Measurement Of Urban Heat Island Intensity In the Megacity Of Bangalore

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ABSTRACT

The present paper enquires the changing trends in the urban climates. Urban climates are considerably different from the climates of the countryside, particularly in terms of the sensible heat. Cities are recognized as urban heat islands because their temperatures are higher from 2°C to 10°C in comparison to the temperatures of the surrounding rural areas. This thermal differential is generally proportional to the city size and morphology. Larger is the city size and more diverse are its residential, industrial and commercial functions, larger and higher is its heat dome. A city has a single heat dome but megacities may have multiple heat domes corresponding to residential, industrial and commercial districts of the megacity. Cities are the built-up surface of concrete, asphalt, steel and glass. Hence, there is considerably great thermal conductivity in the cities which makes an alarming heat island problem.

Urban Heat Island is not a cognizable problem of towns and small cities. It is a matter of great concern to the urban planners, environmentalists and citizens of the large cities, particularly the million and megacities. The problem of urban heat island is most threatening in the megacities. Indian urban climate is changing under the influence of rapid urban sprawl. India's urban population has a distinct characteristic of a growing concentration in the metro and megacities. The problem of urban heat island is already critical in the megacities like Mumbai, Delhi, Kolkata and Chennai. However, this problem is assuming a serious dimension in another emerging megacity of Bangalore.

The present paper estimates the heat island intensity of Bangalore which until recently had a very amiable and pleasant climate. The moderate, salubrious climate of Bangalore is heading towards summer extremity in the wake of its rapidly growing economy, size and population. The city has experienced a population growth from 1.6 million in 1971 to 8.5 million in 2011. The corresponding built-up area growth is from 175 sq.km. to a sprawling 700 sq.km. The paper enquires the adverse impact of this built-up growth on the daytime as well as nocturnal temperature rise. This has rendered the urban climate increasingly taxing to the teeming millions and their labour efficiency.

Keywords: Urban Heat Island, Urban Climate, Built-up Surface, Nocturnal Heat, Megacities.

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Introduction

An appraisal and evaluation of the urban micro climate and changes therein are becoming increasingly important for sustainable urban growth plans and habitat safeguard strategies. Urban heat island formation coupled with global warming trends is a very dangerous phenomenon in view of the fact that the majority of the population (75-80 per cent) in the developed countries is urban. But a unique phenomenon of rapid urbanization in the developing countries is that most of the urban population has an uncontrolled tendency to concentrate in the large cities. Urban Heat Island is a heat differential between the city and the suburbs. Urban heat islands are global warming nuclei. Ever since the industrial-commercial revolution in India the urban climates are under a growing human interference. Megacity-centric globalization has triggered a massive rural-urban migration. Hence, the urban population growth has considerably exceeded the rural population growth. Growing urban built-up area, rapidly increasing population, vehicular combustion growth, diversifying urban functions and rapid commercialization in the capital megacity of Bangalore have induced the greenhouse effect to trigger the climate change and builtup of urban heat dome (Fig. 1).

Schematic of Standard Tropical Urban Heat Island

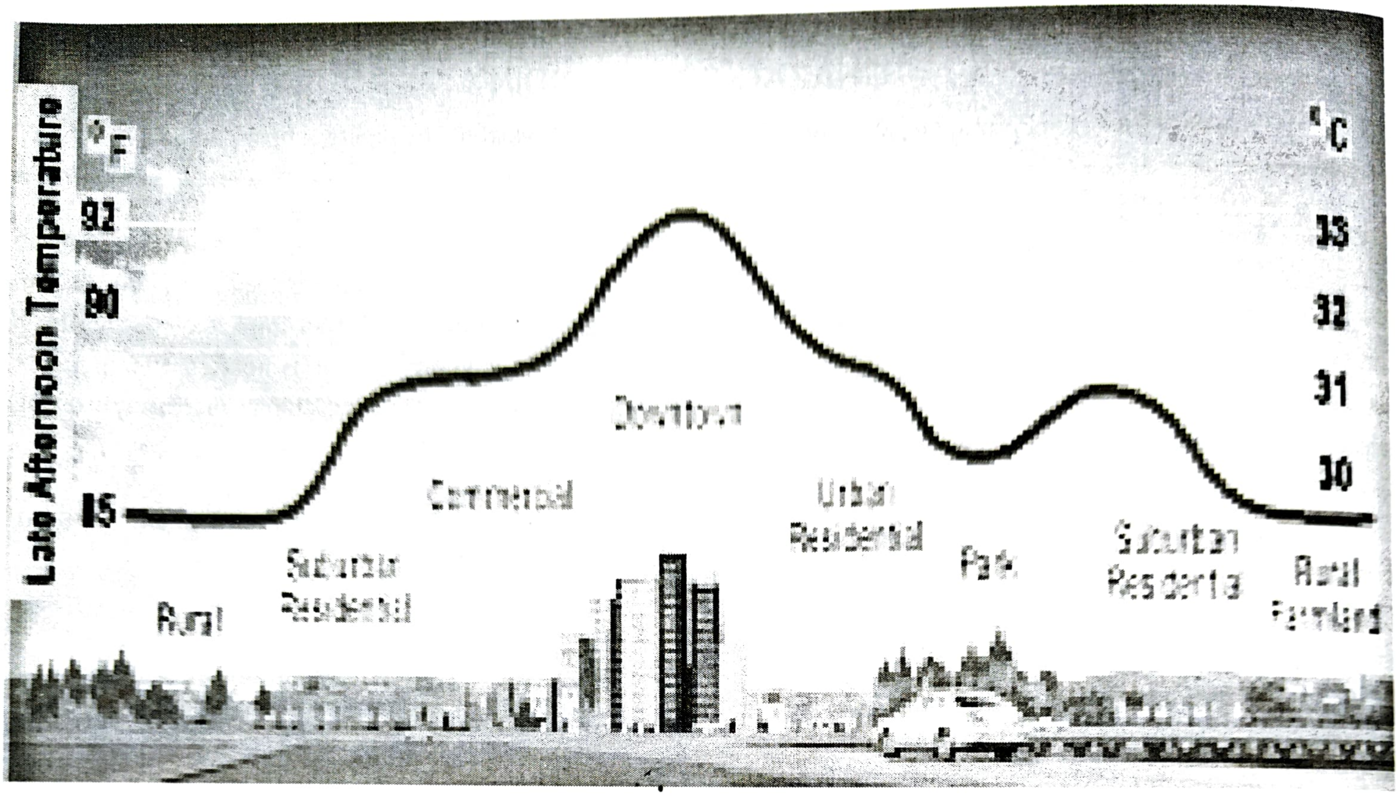


Fig. 1

Several causes of an urban heat island have been diagnosed. Rapid urbanization aimed at attaining the high standard of material living and increased infrastructural amenities have brought in considerable changes in the urban climate. Inside a large city, the high temperature heat dome is significantly developed at night- time under stable atmospheric conditions. Nocturnal heat is more pronounced because of stronger long wave radiation from the high density and three dimensional steel, glass and concrete surfaces. It is also because of long wave absorption by dust, water vapor and CO_2. City built-up surfaces are highly retentive in releasing of heat energy than the bio-surfaces of the surroundings. Urban Surface Heating increases the air mass instability during the summer afternoons and evenings. Heat island is strongly formed under calm conditions.

Database and Research Methodology

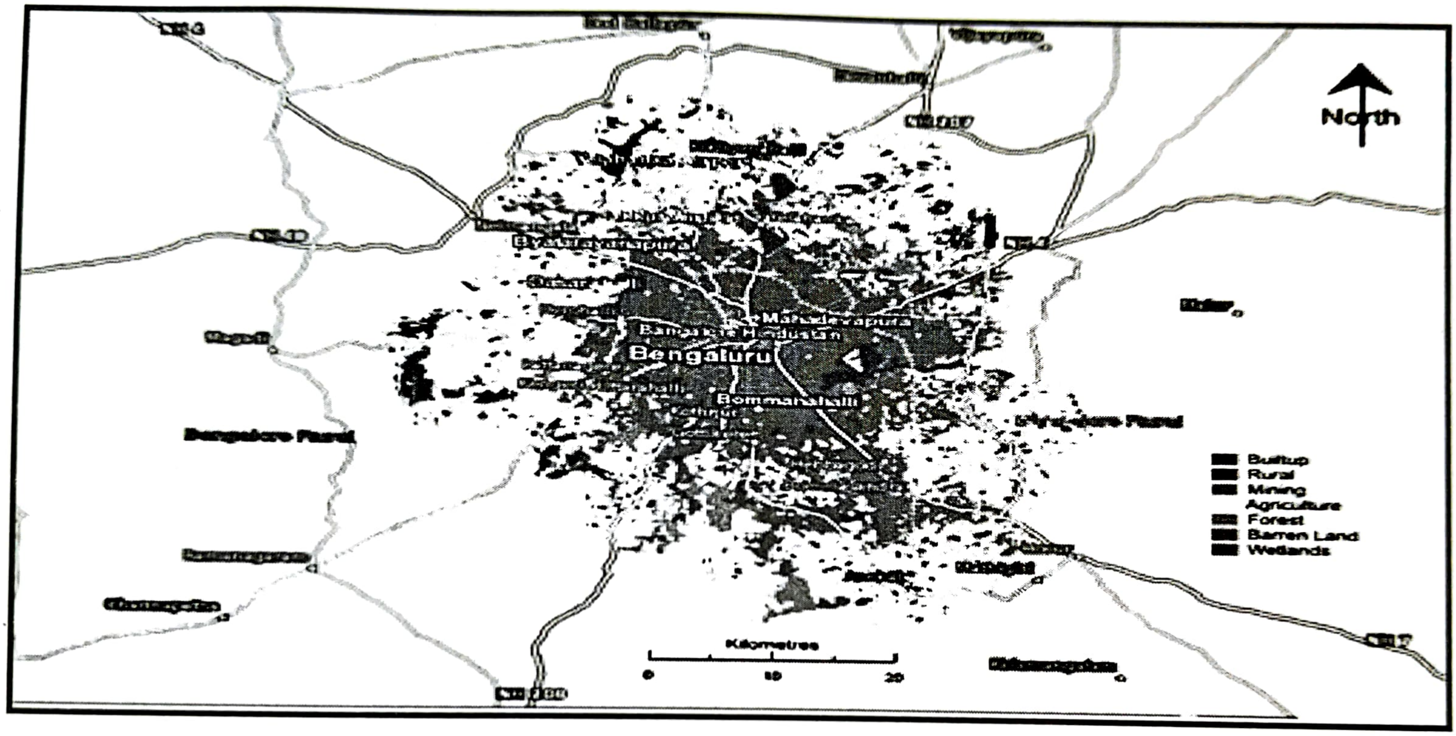
The author in the present study has adopted a different methodological approach in comparison to tangential remote sensing data on the urban heat island of megacities. Almost all the existing studies on the environmental issues of global warming, climate change and urban heat island are based largely on the trends in the temperature change. The present author has measured the urban heat island for the thermal regime. This is a new approach to contribute to the scientific literature. The entire literature on urban heat island is largely based on the nocturnal thermal emissivity from the built-up urban surface by satellite remote sensing methods. But a great limitation of the thermal remote sensing device is that it depicts the urban heat distribution and dome of only one random night or two.

Rao 1972 enquired the urban heat islands with environmental satellite data. Atwater 1975 examined the thermal changes induced by urbanization and pollutants. Ackerman 1985 assessed the temporal march of Chicago Heat Island. Karl 1992 attributed the urban nocturnal heat to the greenhouse effect. Kim 1992 identified the Washington D.C. urban heating as a function of high rise buildings and asphalt surfaces. He noted that the symptoms of diurnal heating begin to appear by mid-morning and the city can be considerably warmer than the woods in the neighbourhood. Qureshi and Khan 1994 estimated the climatic transition of Riyadh city in global warming perspectives with the meteorological data. Chow and Roth 2006 revealed the temporal dynamics of urban heat island in Singapore. Mallick et.al. 2013 examined the Urban Heat Island of Delhi on the basis of nocturnal thermal emissivity for the years 2001 and 2005. It scarcely reveals any long term and persistent trend of urban heat island.

However, in the present study of Bangalore Megacity the urban heat island characteristic through important climatic variables has been examined on the Cumulative Daily Observation of Meteorological Data twice a day for over a period of 51 years from 1961-2012. The monthly data was put to linear regression analysis to measure the monthly urban heat island intensity. Hence, the variable mean monthly average temperature change is based on the mean monthly maximum temperature (daytime) and the mean monthly minimum temperature (night time). The monthly average temperature trend is based on the analysis of a long period of data. Similarly, the average annual temperature trend is based on the cumulative analysis of meteorological data for a still longer period of time.

Geographical Profile of Bangalore City

Bangalore city is located well within the tropics at 12°58'North latitude and 77°34' East longitude. It has a vast geographical extent of 699.67 sq.km. (Fig 2).



Source: Adapted from Bhuvan Geoportal **Fig. 2**

The city is located at an altitude of 921 meters (3,130 feet) over the Karnataka Plateau. Because of the relatively high altitude its atmosphere has a lesser density. The city has shown a massive areal growth from 174.71 sq. km in 1971 to 699.67 sq. km in 2011 (Table - 1).

Table - 1

Bangalore City : Area , Population and Density Growth (1971 – 2011)

Census	Geographical Area (sq.km.)	Total Population	Population Density (persons/sq.km.)
1971	174.71	1,654,000	9,465.85
1981	365.65	2,922,000	7,990.57
1991	413.03	4,130,000	9,999.97
2001	492.55	5,701,000	11,545.72
2011	699.67	8,499,399	12,147.63

Source: Computed from Census data.

The corresponding geographical area growth was 109.3 per cent during 1971-1981 to 42 per cent during 2001-2011. Bangalore has experienced a rapid population growth from 1.6 million in 1971 to 8.5 million in 2011. The city has experienced the highest decadal population growth of 76.66 per cent during 1971-81 and 49 per cent decadal growth during 2001-2011. Bangalore has one of the fastest growing vehicular traffic. The city by 2013 registered nearly 5 million automobiles. The vehicular growth rate is faster than the population growth rate. The enormous fuel combustion by the vehicles tremendously adds to the gaseous pollution and green house effect.

Changing Thermal Regime

(A) Mean Monthly Maximum Temperature

Mean monthly maximum temperature has been analyzed to depict the daytime urban heat island trend over the period 1961-2012. The seasonal pattern of heat growth showed the highest average of 1.904°C for the winter season from December to February. Within this trend the highest monthly heat transition of 2.193°C was recorded for January followed by December (Fig.3). A higher January warming than December could be assigned to the fact that the average daytime temperature of January 27.644°C is higher than the December temperature of 26.379°C. This could also be related to the ascending sun. The mean monthly summer heat island has been measured for an extended 7 months summer season from April to October.

Bangalore City: Transmission of Mean Monthly Maximum Temperature (1961 - 2012)

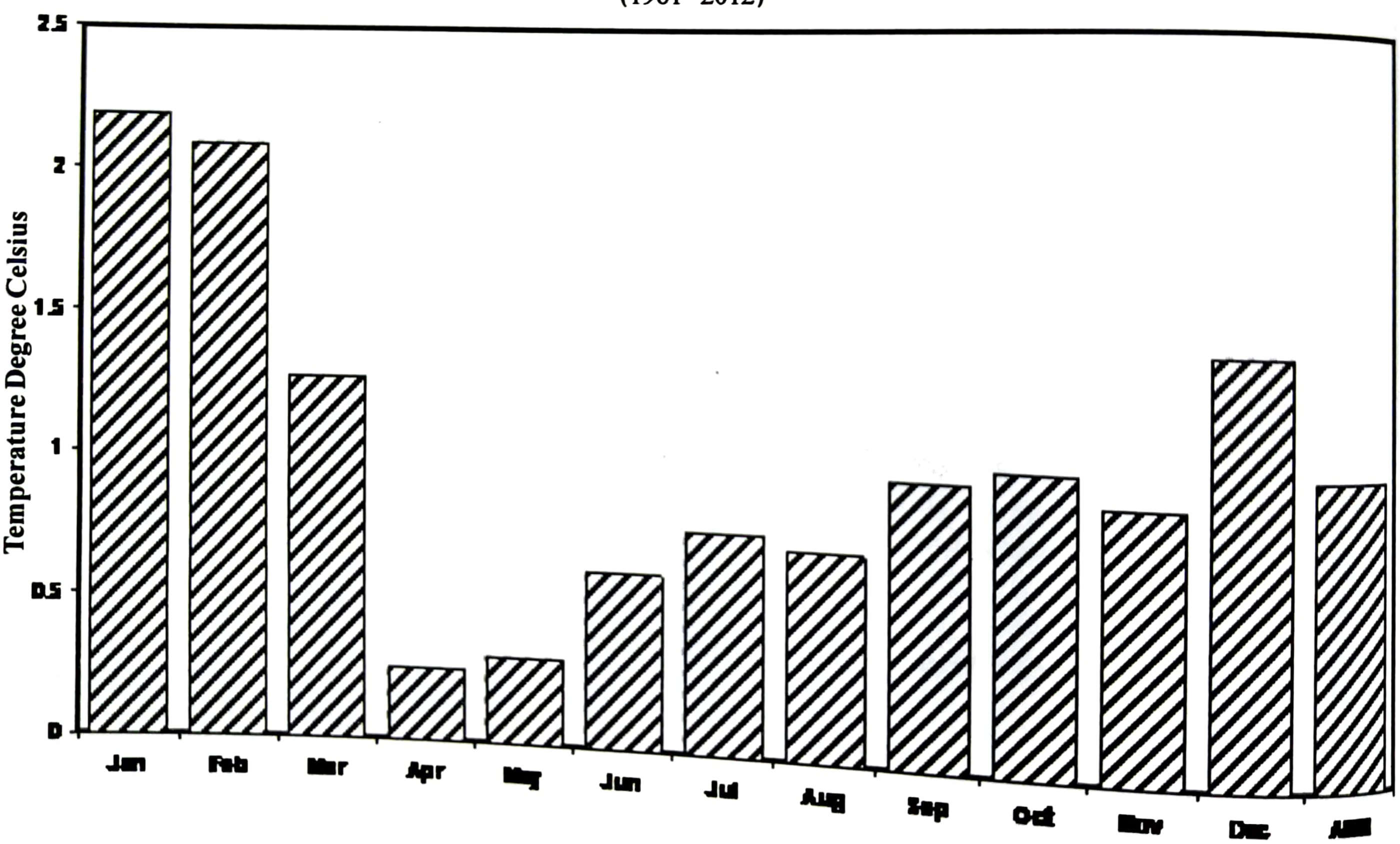


Fig. 3

Source: Computed from Meteorological data obtained from IMD, Pune.

The summer season heat transition over a period of 51 years has been 0.663°C. Although the summer heating is considerably lower (nearly one-third) than the winter season heating yet it has significant adverse effect upon the people's comfort level in the already warmer summer on this city on the Karnataka plateau. The mean maximum annual temperature growth has been witnessed as 1.020°C.

(B) Mean Monthly Minimum Temperature

Mean monthly minimum temperature has been analysed to depict the night-time heat island over the period 1961-2012. The seasonal pattern of heat growth showed again the highest average of 1.343°C for the winter season from December to February. Within the winter heat transition, the maximum heat growth of 1.683°C was recorded again in the month of January. Hence, January has shown the highest heat growth both during the day-time as well as night-time heat transition (Fig. 4). The mean monthly summer heat island has been measured for an extended 7 months summer season from April to October.

The summer season nocturnal heat transition over a period of 51 years has been 0.910°C. This night-time heat growth has been considerably greater than the corresponding day-time heat growth of 0.663°C.

Bangalore City: Transmission of Mean Monthly Minimum Temperature (1961 - 2012)

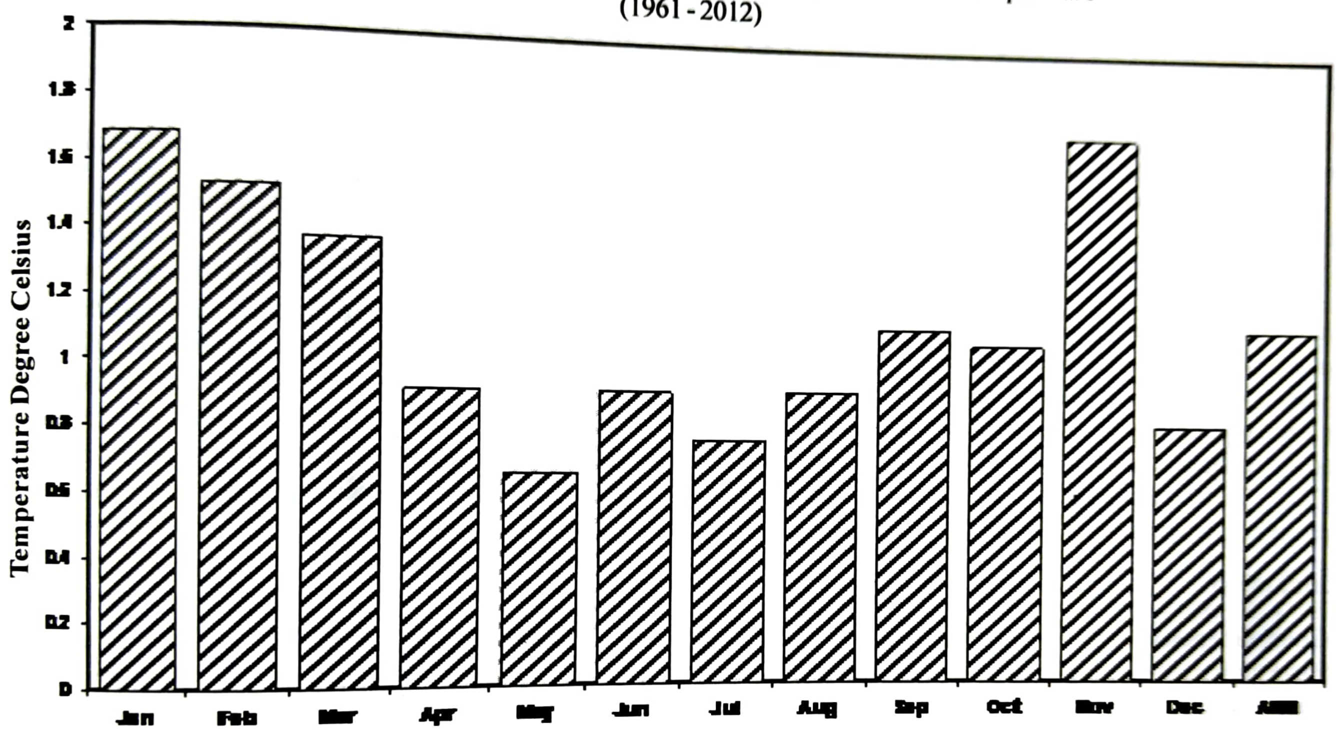


Fig. 4

Source: Computed from Meteorological data obtained from IMD, Pune.

Although the summer season night-time heat growth is lower than the winter season night-time heat growth, still the summer nocturnal heat growth of 0.910°C has made nights all the more unbearable than the pre-heat island period. The comfort levels of the people have considerably been eroded. Under the growing heat in the tropical megacities the compensatory cooling energy consumption is also continuously increasing. The total energy cost is rising. The growing energy consumption is further aggravating the heat island intensity.

(C) Mean Monthly Average Temperature

Mean monthly average temperature change represents a moderated sum of the mean monthly maximum and the mean monthly minimum temperature changes. The average monthly summer season heat island growth tends to be characteristically smaller than the summer nocturnal heat growth but is greater than summer day time heat growth. The average monthly winter season heat island growth, however is greater than the winter nocturnal heat growth, but is smaller than winter season day time heat island effect.

Bangalore City: Transmission of Mean Monthly Average Temperature
(1961 - 2012)

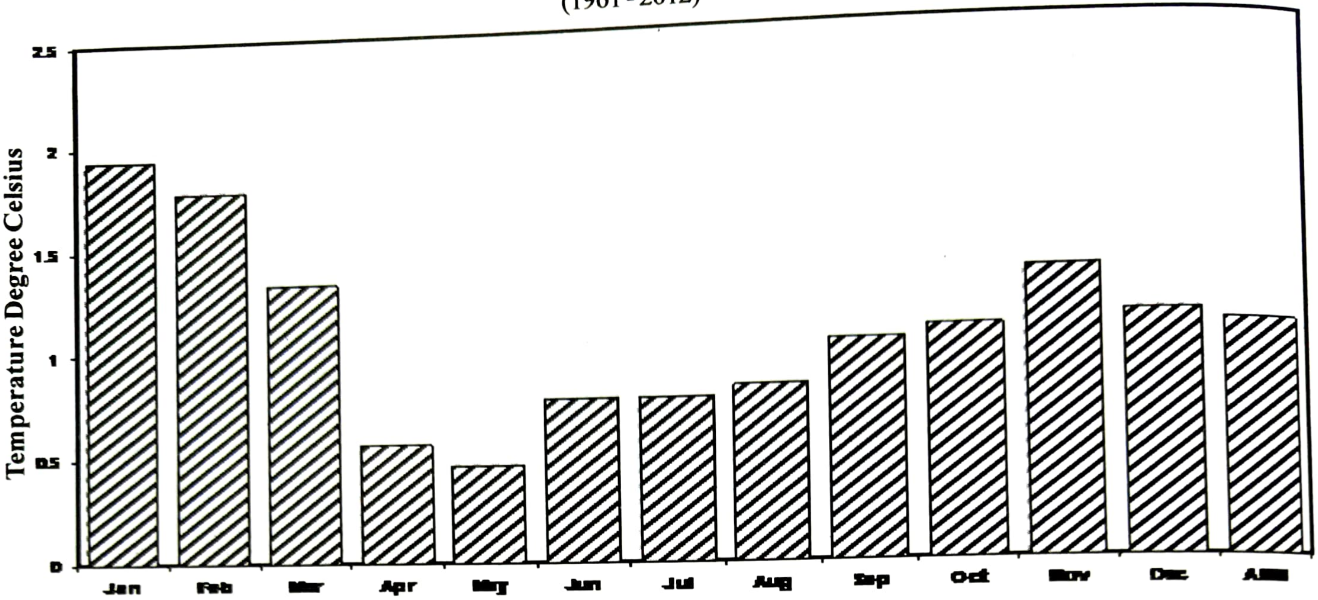


Fig. 5

Source: Computed from Meteorological data obtained from IMD, Pune.

Average monthly winter season urban heat island growth is 1.598°C (Fig. 5). The average monthly summer season heat island growth for the longer summer season of atleast 7 months from April to October has been recorded 0.779 °C. As against this, the average annual heat island growth is 1.071°C. It shows that the average winter season growth of 1.470°C for the day plus night is greater than the average annual heat island growth. On the other hand, the average summer season heat island growth of 0.844°C for the day plus night is smaller than the average annual heat island growth of 1.071°C. The highest monthly average heat island growth of 1.938°C was recorded in January while the lowest monthly average heat island growth of 0.459°C was noticed in the summer month of May.

Conclusion

The phenomenon of growing urban heat island is well founded in the tropical megacity of Bangalore. The findings tend to validate the trends of climatic transition. The thermal parameters such as mean monthly maximum, mean monthly minimum and average monthly temperatures have shown a rising heat island dome. It is alarming to note that the summer nocturnal temperature increase is considerably higher than the summer day-time temperature. The nocturnal heat island would considerably jeopardize the comfort levels in the megacity environments. A unidirectional transition in all the three temperature parameters confirms the growing heat island effect. These trends are in sound conformity with the heat island findings of most cities in the temperate as well as tropical world.

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