ABSTRACT

The present research work is an attempt to estimate the growth of urban heat island intensity in India’s three megacities of Ahmedabad, Hyderabad and Bangalore. It is a study on the climatic transition in the major cities of peninsular India. These megacities have a population ranging from about 6.35 million in Ahmedabad, 7.74 million in Hyderabad to more than 8.53 million inhabitants in Bangalore. The areal expanse of these megacities ranges from 466 sq.km. in Ahmedabad, 851 sq.km. in Hyderabad to 702 sq.km. in Bangalore. As per the Census of India, 2011 the average population density in these three megacities ranges from 13,631 persons per sq.km. in Ahmedabad, 9,106 persons per sq.km. in Hyderabad to 12,142 persons per sq.km. in Bangalore. These megacities have a high built-up density. As a result of extensive built-up area, enormous population and diverse city functions, the urban microclimate of these megacities is considerably different from the surrounding countryside. Cities are recognized as urban heat islands because their temperatures are higher from 2°C to 10°C in comparison to the temperature of surrounding rural areas. This thermal differential is generally proportional to city-size, morphology and function. Larger is the city size, more diverse are its residential, industrial and commercial functions, resultantly, larger and higher is its heat dome. Cities are the built-up surface of concrete, asphalt, steel and glass. Hence, there is considerably large 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. In fact, it is a matter of great concern to the urban planners, environmentalists, administrators and the citizens of 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 the developing as well as the developed countries of the world.

Urban heat island is a major environmental issue in view of rapid urban growth. Urban heat islands are the nuclei of global warming and climate change. The urban heat islands develop over cities as a result of anthropogenic activity, diverse
surface cover and it also represents the quality of climate over a city. Apart from that, the study of urban heat island helps to understand the air quality, energy use, water use efficiency and the level of human comfort. In cities, buildings and paved surfaces replace the existing green cover causing absorption of solar energy by roads and rooftops, resulting in an increase in the surface temperatures of the urban structures.

The present research work has employed the climatic data obtained from India Meteorological Department, Pune for a period from 1961 to 2011 for Ahmedabad and the nearby town of Dahegam. Similarly, the data for Hyderabad and its nearby town of Bibinagar were employed. The meteorological data of Bangalore were employed alongwith the data of Malur town up to an extended period of 2012. Mean Monthly and Annual climatic data in terms of thermal regime, rainfall distribution, relative humidity, wind velocity, calm conditions and evaporation conditions have been acquired, arranged, classified and analyzed to examine the climatic changes therein. Simple linear regression technique has been performed on all the climatic variables except rainfall, which owing to its periodic irregularity and great uncertainty has been analyzed through five-yearly moving averages. Karl Pearson’s Product Moment Coefficient of Correlation has also been conducted to establish the relationships between the variables. Statistical diagrams including bar diagrams and line diagrams have been used. Besides this, ArcView version 3.2 GIS Software and Google Earth imageries have also been used for the representation of maps. The entire thesis on the urban heat island intensity in the three megacities has been structured into ten chapters with as many as seven data based analytical chapters.

Chapter I on ‘Conceptual Framework’ introduces the various concepts of urban heat islands and their relationship with global warming as well as their implications on the urban microclimate. Urban microclimates are complex because of the number and diversity of factors which come into play. Solar radiation, temperature and wind conditions can vary significantly according to topography and local surroundings. The problems and issues of how the heat islands act as global warming nuclei and in what way do they trigger climate change have been dealt with. Urbanization involves concentration of population, loss of natural surface, expansion of living space above and below the ground which alter the balance of radiation, heat and water, generating a climate typical of urban areas as contributed by S. Yamashita (2003). Barry and Chorley (1976) brings out that for the period 1931-1960, the centre
of London had a mean annual temperature of 11°C comparing with 10.3°C for the
suburbs and 9.6°C for the surrounding countryside. It is especially in evidence on
calm nights during summer and early autumn when it has steep cliff-like margins and
the highest temperatures associated with the highest density of urban dwellings. The
thermal contrasts of a city depend on its topographic situation and are greatest for
sheltered sites with light winds.

In **chapter II on ‘Literature Survey and Review’**, the researcher through the
exhaustive and inspiring literature survey has tried to draw inferences from the
definition and concept of megacity, population growth rate, area growth rate, the
density differential in the megacities of the world and the meteorological indicators of
urban heat island. The world’s largest cities, particularly in the developing countries,
are growing at a phenomenal rate. As the growing size of landless rural inhabitants is
attracted by urban opportunities, the population of large cities is ballooning to an
incredible number. Report of the Population Division of United Nations Department
of Economic and Social Affairs’ noted that in 1990, there were ten “megacities” with
10 million inhabitants or more. These were the home to 153 million people
accounting a nearly 7 per cent of the global urban population. Now in 2014, there are
28 megacities worldwide. These are home to 453 million people or about 12 per cent
of the world’s urban dwellers. Out of today’s 28 megacities, 16 of them are located in
Asia, 4 in Latin America, 3 each in Africa and Europe, and 2 in Northern America. It
is appreciable to note that Europe with highest percentage of urban population has
only 3 megacities. It speaks of the most equilibrated urbanization in Europe. By 2030,
the world is projected to have 41 mega-cities with 10 million inhabitants or more.

Tokyo remains the world’s largest city with 38 million inhabitants. The other
megacities like Mexico, Mumbai, Delhi, Kolkata, Karachi, Dhaka, Shanghai,
Djakarta, São Paulo, Osaka, Beijing, New York, Cairo, London and Paris are some of
them to make mention of. The social, economic and environmental problems
associated with a predominantly urbanized population are considerably different from
those of the mostly rural world population of the past.

Urbanization is arguably the most dramatic form of highly irreversible land
transformation. While urbanization is a worldwide phenomenon, it is exceptionally
dynamic in India, where unprecedented urban growth rates have occurred over the last
30 years. In this uncontrolled explosive situation, city planning lacks of data and information to measure, monitor and understand urban sprawl processes. Intra-city migration from smaller to bigger cities is continuing along with the migration from rural to urban areas besides an enormous natural population pressure. This explosive urbanization resulting in unplanned and uncontrolled growth of large cities has had dramatic negative effects on urban dweller and their environment. Cities are facing serious shortage of power, water, sewerage, developed land, housing, transportation, and communication mixed with dramatic pollution, poor public health or educational standards, unemployment and poverty. Thus, understanding and monitoring past and current urbanization processes is the basis for future predictions and preparedness, and thus for sustainable urban planning.

Chapter III on ‘Geography of Study Area and City Morphology’ provides an insight on the climatic characteristics; population size, growth and density; built-up density, land use differential and intensity of the three megacities under study. Geographically, the megacities of Ahmedabad, Hyderabad and Bangalore are the industrial, commercial and political capitals of Gujarat, newly formed Telangana and Karnataka states. Ahmedabad has a tropical monsoon climate, which is hot and dry, except in the rainy season. Hyderabad has a tropical wet and dry climate. Bangalore experiences distinct wet and dry seasons. Due to its high elevation, Bangalore usually enjoys a more moderate climate throughout the year, although occasional heat waves can make things very uncomfortable in the summer. Two of the three megacities namely Hyderabad and Bangalore are primate cities in their respective states. As a result of it, the two are burgeoning in population and area. Demographically, Ahmedabad has grown from 1.15 million in 1961 to 6.35 million in 2011. Correspondingly, Hyderabad grew from 1.12 million to 7.74 million and Bangalore from 1.20 million to 8.53 million people. The areal extent of Ahmedabad grew from 63.1 sq.km. in 1961 to 466 sq.km. in 2011, Hyderabad from 178.3 sq.km. in 1961 to 851 sq.km. in 2011 and Bangalore from 112 sq.km. in 1961 to 703 sq.km. in 2011. Seasonally, Ahmedabad has the shortest 8 months but hottest summer from March to October. Hyderabad and Bangalore have nine months summer. In comparison to temperate cities the problem of urban heat island is more pronounced in the tropical cities, because the inherent and ambient temperatures are already high in the tropical cities. Ahmedabad exclusively lies under the influence of Arabian Sea branch of
Monsoon while Hyderabad and Bangalore largely lie under the influence of Bay of Bengal branch of Monsoon. Ahmedabad has the shortest rainy season while Bangalore has the longest rainy season with modest monthly rainfall. Bangalore lies on the Karnataka plateau while Ahmedabad and Hyderabad are located in the river valleys.

The Ahmedabad Urban Development Authority (AUDA) is responsible for land use planning. Out of the total AUDA area of 1,294.65 sq.km. nearly 50 per cent comprises the built-up area. Water bodies and wastelands cover 12 per cent and 17 per cent of the area respectively. Industries cover 9 per cent of the area. According to the Draft Master Plan 2020 Hyderabad Urban Development Authority (HUDA), the residential area constitutes 44 per cent followed by 12 per cent under open ground and agriculture. The mixed use is around 6.2 per cent. According to data contained in the Bangalore Mahanagara Palike Master Plan, 40.4 per cent of the land in the city is used for residential purposes. Transport uses 24.3 per cent of the land, while land used for industrial, and commercial purposes comprise 6.9 per cent and 2.7 per cent respectively. As the city of Bangalore expands, the BMP expects the percentage of land used for industrial purposes to decrease, while it expects the percentages of land used for residential, commercial and public and semi-public purposes to increase.

The city morphology of Ahmedabad is highly contiguous in response to leveled alluvial terrain in the Sabarmati valley. Although the old city in the eastern part is highly congested and the modern, western part is considerably spacious, even then the built-up density is higher in the modern city because of the greater vertical or three-dimensional city growth. Hyderabad on the other hand is perched on the rocky outcrops, its areal growth has remained sporadic. In the modern, northern part of Hyderabad also there is a spacious built-up growth with higher three-dimensional built-up density. In the megacity of Bangalore, most of the modern built-up expansion is in the southeastern part. The Silicon Valley area of software industries has a larger expanse with relatively smaller built-up density. The C.B.D. in the eastern part of the city has a comparatively higher built-up density.

Chapter IV on ‘Megacities and Transition in Thermal Regime’ evaluates the global analysis of urban heat island as well as the mean monthly and seasonal thermal changes in Ahmedabad, Hyderabad and Bangalore. It also compares the mean
monthly temperature differential between the megacity of Ahmedabad and its small peripheral town of Dahegam. Similarly, the mean monthly temperature differentials have been depicted between the megacity of Hyderabad and its small peripheral town of Bibinagar. Likewise, the thermal differential between the megacity of Bangalore and its peripheral town of Malur has also been examined. The concept of urban heat island is largely confined to the occurrence of higher temperatures over the built-up urban surfaces in comparison to the relatively lower temperatures in the surrounding countryside or the rural landscape. Most of the literature on this issue highlights the rural-urban temperature differential as an urban heat island phenomenon. The present researcher, in this thesis, has tried to identify and project the phenomenon of urban heat island much more than a mere thermal concern.

In the megacity of Ahmedabad, the average annual nighttime heat island intensity has grown more than twice the daytime warming of Ahmedabad city. The average annual warming is also more than the daytime warming of the city. In the megacity of Hyderabad, the average annual daytime heat dome rise has been of lower value. It is evident that the nighttime urban heat has increased more than the average daytime temperature rise. In the megacity of Bangalore, the average annual daytime heat dome rise has also been smaller. This reveals that the annual nighttime urban heat island has grown more than the average daytime urban temperature rise.

Chapter V on ‘Rainfall Transition in the Megacities’ establishes the global evidence of city rains and the changing monsoon behavior in the megacities. An elaboration on the mean annual and monthly rainfall transition in Ahmedabad, Hyderabad and Bangalore has been drawn to find its affinity with the urban heat island. There is considerable evidence on the relationship between the urban heat island and the resultant changing pattern of rainfall in different urban habitats.

Monsoon is globally the most powerful rain-bearing phenomenon. The monsoon behavior, however, gets fairly moderated in the extensive urban environments. Large cities considerably affect the amount and occurrence of rainfall in their ambit. Relatively higher temperatures induce the thermal convection. Increased concentration of aerosols and condensation nuclei improve the dwell period of clouds and the resultant rains. Indian Monsoon has a duration of 120 days from June to September. However, there are recent evidences of behavioral changes in the
monsoon. There is a new trend of delayed onset of monsoon in the interior of the sub-continent.

The monsoon behavior in the three megacities of Ahmedabad, Hyderabad and Bangalore has a variable character. Ahmedabad experiences a strictly defined rainy season with a comparatively lowest number of rainy days from the southwestern monsoon of the Arabian Sea. Hyderabad further south in the peninsula has higher number of rainy days than Ahmedabad. Rains in Hyderabad are the result of the Bay of Bengal Branch of Monsoon. Bangalore is the southern-most megacity of peninsular India. As Bangalore is located on the dissected plateau of Karnataka, it is oriented to both the advancing and retreating monsoons of Bay of Bengal. Bangalore experiences double maxima of rains from the monsoon.

Mean annual and monthly frequency and transition of rainfall in Ahmedabad has been probed for the period 1961-2007. The mean annual rainfall occurrence is 792 mm in this city. Ahmedabad experiences the shortest rainy season which is sharply confined to four months from June to September. As the annual rainfall distribution has high variability, a linear regression analysis was not performed to monitor any reliable changing trend in its occurrence. Large rainfall variability shows more number of years with below normal rainfall and less number of years with above normal rainfall. In view of this situation, it would be significant to examine whether the amount of rainfall and the number of rainy days have increased or decreased in Ahmedabad. It would depict crucial changes in rainfall pattern. The lowest annual rainfall was recorded 284 mm in 1968 while the highest rainfall was experienced as 1306 mm in 1997. The absolute range between the lowest and the highest rainfall depicted 4.6 times variation. Five-yearly moving averages were taken to ascertain the pattern of rainfall homogeneity and regularity. A compact monsoon season of 4 months in Ahmedabad experienced 752.84 mm or 95 per cent of the mean annual rainfall. The moving averages identified the lowest homogeneity in the annual rainfall pattern.

Mean annual and monthly frequency and transition of rainfall in Hyderabad has been probed for the period 1961-2010 due to regular and longer period data availability. The mean annual rainfall occurrence is 832 mm in this city. Hyderabad experiences slightly longer period of rainfall with five monsoon months from June to
October. The monsoon rains of five months, record only 85 per cent of the mean annual rainfall in Hyderabad. Large rainfall variability depicts less number of years with above normal rainfall and more number of years with below normal rainfall. Under this situation, it is significant to examine whether the amount of rainfall and the number of rainy days have increased or decreased in Hyderabad. In either case, it would depict crucial changes in rainfall pattern. The highest annual rainfall was recorded 1383 mm in 1975 while the lowest annual rainfall was recorded 373 mm in 1985. In fact, June and July in 1975 remained below normal rainfall months. Even August recorded a slightly above normal rainfall. It was because of the strongest retreating monsoon which recorded highest rainfall in 1975. September 1975 was a month of exceptionally above normal rainfall. It was closely followed by high rains in October 1975.

In order to measure the changing pattern of rainfall in the megacity of Bangalore under the impact of urban heat island, mean annual and monthly frequency and transition of rainfall has been examined for the period 1961-2010. Bangalore receives the highest 989 mm mean annual rainfall. Bangalore experiences an eight-month protracted rainy period of double maxima of monsoon coupled with the pre-monsoon rains from April to November. The distribution pattern of annual rainfall in Bangalore is more sporadic. As a result of it, Bangalore does not receive persistent heavy showers. The moderate showers are intermittent with clear skies in 5 out of 8 months of rainy period. It should not be a matter of surprise when the prolonged eight months rainy period receives 96 per cent of the mean annual rainfall in Bangalore. The rainfall frequency depicts slightly more number of years with above normal rainfall and less number of years below normal rainfall. In view of this situation, it is crucial to examine whether the amount of rainfall and the number of rainy days have increased or decreased in Bangalore. The highest annual rainfall was recorded 1608.8 mm in 2005 whereas the lowest annual rainfall was recorded 587.2 mm in 1994. The five-yearly moving averages of Bangalore rains depicted a comparatively most homogenous and regular rainfall pattern than Hyderabad and Ahmedabad which has the least homogenous rainfall pattern.

**Chapter VI** on ‘Urban Heat Character and Humidity Transition’ focuses on the impact of humidity changes on urban heat in Ahmedabad, Hyderabad and Bangalore. An account of the percentage transition of relative humidity has been
brought out. Over some urban landscapes, the built-up surfaces reduce evaporation and induce dryness. As a result of it, the relative humidity shows a decreasing sign. Another scenario is that the industrial and commercial exhausts from the chimneys and from the air-conditioners tend to induce the relative humidity. This tendency enhances the sultry conditions along with the rising temperatures. This depicts an impact of urban heat island on other microclimatic features. Although a change in relative humidity is a function of complex interactions among several climatic variables. The studies on urban relative humidity reveal that there exists some linear relationship of change between the temperature, rainfall, wind velocity and the relative humidity.

Relative humidity changes in Ahmedabad megacity have been evaluated over a period of 47 years spanning over 1961-2007. This chapter illustrates the growth in the morning relative humidity, growth in the evening relative humidity and the growth in the average daily relative humidity in the face of the prevalent mean monthly relative humidity. A considerable increase in the morning relative humidity has been noticed. As against this, the average annual evening relative humidity shows a still higher increase in the relative humidity. The average annual daily relative humidity showed a considerable rise in 47 years. The values in the relative humidity increase are clear indicative of the growing sultry conditions in the micro urban climate of Ahmedabad.

Relative humidity transition or temporal humidity changes in Hyderabad megacity have been evaluated over a period of 49 years spanning over 1961-2009. The mean monthly and seasonal humidity growth has been evaluated in the face of the existing monthly and seasonal averages of the relative humidity for the corresponding period. A considerable increase in the morning relative humidity has been found. As against this, the average annual evening relative humidity shows a still higher increase in the relative humidity. The average annual daily relative humidity showed a considerable rise in 49 years. The figures in the relative humidity increase are clear indicative of the growing sultry conditions in the micro urban climate of Hyderabad also.

Relative humidity transition or temporal humidity changes in Bangalore megacity have been evaluated over a period of 52 years spanning over 1961-2012.
The mean monthly and seasonal humidity growth has been evaluated in the face of the existing monthly and seasonal averages of the relative humidity for the corresponding period. A modest increase in the mean annual morning relative humidity was observed. As against this, the average annual evening relative humidity shows a fairly noticeable increase. The average annual daily relative humidity also showed an increase over an enquiry period of 52 years. The growing temperature along with rising humidity would have an adverse impact on the eliminating salubrious climate of Bangalore city.

Chapter VII on ‘Urban Heat Island and Wind Velocity Changes’ deals with the wind velocity transition in the megacities of Ahmedabad, Hyderabad and Bangalore. High density urban built-up surfaces and the heavy industrial, commercial and residential functions considerably enhance the urban temperatures in the megacities. The surface roughness, hurdles and high temperatures may lead to considerable changes in the wind velocity patterns over a period of time. Many investigations have been made on the effects of urbanized landscapes upon the local city wind speeds.

Wind velocity changes in the megacity of Ahmedabad have been measured over a period of 47 years extending from 1961-2007. This chapter illustrates the growth in the mean wind velocity in the face of the existing average monthly wind speeds. The wind velocity measurements depict the wind speed at 2 meter above the surface. The highest wind velocity average in Ahmedabad was recorded in the monsoon onset month of June. Whereas the lowest wind velocity average was recorded in October. The mean annual wind velocity was recorded 7.316 km per hour. The monthly average wind velocity shows a pattern of regularly increasing wind velocity from October to June and a pattern of regularly decreasing monthly wind velocity from July to September. The average monthly and seasonal transition of wind velocity in Ahmedabad over a period of 47 years encompassing 1961-2007 illustrated a negative transition of wind velocity for all the months. This gives a clear evidence of wind velocity reduction in Ahmedabad. The maximum wind velocity reduction was recorded in the month of May whereas the minimum wind velocity reduction was recorded in the month of December. The mean annual wind velocity reduction has been smaller.
The wind velocity measurements demonstrate the average wind speeds at 2 meter above the ground for the peninsular megacity of Hyderabad. The highest wind velocity average in Hyderabad was recorded in the monsoon month of July. While the lowest wind velocity average was recorded in the winter month of December. The mean annual wind velocity was recorded 9.973 km per hour. The monthly average wind velocity showed a pattern of regularly increasing wind velocity from December to July. On the other hand, a pattern of regularly decreasing monthly wind velocity has been noted from August to November. The results illustrate a negative transition of wind velocity for all the months. This shows a clear evidence of wind velocity reduction in Hyderabad. The maximum wind velocity reduction has been recorded for the monsoon month of July whereas the minimum wind velocity reduction has been recorded in October. The mean annual wind velocity reduction has been of moderate value.

The wind velocity values represent the average wind speed at 2 meter above the surface for the southernmost megacity of Bangalore in peninsular India. The highest wind velocity average in Bangalore was recorded in the monsoon month of July. While the lowest wind velocity was recorded in April. The mean annual wind velocity was recorded 7.013 km per hour. It is crucial to note that there has been a pattern of almost regularly decreasing monthly wind velocity in the extended monsoon from June to November in Bangalore. The average monthly and seasonal transition of wind velocity in Bangalore over a period of 52 years extending from 1961-2012 has been studied. The results indicate a negative transition of wind velocity for all the months. This illustrates a clear evidence of wind velocity reduction in Bangalore. The maximum wind velocity reduction has been recorded for the monsoon month of July in Bangalore whereas; the minimum wind velocity reduction has been recorded in the month of October. Here, it is interesting to note that the maximum and minimum wind velocity reduction for both Hyderabad and Bangalore were in the months of July and October respectively. The mean annual wind velocity reduction in Bangalore was also of moderate value.

Chapter VIII on ‘Urban Heat Island and Calm Weather Conditions’ attempts to analyze the calm weather conditions and urban heat islands in the megacities of Ahmedabad, Hyderabad and Bangalore. The high density urban built-up surface and the urban residential, industrial and commercial functions generate heat
and induce the temperatures. This phenomenon is scientifically called the urban heat island. The thermo-dynamics of urban heat island intensity plays a crucial role in modifying the other variables of the urban microclimate. In a complex, yet integrated process the temperature rise induces the rainfall amount and frequency. In a combined effect, it also leads to the changes in the urban wind velocity pattern and the urban humidity scenario. The urban heat island intensity along with urban landscape heterogeneity and the resultant wind velocity reduction promote the occurrence of calm weather conditions.

Mean monthly and seasonal pattern of number of calm days have been enquired in order to estimate their impact on the urban heat island intensity. The mean monthly and seasonal transition of the calm weather conditions has also been evaluated in order to ascertain its impact on the temporal change in urban heat island intensity over a long period of time. Mean monthly and seasonal calm weather changes have been evaluated in relation to average monthly number of calm days and the average seasonal number of calm days. This chapter illustrates the growth in the number of morning calm days and the growth in the number of evening calm days. It also examines if there is any relationship between the existing average number of calm days and the extent of change in the number of calm days which could explain the aggravating intensity of urban heat island. Whether there is a linear relationship between the existing number of calm days and the changing number of calm days or there is an inverse relationship between the two.

The mean monthly and seasonal number of morning calm days recorded at 8:30 hours for the enquiry period of 47 years spanning over 1961-2007 have been studied. The monthly number of morning calm days was invariably higher than the number of evening calm days in Ahmedabad. The largest number of morning calm days was recorded in the month of October. While the smallest number of morning calm days was recorded in May. The transition or growth in the number of morning calm days over a period of 47 years encompassing 1961-2007 has been studied. The largest increase in the number of morning calm days was recorded in October while the smallest calm days increase was reported in February. The mean monthly and seasonal number of evening calm days recorded at 17:30 hours for the enquiry period of 47 years spanning over 1961-2007 have been studied. The largest number of evening calm days was recorded in the month of October. While the smallest number
of evening calm days was recorded in May. The transition or growth in the number of evening calm days over a period of 47 years encompassing 1961-2007 has been studied. The largest increase in the number of evening calm days was recorded in October while the smallest evening calm days increase was reported in May.

The mean monthly and seasonal number of morning calm days recorded at 8:30 hours for the enquiry period of 50 years spanning over 1961-2010 have been studied in Hyderabad. The monthly number of morning calm days was invariably higher than the number of evening calm days in Hyderabad. The largest number of morning calm days was recorded in the month of December. While the smallest number of morning calm days was recorded in the months of June and July. The transition or growth in the number of morning calm days over a period of 50 years encompassing 1961-2010 has been studied. The largest increase in the number of morning calm days was recorded in December while the smallest morning calm days increase was reported in July. The mean monthly and seasonal number of evening calm days recorded at 17:30 hours for the enquiry period of 50 years spanning over 1961-2010 have been studied. The largest number of evening calm days was recorded in the month of April. While the smallest number of evening calm days was recorded in July. The transition or growth in the number of evening calm days over a period of 50 years encompassing 1961-2010 has been studied. The largest increase in the number of evening calm days was recorded in May while the smallest evening calm days increase was reported in July.

The mean monthly and seasonal number of morning calm days recorded at 8:30 hours for the enquiry period of 52 years spanning over 1961-2012 have been studied in Bangalore. The largest number of morning calm days was recorded in the month of March. While the smallest number of morning calm days was recorded in June. The transition or growth in the number of morning calm days over a period of 52 years encompassing 1961-2012 has been studied. The largest increase in the number of morning calm days was recorded in March while the smallest morning calm days increase was reported in May. The mean monthly and seasonal number of evening calm days recorded at 17:30 hours for the enquiry period of 52 years spanning over 1961-2012 have been studied. The largest number of evening calm days was recorded in the month of October. While the smallest number of evening calm days was recorded in June. The transition or growth in the number of evening calm days was recorded in June. The transition or growth in the number of evening calm days was recorded in June. The transition or growth in the number of evening calm days was recorded in June.
calm days over a period of 52 years encompassing 1961-2012 has been studied. The largest increase in the number of evening calm days was recorded in October while the smallest evening calm days increase was reported in February.

Chapter IX on ‘Urban Heat Island and Evaporation Transition’ throws light on the evaporation changes and heat island in Ahmedabad, Hyderabad and Bangalore. Evaporation provides an estimate of the atmospheric water need. Evaporative cooling helps dissipate heat energy trapped by the UHI. The inner city of high built-up surface exhibits dry conditions whereas the sub-urban microclimate is comparatively more humid with higher evapo-transpiration. The curtailed evapo-transpiration from the built-up urban surfaces influences the transfer of latent heat and humidity. Urban built-up surfaces experience less evapo-transpiration in comparison to countryside landscapes. As a result of it, the dry and impervious urban areas have higher surface and air temperatures.

In this chapter, evaporation changes in the megacity of Ahmedabad have been measured over a period of 39 years extending from 1969-2007. The highest evaporation average in Ahmedabad was recorded in the month of May. The lowest evaporation average was recorded in the winter month of January. The results illustrate a negative transition of evaporation for all the months. This shows a clear evidence of reduction in evaporation in Ahmedabad. The maximum evaporation reduction has been recorded for the month of May whereas the minimum evaporation reduction has been recorded in January.

Evaporation changes in the megacity of Hyderabad have been measured over a period of 41 years extending from 1969-2009. The highest evaporation average in Hyderabad was recorded in the month of May. The lowest evaporation average was recorded in the winter month of December. The results illustrate a negative transition of evaporation for all the months. This shows a clear evidence of reduction in evaporation in Hyderabad also. The maximum evaporation reduction has been recorded for the month of May whereas the minimum evaporation reduction has been recorded in August.

Evaporation changes in the megacity of Bangalore have been measured over a period of 44 years extending from 1969-2012. The highest evaporation average in Bangalore was recorded in the month of March. On the other hand, the lowest
evaporation average was recorded in the winter month of December. The results illustrate a negative transition of evaporation for all the months. This shows a clear evidence of reduction in evaporation in Bangalore as well. The maximum evaporation reduction has been recorded for the month of March whereas the minimum evaporation reduction has been recorded in June.

Chapter X on ‘Causes and Consequences of Urban Heat Island and Remedial Measures’ deals with the causes and environmental impact of urban heat island in Ahmedabad, Hyderabad and Bangalore and the remedial measures to contain the urban heat island. Anthropogenic causes are the basic and formidable stimulants of urban heat island and micro climate change. Industrialization, commercialization and urbanization are the major causes of accentuated urban heat domes. The growing phenomenon of urban heat island would have a far-reaching affect on the human life and socio-economic activities. It is all the more crucial in view of the fact that more than 50 per cent of the world population is living in the urban centres. Further, urbanization and urban sprawl is on an unprecedented rise. Urban heat island and the climate change have an inevitable impact on the energy demand and energy consumption patterns. Building orientation and architectural layout are very important factors in mitigating or moderating the urban heat island effect. The environmentally conducive fenestration and ventilation make the urban built-up surfaces less extreme. The orientation of windows towards winter sunshine and summer breeze should be essential considerations to make the house environmentally conducive. This consideration would considerably reduce the energy cost of conditioning the indoor climate. It would enhance the comfort level of living in the events of power cuts and electric load-shedding. The three peninsular megacities of Ahmedabad, Hyderabad and Bangalore have longer summers with already high electricity demand.

The impact of urban heat island is high in the tropics because of the enhanced emissions of pollutants and green house gases. In order to combat air pollution it is required to identify the pollutants, its source of emission and investigate the effects of living and the environment. In this chapter, the Suspended Particulate Matter (SPM), Particulate Matter having an aerodynamic diameter less than or equal to 10 μm (PM₁₀), Sulphur dioxide (SO₂) and Nitrogen dioxide (NO₂) levels for the three megacities have been taken under study. The impact of these pollutants on the accentuation of urban heat island has been derived. The data for 6 air quality
monitoring stations operative in Ahmedabad, 9 air quality monitoring stations operative in Hyderabad and 9 air quality monitoring stations operative in Bangalore has been assessed.

The prominent locations of SPM concentration in Ahmedabad, Hyderabad and Bangalore have been studied. Station of Naroda in Ahmedabad has shown the highest SPM concentration level. In Hyderabad, the Balanagar station has shown the highest SPM concentration level. While in Bangalore, the Yelahanka Industrial Area has recorded the highest level of SPM concentration. The prominent locations of PM$_{10}$ concentration in Ahmedabad, Hyderabad and Bangalore have been studied. Station of Naroda in Ahmedabad has shown the highest PM$_{10}$ concentration level. In Hyderabad, the Paradise station has shown the highest PM$_{10}$ concentration level. While in Bangalore, the TERI Office has recorded the highest level of PM$_{10}$ concentration. The prominent locations of SO$_2$ concentration in Ahmedabad, Hyderabad and Bangalore have also been studied. Station of Naroda in Ahmedabad has shown the highest SO$_2$ concentration level. In Hyderabad, the ABIDS station has shown the highest SO$_2$ concentration level. While in Bangalore, the TERI Office has recorded the highest level of SO$_2$ concentration. The prominent locations of NO$_2$ concentration in Ahmedabad, Hyderabad and Bangalore have been studied as well. Station of Naroda in Ahmedabad has shown the highest NO$_2$ concentration level. In Hyderabad, the Paradise station has shown the highest NO$_2$ concentration level. While in Bangalore, the TERI Office has recorded the highest level of NO$_2$ concentration.

The abstract gives a synoptic view of the urban heat dome and the corresponding changes in the urban micro climate of Ahmedabad, Hyderabad and Bangalore megacities. A set of correlation has been seen among the meteorological variables; such as, between mean monthly temperatures and mean monthly relative humidity, between mean monthly relative humidity and mean monthly evaporation, between mean monthly wind speed and the morning calm days as well as between mean monthly wind speed and the evening calm days for all the three megacities. The present research is largely an enquiry into the urban climate change to assess its impact on the quality of life and well-being of rapidly growing urban inhabitants.