taken from the surrounding air.

#### **3.3 Humidity Control**

Plants in general increase the humidity of the site. They can therefore increase the thermal comfort during hot, dry seasons, although the plants have to be watered. The plants take water from the soil, and when this water evaporates from the leaves it increases the relative humidity while lowering the air temperature. Pools and ponds behave in a similar manner. Water evaporating from the surface increases relative humidity while reducing air temperature.

#### **3.4 Control of Air Velocity and Wind Speed**

Plants are used to reduce wind speed and to increase the velocity of stagnant and slow-moving air. Windbreakers in the form of rows of trees are a very effective way of reducing wind speed and filtering dust. The almond tree effect induces air movement under and around trees even when there is relative calm in unplanted areas.

#### **3.5 Control of Wind Direction**

Landscaping can be used to direct wind away from the building, or towards the building. Fences, walls, hedges and trees can be combined to form an obstruction that will deflect the wind above the building. This can be useful when protecting the building from the cold harmattan wind. The more common use of trees however is to channel air flow towards living space. While trees allow a portion of the wind to pass through them, some wind is deflected above and below the trees. The wind forced to flow beneath the trees increases air movement in living space. On larger plots groups of trees can also be used to channel the wind in a particular direction.

### **3.6 Control of Surface Absorptivity and Reflectance (Albedo)**

Landscaping can be used to control the rate at which surfaces absorb and reflect solar radiation. The use of lawns, plants, colour and careful selection of pavement materials can control the proportion of solar radiation absorbed to that reflected.

### **3.7 Seasonal shading**

The choice of plants can be used to control the amount of shading in different seasons. There are two types of climate in Nigeria: the warm humid and the composite climates. The composite climates have warm humid, hot dry and cold seasons. Seasonal shading usually involves full shading in hot, wet season. In the dry, cold season trees are used to block the cold northern wind while allowing the sun in from the south. The cold season wind can be blocked by plant material, especially thick evergreens and plants with heavy foliage. A good design will have planting with deciduous trees on the South, which cool the air in the hot season and drop their leaves to let in precious sunlight in the cold season (Caudill et al 1974).

### **3.8 Pollution control**

Plants are very effective in controlling levels of pollution. They absorb dangerous gases like carbon dioxide that are associated with the urban heat island. They also reduce the levels of other pollutants, especially from automobiles. Buffer zones planted with trees are used for separating industrial areas from residential areas. The tree belts in Northern Nigeria help reduce the dust content of the harmattan winds.

### **3.9 Glare Control**

Direct glare can be prevented by using trees to block off the relevant portions of the sky while indirect glare can be prevented by planting flowers, shrubs and grass on surfaces that would normally reflect light into the building.

### **3.10 Fresh Air and Fragrance**

Plants produce oxygen and fragrances, which combined with the almond tree effect, create the refreshing atmosphere of gardens. While the freshness of the air and fragrance may not be measurable by climatic variables, the improvement in the microclimate is unquestionable.

## **4. Landscape Elements for Microclimate Control**

The objectives enumerated above can be achieved by using landscaping techniques and elements. Landscaping elements can be grouped into hard landscaping elements and soft landscaping elements. Soft landscaping elements refer to vegetation while the hard landscaping elements are all other elements including simple structures, steps, paving, garden furniture, walls and fences.

### **4.1 Hard landscaping elements**

#### **Steps and paving**

The choice of the surface finishing, material and construction of steps and paving can play a significant role in the reduction of ground temperature. The use of asphalt in parking lots without any form of shade is a primary source of discomfort.

### **Walls and fences**

Walls are used to deflect the wind, and they can be used to channel the wind. Walls are usually solid, while fences are made from stakes, rails, wire, netting, et cetera. Fences thus allow some wind to flow through them, even when they have climbers.

### **Slopes and barriers**

The use of slopes and barriers to direct airflow can be very effective on sites with significant variations in the topography.

### **Stones and boulders**

Stones and boulders can be arranged to direct airflow and to provide shade.

## **4.2 Soft landscaping elements**

### **Trees and shrubs**

Trees and shrubs are the most significant in the provision of shade and the control of relative humidity and air movement. They contribute more to the attainment of thermal comfort than any other element. Ventilation is affected by plant materials. Air crossing hard reflective or absorptive surfaces like parking lots and sidewalks is warmed, but air passing through trees and plants will be cooled (Caudill *et al* 1974).

### **Lawns**

Lawns and flowerbeds are used to reduce ground temperature and to prevent glare. Vegetation generally improves air freshness and fragrance.

### **Pools and ponds**

These water bodies are used for humidification and evaporative cooling.

### **Mulches**

Mulch is a protective covering over the roots of trees and bushes to retain moisture and kill weeds. Mulches include straw, fallen leaves or plastic sheeting. Others are gravel, wood chipping, rotting leaves and grass. Mulches can be used to reduce surface and air temperatures by reducing the heat absorbed by the ground.

### **Trellis and climbers**

A trellis is a light framework of crossing strips of wood, plastic, et cetera used to support climbing plants and it is often fastened to a wall. This can be used to provide shade on western walls.

## **4.3 Outdoor living space**

Outdoor living spaces occupy that region between the house and the garden. These are conditioned outdoor spaces. They are partly garden, partly house. They are partially protected from the elements, yet open to nature. They include courtyards (courts), patios, corridors, terraces, balconies, loggias and porches (verandas). Outdoor living space can be considered a part of the landscape and its design can significantly impact on the indoor comfort conditions.

## **4.4 Use of colour externally**

The amount of solar radiation absorbed by a surface is referred to as the absorptivity and is dependent on the colour of the surface. The absorptivity of colours is shown in Table x.

Colour	Absorptivity (%)
Perfectly black	100
Ordinary black	85%
Dark green	70
Dark grey	70
Light green	40
Light grey	40
White oil paint	20
New whitewash	12
White emulsion paint	12 – 20

Source: BRE (1974).

Boundary walls and screen walls should be in dark colours, browns, greens and blues so as not to reflect heat and glare. Hard landscaping (paving) should preferably be in dark colours, or if light, should have a broken surface to avoid reflecting heat and glare.

## 5. The Design Process

Landscape design for moderation of the microclimate involves five steps:

- Determination of the local climate especially air temperature, radiant air temperature, humidity, rainfall, wind speed and direction.
- Determination of the thermal stress imposed by the local climate during different seasons of the year.
- Analysis of the site in terms of topography, existing vegetation and building structures.
- The proposal of techniques for the alleviation of thermal stress imposed by the local climate during different seasons.
- Design of landscape elements.

### 5.1 Data collection

The climatic data required are the monthly minima and maxima of air and globe temperatures, the monthly minima and maxima of relative humidity, monthly rainfall and monthly averages of wind speed and direction. This information can be recorded on a climatic data sheet. See Appendix A.

### 5.2 Determination of thermal stress

The choice of the most appropriate thermal index has been the subject of academic debate over the last decades. Ogunsote (1990) conducted studies that indicate that the Evans method is the most effective index for the Nigerian climate. The thermal stress imposed by the local climate is determined using the method and comfort limits proposed by Evans (1980). This method uses the air temperature and the relative humidity to establish the thermal stress. See Table x.

Table x. Comfort limits proposed by Evans.

Relative humidity (%)	Day comfort limits (C)	Night comfort limits (C)
0 – 30	29.5 – 32.5	27.5 – 29.5
30 – 50	28.5 – 30.5	26.5 – 29
50 – 70	27.5 – 29.5	26 – 28.5
70 – 100	26 – 29	25.5 - 28

The day thermal stress is obtained by comparing the mean monthly maximum temperature with the day comfort limits using the mean monthly minimum relative humidity. Note that the maximum temperature is used with the minimum relative humidity because both readings are taken in the early afternoon. The night thermal stress is obtained by comparing the mean monthly minimum temperature with the night comfort limits using the mean monthly maximum relative humidity. The thermal stress is categorised as shown in Table x:

Table x. Categories of thermal stress.

Category of thermal stress	Conditions	Symbol
Cold	Temperature below the lower comfort limit	C
Comfortable	Temperature within the comfort limits	O
Hot	Temperature above the upper comfort limit	H

An example of the use of the climatic data and the comfort limits to determine thermal stress is shown in Table x.

Table x. Example of determination of the thermal stress.

Ikeja	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Max. Temp. (C)	31.7	32.9	32.9	32.1	31.1	29.3	27.8	27.9	28.3	29.7	31.3	31.7
Mean Monthly Min. Temp. (C)	22	23.1	23.3	23.2	22.9	22.3	21.9	21.5	21.9	21.9	22.6	22.1
Mean Monthly Max. RH (%)	97	97	96	97	97	97	97	94	97	97	97	97
Mean Monthly Min. RH (%)	63	63	65	69	75	76	81	77	79	78	73	65
Day Thermal Stress	H	H	H	H	H	H	O	O	O	H	H	H
Night Thermal Stress	C	C	C	C	C	C	C	C	C	C	C	C
Temperature control	+	+	+	+	+	+				+	+	+
Humidity control	+	+	+	+	+	+				+	+	+
Air velocity control												

The analysis of the thermal stress should be done not only on a monthly basis, but also on a seasonal basis. The simplest division of the years is into the rainy season and the dry season.

### 5.3 Site Analysis

This involves an analysis of the site in terms of topography, existing vegetation and building structures. The potential assets and potential liabilities of the site must be identified. The way the local climate will interact with the site should be indicated. A good site analysis should show the following:

1. Existing elements of the topography including contour lines to indicate hills, rock outcrops, slopes and valleys. Streams, ponds, pools and other water bodies should be indicated. The nature of the soil should be indicated. Existing and proposed infrastructure such as roads, paths and services should be shown. This analysis can be used to propose vistas and viewpoints.
2. The direction of prevailing and secondary winds, and the direction of hot and cold winds. An indication of how the wind will flow over the site and proposals for channelling and windbreaks should be made where necessary.
3. The type and location of existing vegetation.
4. The location and design of existing and proposed building structures. The ventilation, shading and lighting needs of the structures should be indicated. Areas where trees should be planted and areas where reflection can cause glare should also be shown.
5. Zoning of the site into quiet and noisy zones and a proposal for noise reduction using vegetation and barriers.

### 5.4 Proposed remedies

Shade from the west

Pool or fountain in courtyard

Courtyard with Trees

Lawns

Treatment of pavements

Hedges to filter dust and reduce wind speed

Use topography to direct airflow

Trees for general shading (active shading)

Shade pavements and walks

Shade walls: N, E, S, W

Shade roofs

When the winds are too hot most of the time, what is needed is evaporative cooling and not cross ventilation.

In warm humid climates, the air movement provided by ventilation causes body cooling.

Winds should be avoided in cold weather.

It is best to keep the wind out of inside spaces in hot dry climates.

In cold weather, the sun should be used for warming up people while windbreaks should be used to keep out the wind.

Thermal stress imposed	Climatic variable to be modified	Possible landscaping remedies

#### 5.4 Detailed design

Control of the microclimate is only one of the considerations in landscape design. The landscape architect must approach the design from several angles.

1. The existing site character will influence the choice of design elements. The best approach is to disturb as little of the natural setting as possible.
2. A good understanding of the raw materials available is necessary (hard and soft landscaping elements).
3. Knowledge of plants, the ecology of the various forms of natural vegetation and general knowledge of horticulture.
4. Aesthetics in plant cultivation. Composition is very important.
5. Understanding of the role of new plant breeds.
6. Understanding of the way plants grow with each other.
7. The third dimension. Gardens are not appreciated in plan but experienced in elevation and perspective.

The detailed design includes the selection of the actual plants and landscaping elements to be used and their composition on the site. In doing this there must be a trade-off between achieving the specific objectives of microclimate control and other landscaping considerations.

### 6. Problems of microclimate control through landscaping

The control of the microclimate through landscaping is not a new idea; it has been part of centuries old building practices especially in rural areas. The real challenge is to integrate this practice with modern building technologies, especially in urban areas. There are several factors militating against the successful and effective propagation of this practice.

#### 6.1 Overgrowth of tree roots

Probably the greatest problem of growing trees close to houses is the destruction caused to the building by the roots of the trees. When trees are too close to the building, the roots will eventually reach the building causing foundations, floors and walls to crack. Trees grown close to buildings should be carefully selected and replaced after a certain age.

## **6.2 Excessive shading**

The rainy season is the period when the highest relative humidity is experienced. This coincides with the period when trees grow most profusely and provide more shade. Some walls of a building may therefore be subjected to high humidity and low temperatures as a result of the shade, leading to condensation. This can lead to the growth of moulds, moss and lichen.

## **6.3 Need for maintenance**

Hard landscaping is rarely sufficient for control of the microclimate – trees, shrubs and lawns are usually required. The resultant garden will require tending and thus labour. Water has to be supplied and essential inputs such as manure, fertilisers and pesticides cost money. The garden may suffer irreparable damage if it is left unattended to for too long, especially during the dry season.

## **6.4 Leaves on roofs**

Trees growing close to a house shed leaves on the roof of the house and these leaves should be cleared regularly. Apart from the increased maintenance cost, roofs tend to get damaged in the process of clearing the debris. Leaving the leaves for a long period will cause plants to start growing in the debris, with the roots of such plants attacking the roofing sheets.

## **6.5 Limited plot size**

The size of plots in urban areas is so small that there is usually very little space between the building and the boundary wall. The use of large trees to provide adequate shade therefore becomes difficult, since the space is usually insufficient for the root system to develop without affecting the foundation of the building. Careful selection of tree species can reduce the space required for development of the root system.

Most of the space left around houses in urban areas is used for parking cars or for walkways. There is little space left for lawns, pools or flowerbeds. Careful selection of surface finishes can help reduce heat storage, but reducing the built up area is more effective.

The limited plot size combined with security problems necessitating the use of high walls as fences result in poor ventilation. The solid fences act as barriers to the wind, with the building effectively in the wind shadow of the fence. The use of courtyard design has also been discouraged by the small plot sizes, thereby eliminating the moderating influence of a courtyard on the microclimate. Limiting the built up area of the plot or using double plots can reduce this problem.

## **6.6 Increased Building Height**

The use of trees for shading buildings is most effective for bungalows or two-storey buildings. Many apartment blocks in cities are four-storey buildings, and the effect of landscaping can usually only be felt on the ground and first floors. On the other hand higher floors have better ventilation because they are unaffected by ground obstructions, assuming that there are no adjacent tall buildings.

## **6.7 Snakes and vermin**

Snakes and vermin can easily gain access to a house by climbing trees, shrubs and climbers adjacent to the house. This problem is greater in semi-urban and rural areas. The use of plants that drive away snakes and vermin can be useful.

## 7. Conclusion

## 8. References

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## Appendices

Appendix A: Landscaping climatic data and analysis sheet.

Appendix A: Landscaping climatic data and analysis sheet for Ikeja.

Appendix A: Landscaping climatic data and analysis sheet for Ibadan.

Appendix A: Landscaping climatic data and analysis sheet for Makurdi.

Appendix A: Landscaping climatic data and analysis sheet for Enugu.

Appendix A: Landscaping climatic data and analysis sheet for Sokoto.

Appendix A: Landscaping climatic data and analysis sheet for Zaria.

Appendix A: Landscaping climatic data and analysis sheet for Jos.

Appendix A: Landscaping climatic data and analysis sheet for Nguru.

Appendix A: Landscaping climatic data and analysis sheet for Kaduna.

Appendix A: Landscaping climatic data and analysis sheet for Abuja.

*Table 13: Average degree of thermal stress for selected towns in Nigeria using the Evans scale.*

Design zone	Town	Average degree of thermal stress (%)		
		Comfortable	Overheated	Under-heated
Coastal zone	Ikeja	24.8	19.0	56.2
Forest zone	Ibadan	20.9	19.6	59.5
Transitional zone I	Makurdi	16.7	28.5	54.8
Transitional zone II	Enugu	18.8	25.2	56.0
Savannah zone I	Sokoto	14.2	26.7	59.1
Savannah zone II	Zaria	14.9	14.8	70.3
Highland zone	Jos	5.9	0.6	93.5
Semi-Desert zone I	Nguru	12.5	25.6	61.9
Semi-Desert zone II	Katsina	12.3	20.1	67.6

Design zone	Town	Average degree of thermal stress (%)		
		Comfortable	Overheated	Under-heated
Coastal zone	Ikeja	67.0	25.7	7.3
Forest zone	Ibadan	59.2	15.5	25.3
Transitional zone I	Makurdi	55.0	22.6	22.4
Transitional zone II	Enugu	58.1	17.1	24.8
Savannah zone I	Sokoto	42.2	14.1	43.7
Savannah zone II	Zaria	37.1	4.9	58.0
Highland zone	Jos	16.9	0	83.1
Semi-Desert zone I	Nguru	41.2	15.5	43.3
Semi-Desert zone II	Katsina	36.4	9.2	54.4