Chapter – III

GEOGRAPHY OF STUDY AREA AND CITY MORPHOLOGY

In this chapter the researcher has outlined geographical personality of the study area pertaining to inherent climatic characteristics, demographic contours, city morphology in terms of urbanization and built-up density as well as the landuse differentials. All these features have an integrated effect on the urban identity of Ahmedabad, Hyderabad and Bangalore. Megacities are the highest order urban centres in the urban hierarchy. They are functionally the most diverse and economically the most dominant. Megacities considerably control the regional economy. In the rapidly developing countries like India, there seems a reinvigorated tendency of centralized economy. Infact, megacities have the highest concentration of infrastructural facilities and momentum of economic growth. Consequently, they have the greatest gravity of concentration, agglomeration and attraction of residential, industrial, commercial, educational and administrative functions. India has a high obsession for globalization and the globalization promotes centralization. Hence, economic growth rate might be higher but the concurrent regional imbalances, disparities and social inequalities are likely to widen. Problems of migration, displacement and urban homelessness would be aggravated. India is theoretically committed to decentralization of economy and removal of regional imbalances. However, in the wake of globalization, India is functionally heading towards a renewed and reinvigorated centralization with only a trickle-down trace of decentralization and equilibrium. Today, Indian megacities are the magnets and symbols of globalization.

India with only 30 per cent urban population has higher number of megacities than even China with over 40 per cent urbanization and more than three times the size of Indian economy. This is a clear evidence of centralization of economy in India. India also has the world’s largest megacities. Mumbai, Delhi, Kolkata and Chennai were already the burgeoning megacities. They were the most widely spaced cities with a distance of 1,500-2,500 kilometres from each other. Hence, they were controlling their respective regional economies with an integrating effect on the national economy. Now, Ahmedabad, Hyderabad and Bangalore are the second-tier megacities. In the geometry of urban hierarchy, megacities are most distant-spaced settlements. Figure 3.1 illustrates the geographical location of the three megacities of
Fig. 3.1

Source: Prepared by the Researcher
Ahmedabad, Hyderabad and Bangalore. It shows their respective situation in Gujarat, Telangana and Karnataka. It shows the respective urban agglomerations and the area under municipal corporations. It also gives the relative distance of nearly 1400 km between Ahmedabad and Hyderabad and some 800 km distance between Hyderabad and Bangalore. Here, it is significant to recognize their geographical distance because this large distance tends to explain the variations in the climatic regime of these megacities. Their geographical personality is closely related to the respective location. Apart from being primate cities and commercial hubs, these megacities have distinct politico-administrative gravity. All the seven megacities of India are the capital of their respective states. All the megacities of India including Ahmedabad, Hyderabad and Bangalore are labour-intensive in the domestic, industrial and service sector. Hence, there is high population and built-up density with scanty open spaces and green belts. This depicts a lack of modernization even in the highest order megacities of India. There is largely a tendency of sprawl in Ahmedabad, Hyderabad and Bangalore rather than amicable urbanization. Due to high resultant population growth there is huddling and high energy consumption. This tends to induce the greenhouse effect and urban heat island intensity in these three megacities.

I Synoptic Climatic Characteristics of the Megacities

Ahmedabad on the head of Kathiawar Peninsula is located on the Tropic of Cancer. Hence, its climatic regime exhibits some signs of northern continentality. Summers have very high temperatures but the seasonal extreme is moderate with respect to winters. Ahmedabad has moderate seasonal extreme unlike the subtropical continentality of Delhi. Because of its Cancerian location, the geographical personality of Ahmedabad experiences the hottest summer season in comparison to Hyderabad and Bangalore. And because of the relative nearness to the northern continentality, the climate of Ahmedabad also experiences mild winters with rare occasions of cold wave sweeping down this city. Another climatic characteristic of Ahmedabad is that the monsoon season is highly compact and confined to a period of four months from June to September. Among all the three megacities under enquiry, the geographical personality of Ahmedabad depicts it the smallest both in terms of population and area. It would be interesting to observe if there is some linear
relationship between the population and size with the change in the degree of urban heat island in Ahmedabad.

Hyderabad is located well inside the tropics where Indian Peninsula is fairly wide but the continentality is not quite pronounced. Marine influences do encroach upon the climatic profile of the city. Because Hyderabad is located well within the tropics around 17°30´ north latitude, it experiences a relatively longer summer season than Ahmedabad. Hyderabad is some 1,400 km southeast of Ahmedabad. Due to this large distance between the two megacities, the climatic regime of Hyderabad is inherently different from that of Ahmedabad. However, in general context, the conditions of the Indian sub-continent tend to unify the geographical personality of the places, particularly the climatic features. Summer temperatures remain high in Hyderabad but they do not reach the proportion of extreme like the summer temperatures of Ahmedabad. As Hyderabad is located well inside the tropics, it experiences a longer summer season than Ahmedabad which is located on the edge of the northern tropic. Hyderabad experiences mild to warm winters. Hence, the seasonal range of temperature in Hyderabad is considerably smaller than the seasonal range of temperature in Ahmedabad. There is no concept of cold wave sweeping down as far south as Hyderabad even in the month of January. Because the city of Hyderabad is nearer to the Bay of Bengal, it experiences an extended monsoon season of five months stretching from June to October. This is so, because Bay of Bengal Branch of Monsoon is stronger than the Arabian Sea Branch of Monsoon which influences the rainfall regime of Ahmedabad. The urban personality of Hyderabad depicts it larger both in terms of population size and urban sprawl than the megacity of Ahmedabad. It would be crucial to notice if there is a linear relationship between the population and size with the changing urban heat island intensity in Hyderabad.

Bangalore is located farthest south in the Peninsular India, where the peninsula has an apparently narrower orientation. The city is located even more within the tropics at nearly 13° north latitude. Its geographical location is even more tropical from the perspective of expected thermal regime on a hypothetical isotropic surface with pronounced summers. But, actually the city is perched on the edge of the denuded Karnataka Plateau, which has considerably moderated its climatic regime. The altitudinal location of Bangalore dominates over its latitudinal location in promoting a salubrious climate in the city. Inconsistent with its latitudinal location the
summers of Bangalore are most mild among the three megacities. The winters are also least pronounced in Bangalore. The resultant seasonal range of temperature is smallest in Bangalore. Hence, Bangalore has remained famous for its equable climate. Bangalore is 800 km southwest of Hyderabad. As a result of it, one can expect a different climatic regime in Bangalore in comparison to Hyderabad. The latitudinal, altitudinal and peninsular location of Bangalore mutually complement to harness the longest rainy period coupled with the highest mean annual rainfall. Bangalore along with mild temperatures experiences a longest rainy period of almost 8 months. Bangalore experiences early rainy period in April and May. The city experiences moderate rainfall during the Advancing Monsoon Period from June to August. Bangalore experiences fairly appreciable rainfall during the Retreating Monsoon Period from September to November. This prolonged rainy period has an important bearing on the city water supply and sustainability. The urban personality of Bangalore comprises the highest population, though not the largest geographical extent. It would be significant to note if there is a linear relationship between the population size and the transition in the urban heat island intensity at Bangalore. The geographical characteristics of the three megacities vary from each other with reference to their maritime vicinity. Ahmedabad comes under the influence of Arabian Sea Branch of Monsoon. On the other hand, both Hyderabad and Bangalore experience the influences of Bay of Bengal Branch of Monsoon.

Ahmedabad: Characteristics of Urban Climate

Because Ahmedabad is located on the Tropic of Cancer and nearer towards the continentality, it has a pronounced seasonal range of temperature. Ahmedabad city experiences the hottest summer months in comparison to Hyderabad and Bangalore. However, another important feature is that due to large seasonal range of temperature, Ahmedabad has comparatively shorter summer season than Hyderabad and Bangalore. Nevertheless, in absolute sense of the term all the three megacities have a longer summer season.

Ahmedabad: Daytime Thermal Regime

A temporal analysis of the thermal regime in Ahmedabad shows that the annual average of mean monthly maximum (daytime) temperature for over fifty years
is 34.5°C. The periodic range of annual average daytime temperature recorded a maximum of 36.0°C in 1987 and the annual average daytime temperature recorded minimum of 33.1°C in 1997. The coolest winter month in Ahmedabad is January and the hottest summer month is May. The monthly average of the mean monthly maximum (daytime) temperature for January in winter season recorded a value of 28.2°C. As against this, the monthly average of the mean monthly maximum temperature for May in summer season recorded a value of 41.7°C. The periodic range of mean monthly daytime temperature for the coolest winter month January recorded a lowest value of 26.2°C in 2005 whereas January of 1990 recorded a highest value of 30.9°C. The periodic range of mean monthly daytime temperature for the hottest summer month May recorded a lowest value of 37.7°C in 1982 while the May of 1998 recorded a highest value of 43.0°C. However, the individual month figures for an year or two do not depict any specific trend.

Ahmedabad: Nocturnal Thermal Regime:

A temporal analysis of the thermal regime in Ahmedabad shows that the annual average of mean monthly minimum (nighttime) temperature for over fifty years is 20.8°C. The periodic range of annual average nighttime temperature recorded maximum of 22.3°C in 1987 and the annual average nighttime temperature recorded a minimum of 18.8°C in 1984. The coolest winter month in Ahmedabad is January and the hottest summer month is June. The monthly average of the mean monthly minimum (nighttime) temperature for January in winter season recorded a value of 12.1°C. As against this, the monthly average of the mean monthly minimum temperature for June in summer season recorded a value of 27.4°C. The periodic range of mean monthly nighttime temperature for the coolest winter month January recorded a lowest of 9.4°C in 1967 whereas January of 1988 recorded a highest value of 14.9°C. The periodic range of mean monthly nighttime temperature for the hottest summer month June recorded a lowest value of 26.1°C in 1997 while the June of 2010 recorded a highest value of 29.1°C.

Ahmedabad: Average Thermal Regime:

A temporal analysis of the thermal regime in Ahmedabad shows that the annual average temperature for over fifty years is 27.6°C. The periodic range of
annual average temperature recorded a maximum of 29.2°C in 1987 and the annual average temperature recorded a minimum of 26.2°C in 1983. The coolest winter month in Ahmedabad is January and the hottest summer month is May. The monthly average of the mean monthly average temperature for January in winter season recorded a value of 20.2°C. As against this, the monthly average of the average temperature for May in summer season recorded a value of 34.2°C. The periodic range of mean monthly average temperature for the coolest winter month January recorded a lowest value of 18.3°C in 1964 whereas January of 1965 recorded a highest value of 22.3°C. The periodic range of mean monthly average temperature for the hottest summer month May recorded a lowest value of 31.2°C in 1982 while the May of 2011 recorded a highest value of 35.5°C.

Ahmedabad: Rainfall Pattern and Variability

The mean annual rainfall in Ahmedabad city is 792 mm. This amount of rainfall is little less than to qualify it for a savanna condition. Hence, Ahmedabad lies under semi-arid moisture regime. The mean annual rainfall of Ahmedabad is less than the mean annual rainfall of any other megacity of India such as Mumbai, Delhi, Kolkata, Hyderabad, Bangalore and Chennai. Ahmedabad has the shortest rainy season which abruptly confines to only four months from June to September. The characteristic of rainfall, here, is associated with the Arabian Sea Branch of Monsoon. As compared to this, Hyderabad and Bangalore come under the influence of Bay of Bengal Branch of Monsoon. The monsoon has no prelude or pre-monsoon showers before its onset in Ahmedabad. Similarly, the retreat of the monsoon is also quite sudden. The monsoon onset month of June has a higher amount of rainfall of 119.3 mm than the monsoon retreat month of September with 110.6 mm rainfall. Thus, the onset is slightly stronger than the monsoon retreat at Ahmedabad. The short period monsoon season rainfall at Ahmedabad covers 95 per cent of the mean annual rainfall. Hence, the water availability period for urban green belt and the surrounding areas is very limited. However, this concentrated monsoonal pattern has an advantage for the heavy run-off collection and quick recharge of city water supply lakes like the Kankaria lake. The month of July with a mean monthly rainfall of 280.8 mm is the month of highest rainfall among the four rainy months. It receives 37.4 per cent of the total monsoonal rainfall. July and August are the peak rainy months during the
monsoon season in Ahmedabad. These peak rainy months encompass 69.4 per cent of the total monsoonal rains. It means that the remaining two months of monsoon onset and retreat experience less than half rainfall of 31.6 per cent in comparison to the peak rainy months. This also reveals a great rainfall variability within the monsoon months. Ahmedabad city does not experience any cognizable rains during the winter months of December, January and February with 2.6 mm, 1.7 mm and 1.0 mm rainfall respectively. The month of March experiences the lowest rainfall of 0.9 mm in Ahmedabad. But in view of the thermal regime, March is not a winter season month in Ahmedabad.

**Ahmedabad: Relative Humidity Conditions**

In the tropical urban climates relative humidity is a crucial measure of muggy, scorchy, keen and raw conditions in different seasons. Of all these equations, the sultry (muggy) conditions of high humidity alongwith higher temperatures make the urban climates increasingly unpleasant, particularly in the longer summer tropics. In the megacity of Ahmedabad the mean maximum annual relative humidity is 65.8 per cent. The yearly variation in the mean maximum annual relative humidity ranges from 58.7 per cent in 1972 to 75.4 per cent in 1982.

**Ahmedabad: Mean Monthly Maximum Relative Humidity**

The lowest mean monthly maximum relative humidity prevails in the early summer months with 48.3 per cent in March and 54.4 per cent in April. The winter months from November to February have an average mean monthly maximum relative humidity of 57.4 per cent. The mean monthly maximum relative humidity figures are crucially high during the monsoon season. The relative humidity begins to rise to an average of 74.2 per cent in the month of June. This is followed by still higher relative humidities of 84.9 per cent and 87.2 per cent in the core monsoon months of July and August respectively. The mean monthly maximum relative humidity is 82.1 per cent in September. Here, it is crucial to note that in the monsoon onset month of June the relative humidity is 74.2 per cent only while in the monsoon retreating month of September the relative humidity remains significantly high upto 82.1 per cent. Hence, the retreating monsoon is more humid than the advancing monsoon. This higher relative humidity corresponds to 8:30 hours recording.
Ahmedabad: Mean Monthly Minimum Relative Humidity

In the megacity of Ahmedabad, the mean minimum annual relative humidity is 39.3 per cent. The yearly variation in the mean minimum annual relative humidity ranges from 29.6 per cent in 1974 to 51.1 per cent in 1982. The lowest mean monthly minimum relative humidity prevails in the early summer months with 19.9 per cent in March to 19.6 per cent in April. The winter months from November to February have an average mean monthly minimum relative humidity of 32.1 per cent. The mean monthly minimum relative humidity figures are also obviously high during the monsoon season. The relative humidity begins to rise to an average of 44.5 per cent in the month of June. This is followed by still higher relative humidities of 67.9 per cent and 70.7 per cent in the core monsoon months of July and August respectively. The mean monthly minimum relative humidity is 59.2 per cent in September. Here, it is crucial to note that in the monsoon onset month of June the relative humidity is 44.5 per cent only while in the monsoon retreating month of September the relative humidity remains significantly high upto 59.2 per cent. Hence, the retreating monsoon is more humid than the advancing monsoon in this variable as well. This higher relative humidity corresponds to 17:30 hours recording.

Ahmedabad: Mean Monthly Average Relative Humidity

In the megacity of Ahmedabad, the mean average annual relative humidity is 52.6 per cent. The yearly variation in the mean average annual relative humidity ranges from 44.2 per cent in 1972 to 63.2 per cent in 1982. The lowest mean monthly average relative humidity prevails in the early summer months with 32.1 per cent in March and 36.9 per cent in April. The winter months from November to February have a mean monthly average relative humidity of 44.7 per cent. The mean monthly average relative humidity figures are also obviously high during the monsoon season. The relative humidity begins to rise to an average of 59 per cent in the month of June. This is followed by still higher relative humidities of 76.4 per cent and 78.9 per cent in the core monsoon months of July and August respectively. The mean monthly average relative humidity is 70.6 per cent in September. Here, it is crucial to note that in the monsoon onset month of June the relative humidity is 59.3 per cent only while in the monsoon retreating month of September the relative humidity remains
significantly high up to 70.6 per cent. Hence, the retreating monsoon is more humid than the advancing monsoon in this variable also.

Ahmedabad: Mean Wind Velocity

Wind is the movement of air due to a difference in atmospheric pressure, caused by differential heating of land and water mass on the earth’s surface by solar radiation and rotation of earth. It is a major design consideration for architects because it affects indoor comfort conditions by influencing the convective heat exchanges of a building envelope, as well as causing air infiltration into the building.

Wind velocity on the one hand is an important indicator of climatic comfort in the form of breeze. Breeze plays a highly crucial role in the urban climates. A low wind velocity renders the tropical urban climates highly calm, sultry and uncomfortable. On the other hand, it also indicates the evaporation losses of the rainwater and soil moisture. Wind velocity and wind direction ought to be the major determinants in orienting the ventilation of residential, commercial and institutional buildings. A naturally induced ventilation would considerably reduce the energy burden in the tropical cities. The naturally induced ventilation would reduce the comfort cost in the urban built-up surfaces. In the tropical urban structures the wind can be induced by orienting the buildings in such a way that the winds are naturally propelled into a comfortable and highly welcome ‘Corridor Effect’ particularly in the longer summer climates.

In the megacity of Ahmedabad, the Mean Annual Wind Velocity is 7.3 km/hr for nearly last 50 years. The Mean Annual Variation ranges from 5.2 km/hr in the year 1970 to 13.8 km/hr in 1996. There are considerable seasonal variations in the wind velocity pattern. The lowest wind velocity average records for the winter season. The winter season wind velocity from October to January is 5.1 km/hr. The monthly wind velocities from October to January are highly similar without any cognizable variation. The summer months wind velocity increases to an average of 8.3 km/hr from March to May. The wind velocity averages are understandably highest during the monsoon season from June to September. The average monsoon wind velocity is 9.1 km/hr.
Ahmedabad: Evaporation Averages

Evaporation is an important measure of atmospheric water need of a place. Over the built-up urban surfaces, the actual evaporation losses are low, but the potential evaporation losses from the built-up surfaces are higher than the potential evaporation losses from the surrounding countryside. Hence, the atmospheric water demand over the megacities is considerably higher than the smaller cities and the countryside.

The mean annual evaporation over the megacity of Ahmedabad is 2122 mm. The mean annual evaporation ranges from 1435 mm in the year 1997 to 2692 mm in 1974. There is considerable variation in the mean monthly and seasonal evaporation. The lowest mean monthly evaporation was recorded as 124 mm in January while the mean monthly maximum evaporation was noted as 286 mm in the month of June. The seasonal evaporation is obviously lowest in the winter season. The average evaporation for the winter season is 132 mm from November to February. This is followed by a higher evaporation during the monsoon season from June to September. The summer monsoons despite the rains have higher evaporation than the winter season. The mean seasonal evaporation during the monsoon months of June to September is 171 mm. The highest seasonal evaporation is obviously during the hot dry summer months. The average dry summer evaporation value for the monsoon months from March to May is 244 mm.

Hyderabad: Characteristics of Urban Climate

Daytime Thermal Regime

A temporal analysis of the thermal regime in Hyderabad shows that the annual average of mean monthly maximum (daytime) temperature for fifty years is 32.5°C. The periodic range of annual average daytime temperature recorded a maximum of 34.5°C in 2010 and the annual average daytime temperature recorded a minimum of 31.1°C in 1963. The coolest winter month in Hyderabad is December and the hottest summer month is May. The monthly average of mean monthly maximum (daytime) temperature for December in winter season recorded a value of 28.4°C. As against this, the monthly average for the mean monthly maximum temperature for May in summer season recorded a value of 39.2°C. The periodic range of mean monthly
daytime temperature for the coolest winter month December recorded a lowest value of 25.8°C in 1962 whereas December of 2008 recorded a highest value of 30.6°C. The periodic range of mean monthly daytime temperature for the hottest summer month May recorded a lowest value of 34.0°C in 1990 while the May of 2010 recorded a highest value of 41.6°C.

**Hyderabad: Nocturnal Thermal Regime**

A temporal analysis of the thermal regime of Hyderabad shows that the annual average of mean monthly minimum (nighttime) temperature for fifty years is 20.7°C. The periodic range of annual average nighttime temperature recorded a maximum of 21.7°C in 2010 and the annual average nighttime temperature recorded a minimum of 19.2°C in 1968. The coolest winter month in Hyderabad is December and the hottest month is May. The monthly average of the mean monthly minimum (nighttime) temperature for December in winter season recorded a value of 14.8°C. As against this, the monthly average of the mean monthly minimum temperature for May in summer season recorded a value of 26.1°C. The periodic range of mean monthly nighttime temperature for the coolest winter month December recorded a lowest value of 10.1°C in 1970 whereas December of 2010 recorded a highest value of 17.6°C. The periodic range of mean monthly nighttime temperature for the hottest summer month May recorded a lowest value of 24.1°C in 1990 while the May of 1988 recorded a highest value of 28.2°C.

**Hyderabad: Average Thermal Regime**

A temporal analysis of the thermal regime in Hyderabad shows that the annual average temperature for fifty years is 26.6°C. The periodic range of annual average temperature recorded a maximum of 28.1°C in 2010 and the annual average temperature recorded a minimum of 25.2°C in 1963. The coolest winter month in Hyderabad is December and the hottest summer month is May. The monthly average of the mean monthly average temperature for December in winter season recorded a value of 21.6°C. As against this, the monthly average of the average temperature for May in summer season recorded a value of 32.7°C. The periodic range of mean monthly average temperature for the coolest winter month December recorded a lowest value of 19.0°C in 1970 whereas December of 1997 recorded a highest value
of 23.9°C. The periodic range of mean monthly average temperature for the hottest summer month May recorded a lowest value of 29.0°C in 1990 while the May of 1984 recorded a highest value of 34.6°C.

**Hyderabad: Relative Humidity Conditions**

In the megacity of Hyderabad, the mean maximum annual relative humidity is 67.8 per cent. The yearly variation in the mean maximum annual relative humidity ranges from 62.8 per cent in 2009 to 71.5 per cent in 1978. The lowest mean monthly maximum relative humidity prevails in the summer months with 53.4 per cent in March and 51.5 per cent in April followed by 48.7 per cent in May. The mild winter months from November to February have an average mean monthly maximum relative humidity of 69.1 per cent. The mean monthly maximum relative humidity figures are high during the monsoon season. The relative humidity begins to rise to an average of 69.5 per cent in the month of June. This is followed by still higher relative humidities of 79.1 per cent and 81.6 per cent in the core months of July and August respectively. The mean monthly maximum relative humidity is 79.7 per cent in September. Here, it is crucial to note that in the monsoon onset month of June the relative humidity is 69.6 per cent only while in the monsoon retreating month of September the relative humidity remains significantly high upto 79.7 per cent. Hence, the retreating monsoon is more humid than the advancing monsoon. This higher relative humidity corresponds to 8:30 hours recording.

**Hyderabad: Evaporation Averages**

The mean annual evaporation over the megacity of Hyderabad is 1,901 mm. The mean annual evaporation ranges from 1,443 mm in the year 2005 to 2,706 mm in 1970. There is considerable variation in the mean monthly and seasonal evaporation. The lowest mean monthly evaporation was recorded as 112 mm in December while the mean monthly maximum evaporation was noted as 249 mm in the month of May. The seasonal evaporation is obviously lowest in the winter season. The average evaporation for the winter season is 125 mm from November to February. This is followed by a higher evaporation during the monsoon season from June to September. The summer monsoons despite the rains have higher evaporation than the winter season. The mean seasonal evaporation during the monsoon months of June to
September is 147 mm. The highest seasonal evaporation is obviously during the hot dry summer months. The average dry summer evaporation value for the months from March to May is 224 mm.

**Bangalore: Characteristics of Urban Climate**

**Daytime Thermal Regime**

The thermal regime of Bangalore city is altogether different from that of Ahmedabad and Hyderabad. Because Bangalore is located comparatively at the southern most location of 13°north latitude and also because it is located where peninsula of India is considerably narrower, the summer season is longest due to its proximity to both the Bay of Bengal and the Arabian Sea. The summer now extends to nine months. But it is crucial to note that the summer temperatures in Bangalore are lower than those of Ahmedabad and Hyderabad. This is because Bangalore is located at a higher altitude on the plateau of Karnataka. A temporal analysis of the thermal regime in Bangalore shows that the annual average of mean monthly maximum (daytime) temperature for over fifty years is 29.4°C. The periodic range of annual average daytime temperature recorded a maximum of 30.4°C in 2003 and the annual average daytime temperature recorded a minimum of 28.6° in 1975.

The coolest winter month in Bangalore is December and the hottest summer month is April. The monthly average of mean monthly maximum (daytime) temperature for December in winter season recorded a value of 26.4°C. As against this, the monthly average for the mean monthly maximum temperature for April in summer season recorded a value of 33.9°C. The periodic range of mean monthly daytime temperature for the coolest winter month December recorded a lowest value of 25.0°C in 1993 whereas December of 2004 recorded a highest value of 28.1°C. The periodic range of mean monthly daytime temperature for the hottest summer month April recorded a lowest value of 32.1°C in 1962 while the April of 1983 recorded a highest value of 35.7°C.

**Bangalore: Nocturnal Thermal Regime**

A temporal analysis of the thermal regime in Bangalore shows that the annual average of mean monthly minimum (nighttime) temperature for over fifty years is
19.0°C. The periodic range of annual average nighttime temperature recorded a maximum of 20.0°C in 2010 and the average nighttime temperature recorded a minimum of 17.5°C in 1967. The coolest winter month in Bangalore is January and the hottest summer month is April. The monthly average of the mean monthly minimum (nighttime) temperature for January in winter season recorded a value of 15.6°C. As against this, the monthly average of the mean monthly minimum temperature for April in summer season recorded a value of 21.7°C. The periodic range of mean monthly nighttime temperature for the coldest winter month January recorded a lowest value of 13.5°C in 1972 whereas January of 1998 recorded a highest value of 17.6°C. The periodic range of mean monthly nighttime temperature for the hottest summer month April recorded a lowest value of 20.4°C in 1968 while the April of 1998 recorded a highest value of 22.8°C.

**Bangalore: Average Thermal Regime**

A temporal analysis of the thermal regime in Bangalore shows that the annual average temperature for over fifty years is 24.2°C. The periodic range of annual average temperature recorded a maximum of 25.0°C in 2003 and the annual average temperature recorded a minimum of 23.2°C in 1967. The coolest winter month in Bangalore is December and the hottest summer month is April. The monthly average of the mean monthly average temperature for December in winter season recorded a value of 21.2°C. As against this, the monthly average of the average temperature for April in summer season recorded a value of 27.8°C. The periodic range of mean monthly average temperature for the coolest winter month December recorded a lowest value of 20.0°C in 1971 whereas December of 2009 recorded a highest value of 22.3°C. The periodic range of mean monthly average temperature for the hottest month April recorded a lowest value of 26.4°C in 1962 while the April of 1983 recorded a highest value of 29.2°C.

**Bangalore: Rainfall Pattern and Variability**

Sporadic rains begin in the month of April, further increasing in the month of May and eventually culmination into monsoon rains of June, July and August. The highest monthly rainfall has been noted during the season of retreating monsoon. The fact that the month of September recording the highest monthly rainfall of 211 mm
and the second highest monthly rainfall (165 mm) at Bangalore is recorded in the month of October. Both these months are retreating North East monsoon months. Hence, we can infer that Bangalore city experiences double-maxima of rainfall. It receives rainfall from the advancing monsoon. It also receives considerable rainfall from the retreating monsoon. Further, June, July and August, the three months of advancing monsoon receive a total rainfall of 348 mm while September and October, the two months of retreating monsoon receive a total rainfall of 375 mm. This reveals that a shorter period of retreating monsoon gives a much higher amount of rainfall than the longer advancing season of monsoon rains.

**Bangalore: Relative Humidity Conditions**

In the megacity of Bangalore, the mean maximum annual relative humidity is 81.2 per cent. The yearly variation in the mean maximum annual relative humidity ranges from 76.7 per cent in 1964 to 83.8 per cent in 1977. The lowest mean monthly maximum relative humidity prevails in the summer months with 69.2 per cent in March and 74 per cent in April followed by 76.3 per cent in May. The mild months from November to February have an average mean monthly maximum relative humidity of 78.1 per cent. The mean monthly maximum relative humidity figures are high during the monsoon season. The relative humidity begins to rise to an average of 84 per cent in the month of June. This is followed by still higher relative humidities of 87.2 per cent and 88.7 per cent in the core months of July and August respectively. The mean monthly maximum relative humidity is 87 per cent in September. Here, it is crucial to note that in the monsoon onset month of June, the relative humidity is 84 per cent while in the month of September, the relative humidity is significantly high upto 87 per cent. Hence, the retreating monsoon is more humid than the advancing monsoon. This higher relative humidity corresponds to 8:30 hours recording.

**Bangalore: Evaporation Averages**

The mean annual evaporation over the megacity of Bangalore is 1,601 mm. The mean annual evaporation ranges from 1,864 mm in the year 1969 to 1,361 mm in 1988. There is considerable variation in the mean monthly and seasonal evaporation. The lowest mean monthly evaporation was recorded as 107 mm in August followed by 108 mm in November while the mean monthly maximum evaporation was noted
as 188 mm in the month of March. The seasonal evaporation is lower in the winter season.

II City Size, Morphology, Population Growth and Density

City size and demographic changes in the Indian megacities have mostly taken place due to massive migration and marginally through natural population growth. Migration brings about social and economic changes. Migration also changes the sex and age structure of megacities more than any other settlement in the urban hierarchy. The most rapid migration to the megacities leads to urban sprawl in the ever expanding periphery. Because megacities have the highest infrastructural and employment gravity they lead to both intensive and extensive landuse changes. Intensive landuse growth takes place in the core areas of the city or the C.B.D. while extensive landuse changes occur in the peripheral areas. This inevitable trend is the result of an all pervading gravity differential between the urban core and the urban periphery. In fact, the spatial gravity differential is the essence of the geographical theory of areal differentiation. Hence, the Newtonian Physics explicitly operates in geography. The hallmark of geographical explanation is that there is both inter-urban gravity differential as well as the intra-city gravity differential. The geographical space has inherent as well as evolutionary gravity differential at all levels ranging from macro, meso, micro to sub-micro planks. The resultant landuse changes, diversity and intensity play a crucial role in critically aggravating the problem of urban heat island in the burgeoning megacities of India.

Ahmedabad : City Size and Morphology

Figure 3.2 depicts the physiographic outlay of Ahmedabad, including the prominent waterbodies, alongwith the city morphology. It also shows the meteorological stations of Ahmedabad and the fringe area town of Dahegam. Ahmedabad urban agglomeration has a geographical area of 466 sq.km. with a corresponding population of 6.35 million persons in 2011. The natural features which dominate the city morphology include the Sabarmati river and a few water bodies. Due to its leveled alluvial terrain the city morphology of Ahmedabad is highly contiguous in its expanse. Some man-made lakes are also a distinctive feature of the city. The replenished Sabarmati river runs through the heart of the city and bifurcates
AHMEDABAD: CITY OUTLAY AND BUILT-UP ENVIRONMENT

Source: Adapted from Google Earth, Image 2016 Digital Globe, CNES / Astrium

Fig. 3.2
it into the old and new city. The traditional old city east of ‘Sabarmati Divide’ has smaller buildings and is more congested. On the other hand, the western modern city looks more spacious. However, the per unit area higher infrastructural and municipal facilities, high-rise buildings and the resultant vertical growth render a higher built-up density in the modern city as compared to traditional sectors in the old city. Nonetheless, the river functionally connects the older and the newer city at several places through more than 9 bridges across.

The urban landscape of the old city comprises cotton-textile mills that the city is known for. Even though the cotton-textile industry is mechanized, it is still labour intensive industry. Due to the near-neighbour advantage most of the skilled and semi-skilled labour lives in the old part of the city adding to its congestion. The main railway station lies in the old city. General Post Office is also located in the old city. Most of the historical monuments of the glorious medieval period are also located in the old city.

The urban landscape of the newer western part of the city comprises modern buildings, educational institutions and well-planned residential areas. Western part of the city also comprises shopping malls and multiplexes. The western part also comprises New Business District along the C.G. Road, Ashram Road and the Sarkhej-Gandhinagar Highway. The famous Sabarmati Ashram is on the west bank of the river in northern Ahmedabad. Some modern sectors have also developed along the southeastern periphery of the old city. The modern administrative capital of the state has developed in the northern vicinity at Gandhinagar.

There are a number of large, medium and small lakes in Ahmedabad which may have their influence on the microclimate of the city. Chandola lake is the southernmost lake located at Dani Limbda Road. It is the largest lake covering an area of 1200 sq.ha. It was made by the wife of a Mughal Sultan Tajn Khan Nari Ali. The water of this large reservoir was used for irrigation and industry also. Shah Alam Roza (mausoleum) is north of Chandola Lake. Infact, it is between Chandola and Kankaria lake. Kankaria lake is the second largest lake in the city. It lies northeast of Chandola lake in Maninagar. This lake was constructed by Sultan Qutbuddin in 1451. Its original name was Qutb Hauz. Its inherent attraction lies in a 34-sided polygon with descending step work upto the water level. The lake has a circumference of 4.8
km. Its shore landscape consists of a ‘kids city open space’ and amusement area covering 4.2 hectares. The lake also has a zoo landscape and greenery of 31 hectares along its brim. Inside the lake is a Palace garden called Nagina wadi. The lake is now highly modernised. Its effect on the microclimate is evident from the pleasant evening breeze during the hot and longer summers. The swarming visitors get a lot of respite and solace after the day heat. Another significant lake is Vastrapur lake. It is located in the western part of the city.

All the three megacities under enquiry are the capital of their respective states. It has been noted in all the states of India and in most of the developing countries with many instances in the developed countries also that the largest city is the capital city and it continues to grow the largest due to economic, educational and administrative incentives. Hence, the largest capital cities tend to grow still larger and are vulnerable to urban heat island intensity and climate change. Ahmedabad was founded by Ahmedshah, the ruler of Gujarat in 1411 A.D. Ahmedshah preferred the location of the city on the eastern bank of Sabarmati river for the strategic advantages. Now, the burgeoning megacity of Ahmedabad extensively straddles on either side of the river on its alluvial plains. Both Hyderabad and Bangalore have nearly 500 years history of origin. Both the megacities are perched on the undulating surface of the denuded Andhra plateau and Karnataka plateau.

Table 3.1 shows the decadal growth in the geographical extent of the megacity of Ahmedabad from 1961-2011. Significantly enough, it also displays the changing demographic profile in terms of population, density and growth for the corresponding period. Among the three megacities of enquiry, in 1961 Ahmedabad had the smallest geographical area of 63.1 sq.km. Its total population was 1.15 million persons. The average density of population was 18,225 persons per sq.km. However, there was considerable intra-city variation in the population density. This was the highest population density in the three megacities. This population density was 290 per cent higher than that of Hyderabad and 169 per cent higher to the corresponding density of Bangalore. It clearly depicts a higher congestion and possibly a higher propensity of urban heat island in Ahmedabad.

In 1981, Ahmedabad had recorded an increase in its geographical extent to 145 sq.km. This was a net inter-decadal area growth by 36.8 sq.km. Still, however,
### TABLE 3.1
Ahmedabad: Area, Population, Density and Growth (1961-2011)

<table>
<thead>
<tr>
<th>Year</th>
<th>Area Sq.km.</th>
<th>Area Growth Sq.km.</th>
<th>Population (Millions)</th>
<th>Density Persons/km²</th>
<th>% Pop. Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961</td>
<td>63.1</td>
<td>-</td>
<td>1.15</td>
<td>18,225</td>
<td>-</td>
</tr>
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<td>1971</td>
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<tr>
<td>1991</td>
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<td>2001</td>
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<td>107.2</td>
<td>4.52</td>
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<td>466.0</td>
<td>168.0</td>
<td>6.35</td>
<td>13,631</td>
<td>40.48</td>
</tr>
</tbody>
</table>

Source: Computed from Census of India and Municipal Data.
the geographical area of Ahmedabad was temporally the smallest among the three cities. Its net area growth was also the smallest. The total population of Ahmedabad was 2.55 million persons in 1981. The 1971-1981 aggregate decadal growth was 8,02,000 persons with an annual growth rate of 80,000 persons. The decadal population growth was 45.71 per cent. The average population density reached the highest level of 17,586 persons per sq.km. This was still the highest population density among three megacities. This population density was 257 per cent higher than the population density of Hyderabad and 220 per cent to the corresponding density of Bangalore.

In 1991, Ahmedabad had recorded an increase in its geographical extent to 190.8 sq.km. There was a net area growth by 45.8 sq.km. Despite this, the geographical area of Ahmedabad was the smallest in comparison to the other two megacities. Its net area growth was again the smallest. The total population of Ahmedabad was 3.78 million persons 1991. The 1981-1991 aggregate decadal growth was 1,231,000 persons with an annual accelerated growth rate of 1,23,100 persons. This vividly indicates an urban take-off in Ahmedabad as it was elsewhere in India. The decadal population growth rate was the highest 48.23 per cent. The average population density maintained a high of 17,355 persons per sq.km. This still remained the highest population density among the three megacities. This population density was 291 per cent higher than the population density of Hyderabad and 174 per cent higher to the corresponding density of Bangalore. It reveals the fact that the density of population or the congestion level continues to remain higher in Ahmedabad.

In 2001, Ahmedabad had registered an increase in its geographical area to 298 sq.km. There was a net area growth by 107.2 sq.km. Despite this large areal expansion, the geographical area of Ahmedabad remained the smallest in comparison to the two other megacities under enquiry. It simply means that Hyderabad and Bangalore were expanding their area at a much higher rate to enhance their spatial sustainability and open surface for the urbanites. Its net area growth continued to remain smallest in comparison to the other megacities. The total population of Ahmedabad rose to 4.52 million persons by 2001. The 1991-2001 aggregate decadal growth was only 7,42,000 persons with an annual growth rate of 74,200 persons. The considerably decreased aggregate population growth indicates a reduced in-migration due to stagnant sustainability of the city during this period. Consequently, the decadal
population growth rate was at an all time low of only 19.57 per cent. This was the lowest decadal growth among all the megacities under enquiry. The average population density was still higher with 15,184 persons per sq.km. This continued to remain the highest population density among the three megacities. This population density was 205 per cent higher than the population density of Hyderabad and only 132 per cent higher to the corresponding population density of Bangalore.

In 2011, Ahmedabad had noted an increase in its geographical extent to 466 sq.km. There was the largest net area growth by 168 sq.km. during the decade 2001-2011. Despite this large areal expansion, the geographical area of Ahmedabad was way smaller to Hyderabad and Bangalore. This again indicated that Hyderabad and Bangalore were expanding their urban area at a still higher rate to promote their spatial sustainability and open space availability to its inhabitants. Its net area growth was higher than the corresponding net area growth of Hyderabad but smaller to that of Bangalore. The total population of Ahmedabad increased to 6.35 million persons by 2011. The 2001-2011 aggregate decadal growth was of very high order by 1,831,000 persons with the highest ever annual growth rate of 1,83,100 persons. This reveals a clear sign of urban culmination in the wake of globalization in India. This considerably increased aggregate population growth indicates a re-invigorated trend of migration to qualify Ahmedabad as a megacity. This decadal population growth rate was 40.48 per cent. Because of very large area growth the average population density reduced to 13,631 persons per sq.km. However, even this reduced population density of Ahmedabad was still higher than the corresponding population density of Hyderabad and Bangalore.

The aggregate population growth of Ahmedabad was 4.6 million persons during a period of 40 years from 1971-2011. This population density was 150 per cent higher to that of Hyderabad and only 112 per cent higher to the average population density of Bangalore. These higher population density trends of Ahmedabad are a clear indication of a limited area expansion and consequently a higher degree of urban expansion throughout the period of 1971-2011. The literacy rate at Ahmedabad with 79.89 per cent was a little lesser than Hyderabad and Bangalore. However, the sex-ratio of Ahmedabad by 2011 was considerably lower with only 903 women per 1000 men. This is also indicative of lower gender sustainability in Ahmedabad in comparison to Hyderabad and Bangalore.
Hyderabad : City Size and Morphology

Figure 3.3 illustrates the physiographic outlay of Hyderabad alongwith the city morphology including the prominent waterbodies. It shows the locations of Hyderabad and Bibinagar stations. Hyderabad urban agglomeration has the largest geographical area of 851 sq.km. among the three megacities. It has a fast growing area with even faster growing population of 7.74 million persons in 2011. Hyderabad is distinctly the primate city of Telangana State. Hyderabad is also capital city of the land-locked Telangana state. It is also an interim de jure capital of Andhra Pradesh. The city is located on the visibly feeble Musi river which is the tributary of Krishna-the second largest river basin of Peninsular India and the third largest in India. Today, Musi flows as an urban divide between the sprawling new city and the old city. Hyderabad is seated on the hilly terrain of Cuddapah system. The undulating surface and surroundings are a potential source of several large, medium and smaller waterbodies. The waterbodies have been developed into multipurpose lakes.

Hyderabad is situated at an altitude of 542 metres or 1778 feet above mean sea level. The northern parts of Banjara Hills in Secunderabad are perched on the Granitic outcrops at 672 metres or 2205 feet. The amplitude of relief in the city is 130 metres or 427 feet. The early location of this 16th century city was founded by Muhammad Quli Qutb Shah in 1591. The Qutb Shahi Dynasty had a higher capacity building. They simultaneously developed the city on either side of the river. The Golconda Fort was developed to the north of Musi river on the hillocks, while Charminar area was developed over 12 kms southeast on the Musi.

There are a number of large waterbodies like Hussain Sagar, Osman Sagar and Himayat Sagar which have been built by making dams on the Musi river to sustain the city water supply. Hussain Sagar in the heart of the city is well illuminated. A modern landscaping and laying of spacious lawns along this man-made lake are a major attraction to the people in the evenings which are more comfortable and pleasant due to evaporative cooling and a light breeze over this large lake. Hussain Sagar was built by Ibrahim Quli Qutb Shah in 1563 on a northern tributary of Musi river. Hussain Sagar is over 570 sq.ha. of area with a considerable depth of 32 feet. On the southwestern side is Osman Sagar, a still bigger man-made lake over the Musi river. It covers an area of 4600 sq.ha. It was built in 1920 as a water management measure in
HYDERABAD: CITY OUTLAY AND BUILT-UP ENVIRONMENT

Fig. 3.3

Source: Adapted from Google Earth, Image Landsat, 2013
response to the devastating floods of 1908. Subsequently, Himayat Sagar dam was built on the Esi tributary of Musi in 1927. Himayat Sagar is some 20 km from Hyderabad. Himayat Sagar is southeast of Osman Sagar. Another significant waterbody is Mir Alam Tank which is slightly north east of Himayat Sagar. The 1996 municipal records mention that there were 140 lakes and 834 ponds of varying size. But many smaller ponds have been done away with by rapid urban sprawl. The breeze from the largest Osman Sagar gives respite to the city people.

The commercial areas like ABIDS between the Musi river and the Hussain Sagar is busy in its Quaternary functions. The high-rise buildings are the landmark of commercial district. Charminar is the most congested commercial area in the old city. Balanagar and Uppal are industrial areas. There are a number of mixed residential-commercial-industrial areas in the megacity of Hyderabad. The northern parts of the city are more spacious and modern yet with a higher built-up density. International Crops Research Institute for Semi-Arid Tropics (ICRISAT) is a vast expanse of agricultural research farms in Patancheru which now lies within the outer ring road of Hyderabad in the northwest. Further north, there is Patancheru industrial area. To the southeast of Patancheru industrial area lies Bharat Heavy Electricals Limited (BHEL) industrial area. A highly spacious and modern HITEC Cyber City lies to the northwest of Banjara Hills and Jubilee Hills. Maulana Azad National Urdu University lies on the rocky outcrops west of Hussain Sagar while Osmania University lies east of Hussain Sagar.

Table 3.2 depicts the decadal growth in the geographical dimension of the megacity of Hyderabad for the period 1961-2011. The table also reveals the changing demographic profile related to population, density and growth for the corresponding period. Among the three megacities under analysis in 1961 Hyderabad had the largest geographical area of 178.3 sq.km. Its total population was 1.12 million persons among the three megacities. The average population density was a medium 6,282 persons per sq.km. However, there was considerable intra-city variation in the population density. Because of the largest geographical area, there was the lowest population density among the three megacities. The average population density of Hyderabad was lower and as meagre as only 34 per cent of the density of Ahmedabad but relatively closer to the level of 58 per cent to the density of Bangalore. It clearly depicts Hyderabad to be more spacious with higher open space availability in the city in
TABLE 3.2
Hyderabad: Area, Population, Density and Growth
(1961-2011)

<table>
<thead>
<tr>
<th>Year</th>
<th>Area Sq.km.</th>
<th>Area Growth Sq.km.</th>
<th>Population (Millions)</th>
<th>Density Persons/km²</th>
<th>% Pop. Growth</th>
</tr>
</thead>
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<td>2001</td>
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<td>5.75</td>
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<td>72.9</td>
<td>7.74</td>
<td>9,106</td>
<td>34.60</td>
</tr>
</tbody>
</table>

Source: Computed from Census of India and Municipal Data.
comparison to Ahmedabad and Bangalore. The average literacy in the city was 52.95 per cent. The sex-ratio was considerably higher to 917 females per 1000 males. This is indicative of a high sex-ratio and gender sustainability at a megacity standard in a developing country.

In 1981 Hyderabad had recorded an increase in its geographical area to 371.5 sq.km. This was still the largest areal extent among the three megacities. There was a net inter-decadal area growth by 73 sq.km. during the decade 1971-1981. This indicates that Hyderabad recorded a fairly higher rate in its areal growth. The total population of Hyderabad was 2.54 million persons in 1981. The 1971-1981 aggregate decadal growth was 7,50,000 persons with an annual growth rate of a nominal 75,000 persons on a megacity standard. The decadal population growth was 41.9 per cent. The average population density was a moderate 6,852 persons per sq.km. Because of the large areal expansion, this was still the lowest population density among the three megacities. This average population density of Hyderabad was still lower to as meagre as only 39 per cent of the density of Ahmedabad but was closer to the level of 88 per cent to the density of Bangalore. This depicts a continued trend of more spacious urban growth with larger open space availability in Hyderabad as compared to Ahmedabad and Bangalore. The average literacy in Hyderabad was 57.79 per cent. The sex-ratio further increased to 919 females per 1000 males. Although it was a slight increase in the sex-ratio but it demonstrates a higher gender sustainability in the megacity.

In 1991, Hyderabad had registered a massive increase in its geographical area to 726.6 sq.km. This continued to remain the largest areal extent in Hyderabad in comparison to Ahmedabad and Bangalore. There was a largest ever net area growth of as much as 355.1 sq.km. in Hyderabad during the decade 1981-1991. This areal expansion has remained unsurpassed by Ahmedabad and Bangalore during the entire period of enquiry. The total population of Hyderabad was 4.34 million persons in 1991. The 1981-1991 aggregate decadal growth was 1,798,000 persons with an exponential annual growth rate of 1,79,800 persons in the megacity of Hyderabad. This clearly indicates an emphatic urban take-off in Hyderabad. The decadal period of 1981-1991 has witnessed a general trend of rapid urban growth in many large cities of India. The decadal population growth was exceptionally high with 70.86 per cent. The average population density was moderately low with 5,978 persons per sq.km.
Because of the massive areal growth the population density was rendered at its lowest ever among the three megacities.

The average population density of Hyderabad was still lower to as meagre as only 34 per cent of the density of Ahmedabad but was closer to the level of 60 per cent to the density of Bangalore. This distinctly low population density in Hyderabad indicated a trend of highly spacious urban growth with larger open space availability. Infact, the lowest population density in Hyderabad coupled with maximum open space availability could be attributed to the topographical constraint in Hyderabad. The undulating, rugged topography of Hyderabad surroundings prevented a contiguous city growth and allowed only sporadic habitation. Here, it is crucial to note that Ahmedabad recorded the highest population density because of the topographic permissive of the alluvial plains of the Sabarmati river. This permeated a uniform, compact and high population density in Ahmedabad. In 1991, the average literacy in Hyderabad was 59.37 per cent. The sex-ratio considerably increased to 930 females per thousand males. This fairly high growth in the sex-ratio could also be assigned to a comparatively easy space availability in the wake of largest areal expansion of Hyderabad during 1981-1991.

In 2001, Hyderabad recorded a geographical extant of 778.1 sq.km. This continued to claim the largest areal extent for Hyderabad among the three megacities. There was a net area growth by 51.5 sq.km. during the decade 1991-2001. The total population of Hyderabad was 5.75 million persons. Hence, Hyderabad qualified as a megacity by the census 2001. The 1991-2001 aggregate decadal growth was 1,408,000 persons with an annual growth rate of 1,40,800 persons in Hyderabad. This continued to show a high population growth rate. The decadal population growth was 32.48 per cent in Hyderabad. The average population density was a moderate 7,391 persons per sq.km. The population density showed a fairly reasonable growth. Comparatively speaking, the average population density of Hyderabad was lower to as less as 49 per cent of the density of Ahmedabad but was closer to the level of 64 per cent to the density of Bangalore. The moderate population density in Hyderabad is indicative of a trend of spacious urban growth with larger open space availability. In 2001 the average literacy rose to 68.37 per cent. The sex-ratio marginally increased to 931 females per 1000 males.
In 2011, Hyderabad registered a geographical area of 851 sq.km. This remained the largest areal expansion among the three megacities. There was an increased net area growth by 72.9 sq.km. during 2001-2011. The total population of Hyderabad also increased to 7.74 million persons. The 2001-2011 aggregate decadal growth in Hyderabad was the highest ever 1,994,000 persons with an annual growth rate of 1,99,400 persons in Hyderabad. This depicts a high population growth with an urban culmination in the wake of rapid globalization in India. The aggregate population growth of Hyderabad was 5.95 million persons during a period of 40 years from 1971-2011. The decadal population growth was 34.6 per cent in Hyderabad. The average population density grew to 9,106 persons per sq.km. Although this population density is in the category of moderate density but it is very close to qualify the high population density. In comparative terms, the average population density of Hyderabad was lower, but as close as 67 per cent to the density of Ahmedabad and was also closer to the level of 75 per cent to the average population density of Bangalore. A throughout moderate population density of Hyderabad is indicative of a persistent trend of spacious urban growth with larger open space availability. In 2011 the average literacy of Hyderabad was 79.93 per cent. The sex-ratio further improved to 935 females per 1000 males. This augurs well for the gender equality and sustainability in Hyderabad.

**Bangalore : City Size and Morphology**

Figure 3.4 displays the physiographic outlay of Bangalore with its city morphology. It shows the spread of prominent waterbodies in the city premises. It shows the location of Bangalore and Malur town. Bangalore is the primate city of Karnataka state and has a population of 8.53 million persons with a geographical area comprising 702.7 sq.km in 2011. Today, the city has a burgeoning urban landscape due to unprecedented globalization and the uncontrolled migration of both the skilled and unskilled labour. Bangalore is situated on the Karnataka plateau over the Pre-Cambrian rocks at an altitude of 920 metres (3065′) above mean sea level. Vidyanarayanpura in the northwest has the highest elevation of 962 metres (3156′). Bangalore has the highest altitudinal location among all the megacities of India. The megacity is seated on an undulating surface. Hence, there is considerable variation in
BANGALORE: CITY OUTLAY AND BUILT-UP ENVIRONMENT

Source: Adapted from Google Earth, Image 2016 Digital Globe

Fig. 3.4

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the amplitude of relief. The western part of the city is particularly hilly and undulating. Although, no major river flows through the city, still, however, due to the undulating surface, Bangalore has a large number of run-off lakes and ponds. In 1961 municipal records, there were as many as 262 lakes and tanks in and around the city. However, a recent satellite imagery in 2006 depicted only 33 visible lakes.

Bangalore sustains on a large number of freshwater lakes and tanks. In the wake of depleting waterbodies the city now draws nearly 80 per cent of its water supply from Kaveri river. Hebbal lake is in the northern extremity of the city. Ulsoor lake is within the Central Business District of the city, northeast of M.G. Road. Another significant waterbody is Yediyur lake. Madivala tank is the largest. Hesaraghatta lake lies in the northwest. Hennagara lake is in the southwest while Muthanallur lake lies in the southeast. Sankey tank lies in the western part of the city is 15 sq.ha. in area. A large Cubbon Park lies just across Vidhana Soudha and Karnataka High Court in the modern city. Lalbagh is another major green spot. Bangalore has the largest population size among the three megacities with the second largest areal extent. On the whole, Bangalore has a high index of urban greenery and because of avenue greenery it is called the Garden City of India. It is because of the large extent of greenery in the city which possibly tends to offset the potentially higher urban heat island intensity.

Bangalore is a software capital of Information Technology based industries in India. The city takes a lead in service-based industries. Resultantly, it has a spacious city morphology. It is called the Silicon Valley of India. Silicon Valley is the Technological Innovation Hub of India. Whitefield in the east is a major Information Technology industrial area. Electronic city in the southeastern part is a cyber hub of the city. Bangalore is the headquarters of ISRO, Wipro and Infosys Undertakings. Hence, the opulent landscape of these mini cities within the megacity is highly spacious and bears a modern urban look par excellence. Peenya in the northeast is one of the largest industrial complexes in the country. Yelahanka industrial area in the north has a large concentration of silk handloom, dairy industry, rail road factory and chemical and pharmaceutical industries. Hindustan Aeronautics Limited (HAL) is a defense enforcement industry. It makes aircrafts and helicopters. It has a number of establishments in the eastern part of the city. The pollution inducing Peenya Industrial Estate in the northwest and the highly modern Information Technology ‘Silicon
Valley’ in the southeast are diametrically opposite and distant apart. The imposing Vidhan Saudha and the Karnataka High Court are in the eastern part of the city. Southeast of Vidhan Saudha is the Mahatma Gandhi Road, Central Business District. The famous Chinnaswamy Cricket Stadium is in the vicinity of M.G. Road and lies between Cubbon Road and Queens Road in the highly modern locality of the Central Business District.

Table 3.3 illustrates the decadal growth in the geographical area of the megacity of Bangalore for the period 1961-2011. It also depicts the changing demographic features such as population, density and growth for the corresponding period. In 1961 Bangalore had a geographical area of 112 sq.km. Its total population was only 1.2 million persons only. At this stage in 1961, Bangalore had the largest population among the three megacities. Now, in 2011, Bangalore has become the largest populated among the three megacities. The average density of population was a medium 10,777 persons per sq.km. This density was very close to the high population density. However, there was a considerable intra-city variation in the population density. The average population density of Bangalore was 59 per cent of the density of Ahmedabad but higher to the average density of Hyderabad by as much as 172 per cent. This depicts that Bangalore was more spacious than Ahmedabad but more congested than Hyderabad in the threshold period of reckoning i.e. 1961. The average literacy in the city was 58.9 per cent. The sex-ratio was a low 874 females per 1000 males. The low sex-ratio suggests that there was lower gender sustainability in Bangalore.

In 1981, Bangalore had recorded a considerable increase in its geographical area to 365.6 sq.km. There was a large net area growth by as much as 190.9 sq.km. during the decade 1971-1981. The total population of Bangalore was 2.92 million persons in 1981. The 1971-1981 aggregate decadal growth was 1,268,000 persons with an annual growth rate of 1,26,800 persons. This was a large population growth. This population growth indicates that Bangalore entered into the urban take-off stage as early as in the decade 1971-1981. While the other megacities, namely, Ahmedabad and Hyderabad entered the urban take-off stage later in the decade 1981-1991. The early urban take-off stage in Bangalore was the result of appropriate and urban incentive policy measures. This decadal population growth was all time highest at 76.96 per cent among all the three megacities. Because there was a very large area
### TABLE 3.3

Bangalore: Area, Population, Density and Growth (1961-2011)

<table>
<thead>
<tr>
<th>Year</th>
<th>Area Sq.km.</th>
<th>Area Growth Sq.km.</th>
<th>Population (Millions)</th>
<th>Density Persons/km²</th>
<th>% Pop. Growth</th>
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</table>

Source: Computed from Census of India and Municipal Data.
growth in Bangalore during 1971-1981, the average population density increased to 7,990 persons per sq.km. In comparative terms, the average population density of Bangalore was lower to as less as 45 per cent of the density of Ahmedabad but slightly higher to the average density of Hyderabad by 117 per cent. The average literacy in the city was 63.53 per cent. The sex-ratio considerably improved to 895 females per thousand males. This sex-ratio, however, was still below an appreciable level with respect to gender sustainability in Bangalore.

In 1991, Bangalore registered an increase in its geographical expanse to 413.1 sq.km. There was a small net area growth of 47.5 sq.km. during the decade 1981-1991. The total population of Bangalore was 4.13 million persons in 1991. The 1981-1991 aggregate decadal growth was 1,208,000 persons in the megacity of Bangalore with an emphatic annual growth rate of 1,20,800 persons. This shows a continuously impressive population growth in Bangalore. The decadal population growth was 41.43 per cent. The average population density was a moderate 9,997 persons per sq.km. In a comparative analysis the average population density of Bangalore was lower by as less as 58 per cent of the density of Ahmedabad but considerably higher to the average density of Hyderabad by as much as 167 per cent. The average literacy in Bangalore was 69.31 per cent. The sex-ratio slightly improved to 904 females per 1000 males. This sex-ratio still remained below an appreciable level in terms of gender sustainability in Bangalore.

In 2001, Bangalore recorded a geographical area of 492.5 sq.km. There was a sizeable net area growth of 79.4 sq.km. during the decade 1991-2001. The total population of Bangalore was 5.7 million persons in 2001. Hence, Bangalore qualified to a megacity status by the census 2001. It is crucial to note that both Hyderabad and Bangalore became the megacities in 2001 while Ahmedabad could grow into a megacity as late as by 2011. In Bangalore, the aggregate decadal growth during 1991-2001 was 1,571,000 persons with an annual growth rate of 1,57,100 persons. It continued to show an increasing population growth. The decadal population growth was 38.01 per cent in Bangalore. The average population density was a high 11,545 persons per sq.km. This population density showed a fairly reasonable growth. In comparative terms, the average population density of Bangalore was lower but as close as 76 per cent to the population density of Ahmedabad. However, it was considerably higher than the average population density of Hyderabad by 156 per
In 2011, Bangalore registered an increase in its geographical area to 702.7 sq.km. This remained the largest ever, areal expansion of 210.2 sq.km. in Bangalore during the decade 2001-2011. The total population of Bangalore increased to 8.53 million persons in 2011. The 2001-2011 aggregate decadal growth in Bangalore was the highest ever 2,831,000 persons with an annual growth rate of 2,83,100 persons. This was also the largest ever population among the three megacities. The aggregate population growth of Bangalore was 6.88 million persons during a period of 40 years from 1971-2011. This reveals a high population growth with an urban culmination in the wake of rapid globalization in India. The decadal population growth was 49.65 per cent during 2001-2011. The average population density in Bangalore also increased to a highest ever 12,142 persons per sq.km. despite the largest areal growth of the city. This was possible only because of the largest aggregate population growth. Comparatively speaking, the average population density of Bangalore was lower with as close to 89 per cent to the density of population in Ahmedabad. However, it was considerably higher than the average population density of Hyderabad by 133 per cent. The average literacy of Bangalore further increased to 83.12 per cent. The sex-ratio considerably increased to 917 females per 1000 males. It indicates that the gender sustainability is continuously improving in Bangalore.

Figure 3.5 illustrates a decadal urban expansion of Ahmedabad from 1971-2011. Ahmedabad has comparatively the smallest urban expansion among the three megacities. In 1971 Ahmedabad had a small core area extent of 108.2 sq.km. The city had an almost squarish orientation. It extended on either side of Sabarmati river. A little over one-third of the urban expanse was to the west of Sabarmati and the remaining two-thirds of the urban extent was east of Sabarmati river. As the city of Ahmedabad originated and evolved to a greater period, to the east of the river, it suggests a higher urban gravity on the eastern side. This is evident from the subsequent urban expansion predominantly on the eastern side of the river. The earlier ratio of west-east growth of the city still continues. In 1981, Ahmedabad experienced an expansion to 145 sq.km. There was a small inter-decadal net area growth of 36.8 sq.km. This was the smallest decadal expansion among all the three megacities.
In 1991, the city recorded a geographical expansion to 190.8 sq.km. The inter-decadal net area growth was 45.8 sq.km. This was consecutively a small area growth. It shows that the city expansion did not witness a take-off stage till 1991. In 2001 the geographical area of Ahmedabad expanded to 298 sq.km. The 1991-2001 decadal area growth was a good 107.2 sq.km. By 2011, the geographical area of Ahmedabad expanded to 466 sq.km. The decadal net area growth was largest 168 sq.km. The hand-shaped areal expansion of Ahmedabad reveals its expansion along the radiating highways. The city which had a compact layout in 1971 has witnessed an irregular areal growth by 2001. In the last 40 years during 1971-2011 Ahmedabad recorded a net areal growth of 357.8 sq.km. This was a 331 per cent urban area growth.

Fig. 3.5
The highest built-up density in Ahmedabad is in the inner nuclei of the city. The built-up density has a tendency to decrease towards the fringe. Hence, there is an apparent core-periphery of differential in the built-up density of Ahmedabad. The highest built-up densities in Ahmedabad are in the traditional areas to the east of Sabarmati river. There are a number of very high to high built-up density nuclei to the east of the Sabarmati with only one pocket of very high built-up density to the west of the river. Over 65 per cent of the population of Ahmedabad is concentrated to the east of the river.

The city of Hyderabad was built by Mohammad Quli Qutb Shah, who was the founder of the glorious Qutb Shahi Dynasty, in 1591. The city settlement was originated on the southern flank of Hussain Sagar Lake which was constructed by Hussain Shah Wali in 1562 for the domestic and irrigational use. Hyderabad was built on a strategic location in peninsular India. The city is perched on an undulating landform at 500-600 metres of elevation above mean sea level. The old Hyderabad is located to the south of Hussain Sagar while the twin city of Secunderabad is located to the north of Hussain Sagar. In the western part of the city are posh and prosperous colonies like Banjara Hills, Jubilee Hills, Nanbat Pahad and Golconda which are perched on granite formations. In the east the surface is markedly leveled. In some areas of the city there are residual hills and pediment landform with rock pedestals and strewn talus. The boulder outcrops depict the processes of physical weathering and sub-aerial denudation. In several parts of the city, the residual landforms have been encroached upon by extensive urban sprawl and cyber enclaves. Stone quarrying to sustain the modern building construction has inflicted considerable damage to the neighbouring environment.

Musi River which is a depleted tributary of Krishna runs through the middle of the city and divides it into northern and southern halves. At times of heavy rains, Musi witnesses mild floods thereby inundating the adjacent city areas. A recent flood was experienced in the year 2008. The city and surrounding of Hyderabad in its evolutionary history has sustained on over 1,000 small and big water bodies. Most of these water bodies were the product of undulating topography of the denuded plateau. Upto 1971 there were as many as 935 water tanks in and around Hyderabad which got reduced to nearly 800 water bodies by 2011. The major water tanks in the city and its surroundings are Hussain Sagar, Mir Alam Tank and Himayat Sagar. Microclimate of
Hyderabad has considerably changed in the last 50 years. Industrial and Vehicular pollution has considerably raised the city temperature during the longer summers with longer days.

Figure 3.6 depicts that an amicable Musi river played a crucial role in orienting the expansion of the city into an east-west axis. Recently, the highways radiating from the city have played a major role in defining the geography of city sprawl. The present axis of the city growth is in a northwest-southeast orientation to complement the trade outlet with Mumbai, Bangalore and Chennai. Hyderabad is also growing towards northeast direction. The figure shows that in 1971 Hyderabad had the largest urban expansion. It was up to 298.5 sq.km. in area. Most of the city growth
was north of Musi river. In 1981 the city witnessed an expansion to 371.5 sq.km. in its geographical area.

There was a net area expansion of 73 sq.km. during this inter-decadal period. In 1991, the city recorded an areal expansion to 726.6 sq.km. This was the largest net area growth of 355.1 sq.km. By 2001, the geographical expanse of Hyderabad reached to 778.1 sq.km. with a net area growth of 51.5 sq.km. In 2011 the city acquired a geographical extent of 851 sq.km. The net area expansion was 72.9 sq.km. In the last 40 years from 1971-2011, Hyderabad witnessed a net areal growth of 552.5 sq.km. This was the largest areal expansion with a cumulative 185 per cent growth.

The built-up density is very high in the inner nuclei of the city. The built-up density tends to decrease towards the city periphery. There is a visible core-periphery differential in the built-up density of the city. However, there are a few pockets of higher built-up density in the peripheral areas also. These higher built-up densities could be seen in the newly emerging high-rise residential buildings as well as in the industrial districts towards the inner fringe of the megacities. The highest built-up density in Hyderabad is in the core area of the old city on either side of the Musi river. This highest built-up density area is a mixed residential cum business area towards the south. Another major area of high built-up density is in the northeastern part of Hyderabad. This is residential cum commercial area in Secunderabad and its east. The low built-up density is in the inner fringe while the lowest built-up density in the outer fringe of Hyderabad in the south, west and northwest.

Bangalore is located on the undulating topography of the weathered plateau of Karnataka at 920 metres above mean sea level. This topography coupled with a long rainy period and good amount of rainfall produces a large number of water bodies in and around the city. And because of relatively high altitude coupled with moderate temperatures the tanks or water bodies do not shrink much even during the summer months. These conditions support the water bodies to be more sustainable for the urban function and rural economy. There are rock outcrops and granitic batholiths in the surroundings of Bangalore.

The megacity of Bangalore originated as a small trading town in the year 1537. Bangalore was strategically developed by the British regime after the Indian Mutiny of 1857. By 1872 the Bangalore Cantonment became much bigger with a
population of 83,300 persons against the Bangalore city population of 61,200 persons. It became a city of over one lakh population in the mid-nineteenth century. However, due to its economic and cultural gravity, the city population rapidly increased with the result that in 1921 the city population exceeded over the cantonment population. The population of Bangalore almost doubled during 1941-1951 because this south Indian city did not experience an out-migration to Pakistan in the wake of partition of India and Pakistan in 1947. Bangalore’s continued growth qualified it as a million city in the 1950s itself. Till 1971, Bangalore was India’s sixth largest city next to Hyderabad. In 1981 it surpassed Hyderabad to occupy the rank of fifth largest city and continues to maintain the fifth rank till the year 2015. If the trend of its rapid growth continues, Bangalore would surpass the population of Chennai to become the fourth largest city of India by 2021.

Figure 3.7 depicts a decadal urban expansion of Bangalore from 1971 to 2011.
In 1971 the city had a core area extent of 174.7 sq.km. Most of the city expanse was in a north-south alignment. In 1981 the city witnessed an expansion to 365.6 sq.km. This was a large decadal net area growth of 190.9 sq.km. In 1991, Bangalore recorded an expansion in its geographical area of 413.1 sq.km. The inter-decadal area growth during 1981-1991 was a modest 47.5 sq.km. of net area growth. In 2001 this recorded an areal expansion to 492.5 sq.km. This was a moderate inter-decadal net area growth of 79.4 sq.km. The city has witnessed an outgrowth in a southwest and northeast axis.

It has also experienced its urban expansion along the north-south axis. Infact the city outgrowth is taking place along the major radiating highways from its C.B.D. In the year 2011, Bangalore recorded its total urban expansion to 702.7 sq.km. The inter-decadal area expansion was the largest 210.2 sq.km. In the last 40 years from 1971-2011, Bangalore has recorded a net areal growth of 528 sq.km. This areal expansion registered an average 302 per cent urban area growth.

III Urbanization, Landuse and Built-Up Density of the Megacities

Urban heat island intensity may significantly be related to the processes of urbanization as well as some other qualitative aspects unrelated to urbanization. However, the processes of urbanization may include the urban population growth, urban built-up area growth and urban infrastructural growth such as the urban vehicular growth, industrial pollutant chimneys, commercial air-conditioning and the like. The qualitative aspects include changing lifestyle, increasing per capita consumption and growing per capita wastage of resources particularly in the megacities of the developing countries like India where waste disposal is far from adequate and the waste recycling is almost non-extent in many Indian cities. Conservation ethics is poor among the neo-rich. For example, conservation ethics on energy utilization (electricity) in the public sector domain like classrooms and offices is a sight of neglect and unconcern. The problem is also related to the lack of urbanism as well as the degree of urbanization or urban sprawl. There seems an equally compound problem of behavioral ethics and lack of awareness towards the environmental issues.

During 1961-2011 period of urbanization, the megacity of Ahmedabad has witnessed 452 per cent population growth followed by 639 per cent built-up area
growth. The number of vehicles recorded a 113 per cent growth from 9,08,356 automobiles in 2001 to 1,935,726 vehicles in 2011. Similarly, the megacity of Hyderabad has experienced 591 per cent population growth followed by 377 per cent area growth. The number of vehicles recorded a 113 per cent growth from 1,091,734 road vehicles in 2001 to 2,326,028 vehicles in 2011. Likewise, the megacity of Bangalore has recorded 607 per cent population growth. This is followed by 527 per cent built-up area growth. The number of vehicles recorded a 170 per cent growth from 1,438,057 vehicles in 2001 to 3,886,441 automobiles in 2011.

Table 3.4 illustrates the decadal changes in the landcover and landuse in the Ahmedabad Urban Agglomeration Region from 1971 to 2011. The major landcover and landuse changes have been shown in the categories of mixed built-up residential and commercial areas, land under various crops, area under parks or gardens or public or semi-public category. It also shows the area under scrubland or grasses. The area under industrial landuse has been shown in and around the megacity. Apart from it the extent of open land and water bodies have also been shown. The areal extent of the landcover and landuse categories have been shown in percentages of the changing total geographical area for the respective decades.

Out of a total urban agglomeration area of 108.2 sq.km. in 1971 the mixed residential and commercial landuse comprised 21.76 per cent of the total geographical area. This coverage is second to the cropland area in the entire urban agglomeration of Ahmedabad. The largest cropland coverage was 56 per cent of the total area under scrutiny. Parks or gardens or the public greenery represented 5.35 per cent of the total area. Scrubland or grasses reported 4.56 per cent of the total geographical area under analysis. Ahmedabad recorded a significant industrial area coverage of 3.61 per cent of the total area. Next areal coverage was recorded in the open land category with an extent of 3.34 per cent of the total area. Water bodies registered an areal extent of 3.1 per cent. The area under educational landuse was a paltry 0.7 per cent of the total area.

In 1981, the urban agglomeration area of Ahmedabad increased to 145 sq.km. Out of this total area the mixed residential and commercial landuse covered 26.93 per cent of the geographical area. The inter-decadal percentage growth difference was 5.17 per cent expansion during 1971-1981. The percentage cropland in 1981 covered
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**Source:** Adapted from Iyer *et al.* and National Remote Sensing Agency, Hyderabad.
a high 52.83 per cent of the total area. Although the inter-decadal change witnessed a negative percentage growth difference of -3.17 per cent area reduction during 1971-1981, however, in actual terms there was an increase in the aggregate crop area coverage because of increase in the total geographical area under the command of the city. The percentage area under parks or gardens was a low 4.21 per cent. The inter-decadal change recorded a negative percentage growth difference of -1.14 per cent area reduction. The scrubland or grass cover reported an area of 3.51 per cent in the vicinity of Ahmedabad.

The low scrubland coverage was due to the environmental constraint of arid to semi-arid conditions. However, the inter-decadal change recorded a negative percentage difference growth of -1.05 per cent area reduction. Ahmedabad, the largest producer of cotton textiles has a considerable industrial coverage of 4.18 per cent of the total geographical area. The inter-decadal percentage area growth difference was 0.57 per cent expansion during 1971-1981. The area coverage in the open land category was 2.78 per cent of the total area. The open land coverage in Ahmedabad recorded a lower percentage in comparison to Hyderabad and Bangalore. The inter-decadal change in open land witnessed a negative percentage growth difference of -0.56 per cent during 1971-1981. The water body area recorded a low 2.72 per cent of the total area due to the climatic constraint. The inter-decadal change has witnessed a negative percentage growth difference of -0.38 per cent. Among the significant social factors, the educational landuse comprised a small 0.92 per cent of the total geographical area in Ahmedabad. The inter-decadal percentage area growth difference in education was 0.22 per cent expansion during 1971-1981.

In 1991, the urban agglomeration area of Ahmedabad expanded to a total of 190.8 sq.km. Out of this total geographical area, the mixed built-up residential and commercial landuse comprised the highest 40.77 per cent area which for the first time surpassed the percentage cropland coverage. The inter-decadal percentage growth difference was the highest 13.84 per cent during 1981-1991. The percentage cropland in 1991 represented a reduced 36.41 per cent of the total area. The inter-decadal change witnessed a negative growth differential of -16.42 per cent area reduction during 1981-1991. The percentage area under parks and gardens covered 4.4 per cent of the total area. The inter-decadal percentage growth differential was 0.19 per cent expansion in the parks and gardens.
The percentage scrubland or grass land in 1991 represented 4.23 per cent of the total area. The inter-decadal percentage growth differential was 0.72 per cent area expansion. The percentage industrial area coverage was a sizeable 4.85 per cent in 1991. The inter-decadal percentage area growth difference was 0.65 per cent expansion. The open land percentage area was 3.26 per cent of the total area in 1991. The inter-decadal percentage growth difference was a moderate 0.48 per cent expansion. In 1991 the percentage water bodies area recorded 1.67 per cent of the total area. The inter-decadal percentage water bodies area change witnessed a negative growth difference of -1.05 per cent. The percentage education area in Ahmedabad in 1991 reported 1.71 per cent of the area. Although this was a moderate area coverage, the inter-decadal percentage growth difference, in the capital city, was 0.79 per cent expansion during 1981-1991.

In 2001, the urban agglomeration area of Ahmedabad expanded to a total geographical area of 298 sq.km. Out of the total geographical area the mixed built-up residential and commercial landuse represented the highest 41.47 per cent area exceeding over the cropland in its extent. The inter-decadal percentage area growth difference was a nominal 0.70 per cent during 1991-2001. The percentage cropland area in 2001 reported a slightly reduced 36.12 per cent of the total area. The inter-decadal change witnessed a negligible negative growth difference of -0.29 per cent area reduction during 1991-2001. The percentage area under parks or gardens covered 3.71 per cent of the total area. The inter-decadal change witnessed a negative growth differential of –0.69 per cent reduction in the parks and gardens in proportion to the highly enlarged total geographical area.

The percentage scrubland and the coarse grasses in 2001 registered a considerably reduced 2.17 per cent to the total area. The inter-decadal change noted a negative growth differential of -2.06 per cent reduction during 1991-2001. The percentage industrial area coverage was a handsome 5.07 per cent of a large geographical area. The inter-decadal percentage area growth difference was a modest 0.24 per cent expansion in the wake of a very large increase in the total area. The percentage area under open land was 2.89 per cent of the total area. Its inter-decadal change reported a negative growth difference of -0.37 per cent area reduction during 1991-2001. The percentage area under water bodies has reported a decreasing 1.45 per cent to the total area. The inter-decadal percentage growth difference was -0.22
per cent reduction. The educational area change is a very important social indicator. The percentage educational area in Ahmedabad was a growing 2.53 per cent of the total area. The inter-decadal percentage growth difference was 0.82 per cent expansion during 1991-2001.

Figure 3.8 illustrates the landuse landcover scenario for Ahmedabad for the period 2005-2006. It has been generated from the multi-temporal satellite data of Resourcesat-1, LISS III. This satellite generated map covers a total geographical area of 382 sq.km. It depicts the major landuse categories such as the built-up residential, commercial, industrial and institutional areas. The rural built-up areas and mining spoils have also been covered. Among the agrarian landuse cropland, plantations and fallow lands have been shown in different yellow hues. Among the land cover categories are shown the scrubland and grasses.

Other land cover categories comprise the barren and unculturable wastes as well as the gullies and ravine lands in purple to violet hues. Water bodies, streams and wet lands have also been depicted in the conventional blue colour. It also depicts a well laid out transportation arteries. The built-up expanse is fairly compact. There is a tendency of the built-up area to sprawl along the radiating transportation lines. The built-up city expanse in 2005-2006 has spread well outside the inner ring road. The built-up area is sprawling mostly east of the Sabarmati river. Most of the city is well within the outer ring road.

Agricultural fallow land can be seen all around the city built-up area. Most of the fallow lands can be seen towards the western and northern fringes of the city. It is surprising to see the agricultural fallow land just outside the gravity of a megacity. Generally, there is a higher agricultural intensity without fallow lands in the close vicinity of the major cities. It is quite likely that the fallow lands along the outer ring road are actually not the agricultural fallow of the farmers. These fallow patches may infact be the non agricultural land purchased by the industrial and commercial houses for their future infrastructural development.

Kankaria lake to the east of Sabarmati river is a major water body well within the inner ring road. The gullied and ravenous areas can be noticed along the tributary stream on the eastern margin. Barren and unculturable wastes can be seen to the west and north of the Sabarmati River in the violet hue. The built-up area shows a
Fig. 3.8
maximum extension along the National Highway No. 8A towards the south-westerly directions. The major axis of the city growth is along the north-east and south-westerly directions.

Fig. 3.9 demonstrates the landuse and landcover condition of Ahmedabad for the period 2011-2012. The information has been harnessed from the multi-temporal satellite data of Resourcesat–2, LISS III. It covers an extended geographical area of 466 sq.km. It displays the major landuse categories covering the built-up residential, commercial, industrial and institutional areas. Because of its multi-temporal data the agricultural landuse depicts the area under the monsoon or Kharif season, the area under winter or Rabi season and a marginal proportion under hot, dry summer crop of Zaid. This is a very crucial imagery from the view of double or even triples cropping under the stimulating urban gravity of a megacity. It clearly reveals a very high order of agricultural intensity propelled by the city market. A very high proportion of multiple cropping area can be seen closely surrounding the city accessibility.

In addition to the main Kharif and Rabi crops, there is a distinctly high proportion of Zaid crops particularly in the western and northern outcrops of the city. There is a sizeable occurrence of current fallow strangely along the major roads. The occurrence of fallow land along the highly accessible transportation routes is unnatural. This location-association of current fallow suggests that it is no longer under agricultural landuse. The presence of scrubland and grassland is relegated to the outer fringe of the city. The major water body in the northwestern part of the imagery is Thol lake. Kankaria lake and Vastrapur lake is in the old city region within the inner ring road. It can be clearly differentiated from the figures of 2005-2006 and that of 2011-2012 that the built-up area in the later figure has expanded beyond the outer ring road in all the directions.

The mixed built-up residential and commercial landuse in 2011 represented the highest 48.51 per cent of the total area. The inter-decadal percentage area growth difference was a high 7.04 per cent urban expansion. The overall mixed built-up area change from 21.76 per cent in 1971 to 48.51 per cent in 2011 showed a positive percentage growth difference of 26.75 per cent in 40 years. The percentage cropland area in 2011 comprised a decreasing 27.06 per cent of the total area. The inter-decadal change observed a significant negative growth difference of -9.06 per cent reduction.
in the cropland coverage. The overall cropland area change from 56 per cent area in 1971 to only 27.06 per cent area in 2011 showed a very high negative growth difference of -28.94 per cent. The highest percentage decrease in the cropland coupled with the highest 26.75 per cent increase in the built-up area is a clear evidence that most of the urban expansion of Ahmedabad has occurred by an encroachment upon the agricultural land in the immediate vicinity of the city.

The percentage area under parks and gardens covered 3.19 per cent of the total area in 2011. The inter-decadal change witnessed a negative growth differential of -0.52 per cent reduction. The overall parks and gardens area change from 5.35 per cent in 1971 to 3.19 per cent of the corresponding area in 2011 showed a negative percentage growth difference of -2.16 per cent area reduction. The percentage area under scrubland and grasses covered 2.64 per cent of the total geographical area in 2011. The inter-decadal change witnessed a growth differential of 0.47 per cent expansion. The overall scrubland and grassland area change was from 4.56 per cent in 1971 to 2.64 per cent area in 2011 showed a negative percentage growth differential of -1.92 per cent reduction in a period of 40 years. The percentage area under industrial expanse in 2011 covered 5.19 per cent of the corresponding total area. The inter-decadal percentage growth difference was a meager 0.12 per cent expansion. The overall industrial area change was from 3.61 per cent in 1971 to 5.19 per cent area in 2011. It showed a positive percentage growth differential of 1.58 per cent expansion in 40 years.

The percentage area under open land covered 3.17 per cent of the total area in 2011. The inter-decadal percentage growth difference was a small 0.28 per cent expansion. The overall open area change was from 3.34 per cent in 1971 to 3.17 per cent area in 2011. It showed a negative percentage growth of a paltry 0.17 per cent reduction. The percentage area under water bodies represented 1.32 per cent of the total area in 2011. The inter-decadal percentage change witnessed a negative growth differential of -0.13 per cent reduction. The overall change in the water bodies was from 3.1 per cent area in 1971 to 1.32 per cent area in 2011. It showed a negative percentage growth difference of -1.78 per cent reduction. The percentage area under educational expanse comprised a good 3.46 per cent of the total geographical area in 2011. The inter-decadal change witnessed a growth differential of a sizeable 0.93 per cent expansion. The overall educational area change was from 0.70 per cent in 1971
to 3.46 per cent area in 2011. It showed an overall positive percentage growth differential of 2.76 per cent expansion in 40 years.

Table 3.5 demonstrates the decadal changes in the land cover and land use in the Hyderabad Urban Agglomeration Region for the period from 1971-2011. This is a means to understand the decadal urban expansion of the city. The major land cover and land use changes have been shown in the categories of mixed built-up residential and commercial areas. A major coverage of scrubland and grassland has been demonstrated along with the land under the crop cover, area under parks and gardens. It also shows the area under scrubland or grasses. The area under industrial land use has been shown in and around the megacity. The extent water bodies and open land has also been depicted. The area covered by barren rocky land has also been shown. The extent of land cover and land use categories has also been shown in proportion to the total geographical area.

Out of the total urban agglomeration area of 298.5 sq. km. in 1971 the mixed built-up residential and commercial land use comprised 22.56 per cent of the total geographical area. The aggregate residential-commercial area of Hyderabad in 1971 was 67.34 sq. km. as against the residential-commercial extent of only 23.54 sq. km. in Ahmedabad. In Hyderabad the largest land cover extent was in the scrubland and coarse grasses category representing 54.09 per cent of the total area in 1971. The cropland strangely covered an area of only 6.43 per cent of the total area. Industrial coverage was only 1.11 per cent of the total urban agglomeration area.

The land cover extent of water bodies was comparatively higher with 4.86 per cent of the total area. Open land also represented a fair extent of 3.16 per cent of the total area. Barren rocky extent also represented a sizeable 3.12 per cent of the total area. Parks, gardens and public utility area covered 2.77 per cent of the total extent. The educational area in Hyderabad covered 0.89 per cent of the total area in 1971. This was higher to the corresponding coverage of 0.70 per cent educational area in Ahmedabad. However, in aggregate terms the educational area covered in Hyderabad was much higher comprising 2.66 sq. km. in 1971 as compared to aggregate educational area coverage of only 0.76 sq. km. in Ahmedabad. Hyderabad had more than three times the educational area than Ahmedabad in 1971.
## TABLE 3.5

Hyderabad UA: Percentage Land Use/Land Cover Changes

(1971 - 2011)

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Source: Adapted from Iyer et al. and National Remote Sensing Agency, Hyderabad.
In 1981 the urban agglomeration area of Hyderabad increased to 371.5 sq. km. Out of this total area the mixed built-up residential and commercial area was 32.11 per cent of the total agglomeration area in 1981. The inter-decadal percentage growth difference was 9.55 per cent expansion during 1971-1981. The percentage scrubland and grassland cover was 43.16 per cent of the total area. The inter-decadal percentage change witnessed a negative growth difference of -10.93 per cent area reduction. The percentage cropland in 1981 comprised 6.21 per cent of the total geographical area. The inter-decadal percentage change witnessed a negative growth difference of -0.22 per cent reduction. The percentage industrial area in Hyderabad comprised 1.72 per cent of the total geographical area in 1981. The percentage water bodies in 1981 covered 4.86 per cent of the total area. There was no inter-decadal percentage change in the extent of water bodies during 1971-1981. The percentage industrial area in the open land category was 3.16 per cent of the total area. There was again no inter-decadal percentage change in the extent of open land during 1971-1981. The percentage barren rocky land in 1981 covered 3.12 per cent of the total area. Once again, there was no inter-decadal percentage change in the extent of barren rocky area. The percentage under parks and gardens represented 2.77 per cent of the total area. The inter-decadal percentage change witnessed a zero growth per cent. The percentage educational area covered 1.34 per cent of the total area in 1981. The inter-decadal percentage growth difference was 0.54 per cent area expansion.

In 1991, the urban agglomeration area of Hyderabad increased to 726.6 sq. km. This was suddenly a very large area increase. Out of this total geographical area, the percentage mixed built-up residential and commercial area covered 32.31 per cent. The inter-decadal percentage growth difference was of 0.2 per cent expansion during 1981-1991. The percentage scrubland and coarse grasses in 1991 covered only 4.31 per cent of the total area. The inter-decadal percentage area change witnessed a massive negative growth difference of -38.85 per cent reduction during 1981-1991. This was the largest inter-decadal area reduction among all the land use and land cover categories. The percentage cropland area in 1991 represented 9.36 per cent of the total area. The inter-decadal percentage growth difference was 3.15 per cent expansion. The percentage industrial area in 1991 comprised 3.84 per cent of the total geographical area. The inter-decadal percentage growth difference was of 2.12 per cent expansion. The percentage water bodies in 1991 covered 3.59 per cent of the
total agglomeration area. The inter-decadal percentage change witnessed a negative growth difference of -1.27 per cent area reduction.

The percentage area under open land category in 1991 covered a very large 24.08 per cent of the highly total geographical area in 1991. The inter-decadal percentage growth difference was a very high 20.92 per cent area expansion. The percentage barren and rocky land in 1991 reported 1.21 per cent of the total area. The inter-decadal percentage change witnessed a negative growth difference of -1.91 per cent area reduction. The percentage parks and gardens in 1991 recorded 7.07 per cent of the total area. The inter-decadal percentage growth difference was 4.3 per cent area expansion. Among the social well-being land use category the percentage educational area covered 1.97 per cent of the total area. The inter-decadal percentage growth difference was 0.63 per cent expansion.

In 2001, the urban agglomeration area of Hyderabad increased to 778.1 sq. km. Out of this total geographical area the mixed built-up residential and commercial land use covered 36.62 per cent area. The inter-decadal percentage growth difference was 4.31 per cent expansion. The percentage scrubland and coarse grasses in 2001 represented 1.99 per cent of the total area. The inter-decadal percentage change witnessed a negative growth difference of -2.32 per cent area reduction. The percentage cropland in 1991 covered 9.36 per cent of the total area. There was no inter-decadal percentage change in cropland coverage during 1991-2001.

The percentage industrial area in 2001 comprised 5.58 per cent of the total area. The inter-decadal percentage growth difference was 1.74 per cent expansion. The percentage water bodies covered 3.59 per cent of the total urban agglomeration area in 2001. There was no inter-decadal percentage in the water-bodies. The percentage open land registered 15.85 per cent of the total area. The inter-decadal percentage change reported a negative difference of -8.23 per cent reduction. There was a large reduction in the open land. The percentage barren and rocky land recorded 1.21 per cent of the total area in 2001. There was no inter-decadal percentage change in the barren rocky coverage. The percentage parks and gardens represented 7.07 per cent of the total area in 2001. There was no inter-decadal percentage change in the parks and gardens coverage during 1991-2001. The socially significant educational
area coverage was 2.73 per cent in 2001. The inter-decadal percentage growth difference was of 0.76 per cent area expansion.

Figure 3.10 illustrates the land use, land cover position in Hyderabad for the period 2005-2006. It has been generated from the multi-temporal satellite data of Resourcesat-1, LISS-III. This satellite generated map covers the total geographical area of 814.55sq.km. It shows the major land use categories such as the built-up residential, commercial, industrial and institutional areas. The rural built-up areas and the mining spoils have also been depicted. In the agricultural land use the cropland, plantations and fallow lands have also been shown in different yellow hues. The other land cover categories consist of barren and unculturable wastes as well as gullies and ravine lands in purple to violet hues. Water bodies, streams and wetlands have been depicted in the conventional blue hues. The figure also depicts a well laid out transportation arteries.

The built-up expanse is not compact. It is rather sporadic along the peripheries because of very large urban agglomeration area. There is a visible tendency of the built-up area to sprawl along the radiating transportation lines. The built-up city expanse in 2005-2006 has spread well outside in the inner ring road. The built-up area of Hyderabad is considerably concentrated to the north on Musi River. Among the water bodies, Husain Sagar tank is located almost in the centre of the city. Husain Sagar narrowly separates the old Hyderabad from the twin city of Secunderabad. The other major water bodies are Himayat Sagar tank and Mir Alam tank. Most of the major tanks are to the west of the city expanse.

Agricultural fallow land can be noted all around the city built-up area. Most of the agricultural fallow land can be seen towards the Southwestern limit of the city. Although the agricultural efficiency and agricultural intensity are generally very high near the major cities because of the incentive of market vicinity, yet a sizeable presence of fallow land is only in the name of agricultural fallow. On the contrary, an altogether new phenomenon of urban fallow land is emerging around the major cities. Most of these fallow lands are pseudo fallow lands. Actually, these lands appear fallow and uncultivated because most of them have already been purchased by the industrial and commercial houses for their future programmes.
Hyderabad: Land Use, Land Cover (2005-2006)

Fig. 3.10
The researcher has termed such seemingly agricultural fallow lands as urban fallow lands for the first time. This new phenomenon of urban fallow land is fast emerging particularly around the large cities of the centralized economy of the developing countries. In the age of globalization, the rich corporate sector is in the spree of purchasing the cheap agricultural lands in bulk due to their monetary strength. This sort of urbanization is counter to agricultural sustainability in a country like India where the poor farmers can easily be lured to dispense off their farm lands for the sake of quickly obtained rather than earned money. The cyber city has recently emerged as a mirror image of foreign economy which is massively operating in the Indian megacities. Barren and unculturable waste can be vividly seen towards the northwestern, northeastern and southeastern fringe of the burgeoning Hyderabad.

Figure 3.11 illustrates the land use and land cover profile of Hyderabad for the period 2011-2012. The information has been harnessed from the multi-temporal satellite data of Resourcesat-2, LISS-III. It covers a very large geographical area of 851 sq.km. It depicts the major land use categories covering the built-up, residential, commercial, industrial and institutional areas. Due to its multi-temporal data the agricultural land use demonstrates the area under monsoon or Kharif season crops, the area under winter or Rabi season cropping and a small proportion of Zaid period cropping in the hot, dry, pre-monsoon summer months. The figure is highly valuable as it clearly depicts the double cropped areas of Kharif and Rabi seasons in different yellow hues. It also shows multiple cropping under the most powerful urban gravity of the megacity. It also shows considerable extent of high agricultural intensity because of the incentive of market vicinity.

Apart from the main Kharif and Rabi crops, there is a visibly high proportion of Zaid cropping. Zaid cropping is largely concentrated along the northeastern and southeastern fringe of the megacity. The largest chunk of double-cropped area is to the east of the city along the widening valley of Musi River. Sizeable patches of double-cropped area are visible in the northwest and southeast along the major highways. Current fallow lands were seen among the comparatively larger size fields in the southeastern parts. Scrubland or degenerated forests have been encroached upon. The scrublands in the close vicinity of the built-up areas suggest that this land cover is highly vulnerable to urban encroachment.
Fig. 3.11
The mixed built-up residential and commercial land use in 2011 comprised the highest 41.32 per cent of the total urban agglomeration area of Hyderabad. The inter-decadal percentage area growth difference was 4.7 per cent expansion. The overall mixed built-up area change from 22.56 per cent in 1971 to 41.32 per cent in 2011 showed a positive percentage growth difference of 18.76 per cent expansion in 40 years. Although this 18.76 per cent built-up area growth in Hyderabad was smaller to 26.75 per cent built-up growth in Ahmedabad, the aggregate area growth of Hyderabad was 159.65 sq.km. The percentage scrubland and coarse grass area in 2011 comprised a rapidly decreasing on 1.05 per cent of the total urban agglomeration area of Hyderabad. The inter-decadal change observed a negative growth difference of -0.94 per cent reduction in scrubland and grass coverage.

However, the overall scrubland area change in 40 years was from 54.09 per cent in 1971 to a diminishing 1.05 per cent in 2011. This shows the highest negative growth percentage difference of 53.04 per cent reduction. Here, it is very crucial to note this very large decrease in the scrubland and grassland area indicates that most of the urban expansion of Hyderabad was not on the fertile cropland or agricultural land. In fact, the urban encroachment took place on the scrubland and grassland cover. There is no evidence of urban encroachment of Hyderabad on the cropland because the percentage cropland has increased.

The percentage cropland in 2011 comprised 8.15 per cent of the total area. The inter-decadal change witnessed a negative percentage growth difference of -1.21 per cent reduction during 2001-2011. The overall cropland area change over 40 years was from 6.43 per cent in 1971 to 8.15 per cent area in 2011. This percentage change difference was a positive 1.72 per cent area expansion. The evidence that the cropland has increased over the period of analysis tends to prove that the built-up area urban expansion in Hyderabad has not occurred on the agricultural land. The percentage industrial area in 2011 was 6.17 per cent of the total area. The inter-decadal percentage growth difference was 0.59 per cent expansion. The overall industrial area growth from 1.11 per cent in 1971 to 6.17 per cent in 2011 showed a percentage area growth difference of 5.06 per cent.

The socially significant educational area in 2011 was 3.69 per cent. The inter-decadal percentage growth difference was a positive 0.96 per cent change during
2001-2011. This was quite an appreciable and socially relevant area growth in the educational sector. In 40 years the overall percentage educational area change was from 0.89 per cent of the total area in 1971 to 3.69 per cent educational area in 2011. To view it better in aggregate area growth of the educational sector, the total educational area in 1971 was 2.66 sq. km. By 2011, the aggregate educational area witnessed an expansion to 31.4 sq. km. of the total urban agglomeration area of Hyderabad.

Table 3.6 illustrates the decadal changes in the land cover and land use in Bangalore Urban Agglomeration Region for the period 1971-2011. It is meant to measure the decadal urban expansion of the city and the associated land use and land cover changes in the surrounding neighborhood of Bangalore. The major land use and land cover changes have been depicted in the categories of mixed built-up residential and commercial areas. A major coverage of cropland has been illustrated. In addition to it the scrubland and coarse grass coverage has also been shown. From the environmental point of view the parks, gardens and public facility coverage have also been shown. The area under open land in and around the city has been noted. The area under water bodies has been shown in the topographic and climatic perspectives. The area under industrial land use has been shown in proportion to the megacity area. The socially important educational coverage has also been enumerated.

Out of the total urban agglomeration area of 174.7 sq.km. in 1971 the mixed built-up residential and commercial land use consisted of 19.69 per cent in Bangalore. The aggregate residential - commercial area of Bangalore in 1971 was 34.4 sq.km. as against the corresponding residential-commercial area 23.54 sq.km. for Ahmedabad and 67.34 sq.km. for Hyderabad. It is for this largest extent that Hyderabad was ranked as the fifth largest city of India both in population and size. In Bangalore urban agglomeration area the largest land use extent was in the cropland which represented 49.9 per cent of the total area in 1971. The scrubland and grasses covered 7.85 per cent of the total area. The parks and gardens area comprised a handsome 5.39 per cent to maintain a congenial urban environment. It is for this reason that Bangalore was known as a city of parks and gardens. The open land area also covered a good 5.81 per cent of the total area in 1971 to sustain a healthy urban environment. The percentage area under water bodies was 3.49 per cent in Bangalore. Industrial area comprised a paltry 0.71 per cent of the
TABLE 3.6

Bangalore UA: Percentage Land Use/ Land Cover Changes
(1971 - 2011)

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Source: Adapted from Iyer et al. and National Remote Sensing Agency, Hyderabad.
total urban agglomeration of Bangalore. The area under educational sector was 0.92 per cent of the total area.

In 1981, the urban agglomeration area of Bangalore had increased to 365.6 sq. km. Out of this total area the mixed built-up residential and commercial area was 26.37 per cent, comprising an aggregate built-up area of 94.41 sq. km. in 1981. The inter-decadal percentage positive growth difference was 6.68 per cent during 1971-1981. The percentage cropland cover was 44.79 per cent of the total area. The inter-decadal percentage change witnessed a negative growth difference of -5.11 per cent area reduction. The percentage scrubland and grasses in 1981 covered 6.69 per cent of the total area. The inter-decadal percentage change witnessed a negative growth difference of -1.16 per cent reduction. The percentage parks and gardens area comprised 5.39 per cent of the total area in 1981. There was no inter-decadal percentage growth in parks land during 1971-1981. The percentage open land covered 5.81 per cent of the total area in 1981. Here, also there was no inter-decadal change in the per cent coverage. The percentage area under water bodies was 3.49 per cent of the total area in 1981. In water bodies’ area coverage, there was no inter-decadal percentage change during 1971-1981. The percentage industrial extent in 1981 comprised 1.22 per cent in Bangalore. The inter-decadal percentage positive growth difference was 0.51 per cent expansion during 1971-1981. The percentage area in the educational sector represented 1.66 per cent in Bangalore. The inter-decadal percentage growth difference was 0.74 per cent. It is significant to note that in Bangalore the percentage area in the educational sector was higher with 1.66 per cent to the total area as against the industrial sector area of 1.22 per cent in 1981.

In 1991, the urban agglomeration area of Bangalore had increased to 413.1 sq. km. Out of this total area the mixed built-up residential and commercial area comprised 38.99 per cent, consisting of an aggregate built-up area of 161.07 sq. km. in 1991. The inter-decadal percentage positive growth difference was 12.62 per cent expansion during 1981-1991. The percentage area under cropland in 1991 was only 10.84 per cent of the total area. There was a massive reduction in the cropland area. The inter-decadal percentage growth witnessed a negative growth difference of -33.95 per cent reduction during 1981-1991. The percentage scrubland and grass coverage in 1991 recorded 6.6 per cent of the total area in Bangalore. The inter-decadal percentage change witnessed a negative growth difference of -1.16 per cent. The
percentage area under parks, gardens and public utility services in 1991 was 3.01 per cent of the total area. Its inter-decadal percentage change witnessed a negative growth difference of -2.38 per cent reduction. In fact, there was no aggregate area reduction under parks and garden was because of the enlargement of the total urban agglomeration area of Bangalore in 1991.

The percentage open land in 1991 was recorded 29.37 per cent of the total area. This appears to be an aberration in the recorded increase. It may be because of this aberration that the inter-decadal percentage growth difference in the open land was of 23.56 per cent expansion. This inter-decadal percentage increase was not in proportion to the corresponding increase in the total agglomeration area of Bangalore. The percentage area under water bodies in 1991 was 3.15 per cent of the total area. The inter-decadal percentage change witnessed a negative growth difference of -0.34 per cent reduction. The percentage industrial area recorded 1.93 per cent of the total area. Its inter-decadal percentage growth difference was 0.71 per cent towards industrial expansion. Significantly, the percentage educational area in 1991 was 2.53 per cent of the total area. It is important to note that the educational area continued to exceed the corresponding industrial area. The inter-decadal percentage growth difference of educational area was 0.87 per cent.

In 2001, the urban agglomeration area of Bangalore increased to 492.5 sq. km. Out of this total area the mixed built-up residential and commercial area comprised 69.05 per cent of the total area, consisting of an aggregate built-up area of 340.07 sq. km., in 2001. Its inter-decadal percentage positive growth difference was a very large 30.05 per cent expansion. The percentage area under cropland in 2001 was 7.7 per cent of the total area. Its inter-decadal percentage growth witnessed a negative growth difference of -3.14 per cent. The percentage scrubland and grass coverage was 6.56 per cent of the total area. Its inter-decadal percentage change witnessed a negative growth difference of an insignificant -0.04 per cent during 1991-2001. The percentage parks and gardens coverage was 3.01 per cent of the total area.

Its inter-decadal percentage change was zero. The percentage open land coverage in 2001 was 0.08 per cent in proportion to enlarged total area. However, its inter-decadal percentage change witnessed a negative growth difference of -29.29 per cent. The percentage area under water bodies in 2001 was 3.15 per cent of the total area.
There was no inter-decadal percentage change in its area. The percentage industrial area in 2001 showed an increasing 4.3 per cent of the total area. Its inter-decadal percentage growth difference was 2.37 per cent of the previous. The socially significant educational area in 2001 represented 2.53 per cent of the total area. Although, there was no inter-decadal percentage change in the educational area, yet there was a significant aggregate area increase from 10.45 sq. km. in 1991 to 12.46 sq. km. in 2001.

Figure 3.12 depicts the land use and land cover profile of Bangalore for the period 2005-2006. It has been harnessed from the multi-temporal satellite data of Resourcesat-1, LISS-III. The satellite generated scene covers a total geographical area of 597.6 sq. km. It depicts the major land use categories such as built-up residential, commercial, industrial and institutional areas. The rural built-up areas and the mining spoils have also been shown. In the agricultural land use, the cropland, plantations and fallow lands can be identified in the different yellow hues in the spatial frames. The other land cover categories consist of barren and unculturable wastes as well as the gullies and ravenous lands in purple to violet hues. Water bodies, streams and wetlands have been demonstrated in the conventional blue hues. The figure also illustrates a well laid out rail and road transportation arteries.

The built-up area expanse of Bangalore city appears fairly compact. There is also a noticeable outgrowth of the city along the major radiating highways. In addition to it, there is sporadic city expansion in the inner fringe areas because of a large urban agglomeration area. As Bangalore is located on the edge of a plateau there is undulating topography. And the topographic heterogeneity is the major reason for the occurrence of a number of large and medium size water bodies in and around Bangalore city. There are also hundreds of small water bodies and wetlands. Because of high rainfall and longer rainy season with moderate temperatures the rainfall efficiency is high to support good deciduous forest stands around the city. There is also considerable extent of forest plantations in the vicinity of the city. A cursory perusal of the map instantly reveals that there are environment friendly urban green belts in Bangalore.

In the agricultural land use, there is a sizeable proportion of cropland as well as the agricultural fallow land. The fallow land concentration is closest to the urban
Bangalore: Land Use, Land Cover (2005-2006)

Fig. 3.12
built-up area in the north near the Jakkur Airfield. The barren and unculturable waste lands are concentrated southwest of Gottikere and Kengeri. Other large areas of barren and unculturable wastes are in the northwestern and northern outskirts of the city. There are no barren, rocky and unculturable areas in the east and southeast of Bangalore city.

Figure 3.13 depicts the land use and land cover scenario of Bangalore for the period 2011-2012. The information has been harnessed from the multi-temporal satellite data of Resourcesat-2, LISS-III. It covers a very large geographical area of 702.7 sq. km. It shows the major land use categories covering the built-up, residential, commercial, institutional and industrial areas. Due to its multi-temporal and multi-spatial data the agricultural land use demonstrates the area under monsoon period or Kharif crops, area under winter season or Rabi crops and a small proportion of additional or Zaid crops grown during the hot, dry, pre-monsoon summer months. The figure is of high significance as it vividly depicts the double-cropped areas of Kharif and Rabi seasons in different yellow hues. It also reveals multiple cropping areas under the influence of urban market gravity of the megacity of Bangalore. It also depicts the sizeable areas of high agricultural intensity near the city market.

In addition to the main Kharif and Rabi crops, there is a visibly high proportion of Zaid crops. The additional Zaid cropping in the Bangalore outskirts is largely concentrated in the southwestern parts. A significant feature of the market value but perishable Zaid crops is that they have been located closer to the city of Bangalore than the Kharif and Rabi crops. Zaid crops in their spatial frame are mostly cultivated on the inner fringe of Bangalore. The highest concentration of double-cropped area, shown in the parrot green colour, can be seen in the intensity gradient concentric rings all around the Bangalore city. Plantation farms are also widespread around Bangalore. There are only a few patches of current fallow land around Bangalore. Because there is high intensity double-cropping in the vicinity of Bangalore, there is scanty evidence of current fallow lands in this figure.

The mixed built-up residential and commercial land use in 2011 comprised the highest 67.18 per cent of the total urban agglomeration area of Bangalore. The aggregate built up area was 472.07 sq.km. in Bangalore. This aggregate built-up area
of Bangalore in 2011 was much larger than the corresponding built-up area of 226.06 sq. km. in Ahmedabad and 351.63 sq.km. for Hyderabad. Hence, Bangalore has a distinctly higher order of built-up area among the megacities. In Bangalore the inter-decadal percentage area growth difference witnessed a negative growth of -1.87 per cent. However, this negative percentage growth was contrary to a large positive area growth in the wake of a large expansion of the agglomeration area.

During the last 40 years, an overall mixed built-up area change was from 16.69 per cent of the total area in 1971 to 67.18 per cent mixed built-up area in 2011. A positive percentage growth difference was 47.49 per cent in 40 years. This percentage built-up area change as well as the aggregate area change in Bangalore was largest among all the megacities. During the last 40 years the aggregate built-up area growth of Ahmedabad was 124.65 sq. km. whereas the corresponding built-up area growth of Hyderabad was 159.65 sq. km. As compared to this, the corresponding built-up area growth of Bangalore was distinctly higher by 333.71 sq. km. This exorbitant rate of urban expansion in Bangalore might play a critical role in weathering the Salubrious climate of Bangalore.

The percentage cropland in 2011 comprised 6.74 per cent of the total agglomeration area of Bangalore. The inter-decadal percentage change witnessed a negative growth difference of -0.96 per cent reductions in the cropland. It is crucial to note that the cropland area in 40 years changed from 49.9 per cent of the total area in 1971 to a rapidly decreasing 6.74 per cent of the total area in 2011. This shows the highest negative percentage growth difference of 43.16 per cent reduction. Here, it is pertinent to note that the massive decrease in the agricultural land is a strong evidence that most of the explosive urban expansion of Bangalore has taken place mostly through encroachment upon the surrounding agricultural land and moderately on the open land and marginally on the scrubland.

The parks, gardens and public utility services in 2011 comprised a growing area of 3.49 per cent. These environment conducive green areas covered an aggregate area of 10.56 sq.km. in and around Bangalore city. Its inter-decadal percentage change witnessed a growth difference of 0.48 per cent during 2001-2011. Despite the percentage decreases, the aggregate change in the parks and gardens area was from
9.42 sq.km in 1971 to 10.56 sq. km in 2011. The percentage open land in 2011 was reduced to only 0.14 per cent of the total area. The aggregate area coverage under open land category decreased from 10.15 sq. km. in 1971 to a meager 0.98 sq. km. in 2011. It depicts that open land was also a sizeable victim of urban encroachment. However, the inter-decadal percentage growth difference of open land was a meager 0.06 per cent expansion. The percentage area under water bodies in 2011 was a sizeable 3.02 per cent of the total area. Its inter-decadal percentage change witnessed a negative growth difference of -0.13 per cent.

The percentage industrial area in 2011 was 4.97 per cent of the total urban agglomeration area of Bangalore. The aggregate area under industrial coverage was 34.92 sq. km. The overall area under industrial occupance increased from 1.24 sq. km. in 1971 to 34.92 sq. km. in 2011. It was a net industrial area increase of 33.68 sq. km. in 40 years. The percentage area under educational sector in 2011 was 4.52 per cent of the total area of Bangalore. The aggregate area under educational sector was 31.76 sq. km. This was close to the aggregate area under industrial coverage. The overall area under educational occupance increased from 1.61 sq. km. in 1971 to 31.76 sq. km. in 2011. It was a net educational area growth of 30.15 sq. km. in the last 40 years. It is good to note such an area increase in the socially relevant educational sector. However, there is a considerable scope and need for expansion in the educational area in near future.