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Low-cost Sun Control Designs using Shading Devices and Mobile Gardens

M. Kamakshi Kanchana (Asst. Professor),
B.Design (I.D), Jawaharlal Nehru Architecture and Fine Arts University, Hyderabad- India

Abstract

Climate change and global warming are real issues that are adversely impacting lower-income households in India. Extreme heat and rising temperatures are causing severe discomfort and health issues to people living in low-cost homes. Street vendors set up their roadside shops with makeshift plastic sheet tent covers and face the brunt of extreme summer heat. Consumers who depend on inexpensive street shopping are also impacted by severe heat. The lack of shaded pathways compounds the problem. Expensive air conditioners are not affordable and viable in terms of initial investment and running expenses and other environmental issues. Low-cost shading devices and mobile garden schemes offer a promising solution to the problem. Low-cost nature-based design solutions can offer a sustainable approach. This paper proposes low-cost shading devices which can be deployed on existing buildings and structures to reduce the peak heat of the building drastically. Mobile gardens are emerging landscaping design ideas to mitigate the impact of climate change. Mobile garden platforms and mobile green walls can be deployed on streets and homes to give immediate relief from the extreme summer heat. This paper proposes simple designs which can be easily implemented by individuals or self-help groups. As a proof of concept, prototypes are built and details are reported. Tall trees can be grown in large pots and transported as mobile forests to areas in the city that are like "heat islands" due to lack of vegetation. The designs proposed will improve life quality in congested and overpopulated urban areas. With proper funding from the government, these designs are scalable and can cover whole urban areas dramatically increasing comfort levels.

Keywords: Garden Platforms, Green Walls, Mobile Forests, Mobile Gardens, Shading devices, Sun control, Urban heat islands, Miyawaki forests

1.0 Introduction

Climate change and rapid urbanization are causing extreme heat wave conditions during summers in Indian cities. People living in low-cost homes and on top floors of apartment complexes are worst impacted by heat. Summers are dreadful, affecting the health of millions. Children, old and sick people are vulnerable. Non-availability of electricity due to frequent power failures, initial investment needed to install air conditioners, and huge energy bills every month are formidable challenges to opting for air conditioners. Exploring low-cost nature-based solutions is required to find a sustainable solution to the problem.

According to the World Bank research report, India is experiencing extremely hot summers (*India: Climate Change Impacts*, 2023).

India is already experiencing sweltering summers. Spells of hot weather are expected to occur far more frequently and cover much larger areas. Unprecedented extreme weather conditions involving extreme heat and very high rainfall are now common weather events. Under 4°C warming, the west coast and southern India are projected to shift to new, high-temperature climatic regimes with significant impacts on agriculture. Built-up urban areas rapidly become "heat islands", and urban planners will need to adopt measures to counteract this effect. High-rise buildings and glass facades are increasing local temperatures.

While air conditioners make indoors cozy and comfortable, they have adverse impacts on outside temperatures and serious environmental issues. Climatologists made several studies to measure the impact of air conditioners on outside temperatures (Lundgren-Kownacki et al., 2017).

In 2007 Yukitaka Ohashi of the Okayama University of Science in Japan found that ACs can raise temperatures in downtown Tokyo by as much as 2°F (approximately 1°C) (Engber, 2015). A 2013 study modeling temperatures on the streets of Paris found that the effect was most acute at night–surprising, given that we use the most air conditioning when the sun is up.

Air conditioning units that cool interiors, make the exteriors hot impacting pedestrians and occupants of people living in non-air conditioned buildings in the neighborhood.

The IISc-Indian Institute of Science- Bangalore, conducted a study by Dr. T. V. Ramachandra where it was stated that having glass facades leads to higher use of air conditioners, since the temperature inside the buildings has to be kept cool (Ramachandra et al., 2022, 305). This results in an adverse environmental impact ("Karnataka: NGT Seeks Report on Environmental Impact of Glass Facade Buildings," 2023).

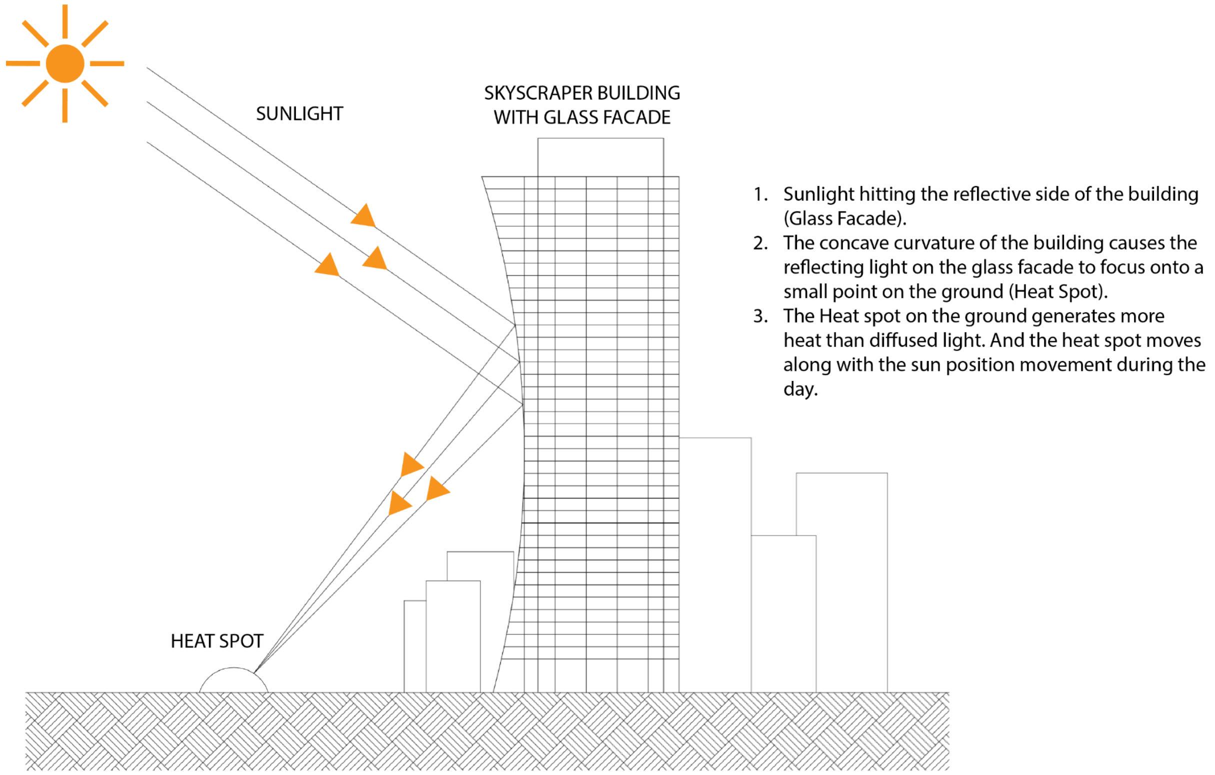

Fig 1: An illustration showing the effect of buildings with glass facades in regions that are exposed to ample sunlight (Illustraion by Kamakshi M.K (Kanchana, 2023))

A study was conducted around the neighbourhood of Walt Disney Concert Hall, which has a concave-shaped glass façade. The ground temperature in the neighborhood rose by 9 degrees Celsius and neighbouring buildings were forced to enhance their air conditioning units (Raghunath, 2022).

India National Green Tribunal and other statutory bodies are closely examining the environmental impact of glass facades (Kulkarni, 2023).

This paper proposes designs to naturally cool pathways, implement shading devices on existing buildings to drastically reduce the heating caused to buildings and public utilities.

2.0 Shading the pathways

In India around 63% of GDP is contributed by street side vendors. Street side vendors are self-employed and offer goods and services with minimal overheads and form the backbone of the economy. They operate under extreme heat during summer under makeshift plastic tents (Singh, 2022, 1788).

Fig 2: Street vendor stall closed during afternoons when the outside temperature are high (Location: Hyderabad)

Typical street vegetable vendor-under the shade of plastic sheet-closing the shop in the afternoon when the temperature is above 40 degrees Celsius.

Temperature differences under Street Vendor Stalls	Street Vendor stall 1, Time: 15:02 hrs (29/04/2023) Temperature (degree celsius)	Street Vendor stall 2, Time: 13:07 hrs (30/04/2023) Temperature (degree celsius)
Outside Temperature	45.2	42.1
Under Shelter	42.1	38.2 (Near vegetation)

Table 1: The above table indicates the temperature differences under Stall shelters.

Various studies highlight the effectiveness of shade created by trees and vegetation. About 5-10 degrees reduction can be achieved under shaded areas. Creating a mobile garden shaded pathway is a sustainable option.

Exposure to direct sunlight is uncomfortable and people feel 5 to 10 degrees Celsius more than the actual temperature when they are exposed to direct sunlight. Skin burns due to UV radiation in sunlight and sun stroke are common health problems. A shaded area will alleviate the severity of sunlight exposure (*Using Trees and Vegetation to Reduce Heat Islands | US EPA*, 2022) (Pierce, 2022).

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2.1 Field study and experimental results

A detailed field study was conducted at Hyderabad and Bangalore during peak summer afternoons to measure the temperatures inside the shaded areas and directly under the sun. Around 2-4 degrees Celsius lower temperature was observed. Comfort and ambiance were more under shaded areas. Giving tangible comfort and people under the shade.

Fig 3: Plants growing under shade nets at nurseries.

2.2 Tensile Fabric Shade Structures

Fabric Shade Structures are economical. Tensile Fabric Structures are relatively easy to install, and maintain, and exhibit good strength, durability, and elegance. Modern designs are weatherproof and flame resistant.

Fabric Shade Structures or Tensile Structures are designed using many individual components. Each shade structure uses different fabric membranes, which are put together using clamps, cables, or stainless steel supports. The tensile structures are lightweight and can easily span large distances.

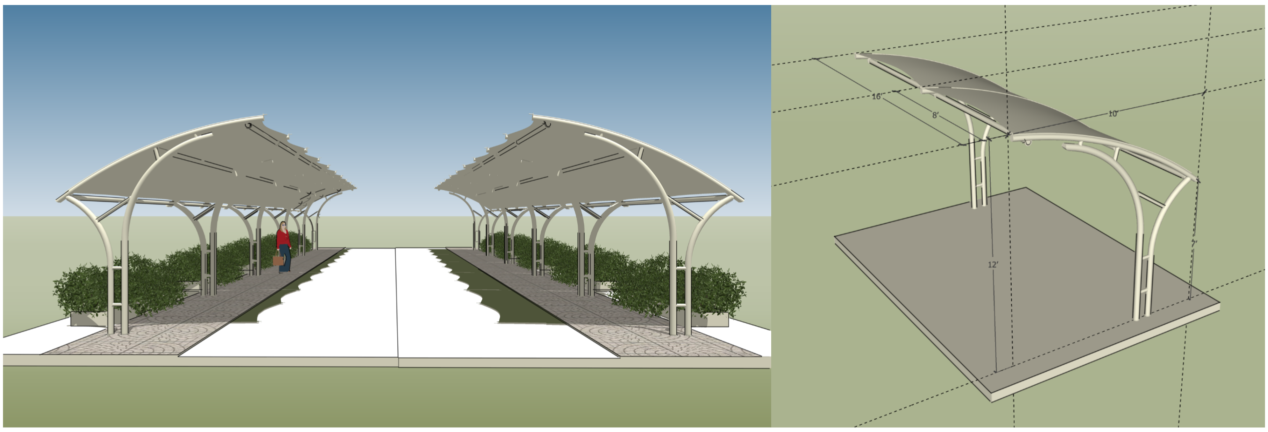

Fig 4:Tensile shade fabric concept

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Trellis

A trellis is an architectural structure, made from an open framework or lattice of interwoven or intersecting pieces of wood, bamboo, or metal that is normally made to support and display climbing plants, especially shrubs (*Trellis (Architecture)*, 2023).

A combination of tensile fabric structure with trellis can create a green pathway .

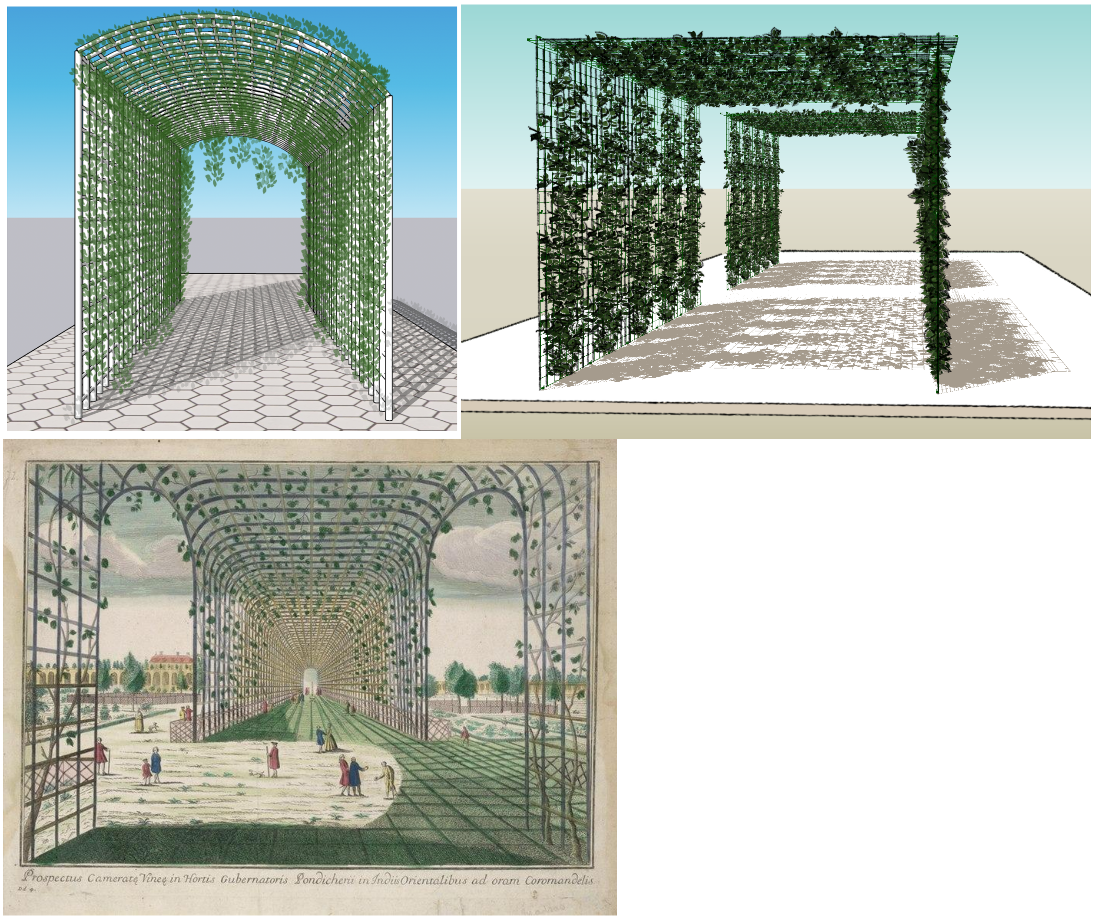

Fig 5: Green pathway concepts using trellis

2.2 Mobile Creepers

Leafy vegetable creepers can be grown in suitable containers and can be laid and trained to cover tensile fabric shades. Greening of fabric shades will be an additional comfort under the shade. A prototype is made by planting leafy creeper Epipremnum aureum (*Epipremnum Aureum*, 2023).

Fig 6: A money plant being trained to cover a makeshift framework.

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2.3 Green facades to reduce heat islands

Reflective glass facades of high rise buildings adversely impact the micro climate in the neighbourhood. Implementing green facades is one of the best sustainable solutions (*Green Facades*, 2023).

Fig 7: Various structures encouraging green facades.

2.4 Full grown trees and mobile forests

Many nurseries in India are offering full grown trees like bottle palms in pots. They can be transported and either planted are place near the pathways to give immediate relief.

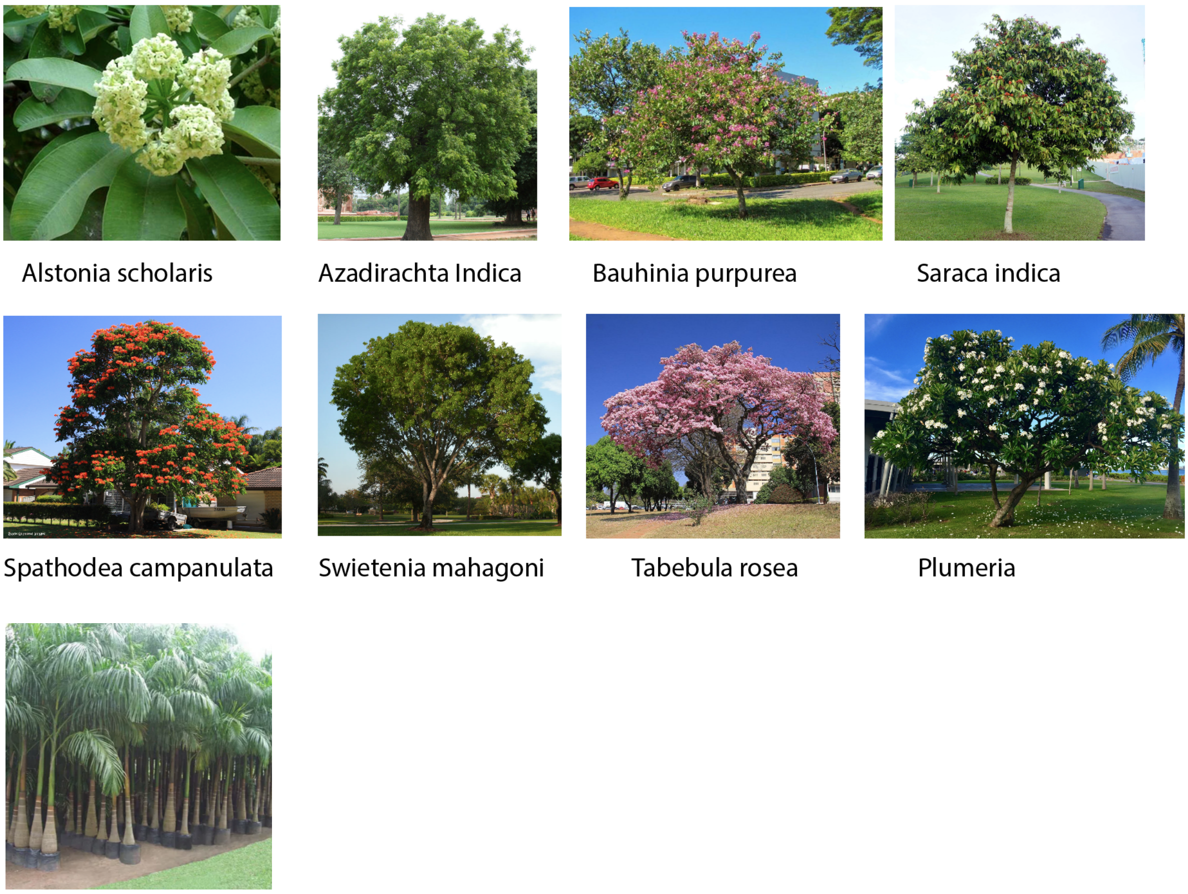

Fig 8: List of local trees that are readily available and can be planted near pathways.

The following picture shows a fully grown potted Plumeria tree shading a east facing wall.

Mobile forests can be a sustainable solution to handle city heat islands and to deal with climate change. Cities across Europe are experimenting with such mobile forest ideas to deal with climate change (Gillman, 2019) (D'Mello, 2019).

2.5 Miyawaki forests

Miyawaki method was invented by Japanese botanist Akira Miyawaki (*The Miyawaki Method for Creating Forests – SUGi*, 2023). It is a sustainable and accelerated method to create mini forests in urban and semi urban areas. It can be effectively used to convert mini plots of land in cities into miniature forests providing lung space and comfort to the residents in the neighbourhood. The following steps are involved in creating a mini forest using the technique.

Step 1: Procure saplings of native tree and shrub varieties.

Saplings of native tree varieties are collected. Saplings are grown in pots or bags with rich nutrients. Saplings are grown under shade for several months. Once the saplings grow to a meter height the next steps are initiated for transporting them to required locations.

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Step 2: Preparation of soil.

Pits of one-meter depth are dug and filled with compost, cocopeat, groundnut shells, beneficial microorganisms and shredded leaf litter are added to enhance the soil.

Step 3: Planting of a sapling.

Once the soil is treated, the healthy saplings from step 1 are placed into the pits.

Step 4: The trees planted need to be watered regularly.

The trees need to be watered every day to keep the soil moist and support the growth of the trees. Drip irrigation can be tried to conserve water.

Step 5: Insert support for the saplings.

Wooden sticks are inserted as support and the saplings are tied to the stick. It helps saplings to grow straight and protects them from bad weather conditions.

Step 6: The soil is covered with mulch

The soil is covered with organic matter, spread out hay or leaf litter to create a blanket layer to protect the soil from direct sunlight, slow the rate at which soil moisture is lost, and promote the growth of beneficial biodiversity. Leaf litter also slowly decomposes, which improves the health of the soil.

Step 7: Continuous assessment of the growth of the Miyawaki Forest

Visits to the forest patch frequently to check the saplings' health, removing the weeds and turning the mulch to promote healthy growth

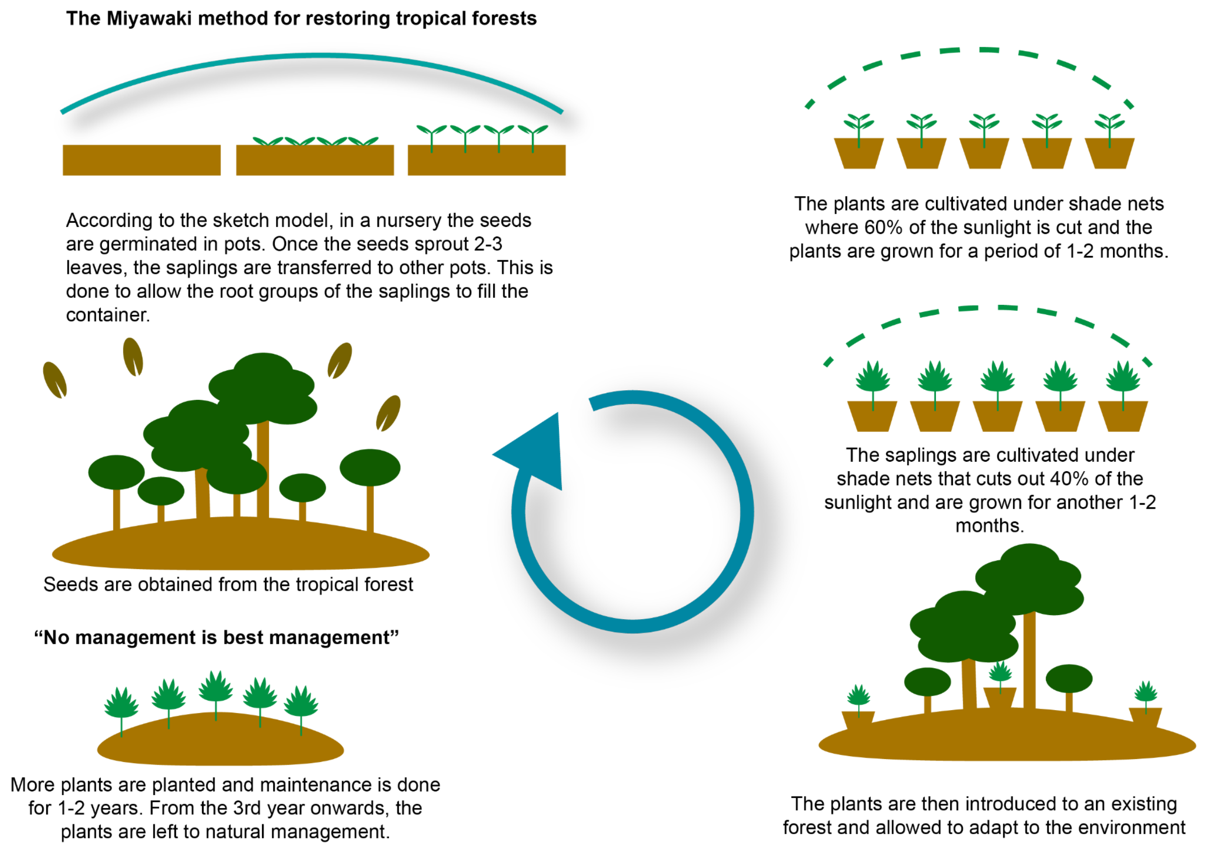


Fig 9: An illustration showing the concept of Miyawaki method for restoring tropical forests

The following pictures show a mini forest created in a vacant plot.

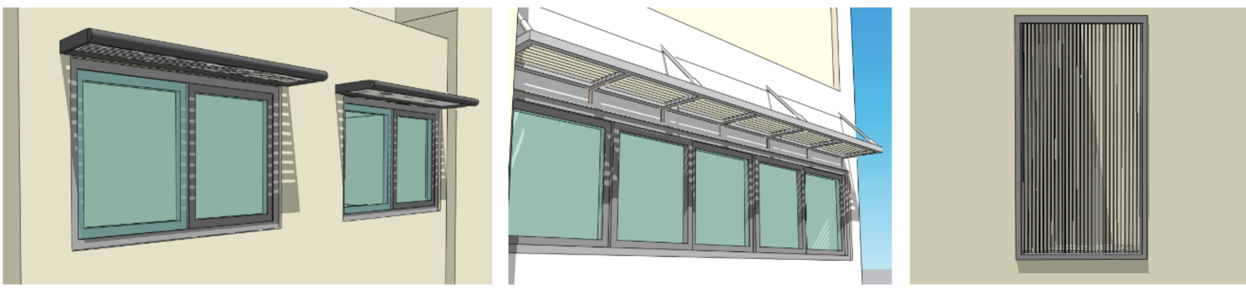
Fig 10: Natural forest like development of vegetation in vacant land (Location: Bangalore)

3.0 Shading schemes for existing buildings and structures

East facing walls get heated during morning hours and west facing walls during the evenings. Sun exposed roofs get heated throughout the day. Air conditioning is not a viable option for most of the households due to initial capital investment and running costs. It is important to design and implement natural shading solutions. Sun control can be achieved by landscaping features, exterior architectural elements like overhangs, vertical fins etc (Prowler & Bourg, 2016).

Solar Control and shading can be provided to a wide range of building components including:

- Landscape features such as mature trees or hedge rows;
- Exterior elements such as overhangs or vertical fins;
- Horizontal reflecting surfaces called light shelves;
- Low shading coefficient (SC) glass and,
- Interior glare control devices such as Venetian blinds or adjustable louvers.



(a) Aluminium sun shade, (b) Horizontal sun control device, (c) Vertical fins

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Planting deciduous trees allow the heating of buildings during winter and provide shade in the winter.

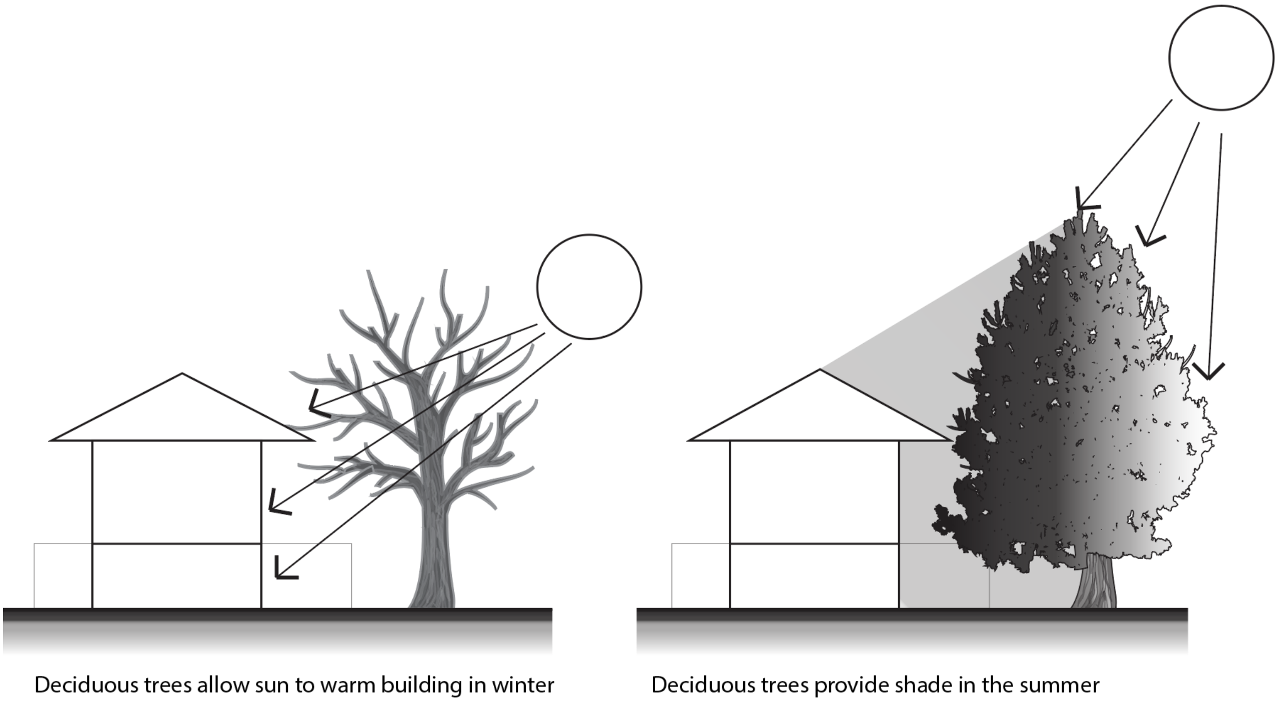
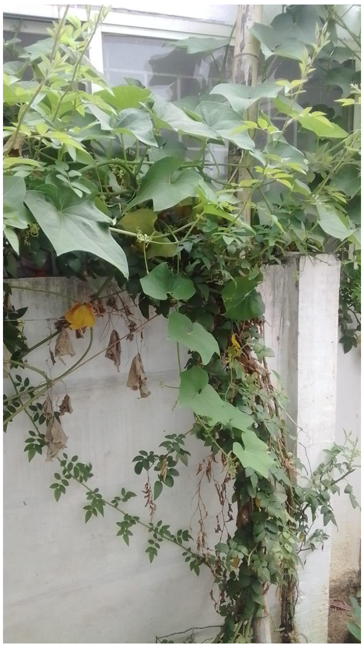
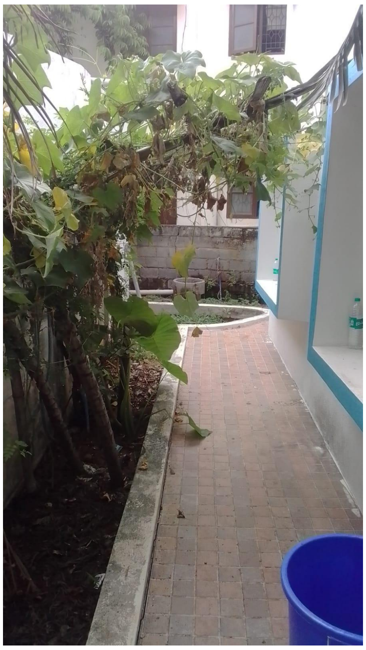


Fig 11: Concept of how vegetation can help shade structures

Practical implementation of schemes is shown in the following designs:




Peepal tree (Ficus religiosa) is a deciduous tree. If planted on the east side of a building, it will keep the structure warm in winter and cool in summer. Bougainvillea is an ornamental vine and can be trained to create a canopy and cover balconies. Money plant (Epipremnum aureum) with evergreen foliage will shade the buildings throughout the year.

3.1 Mobile gardens and vertical green walls

Low cost green walls and vertical gardens can be created to insulate the building,



Curtain creeper -Pardha Bel in Hindi (Veronia elaegnifolia) is an elegant and aesthetic solution to cover windows and east facing walls to give a sustainable and lasting solution to shade and cool.

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3.1 Cooling the rooftops

Covering rooftops with reflective paint is effective. However, it will adversely impact micro climate in the neighborhood. Shade nets and roof gardens are sustainable solutions to reduce the heat of the building from the roof.

A well laid roof kitchen garden can drastically reduce the temperature of the upper floors. However, proper care has to be taken in terms of load consideration and water-proofing of the surface to avoid structural damage to the building.

4.1 Experimental results

On hot sunny days the author has measured the temperature before and after implementation of shading devices and designs. Consistently 2-3 Degrees Celsius reduction was observed and manifold increase in the human comfort due to the control of direct sunlight.

4.2 Future scope of work

Urban civic bodies can fund these projects and improve the living conditions in cities. Self-help groups and community volunteers can come together and implement the schemes. Business and corporate bodies can undertake many such urban greening projects under the CSR funded (corporate-social responsibility) projects. Municipalities and electric power supply companies can give incentives to residents to implement shading devices as it is going to reduce electric power consumption and reduce overall pollution.

5.0 Conclusion

Climate change and global warming are real issues facing the world today. Rapid urbanization and growth of high rise buildings is adversely impacting the micro climate in the neighbourhood. This paper proposed several low-cost solutions to naturally shade and control direct sunlight exposure to buildings, roads and pathways. Designs proposed are simple and give immediate relief to people living in low-cost homes and people like street vendors and pedestrians who are impacted by extreme heat. Prototypes built as proof of concept are promising. Experimental results after implementing the designs are encouraging and will go a long way to give comfort to people.

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