Mitigating Climate Change through Traditional Knowledge in Tropical Housing: An Overview

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Abstract

Climate Change and Rapid Urbanization have brought a new challenge for architects and urban planners. Errant weather conditions in the form of prolonged heat waves causing heat strokes, torrential rainfall leading to floods in urban settlements, and extreme cold conditions have worsened the situation. The Urban Heat Island (UHI) effect has further elevated the temperatures of cities and towns. Urbanization has brought more construction activities and increased vehicles on the road leading to polluted environments. It has resulted in degrading the quality of life in both indoor and outdoor spaces.

Tropical houses have some of the highest population concentrations in the world. Tropical climate consists of hot summers and cool winters with plenty of rainfall which makes the weather hot and humid. Proper ventilation is essential in this weather. The application of mechanical means of cooling and heating has made the buildings feel thermally comfortable but resulting in environmental degradation and other problems. However, before the advent of electricity, all vernacular houses have been naturally ventilated. Windows is used to control light, solar radiation, and ventilation in a building.

In this context, this paper examines climate change adaptation in tropical housing through basic knowledge of locally available techniques. It focuses on the change of climate in the tropical regions of India. It employs examining documented studies related to the mitigation of climate change as a research methodology.

It concludes that climate change can be significantly reduced by implementing efficient design practices, such as green walls, roofs, and balconies, minimizing energy use in traditional and vernacular houses.

Keywords: Traditional Knowledge, Climate Change, Built Environment, Urbanisation, Urban Heat Island (UHI).

1. Introduction

The most important anthropogenic greenhouse gas emitted by burning fossil fuels is Carbon Dioxide. The content of this gas in the atmosphere has increased from 280 ppm in pre-industrial areas to 379 ppm in 2005. Carbon dioxide along with other Green House Gases (GHG) has led to an increase in the global temperature by 0.76°C from the period during 850-1899 to 2001-2005 (IPCC, 2007). This has led to the rise of seawater and a change in climate. Urbanization has also led to the loss of natural green and blue spaces. Concrete buildings, hard paved surfaces, and loss of greenery have given a thrust to the miseries of urban dwellers in the form of the Urban Heat Island (UHI) effect thereby further increasing the urban temperature as compared to its rural suburbs. Unfortunately, the reversal of climate change may take several centuries, and the only option left with the planners today is to devise means to counteract these challenges.

In this context, this paper examines mitigation strategies adopted in building and site planning. It examines the adaptation of climate change in tropical housing through basic knowledge of locally available techniques while focusing on the change of climate in the tropical regions of India. Its aim is to explore the traditional practices in modern construction to mitigate the ill effects of climate change and provide amicable solutions for thermal comfort.

Its objectives are:

1. To investigate the building elements adopted in traditional buildings for achieving thermal comfort when no mechanical means of heating/cooling were available.
2. To adopt those building elements in modern edifices along with HVAC systems to reduce energy consumption.

2. Theoretical Framework

2.1 Green Infrastructure

Tropical housing used to be amidst a green environment. Sufficient rainfall kept the plant green throughout the year enabling them to modify the micro-climate. Green Plants and water bodies (Green-Blue Infrastructure) are integral parts of an ecosystem creating a harmonious co-existence between flora and fauna. Cities are characterized by high population density, altered land use/land cover with lesser blue and green spaces, more impervious layers, higher levels of vehicular pollution, and decreased environmental standards. The mitigation strategy is to recreate the greenery in a novel way. It's not only the green spaces but water bodies (blue spaces) that are equally decreasing. (Kumar & Das, 2022). According to Haggag et al. (2014), the usage of greenery on a site and the landscape elements modifies the micro-climate and reduces the energy demand significantly in the long term.

However, today, in tropical climates, there is an excessive usage of air conditioners to get amiable thermal comfort at workplaces, at the expense of polluting air by power plants. Heating the surrounding air with outdoor units of ACs reduces the outdoor comfort level (Jaffal et al., 2012).

Urban green spaces are cost-effective mitigation strategies for climate adaptation both for indoor and outdoor spaces. Elements of urban green infrastructure (UGI) are parks, trees, green roofs (GR), and green walls (GW) (Lu et al., 2017). These elements influence the thermal environment through shading, insulation, evapotranspiration, and wind barrier effect (Manoli et al., 2019). Meteorological factors like temperature, humidity, air velocity, and thermal radiation determine the efficiency of these green elements in varying climatic conditions (Yu et al., 2018). For climate-conscious design in the tropics, the use of vegetation is an important design criterion to be adopted (Emmanuel, 2016).

2.2 Blue Infrastructure

Blue infrastructure refers to water bodies. Lakes, ponds, water pools, and fountains are all included in blue infrastructure. It has been estimated that blue spaces (water bodies) can modify temperature by 1- 3° C within their vicinity of 30 m (Kleerekoper et al., 2012). Sprinklers, water fountains and water curtains can also mitigate heat stresses (Santamouris et al., 2017). In hot and dry climates, water bodies will play a crucial role in reducing the temperature and adding humidity to the air. The psychological effect of water as a cool element also plays its part.

2.3 Building Typologies

2.3.1 Courtyards

Courtyards have been present in the Indian subcontinent, South East Asia, and the Middle East for a long time. In India for example, this space has a special significance. There, a courtyard is considered a '*Brahmasthan*' place where the central deity *(Brahma)* resides as per *Vastushastra*. Indeed, this space is regarded as a cosmic space directly connected to God. Therefore, a *tulsi* plant is planted in a courtyard. All the family functions are held here. Verma & Bano (2021) believe that traditional courtyard houses not only modify the micro-climate but also modify the user's perception, experiences, and activities as is evident in courtyard houses of Lucknow and Varanasi.

Courtyards act as multi-utility spaces serving day to day affairs of a common household. It is used for drying clothes and in rural areas it is also used for drying grain and all the farm products which need sunlight. Children play safely under the supervision of the elders within the house in a courtyard. Apart from this, the openness of a courtyard provides light and ventilation to the interior of a house. Sthapak & Bandyopadhyay (2014) consider courtyard as a microclimate modifier for its unique ability to mitigate high temperature, channel breeze and modify humidity. Usage of high reflective surfaces in courts help in diffused light reaching the interiors of houses. Using landscape and water bodies like cascade and water fountains increase moisture in the air and thereby increases Relative Humidity (RH) which is beneficial in hot and dry climates.

The geometry of a courtyard is described in terms of an aspect ratio as follows.

$$\text{Aspect Ratio} = \frac{area\ of\ the\ courtyard}{(avg\ ht.of\ the\ surrounding\ wall)^2}$$

A wide and shallow (high aspect ratio) courtyard collects heat, while a narrow and deep (Low aspect ratio) courtyard protects the space from the Sun. A shady courtyard in winter opens to a sunny courtyard in summer because of the Sun's altitude angle. Sun has a lower altitude angle in winter. Some of the popular courtyard house in India is listed below. A courtyard is followed by an open verandah around the courtyard and rooms behind it. This arrangement protects the room walls from exposure to solar direct radiation. Table 1 lists the popular courtyard houses in India in different states.

Table 1: Courtyard Houses in India
Source: Author

Name	Location
1. Havelis	Rajasthan
2. Wada	Maharashtra
3. Nalukettu	Kerala
4. Chettinad, Chaturmukham	Tamil Nadu
5. Rajbari	Bengal
6. Badas	Chattisgarh

3. Literature Review

Tropical climates are those climates where heat is the dominant problem, where, for the greater part of the year buildings serve to keep the occupants cool, rather than warm, and where the annual mean temperature is not less than 20°C (Szokolay & Koenigsberger, 1973). In accordance with the Framework Convention on Climate Change, "climate variability" will be used to refer to non-anthropogenic climate fluctuations, and "climate change" will be used to refer to the current shifts, where a significant portion of the change can be attributed to anthropogenic causes (Orlove, 2005)

Traditional house types have developed in response to the needs of a predominantly peasant population. The surrounding country provides the building materials: in the humid tropics timber, bamboo and thatch; in arid zones stone, earth, and bricks; and in composite climates a mixture of organic and inorganic materials. (Szokolay & Koenigsberger, 1973)

The most popular walling materials used in many developing nations for those living in poverty including South Asia, and Africa include adobe, cob, rammed earth, wattle and daub (also known as mud and poles), burned bricks, stabilized earth blocks and concrete (Hashemi, 2017).

The rhythm of country life includes time for building as much as for tilling, sowing, and harvesting. Everybody is a house builder as much as he is a cultivator or herdsman. Traditional rural building is based on low investment and high maintenance. Monetary transactions are minimal. The assistance of relations, friends, and neighbors is rewarded by food, drink, and mutual help. This is the self-help group mechanism to minimize the cost.

Man-made environments can create microclimates of their own, deviating from the macroclimate of the region to a degree depending on the extent of man's intervention. Such intervention with the natural environment is greatest in large towns or cities, thus it is justifiable to speak of an 'urban climate’. The factors causing deviations of the urban climate from the regional macro-climate are the following:

(a) Changed surface qualities (pavements and buildings) - increased absorbance of solar radiation; reduced evaporation.
(b) Buildings-casting a shadow and acting as barriers to winds, but also channeling winds possibly with a localized increase in velocity or by storing absorbed heat in their mass and slowly releasing it at night.
(c) Energy seepage through walls and ventilation of heated buildings; the output of refrigeration plants and air conditioning (removing heat from the controlled space to the outside air); heat output of internal combustion engines and electrical appliances; heat loss from industry, especially furnaces and large factories.
(d) Atmospheric pollution - waste products of boilers and domestic and industrial chimneys; exhaust from motor cars; fumes and vapors, which both tend to reduce direct solar radiation but increase the diffuse radiation and provide a barrier to outgoing radiation. The presence of solid particles in the urban atmosphere may assist in the formation of fog and induce rainfall under favorable conditions. The extent of deviations may be quite substantial.

Air temperature in a city can be 8 degrees higher than in the surrounding countryside and a difference of 11 degrees has been reported. Relative humidity is reduced by 5 to 10%, due to the quick run-off of rainwater from paved areas, the absence of vegetation, and higher temperature (Vyas et al., 2014). Wind velocity can be reduced to less than half of that in the adjoining open country, but the funneling effect along a closely built-up street or through gaps between tall slab blocks can more than double the velocity. Strong turbulence and eddies can also be set up at the leeward corners of obstructions. We observe the climate change and Urban Heat Island Effect has worsened the situation in Urban areas.

4. Research Methodology

The paper employs the examination of literature as research methodology along with structured interview and common observation. In order to do so, it conducts a ‘document survey’. Research documents were collected from research papers and were classified on the basis of offering cooperative solutions for thermal comfort, lessening the negative effects of climate change and investigating traditional practices in modern construction.

The research method adopted was, by performing the common observations during field surveys done by authors and upon interaction with the local users and stakeholders.
The two common observations during field surveys done by authors are as under:

- The ventilators which were present just below roof now are opted out in modern buildings by coming of air conditioners. If the ventilators were already present, they are closed down using cloth or plywood board because they were the root cause of dust entering the house in form of Suspended Particulate Matter (SPM). House lizards and insects too entered the house. The authors also observed that the manually operated ventilators are most prevalent nowadays so that they can be closed down during air conditioners are on.

- Another observation was, people were forced to shut down doors and windows because of mosquito's menace, which hampers cross ventilation and natural ventilation system is compromised. Instead of using double door/ double window with wired mesh, which has of high cost and is uneconomical. Local people are using mosquito repellents which are electric-operated (mosquito bat), vapor-type or fuel-type, incense sticks and mosquito nets. Further using mosquito nets reduces the air velocity inside the mosquito net thereby reducing the thermal comfort and sleep of a person is compromised(Anshu et al., 2023).

5. Findings

Outdoor comfort at any location is greatly dependent on Meteorological parameters and micro modifications can be done through efficient planning and design. Urban Planning and Urban Design can mitigate the severities of climate change. Asadi Eskandar et al. (2022) infers that morphological character in terms of street layout, its width, abutting building orientation and height, street landscaping and prevailing wind direction control the micro-climate.

The Building Elements for mitigating the adverse effect of Climate Change

5.1 Walls:

Walls are opaque components with high thermal resistivity which maintains the indoor temperature as desired. There is evidence that traditional buildings perform better than modern buildings in thermal comfort if energy is taken into consideration. Thicker walls of traditional buildings with high U- U-values were able to resist heat flow to/away from buildings. These buildings were cooler in hot weather and warm during cold weather. Nix et al. (2015) in a study conducted in Delhi, point out that the biggest range of temperature difference was observed in the *katcha* (not permanent) dwellings made from GI sheets, constructed with temporary materials, and the smallest range of temperature was in pucca dwellings, with brick wall and concrete roofs.

The thermal properties of a wall are governed by the materials and thickness of the walls. Material with high thermal resistivity is beneficial in composite climates(Szokolay & Koenigsberger, 1973). This can be useful for achieving a high U-value of the walls if the thickness of the walls is increased. External claddings of wall materials govern the amount of trapped radiation that will transfer inside the building. Materials with high thermal reflectivity keep the building cooler as compared to buildings with low reflectivity.

Colour also plays an important role in heating or cooling a wall. Dark colors absorb heat at a faster rate as compared to cool colours. Traditionally, before the advent of modern paints, buildings were whitewashed with quick lime and its brilliance reflected the solar energy back.

In vernacular housing, creepers are used to climb the walls of houses and keep the wall cool by blocking the direct Sunlight. In tropical regions, dwelling units used to be surrounded by tall trees providing shade to the houses.

Bio-mimic solutions involve green walls and living walls. Green walls are innovative solutions with several advantages. In 'direct green façade' creepers attach themselves to building elevation and grow vertically. In the 'indirect green façade,' a modular arrangement is erected so that creepers can grow. 'Living walls' have turned out as a solution to integrate plantations in high buildings (Nagdeve et al., 2020). A modular living wall system consists of modules in the form of vessels, trays planter tiles, or flexible bags, contained with growing media to support plant growth. Each module is then fixed on a support structure or is directly fixed to the vertical surface of the envelope. Green façades and living walls have the advantages of higher thermal insulation, enhanced sound absorption (Azkorra et al., 2015), pollution mitigation and improved air quality (Radić et al., 2019), increased biodiversity (Collins et al., 2017) and psychological benefits (Maron & Ramirez, 2020) through visible organic aesthetic.

Biologists have shown how solar energy is used by vegetation, with 5–20% used for photosynthesis, 5–30% being reflected, 10–50% turned into heat, 5–30% transmitted through the leaves, and 20-40% of solar exposure is required for evapotranspiration which is the process of drawing heat from surrounding for evaporating moisture from the leaves (Besir & Cuce, 2018). In the UK, during the winter conditions, there is a saving of 21% - 37% in facade energy saving as compared to bare walls (Cameron et al., 2015). Green walls offer the greatest benefit during maximum and minimum temperatures of the day (Riley, 2017).

5.2 Windows

Windows act as dynamic transparent apertures which can be opened or closed according to ventilation and illumination needs. They are unlike opaque walls and provide life to the building connecting it with the outside environment. They provide visual connectivity between indoor and outdoor spaces. They improve the façade of the building. With these advantages, they come with certain negativities of heat gain/loss, source of dust and insects, excessive glare, and security threats. Thus, an optimization is required to get the desired results.

Window-to-wall Ratio (WWR) is important to understand the behaviour of windows on energy consumption of buildings. A window consists of wood or metal or composite sash with a glazing. The concept of the Solar Heat Gain Factor (SHGF) is utilized while calculating heat transfer through windows.

Kumar et al. (2017) examined office building heat gained through different window materials in Delhi and said that because of its varied climate, the windows gain higher heat as compared to the cities of Ahmedabad, Bangalore Guwahati, and Madras. Kirankumar et al. (2016) have noticed that walls of fly ash brick buildings with grey glass windows placed in a South orientation is the optimized selection for the lowest heat (24.13 kWh) gain in the climate of New Delhi and its surrounding region. The study has been conducted in office buildings. The worst combination of wall and glass materials for Delhi among studied models was found to be dense concrete with a clear glass window due to high heat gain (31.20 kWh) in the south direction of Delhi and its adjoining region. For the Northern hemisphere and climate like that of India, maximum WWR should be in the North direction, followed by the East, West, and minimum in the South direction. It should be noted that this assertion only applies in the context of this study of buildings in New Delhi which lies in the Northern Hemisphere and is dominated by a high cooling load and a small heating load for specific office buildings.

In another research conducted in Delhi, the process recommended 270° Orientation (major axis in East-West direction), AAC block wall construction, Double glazed window (U = 3.094 W/m2K), 30% WWR and 0.45 SHGC for the optimal solution (Krishnan et al., n.d.). Windows also provide daylight which is essential for psychological comfort. The desired illumination level is also specified by the National Building Code of India (NBC 2016) and the Bureau of Indian Standards (BIS) for different occupancies which is listed below. (Table 1)

Table 2: Desired illumination level for various spaces

Source: National Building Code of India, (NBC) 2016

Location	Desired Lux	% (Day Light Factor)
Kitchen	200	2.00
Living Room	50	0.50
Study/ Drawing Room	152	1.52
Circulation	25	0.25

The Bureau of Indian Standards (BIS) has adopted a clear design sky for daylighting corresponding to 15° solar altitude and the design illumination has been considered as 8000 lux. It is recommended for calculating of the sky component for the entire country of India. Environmental psychologists have claimed that the green environment are remedy for several mental illnesses. There are several cognitive benefits of 'Nature exposure', but psychological results are still in the preliminary stages of research (Veitch & Galasiu, 2011). Urban dwellers residing in high-rise apartments improve their well-being if the view of green space from their dwelling unit is facilitated (Elsadek et al., 2020). In urban areas, more people work indoors, as compared to outdoor activities and individuals experience adverse implications if the time spent in the natural environment is reduced (Kaplan, 1995). An outside view from a window or a balcony to natural green spaces improves the productivity and wellness of the occupant.

5.3 Roof

Vernacular housing mostly has pitched roofs made of natural materials. They are often adorned with creepers covering the whole roof providing vegetables like pumpkin, gourd, etc(Srivastava & Das, 2023).

Coming to the thermal performance of the roof, the top floor of the modern building is the most vulnerable part of the building system exposed to severe solar radiation in summer. Cool paints with high thermal reflectance (0.3-0.8) can negate the ill effects of roof heating thereby protecting the occupants living in a non-AC building and reducing the electrical load in an AC building (Nihar et al., 2017). Today various coatings are available with a thermal reflectance of 0.9, which will keep the thermal transmission at bay. An insulated black roof with low wind velocity and solar radiation of (1000W/m^2), can increase the roof surface temperature by an additional 50° C as compared to the ambient air temperature. Changing of roof albedo from 0.18 to 0.73 resulted in a reduction of 2.2 kWh/day of a residence in Sacramento, California, USA (Akbari et al., 1997). Another study in Hongkong showed that a 30% reduction in solar absorptance results in a reduction of 12% in cooling energy (Cheung et al., 2005)

A green roof is another novel way to resist the menace of excessive heating of the roof. Roof gardening is gaining importance in private dwelling units but in community housing it is difficult to maintain because the right to roof usage is shared by all the residents. A few planter boxes are the only visible sign of roof greenery in public apartment MIG housing. Extensive vegetable cultivation has been done by some of the occupants in the planter boxes which reminds of a vernacular system with vegetable gardens attached to dwelling units.

5.4 Balcony

Balcony: Balcony or *jharokha* in Rajasthan, India is an important element of building that gives an elegant look to the elevation of the house. Several studies have revealed that a balcony is the most desired feature in multifamily apartment living imparting huge satisfaction for the dwellers (Kotulla et al., 2019). It contributes to the happiness and satisfaction level of the occupants in the cities. The liveability index of dwelling units increases which further increases at the city level. During the global confinement (lockdown) it was felt that there is a need for semi-open spaces within the dwelling units that could ease the psychological barrier of household confinement. Throughout history, balconies have been recognized as the 'buffer space' negotiating between the indoor and outdoor environment. Requena-Ruiz (2012) argues that balconies have a high capacity for social and spatial transformation, enhancing the image of buildings, upgrading indoor comfort conditions, and creating additional living space. Balcony overhangs provide shade to the building and stop the sun radiation from touching the walls of buildings. It protects the ultraviolet rays reaching the interior spaces reducing uncomfortable glare (Kim & Kim, 2010; Xue et al., 2015).

In tropical conditions when the weather is dry, the problem of Suspended Particulate Matter (SPM) has made the air highly polluted leading to respiratory diseases among children and older people. Green Balconies are the lungs of apartment-type group housing. They are interlinking between the interior space and the open outdoor environment. The vagaries of the outdoor environment are filtered in the form of dust, unwanted heat, dry air, and noise and provide a soothing green environment not only a 'visual delight' but a positive environmental value. Green balconies help in mitigating climate change, adversaries of UHI, and the psychological effect of a natural indoor plant on mental health.

Three types of balconies are discussed here. Open balcony which is most common in Southeast Asia in MIG housing units. Some households have transformed their balconies into glazed balconies by putting glass and openable or sliding windows. A few of them have eliminated the balcony and made the balcony area part of the room increasing the area of the room. In Tropics open balconies act as multi-utility spaces; a clothes drying yard in the daytime, and a family gossip space in the evening.

5.5 Ventilators

In modern construction, people are abstaining from providing ventilators in houses in urban areas. All the ventilation is through windows. Even toilets and kitchens are deprived of ventilators as was in practice some decades ago. In framed constructions, beams lay under the roof, and if ventilation is provided will be under the beam. So, the practice of providing ventilators is obsolete in urban areas. Very few households are opting for it in modern construction. Ventilation to the kitchen is either through the window or through mechanical means (exhaust or kitchen chimney). Toilet ventilation is through a window or exhaust fan. Windows also provide daylight which is essential for psychological comfort.

6. Conclusions

Although the temperature change is less than a degree Celsius from a wider perspective of climate change, the accumulated savings on energy usage will be significant. This can be minimized by mitigating the adversaries by efficient design of the built environment. Thicker walls with higher thermal resistivity will reduce the cooling load. Windows and balconies having overhangs, as they used to be in traditional housing need to be incorporated in modern buildings to stop the thermal radiation from directly entering the interiors. Green walls, living walls, green roofs, solar radiation-reflecting paints, and green balconies will have a cumulative effect in reducing the energy consumption of the building. Greenery in site planning and the introduction of Green- Blue Infrastructure at the Urban Planning level will help reduce the Urban Heat Island effect. Compact planning is another solution derived from traditional settlements in tropical regions to utilize the shading effect of one building to another. The HVAC system will work efficiently on Traditional houses that are climate-conscious design. Best practices in Vernacular and Traditional houses be implemented for energy efficiency. The energy load will be less, and the building will be green and sustainable.

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