Chapter – IX

URBAN HEAT ISLAND AND EVAPORATION TRANSITION

The built-up surface, structural modifications and the meteorological changes considerably influence the evaporation scenario and the overall urban microclimate. For example, the expanse and density of built-up surfaces visibly modify the evaporation trends and patterns in the major cities. The changing evaporation patterns are also related with temperature trends, rainfall amount and intensity, relative humidity, wind velocity and calm conditions. One can seek an intimate relationship between the several climatic factors in explaining the resultant evaporation condition.

Temperature is generally considered as an immediate determinant of evaporation patterns. There is a general perception with an evidence of a linear relationship of change between the temperature and evaporation. For example, if the temperature increases the amount of evaporation also increases and likewise a decrease in temperature tends to reduce the evaporation.

Similarly, the number of rainy days and the amount of rainfall also influence the evaporation. As the number of rainy days increase accompanied with increased cloud cover and rainfall the evaporation tends to decrease. Hence, there appears an inverse relationship between the increasing number of rainy days and the amount of rainfall with the decreasing amount of evaporation. Relative humidity bears a still closer relationship with the amount of evaporation. As the relative humidity would increase, there is every likelihood for evaporation to decrease. This also indicates an inverse relationship between the relative humidity and evaporation.

In the tropical cities, high and hot summer winds also hold a formidable relationship with the potential evapo-transpiration. The average wind speed and a transition therein significantly influence the amount of evaporation. If there is an increase in the wind velocity over a period of time, there may be a significant increase in evaporation in the rural surroundings. But if there is a decrease in the wind velocity there is every likelihood of evaporation reduction in the cities. This might indicate a linear relationship between the wind velocity and the evaporation changes. There are a number of empirical evidences of actual evaporation reduction over the vast built-up
surfaces of the large cities where water bodies are shrinking and vegetation cover is reducing. At the same time there are evidences of increasing water vapour and rising humidity in the urban atmosphere. The latter could be attributed to the growing industrial-commercial exhaust over a long time.

The present study has also sought a relationship between the calm weather conditions and the amount of evaporation. It may be submitted that an increase in the number of calm days tends to decrease the amount of evaporation. Hence, there appears an inverse relationship between growing number of calm days and the decreasing evaporation. However, the nature and degree of evaporation is a function of combined and complex effect of all the above climatic variables rather than an influence of a solitary and separate condition.

For example, even in the wake of high temperatures there may be a relative decrease in evaporation coupled with an increase in the relative humidity which might greatly influence the evaporation reduction. Similarly, a decrease in hot, dry summer wind velocity in the tropics may lead to the evaporation reduction. This equation suggests that the relative humidity and wind velocity play a considerable role along with the temperature in determining the evaporation changes. However, there is another fact of the matter that the calm days tend to increase the urban heat island intensity as well as the sensible heat more than the days with slight breeze. Further, a calm and humid day inflicts more sensible heat than a calm and dry day.

The study seeks evidence on the urban heat island and evaporation changes in Ahmedabad, Hyderabad and Bangalore megacities. Pan evaporation values provide an estimate of surface water evaporation. It is significant to note that the evaporative cooling helps dissipate heat energy trapped by urban heat island. An evaporation reduction is an evidence of aggravating the urban heat island intensity and an overall discomfort.

The inner city of high built-up surface exhibits dry conditions whereas the suburban micro climate may be comparatively more humid with higher evapo-transpiration. The curtailed evapo-transpiration from the built-up urban surfaces influences the transfer of latent heat and humidity. Urban built-up surfaces with scanty green belts experience less evapo-transpiration in comparison to countryside
landscape. As a result of it the dry and impervious urban areas have higher surface and air temperatures.

I Evaporation Changes and Heat Island in Ahmedabad

Average monthly and seasonal evaporation pattern has been probed in this section. Along with this the mean monthly and seasonal transition of evaporation has also been measured.

Average Mean Monthly Evaporation in Ahmedabad

Figure 9.1 illustrates the mean monthly and mean seasonal evaporation pattern of Ahmedabad city for the enquiry period of 39 years encompassing 1969 – 2007. The evaporation measurements depict surface water loss. Evaporation values represent the atmospheric water need of this city.

The highest monthly evaporation value of 285.7 mm. was recorded in the summer month of May. Whereas the lowest monthly evaporation value of 124.2 mm. was recorded in January. The average monthly evaporation for all the months was 176.9 mm. The total annual evaporation of Ahmedabad is a very high value of 2122.5 mm. There is a considerable monthly and seasonal variation in the average evaporation values of Ahmedabad.

The minimum and the maximum evaporation values had a ratio of 1: 2.3 mm. The average evaporation values for the winter season were obviously at a lowest 147.35 mm. from December to March. However, the total evaporation of the winter season was 589.4 mm. The intra-seasonal winter variation in evaporation ranged from 124.2 mm in January to 202 mm. in March. There is a pattern of regularly rising monthly evaporation in the winter season.

The early summer average evaporation value for April to May has been recorded 265.4 mm. The total evaporation of the two months was 530.8 mm. The monsoon season average evaporation from June to September has been recorded 170.5 mm. The total evaporation value of the season is 682 mm. The intra-seasonal variation in the evaporation ranged from 237.1 mm in June to 131.7 mm in August. The monsoonal monthly evaporation pattern at Ahmedabad considerably confirms with its monthly rainfall pattern with a clear inverse relationship. June experienced
Ahmedabad: Mean Monthly and Annual Evaporation (1969-2007)

Source: Computed and Cartographed by the Researcher from IMD Data, Pune.

Fig. 9.1
the lowest monsoonal rainfall. It has recorded an inversely highest evaporation in a monsoonal month.

Similarly, an inverse relationship has been noted between the percentage monsoonal humidity pattern and its corresponding monsoonal evaporation pattern at Ahmedabad. June experienced the lowest monsoonal relative humidity and it has recorded the highest monthly evaporation. While August had recorded the highest monsoonal relative humidity and it has recorded the lowest monsoon evaporation. This again depicts a clear inverse relationship between monsoonal relative humidity pattern and the monsoonal evaporation pattern. The mean monthly evaporation values for the retreating monsoon months of October to November had an average 160.15 mm. The total evaporation of the two months has been recorded 320.3 mm.

**Mean Monthly Evaporation Reduction: Ahmedabad**

Figure 9.2 reveals the evaporation transition of Ahmedabad for a period of 39 years spanning over 1969-2007. The figure depicts a negative transition in the mean monthly and seasonal evaporation. It shows a linear decrease in evaporation values of all the months. However, there is a considerable variation in the monthly and seasonal reduction of the evaporation values. The highest monthly evaporation reduction of -120.802 mm has been revealed in the month of May along with the highest average evaporation. Similarly, the lowest monthly evaporation reduction of -12.882 mm. was recorded in January along with the lowest average evaporation.

The mean annual evaporation reduction in Ahmedabad has been noted as -48.982 mm. over a period of 39 years. The average evaporation reduction for the winter season from December to March has been recorded -35.549 mm. However, the total evaporation reduction in the four winter months was -142.196 mm. The intra-seasonal winter variation in evaporation transition ranged from -12.88 mm in January to -78.356 mm in March. It also reveals a pattern of regularly growing evaporation reduction from January to March.

The early summer average evaporation reduction from April to May recorded a value of -115.482 mm. The total evaporation reduction for the two months was -230.964 mm. The monsoon season average reduction has been recorded -34.59 mm from June to September. The aggregate evaporation reduction for the four months was
Ahmedabad: Transition in Mean Monthly and Annual Evaporation
(1969-2007)

Fig. 9.2

Source: Computed and Cartographed by the Researcher from IMD Data, Pune.
-138.358 mm. Its intra-seasonal variation of evaporation ranged from -51.604 mm reduction in June to -14.592 decrease in August. This monsoonal monthly evaporation reduction pattern in Ahmedabad holds an inverse relationship with the rainfall distribution pattern and the percentage relative humidity for the corresponding months. For example, in the monsoon season, June had the highest evaporation reduction in the wake of lowest rainfall as well as the lowest seasonal relative humidity. The monsoonal month of June also experienced the highest evaporation reduction in the face of correspondingly the highest average evaporation.

On the other hand, August experienced the lowest seasonal reduction of evaporation with effect to highest monthly rainfall as well as the highest relative humidity. This again depicts an inverse relationship between the average relative humidity and the evaporation reduction pattern. The mean monthly evaporation reduction for the retreating monsoon months of October to November had an average reduction of -38.019 mm.

II Evaporation Changes and Heat Island in Hyderabad

Average Mean Monthly Evaporation in Hyderabad

Figure 9.3 depicts the mean monthly and mean seasonal evaporation pattern of Hyderabad for the enquiry period of 41 years spanning over 1969-2009. The highest monthly evaporation value of 249.3 mm was recorded in the summer month of May. It is interesting to note that May recorded the highest evaporation values for both Ahmedabad and Hyderabad. Whereas the lowest monthly evaporation value of 112.7 mm was recorded in December. Ahmedabad also recorded nearly the lowest evaporation in December. The average monthly evaporation for all the months was 158.4 mm. The total annual evaporation was 158.4 mm. The total annual evaporation of Hyderabad was recorded 1901.4 mm. It is considerably lower than the mean annual evaporation of 2122.5 mm at Ahmedabad.

There is a considerable monthly and seasonal variation in the average evaporation values at Hyderabad. The minimum and maximum evaporation values have a ratio of 1: 2.2 mm which is so close to the corresponding ratio of 1: 2.3 mm at Ahmedabad. The average evaporation values for the winter season were at a lowest 146.075 mm from December to March. The average winter season evaporation at
Hyderabad: Mean Monthly and Annual Evaporation (1969-2009)

Source: Computed and Cartographed by the Researcher from IMD Data, Pune.

Fig. 9.3
Hyderabad is a shade lower than Ahmedabad. In fact, it is almost identical. The intra-seasonal evaporation variation ranged from 112.7 mm in December to 202.3 mm in March. There is a pattern of regularly growing average monthly evaporation during the winter season in Hyderabad.

The early summer average evaporation for April and May has been recorded 235.3 mm. The monsoon season average evaporation from June to October in Hyderabad has been registered 145.38 mm. Its intra-seasonal variation in the evaporation ranged from 179.5 mm in June to 130.1 mm in August. This monsoonal monthly evaporation pattern inversely conforms to its monthly rainfall pattern. This is evident from the fact that June experienced the lowest monsoonal rainfall along with the highest evaporation. Similarly, an intimate inverse relationship has been noted between the percentage monsoonal humidity pattern and its monsoonal evaporation pattern. For instance, June has experienced the lowest monsoonal relative humidity pattern and it has recorded the highest monsoonal evaporation.

While August had recorded the highest monsoonal relative humidity and it has registered the lowest monsoonal evaporation. This clearly depicts an inverse relationship between the monsoonal relative humidity pattern and the monsoonal evaporation pattern. Here, it is interesting to see that there is a closely resembling monsoonal monthly evaporation pattern both in Ahmedabad and Hyderabad. The mean monthly evaporation for the retreating monsoon month of November was 119.6 mm. This pattern of lower evaporation than the monsoon season also holds a resemblance between Ahmedabad and Hyderabad.

**Mean Monthly Evaporation Reduction: Hyderabad**

Figure 9.4 reveals the evaporation transition of Hyderabad over a period of 41 years encompassing 1969-2009. The figure indicates a negative transition in the mean monthly and seasonal evaporation. It shows a linear decrease in the evaporation values of all the months with no exception of a positive transition. Nevertheless, there is a considerable variation in the monthly and seasonal reduction of evaporation. The highest monthly evaporation reduction of -111.92 mm has been identified in the month of May. Ahmedabad also recorded the highest monthly evaporation reduction of 120.802 mm in May.
Hyderabad: Transition in Mean Monthly and Annual Evaporation (1969-2009)

Evaporation (mm)

Source: Computed and Cartographed by the Researcher from IMD Data, Pune.

Fig. 9.4
It is significant to note that the summer month of May recorded the highest evaporation reduction both in Ahmedabad as well as in Hyderabad. The lowest monthly evaporation reduction of -43.64 mm has been reported for the month of August. Ahmedabad also recorded a nearly lowest evaporation reduction in August. The mean annual evaporation reduction in Hyderabad has been recorded -69.52 mm over a period of 41 years. The average evaporation reduction for the winter season from December to March has been recorded -74.96 mm. However, the total evaporation reduction in the four months was -299.84 mm. The intra-seasonal variation in evaporation transition ranged from -44.44 mm in December to -108.64 mm in March. It also reveals a pattern of regularly growing evaporation reduction from December to March. Almost similar is the monthly evaporation reduction pattern in Ahmedabad during the winter transition.

The early summer average evaporation reduction from April to May recorded a value of -106.92 mm. The total evaporation reduction for the two months was -213.84 mm. The monsoon season average evaporation reduction has been recorded -53.76 mm from June to October. Its intra-seasonal variation in evaporation reduction ranged from -69.04 mm in June to -43.64 mm decrease in August. This monsoonal monthly evaporation reduction pattern in Hyderabad holds an inverse relationship with the rainfall distribution pattern and the percentage relative humidity for the corresponding months. For example, June experienced the lowest monsoonal rainfall and that is why it might have recorded the highest evaporation reduction.

On the other hand, August experienced the highest monthly rainfall and consequently it has recorded the lowest evaporation reduction. This equation once again reveals an inverse relationship in the average relative humidity and the corresponding evaporation reduction pattern. The mean evaporation reduction was -51.88 mm for the month of November.

**III Evaporation Changes and Heat Island in Bangalore**

**Average Mean Monthly Evaporation in Bangalore**

Figure 9.5 illustrates the mean monthly and mean seasonal evaporation pattern of Bangalore megacity for the enquiry period of 44 years extending from 1969-2012. It is significant to realize that the climatic pattern and parameters of Bangalore are quite different from those of Ahmedabad and Hyderabad. Bangalore experiences the
Bangalore: Mean Monthly and Annual Evaporation (1969-2012)

Source: Computed and Cartographed by the Researcher from IMD Data, Pune.
highest 187.8 mm monthly evaporation in the non-rainy month of March unlike the month of May which recorded the highest evaporation both in Hyderabad and Ahmedabad. This may also be due to the fact that May is a rainy month in Bangalore.

The lowest monthly evaporation value of 114.3 mm was recorded in December. The lowest evaporation in December is characteristic of all the three megacities of Ahmedabad, Hyderabad and Bangalore. The average monthly evaporation for all the months in Bangalore has been only 136.5 mm. Bangalore has reported a lowest total annual evaporation of 1637.6 mm among all the three megacities, possibly due to highest altitudinal location on the plateau of Karnataka. Bangalore experiences the lowest average annual evaporation while Ahmedabad has recorded the highest average annual evaporation.

There is a considerable monthly and seasonal variation in the evaporation pattern in Bangalore. The minimum and maximum evaporation values here have a ratio of only 1:1.64 mm. It suggests the smallest range between the monthly evaporation extremes in Bangalore. The average evaporation values for the winter season of December to March were still at the lowest of 144.5 mm despite an unlikely winter month of March in Bangalore.

However, the fact remains that the average winter season evaporation values of all the three megacities were remarkably identical. These values recorded an average winter season evaporation of 147.35 mm for Ahmedabad, 146.075 mm for Hyderabad and 144.5 mm for Bangalore. It depicts a very gentle gradient of average winter evaporation in the three megacities from north to south. In Bangalore, the intra-seasonal winter evaporation variation ranged from 114.3 mm in December to 187.8 mm in March. It shows a pattern of regularly growing evaporation values from December to March in Bangalore. This intra-seasonal evaporation pattern in the winter season of Bangalore is in identical resemblance with the corresponding intra-seasonal monthly evaporation pattern in Ahmedabad and Hyderabad.

The early rainy period average evaporation for April and May in Bangalore has been recorded the largest 170.95 mm. Although it is the largest average in Bangalore, still it is way smaller than the corresponding averages of 265.4 mm in Ahmedabad and 235.3 mm in Hyderabad. The Advancing Monsoon Period average evaporation from June to August has been recorded 120.4 mm in Bangalore. Its intra-
monsoonal variation showed an insignificant range from 124 mm in June to 117.5 mm in August. This intra-monsoonal variation depicts an almost smooth surface of uniformity throughout the advancing monsoon period. The average evaporation during the retreating monsoon period of September to November recorded the lowest 118.83 mm. Its intra-monsoonal variation depicts a very insignificant range from 121.1 mm in September to 116.4 mm in November. This intra-monsoonal monthly variation demonstrates an even smoother surface of uniformity quite like a levelled plane table. This is the unique characteristic of monthly and seasonal evaporation pattern in Bangalore.

Another interesting feature of average evaporation pattern during the advancing monsoon period and the retreating monsoon period is an inverse relationship between the corresponding amount of rainfall and the average evaporation in Bangalore. For example, the total rainfall during the advancing monsoon period was comparatively lesser and resultantly the average evaporation is a little higher. On the other hand, the total rainfall during the retreating monsoon period was comparatively higher and consequently the average evaporation is a shade lower in Bangalore.

**Mean Monthly Evaporation Reduction: Bangalore**

Figure 9.6 reveals the mean monthly and mean seasonal evaporation reduction in Bangalore over a period of 44 years encompassing 1969-2012. The figure indicates a negative transition in the mean monthly and seasonal evaporation. Bangalore experiences the highest monthly evaporation reduction of -76.196 mm in the non-rainy month of March. The lowest monthly evaporation reduction -14.233 mm was recorded in June. The average annual evaporation reduction for all the months in Bangalore has been -30.831 mm over a period of 44 years. There is a considerable variation in the monthly and seasonal evaporation reduction. The average evaporation reduction for the winter season from December to March has recorded a decrease of -36.53 mm. The intra-seasonal variation in the evaporation transition ranged from -14.534 mm in January to -76.196 mm in March. There is a fairly reasonable degree of regularity in the monthly evaporation transition during the winter season.

The early rainy period average evaporation transition has been recorded -47.6 mm for April and May. The total evaporation reduction for the two months has been
Bangalore: Transition in Mean Monthly and Annual Evaporation (1969-2012)

Source: Computed and Cartographed by the Researcher from IMD Data, Pune.

Fig. 9.6
-95.202 mm. The Advancing Monsoon Period average evaporation reduction has been recorded -20.826 mm from June to August. Its intra-period variation in evaporation reduction ranged from -14.233 mm decrease in June to -25.542 mm in July. The Retreating Monsoon Period average evaporation reduction has been recorded -22.116 mm decrease from September to November. Its intra-period variation in evaporation reduction ranged from -26.316 mm in September to -19.479 mm for November. The retreating monsoon period has witnessed a pattern of regular monthly reduction in evaporation. A linear relationship has been observed between a comparatively lower amount of rainfall during the advancing monsoon period and a comparatively lower amount of evaporation reduction. On the other hand, the retreating monsoon period has experienced a much higher amount of rainfall with a comparatively higher amount of evaporation reduction.