CLIMATE RESEARCH AND SERVICES
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PUNE

Observed Rainfall Variability and Changes over Delhi State



Met Monograph No. : ESSO/IMD/HS/Rainfall Variability/06(2020)/30

Pulak Guhathakurta, Nitin Narkhede, Preetha Menon, Ashwini Kumar Prasad and S T Sable



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16	Abstract	India is in the tropical monsoon zone and receives plenty of rainfall as most of the annual rainfall during the monsoon season every year. However, the rainfall is having high temporal and spatial variability and due to the impact of climate changes there are significant changes in the mean rainfall pattern and their variability as well as in the intensity and frequencies of extreme rainfall events. The report brings the result of the analysis based on the recent 30 years of data (1989-2018) on the mean spatial rainfall pattern as well as mean spatial pattern of different rainfall events, trends and variability as well as extreme rainfall events during the monsoon months and annual for the state.
17	Key Words	Rainfall trend, variability, extreme events, dry days

1. Introduction

Delhi state is located in the northern part of India between the 28°24'17" N -28°53'00" N latitudes and 76°50'24"E-77°20'37"E longitudes. Itshares the boundaries with Haryanato the west,south and north andshares Uttar Pradesh to the east. Delhi state has geographical area about 1483sq.km.River Yamuna flowing in the eastern part of Delhi and terminal part of Aravalli hill range are the two main physiographic features of Delhi. Delhi is bounded by Aravalli range in the south, Indo-Gangetic alluvial plains in north and east and by Thar Desertin the west.The ridge is seemed to enter Delhi from southwest and its eastern part disappears below Yamuna alluvium in northeast. Ecologically the ridge acts as a barrier between Thar Desert and alluvial plains; and slows down the movement of air from the desert. Ridge and its four sections, northern, central, south central and southern constitute the farthest extension of Aravalli range, its meeting with Yamuna at two points, in the north and east. Delhi Ridge is the most important characteristics of the state and it is a part of the Aravalli range that passes through Delhi.The average elevation of the state is about 216metre above mean sea level.

Many studies available on the observed trends and variability of rainfall and also extreme rainfall events over India, but all the studies are based on past 100 years or more data and also the recent years are not included (Guhathakurta et al, 2015; Guhathakurta et al, 2011; Guhathakurta & Rajeevan, 2008 etc). Also, there are limited studies on district rainfall trends and variability of Delhi. In the present report all the analysis of observed rainfall patterns, trends and variability have been done based on recent past 30 years (1989-2018) that will help to have idea of the recent changes for climate change adaptation and management by the state authorities.

2. Data and Methodology

Daily Rainfall data from 1989 to 2018 is considered for analysis of trend variability and mean rainfall patterns. From the daily rainfall data monthly rainfall series of each stations are computed and then monthly district rainfall series has been constructed by considering arithmetic average of all the station rainfall values within the district. The monthly rainfall series of the state has been computed by using area weighted rainfall values of all the districts within the state. Fig.1 gives the location of the districts of the state. The objective of the analysis is to:

1. Identify the spatial pattern of the mean rainfall

2. Understand district wise observed rainfall trend and variability in annual and SW monsoon season (June, July, august and September).

Daily station rainfall data is utilized for identification of the mean spatial patterns and rainfall intensity trends. From mean and standard deviation (SD), the coefficient of variation (CV) is calculated as follows:

$$\text{Coeffcient of variation (CV)} = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100$$

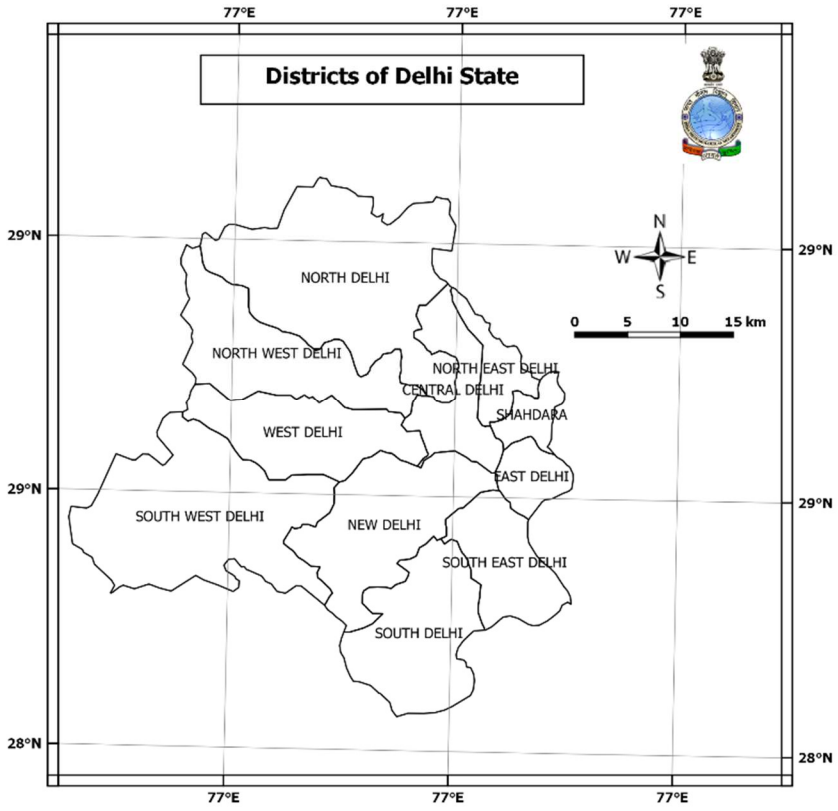


Fig. 1 Location of the districts of Delhi NCR

3. State rainfall mean and variability and trend

Table 1 shows the mean rainfall (mm) and coefficient of variation of the state for the monsoon months, southwest monsoon season and annual during the period 1989-2018. It can be seen that the state gets highest rainfall (34%) of south west monsoon rainfall in August month while the July month get 31%

of the south west monsoon rainfall. June and September receive 13% and 22% of south west monsoon rainfall. Also around 83% of annual rainfall receives during the southwest monsoon season only. The variability of monsoon or annual rainfall lies between (28-33%).

	June	July	August	September	JJAS	Annual
Mean	69.5	172.7	188.7	122.8	553.8	670.7
C V	60.5	67.1	51.6	73.4	33.3	28.2

Table 1 Mean rainfall (mm) and coefficient of variation of the state for the monsoon months, southwest monsoon season and annual

Fig. 2 and 3 show the time series of rainfall in mm for the months of June, July, August, September and southwest monsoon season, annual respectively. The trend lines are also displayed for each of the series. Neither monthly rainfall nor seasonal or annual rainfall show any significant increasing/decreasing trend. In the monthly rainfall June and July rainfall show non significant increasing trend while August and September rainfall show non significant decreasing trend. Both seasonal and annual rainfall show non significant decreasing trend. During the last 30 years highest rainfall of June month 146mm in year 2008 and July month 456.2mm received in the year 2003 while highest rainfall of 457.8mm in August received in the year 1995 and of 325.3 mm in September received in the year 2010. Highest annual rainfall of 992.4 mm received in the year 1990 and highest southwest monsoon rainfall of 880.5 mm received in the year 1993.

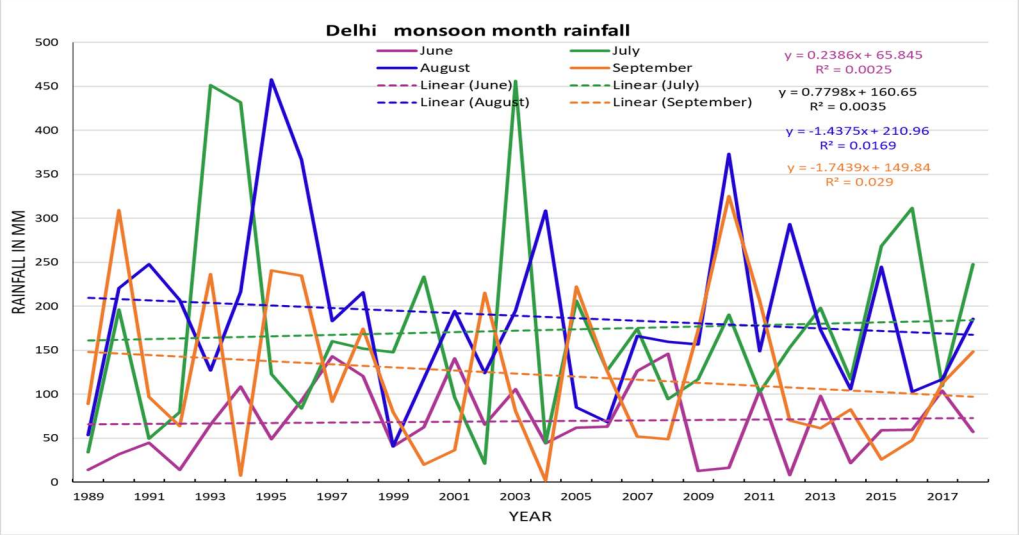


Fig. 2 Time series of rainfall in mm for the months of June, July, August, September and trends

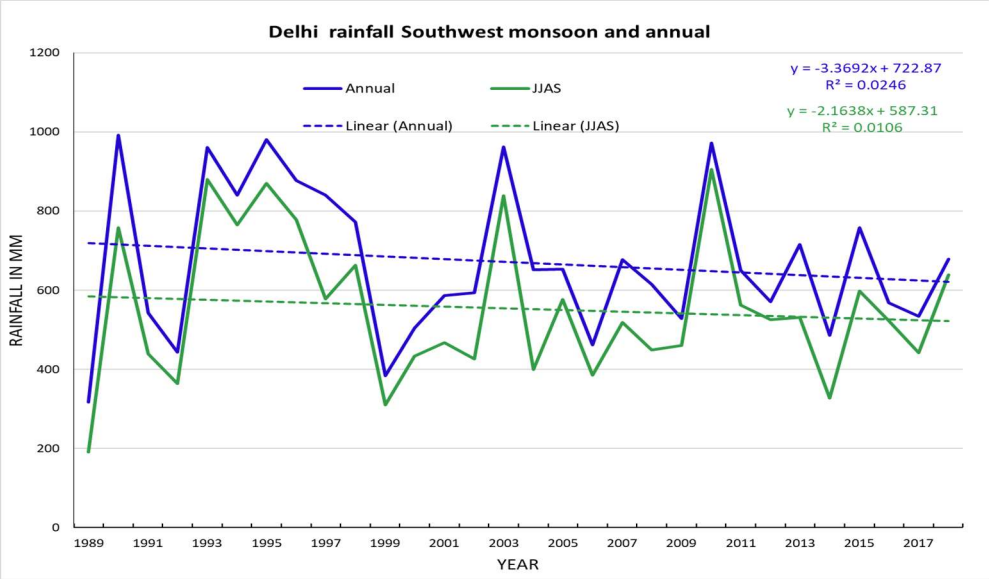


Fig. 3 Time series of rainfall in mm for the southwest monsoon season and annual trends

4. District rainfall mean, variability and trend

4.1 Mean and coefficient of variation

Table 2 gives the rainfall statistics for the districts of Delhi NCR for the four monsoon months, southwest monsoon season and annual while Fig. 4-5 show the spatial pattern of these statistics. It can be seen that New Delhi receives highest rainfall over other districts during all the months and season. Rainfall receives over these districts are around 48-78 mm in June, 100-192mm in July, 108-216mm in August, 80-139mm in September and during the SW monsoon and annual 438-732mm. Lowest rainfall receives during the SW monsoon season and annual rainfall over North East Delhi district (438mm) and 495.6mm resp. The highest rainfall received by New Delhi District 609mm during SW monsoon season and 732mm rainfall received during annual rainfall.

It is seen from Fig 4 (average rainfall) that districts, North to South Delhi through western and central Delhi gets rainfall ranging from 565-617mm while districts at south western and north eastern end has less rainfall ranging from 513-565mm and North east Delhi gets lowest rainfall 357-410mm during SW Monsoon season while almost same scenario is observed in case of annual rainfall.

Fig.5 shows the rainfall variability over the Delhi state, it is seen that districts of Delhi state shows different variability in rainfall amount as month changes, it does not shows any uniform spatial pattern. For monsoon season, North West Delhi, Central Delhi, North East Delhi, Shahadara, South East Delhi and South Delhi shows greater varability(51-60%), over other Districts of Delhi while annual rainfall shows addition of North Delhi to this.

DISTRICT	JUNE		JULY		AUGUST		SEPTEMBER		MONSOON		ANNUAL	
	MEAN	CV	MEAN	CV	MEAN	CV	MEAN	CV	MEAN	CV	MEAN	CV
NEW DELHI	78.2	71.4	182.2	75.2	216.1	53.1	133.3	65.3	609.8	32.7	732.2	32.1
CENTRAL DELHI	79.6	72.7	167.4	68.8	207.0	64.2	129.7	76.1	583.6	55.8	712.1	51.9
NORTH DELHI	62.5	74.1	191.9	62.8	190.5	52.9	128.9	83.9	573.8	43.8	682.9	52.0
NORTH WEST DELHI	67.6	71.1	174.9	83.9	182.0	69.4	117.8	87.3	542.2	55.8	621.6	51.5
SOUTH DELHI	74.2	55.7	181.4	72.1	182.3	66.8	80.1	77.1	518.0	52.6	624.6	50.4
SOUTH WEST DELHI	69.8	65.7	186.0	55.1	181.1	51.7	108.9	73.7	545.7	37.0	664.5	39.8
WEST DELHI	68.7	91.9	183.1	61.8	185.9	58.2	126.8	80.4	564.5	39.5	680.3	51.5
EAST DELHI	43.2	83.9	101.8	56.2	162.0	66.3	112.3	99.0	419.2	48.4	503.6	35.4
NORTH EAST DELHI	47.6	71.0	144.4	56.5	108.6	55.3	138.1	104.4	438.6	55.7	495.3	50.9

Table2. Rainfall statistics for the districts of Delhi NCR for the four monsoon months, southwest monsoon season and annual

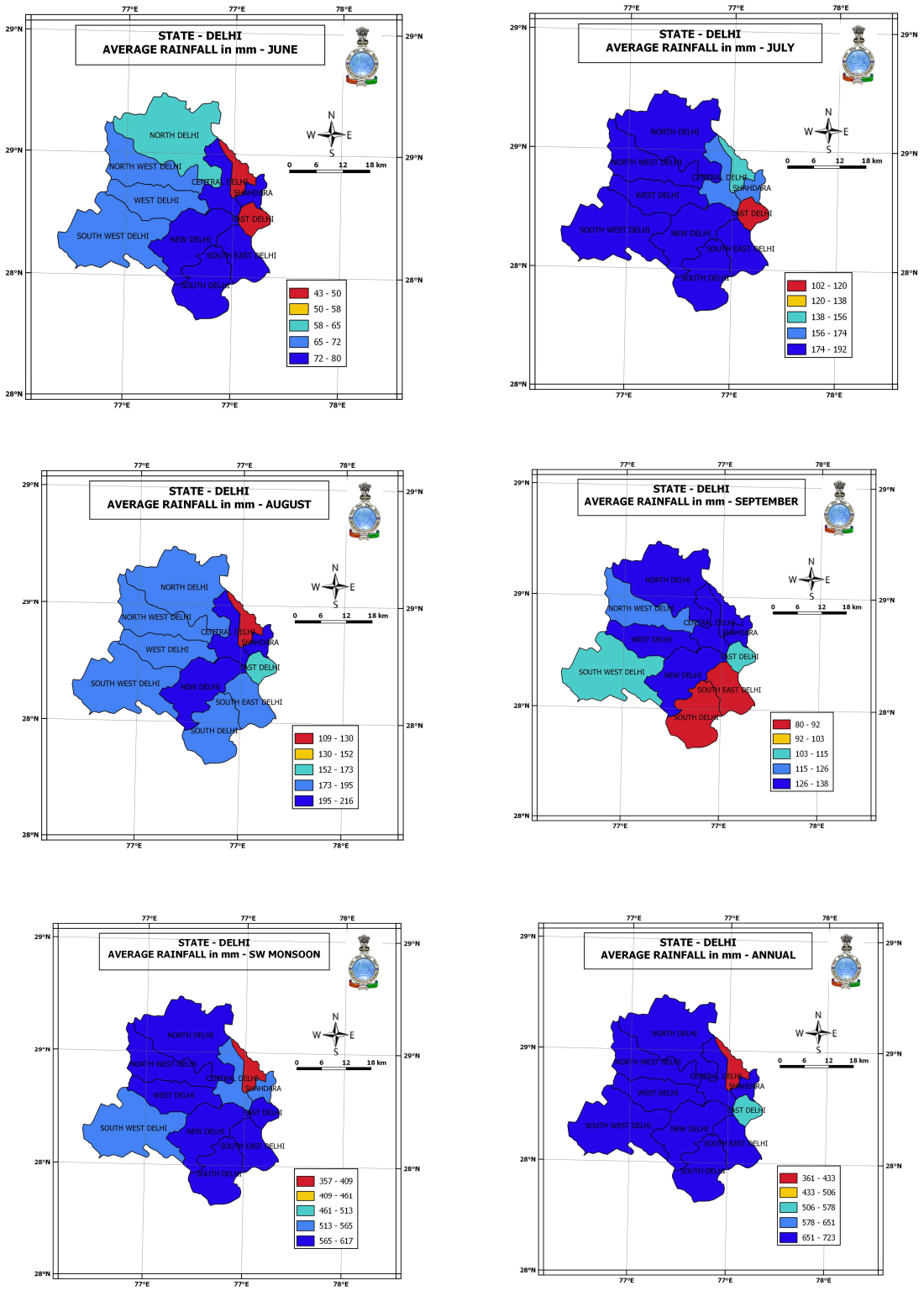


Fig.4 Mean rainfall pattern over districts of Delhi NCR

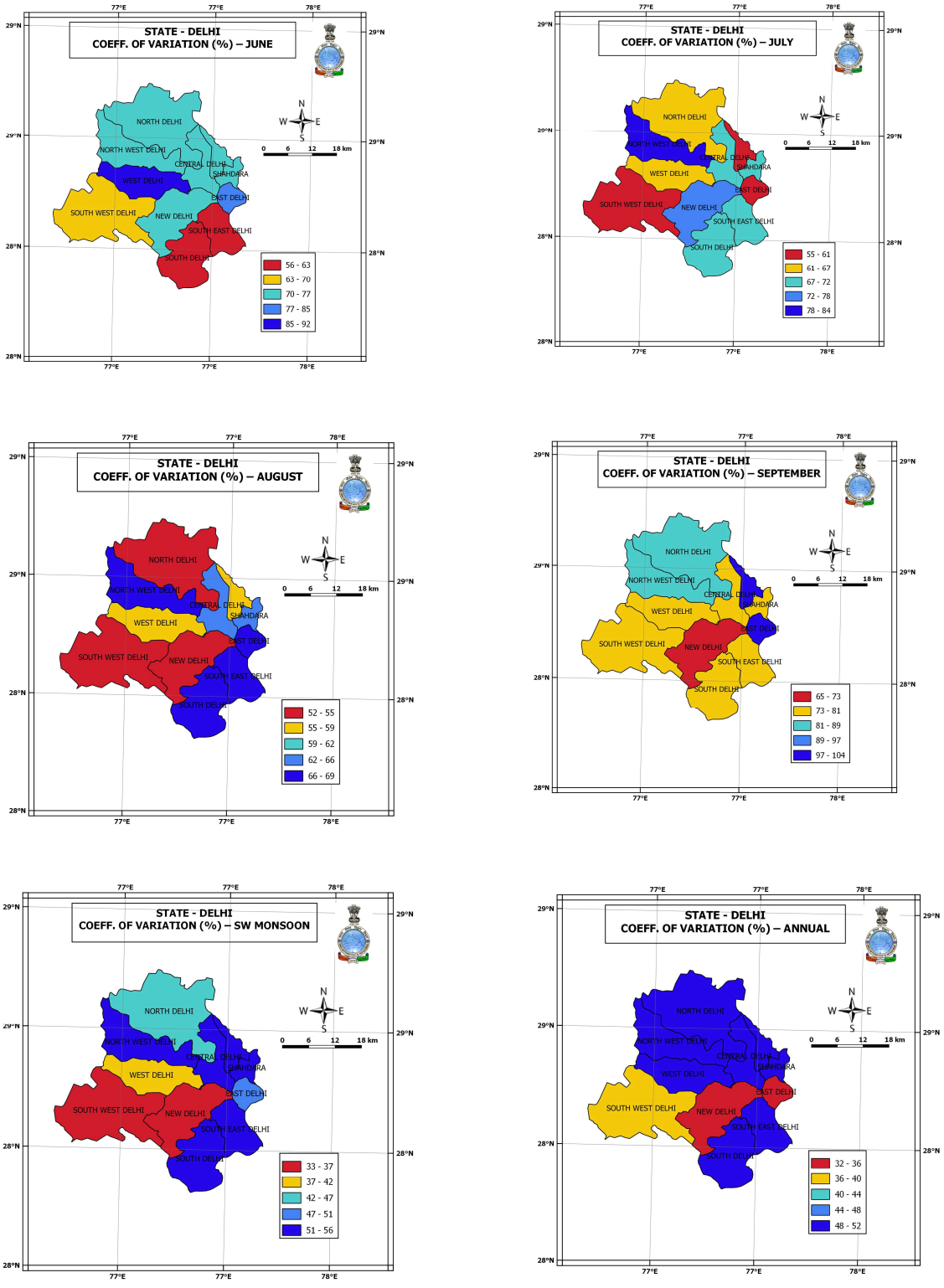
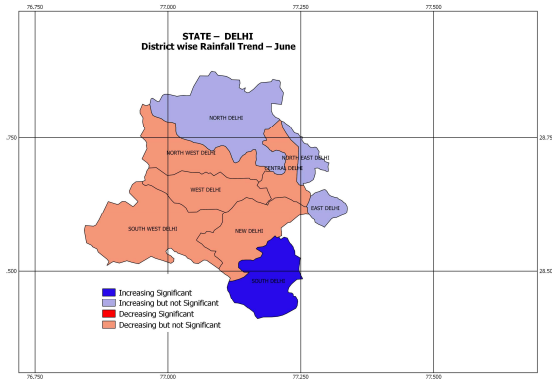


Fig.5 Coefficient of Variation (%) over districts of Delhi NCR

4.2 Trend in district rainfall

Fig.6 shows the trends in district rainfall for (a) June, (b) July (c) August (d) September (e) JJAS and (f) annual. It can be seen that June rainfall has shown significant increasing trend in the district South Delhi while no district has shown any significant increasing trend. For the July month no district shows significantly increasing or decreasing trend. North West Delhi, East Delhi and North East Delhi districts of Delhi state have shown significantly decreasing trend in August rainfall while September rainfall of North East Delhi and East Delhi district of Delhi state has shown significant increasing trend. During the whole southwest monsoon season only one district viz. South Delhi has shown significant increasing trend while North West Delhi, North East Delhi, East Delhi has shown significantly decreasing trend. For the annual rainfall two districts viz. North West Delhi, North East Delhi, Central and North West Delhi districts show significant decreasing trend.



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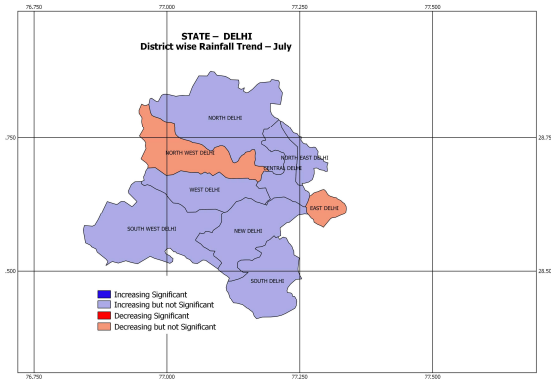

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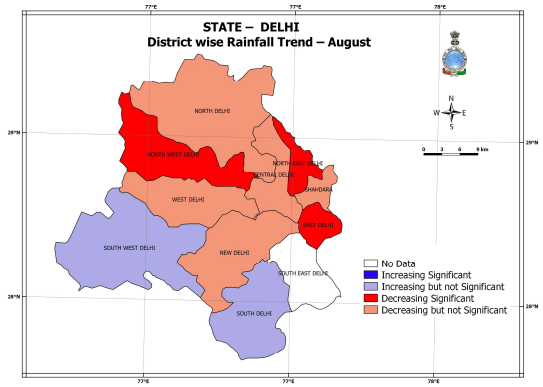

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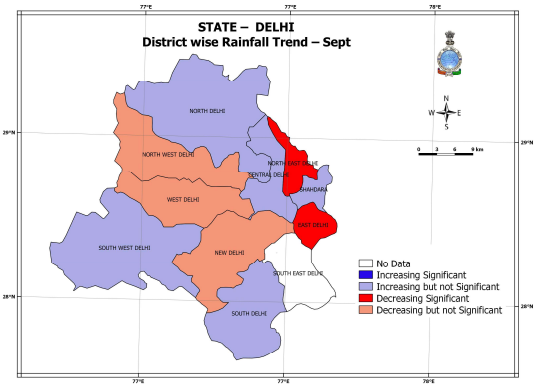

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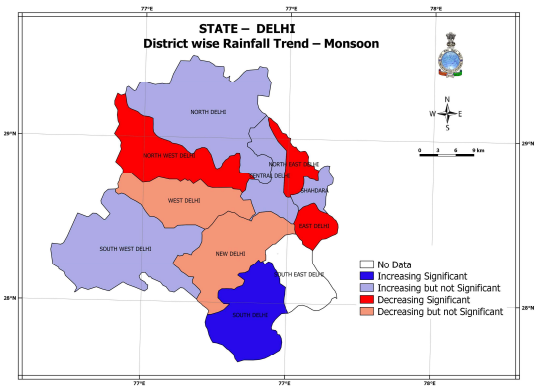

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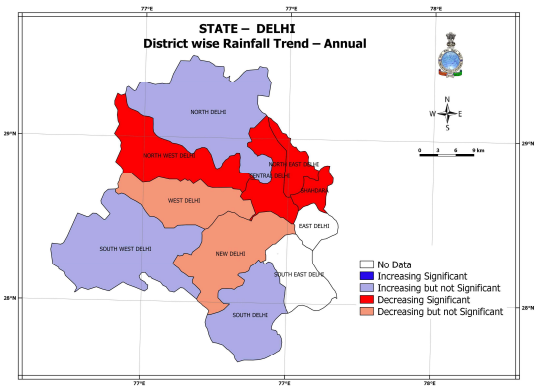

f

Fig.6 Trends in district rainfall for (a) June, (b) July (c) August (d) September (e) JJAS and (f) annual

5. Analysis of Average frequencies for rainfall events of different intensities

5.1 Average frequency of Rainy days

The average frequency of rainy days is calculated for Delhi NCR for June, July, August, September, June to September and Annual. Figure 7 shows that in the month of June the maximum number of rainy days lies in the range of 4 to 5 days especially in some parts of New Delhi, Central and West and southern part of North Delhi districts. While minimum number of rainy days lies in the range of 3 days especially in some western parts of North West Delhi, West and South West Districts. Whereas in remaining districts, the number of rainy days lies in the range of 3 to 4 days.

Figure 8 shows that in the month of July the maximum number of rainy days lies in the range of 8 to 9 days especially in some parts of Central Delhi, eastern end of North west Delhi, West Delhi, South West Delhi, South Delhi districts. While minimum number of rainy days lies in the range of 7 days especially in some Western parts of North, North West, West Delhi, South West Delhi districts. Whereas in remaining districts, the number of rainy days lies in the range of 8 days.

Figure 9 shows that in the month of August the maximum number of rainy days lies in the range of 9 to 11 days especially in some parts of Central Delhi, eastern end of North west Delhi, West Delhi, South West Delhi, South Delhi districts. While minimum number of rainy days lies in the range of 7 to 8 days especially in some Western parts of North, North West, West Delhi, South West Delhi districts. Whereas in remaining districts, the number of rainy days lies in the range of 8 to 9 days.

Figure 10 shows that in the month of September the maximum number of rainy days lies in the range of 5 to 6 days especially in some parts of Central Delhi, eastern end of North west Delhi, West Delhi, South West Delhi, South Delhi and New Delhi districts. While minimum number of rainy days lies in the range of 4 days especially in some parts of Western parts of North, North West, West Delhi, South West Delhi districts. Whereas in remaining districts, the number of rainy days lies in the range of 4 to 5 days.

Figure 11 shows that during June to September the maximum number of rainy days lies in the range of 25 to 26 days especially in eastern parts of Delhi State Viz. North East ,Central, New Delhi, Some parts of North Delhi, North West Delhi, West Delhi, South West Delhi, South Delhi districts. While minimum number of rainy days lies in the range of 21 to 22 days especially in western parts of North Delhi, North West Delhi, West Delhi, South West Delhi districts. Whereas in remaining districts, the number of rainy days lies in the range of 22 to 25 days.

Figure 12 shows that during the entire year the maximum number of rainy days lies in the range of 33 to 35 days especially in some parts of North East ,Central, New Delhi, Some parts of North Delhi, North West Delhi, West Delhi, South West Delhi, South Delhi districts. While minimum number of rainy days lies in the range of 27 to 29 days especially in western parts of North Delhi, North West Delhi, West Delhi, South West Delhi districts. Whereas in remaining districts, the number of rainy days lies in the range of 29 to 32 days.

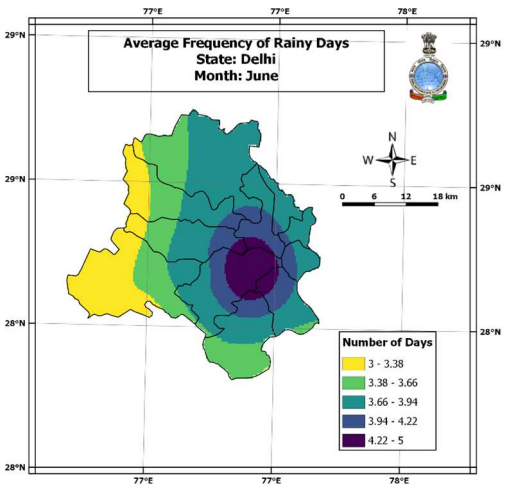

Fig. 7 Average frequency of rainy days: June

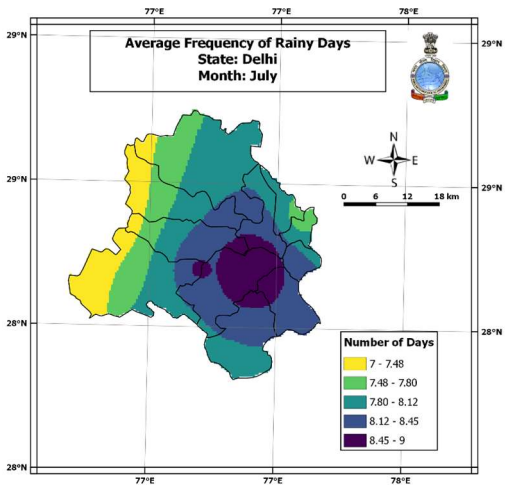

Fig. 8 Average frequency of rainy days: July

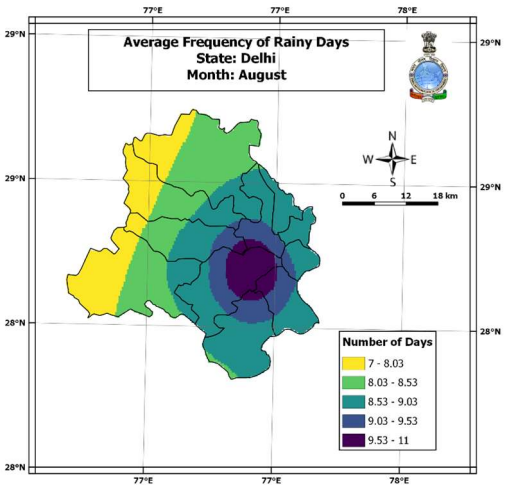

Fig. 9 Average frequency of rainy days: August

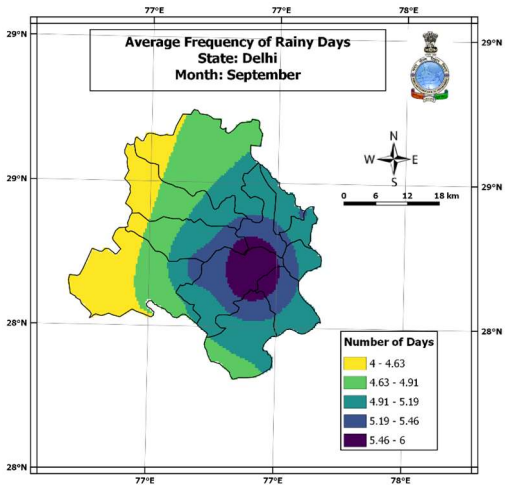

Fig. 10 Average frequency of rainy days: September

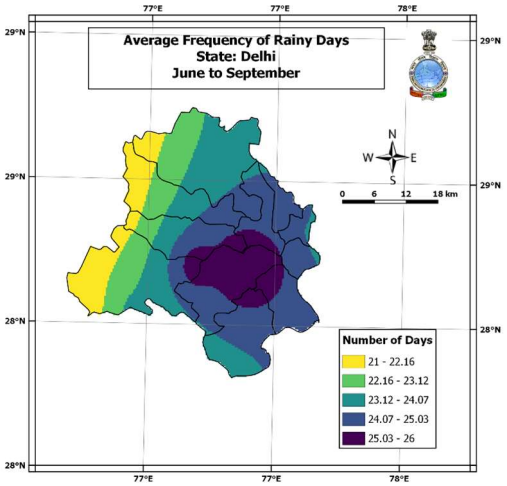

Fig. 11 Average frequency of rainy days: JJAS

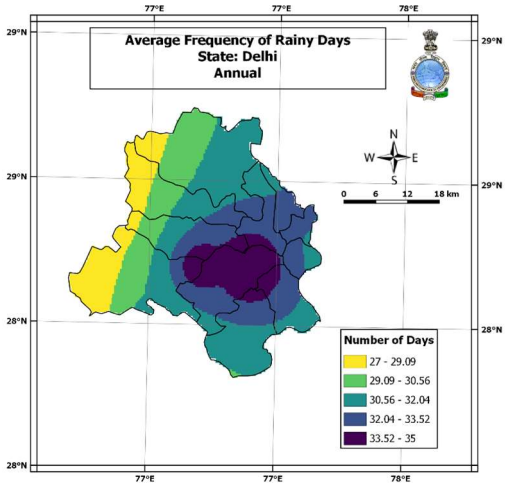

Fig. 12 Average frequency of rainy days: Annual

5.2 Average frequency of Heavy rainfall days

The average frequency of Heavy rainfall days is calculated for Delhi NCR for June, July, August, September, June to September and Annual. Figure 13 shows that in the month of June the maximum number of heavy rainfall days lies in the range of 0 to 1 days especially in East Delhi, North East Delhi, Shahadara, some Eastern Parts of North and North East districts, Central and South East Delhi. While minimum number of Heavy rainfall days almost Zero days especially in Western end of districts in west of Delhi State viz. North West Delhi, West Delhi, South West Delhi and in some parts of New Delhi. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 0 to 0.1 days.

Figure 14 shows that in the month of July the maximum number of heavy rainfall days lies in the range of 0.5 to 1 days especially in almost all parts of all Districts of Delhi state. While minimum number of Heavy rainfall days lies in the range of 0.3 to 0.4 days i.e. almost Zero especially in north eastern parts of New Delhi and adjoining parts of Central, Southwest, South and West Delhi districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 0.4 to 0.5 days.

Figure 15 shows that in the month of August the maximum number of heavy rainfall days lies in the range of 0.5 to 1 days especially in southern parts of Delhi State spanning, southern parts North Delhi and adjoining parts of North west and West Delhi districts and almost all Central Delhi, New Delhi, South Delhi, South East Delhi and southern part of South West Delhi. While minimum number of Heavy rainfall days lies in the range of 0.4 to 0.45 days especially in far western parts of North Delhi, North West Delhi, West Delhi, South West Delhi districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 0.4 to 0.5 days.

Figure 16 shows that during September the maximum number of heavy rainfall days lies in the range of 0.35 to 1 days especially in some parts of New Delhi, Central Delhi, South East Delhi, East districts. While minimum number of Heavy rainfall days lies in the range of 0.1 to 0.3 days especially in western parts of North West Delhi districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 0.3 to 0.35 days.

Figure 17 shows that during June to September the maximum number of heavy rainfall days lies in the range of 1.45 to 2 days especially in some north eastern parts of Delhi state viz. north eastern parts of North Delhi, Central Delhi, North East Delhi, Shahadara and southern parts of South West Delhi and New Delhi districts. While minimum number of Heavy rainfall days lies in the range of 1 to 1.3 days especially in some parts of especially in far western parts of North Delhi, North West Delhi, West Delhi, South West Delhi districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 1.3 to 1.45 days.

Figure 18 shows that during the entire year the maximum number of heavy rainfall days lies in the range of 1.56 to 2 days especially in some north eastern parts of Delhi state viz. north eastern parts of North Delhi, Central Delhi, North East Delhi, Shahadara and southern parts of South West Delhi and New Delhi districts. While minimum number of Heavy rainfall days lies in the range of 1 to 1.4 days especially in some parts of especially in far western parts of North Delhi, North West Delhi, West Delhi, South West Delhi districts as well as some Northern parts of New Delhi District. Whereas in remaining districts, the

number of Heavy rainfall days lies in the range of 1.4 to 1.5 days.

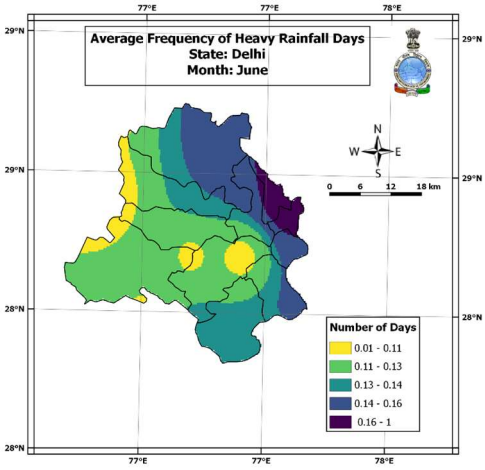

Fig. 13 Average frequency of heavy rainfall days: June

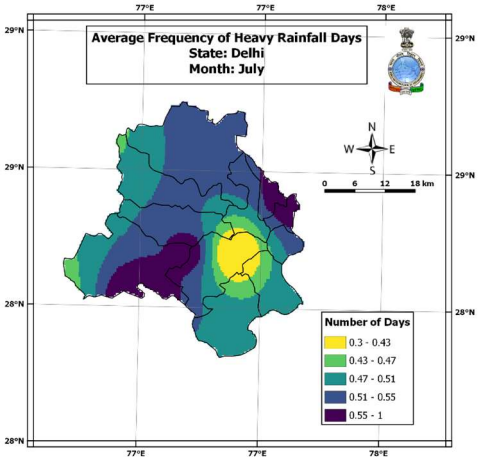

Fig. 14 Average frequency of heavy rainfall days: July

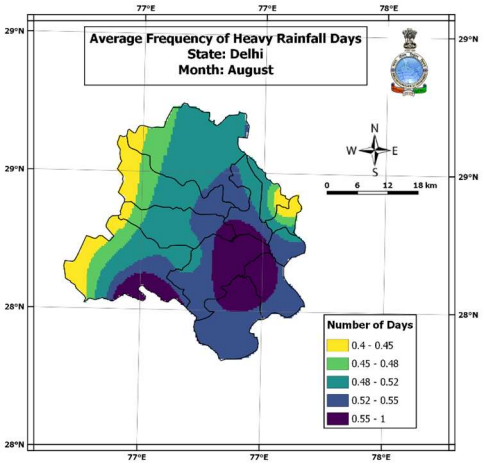

Fig. 15 Average frequency of heavy rainfall days: August

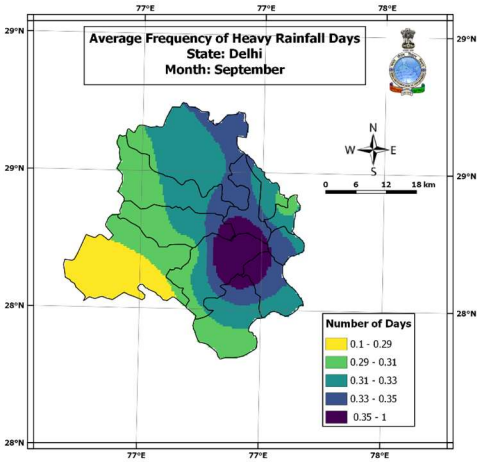

Fig. 16 Average frequency of heavy rainfall days: September

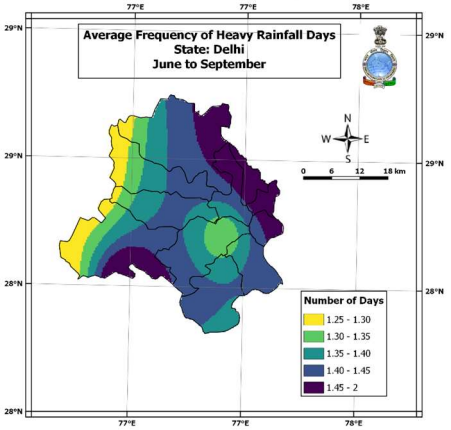

Fig. 17 Average frequency of heavy rainfall days: JJAS

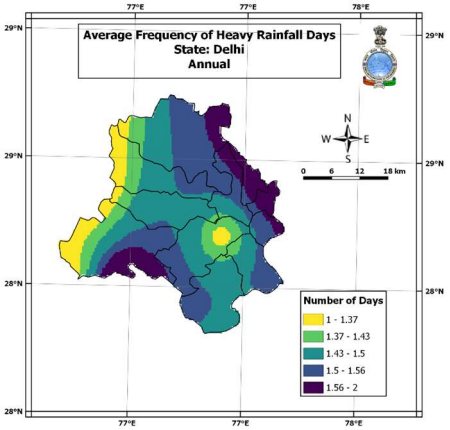

Fig. 18 Average frequency of heavy rainfall days: Annual

5.3 Average frequency of Dry days

The average frequency of dry days is calculated for Delhi NCR for June, July, August, September, June to September and Annual. Figure 19 shows that in the month of June the maximum number of dry days lies in the range of 25 to 26 days especially in southern part of South West Delhi, western parts of West Delhi and North West Delhi in addition to southern part of South Delhi districts. While minimum number of dry days lies in the range of 22 to 23 days especially in some parts of New Delhi, Central Delhi districts and adjoining parts. Whereas in remaining districts, the number of dry days lies in the range of 23to 25 days.

Figure 20 shows that in the month of July the maximum number of dry days lies in the range of 21 to 23 days especially in some parts of especially in far western parts of North Delhi, North West Delhi, West Delhi, South West Delhi districts. While minimum number of dry days lies in the range of 17 to 18 days especially in some parts of New Delhi(northern part), Central Delhi districts and adjoining parts. Whereas in remaining districts, the number of dry days lies in the range of 18 to 21 days.

Figure 21 shows that in the month of August the maximum number of dry days lies in the range of 20 to 22 days especially in some parts of especially in far western parts of North Delhi, North West Delhi, West Delhi, South West Delhi(80%part of district) districts. While minimum number of dry days lies in the range of 17 to 18 days especially in some parts of New Delhi(northern part), Central Delhi districts and adjoining parts of West and South West Delhi. Whereas in remaining districts, the number of dry days lies in the range of 18 to 20 days.

Figure 22 shows that in the month of September the maximum number of dry days lies in the range of 24 to 25 days especially in some parts of especially in far western parts of North Delhi(western tip only), North West Delhi, West Delhi, South West Delhi(60%part of district) district. While minimum number of dry days lies in the range of 22 to 23 days especially in some parts of New Delhi(northern part), Central Delhi districts. Whereas in remaining districts, the number of dry days lies in the range of 23 to 24 days.

Figure 23 shows that during June to September the maximum number of dry days lies in the range of 87 to 91 days especially in some parts in far western parts of North West Delhi, West Delhi, South West Delhi(80%part of district) district as well as southern line of South Delhi. While minimum number of dry days lies in the range of 72 to 75 days especially in some parts of New Delhi(northern part), Central Delhi districts. Whereas in remaining districts, the number of dry days lies in the range of 75 to 86 days.

Figure 24 shows that in the month of during the entire year the maximum number of dry days lies in the range of 302 to 310 days especially in some parts in far western parts of North West Delhi(10%part at southern end), West Delhi, South West Delhi(80%part of district) district as well as southern small belt of South Delhi districts. While minimum number of dry days lies in the range of 274 to 281 days especially in some parts of New Delhi(northern part), Central Delhi and north western part of South East Delhi districts. Whereas in remaining districts, the number of dry days lies in the range of 282 to 302 days.

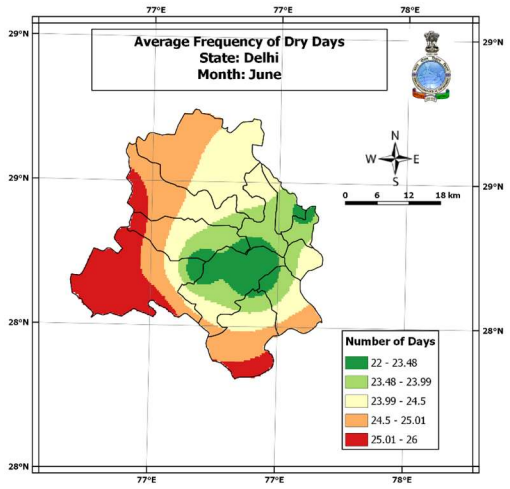

Fig. 19 Average frequency of dry days: June

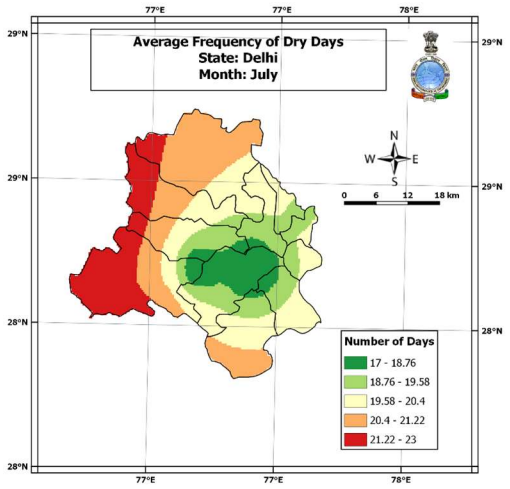

Fig. 20 Average frequency of dry days: July

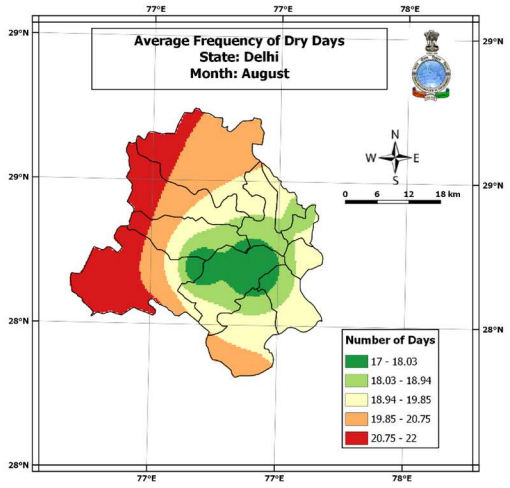

Fig. 21 Average frequency of dry days: August

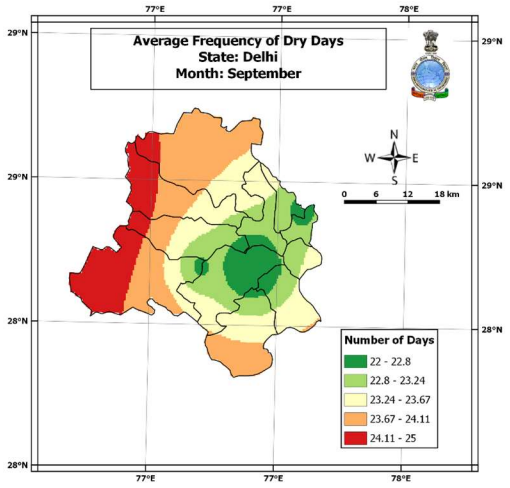

Fig. 22 Average frequency of dry days: September

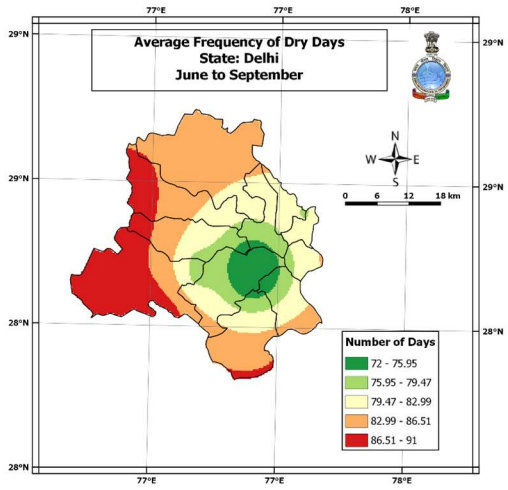

Fig. 23 Average frequency of dry days: JJAS

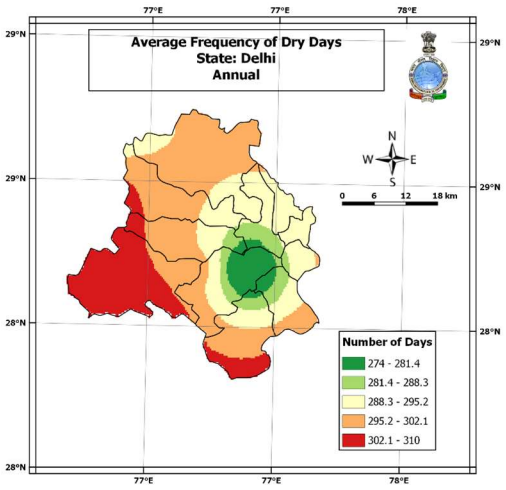

Fig. 24 Average frequency of dry days: Annual

6 Trends in the frequencies of different rainfall events

6.1 Trend in frequency of Rainy days

The Trend in frequency of rainy days is calculated for the raingauge stations of Delhi NCR for June, July, August, September, June to September and Annual. Figure 25 -28 shows that in the monthwise frequency of rainy days of June, July, August, September respectively, there is no significantly increasing or decreasing trend(no Change) in Rainy days in stations of all Districts Delhi state.

Figure 29 shows that in the month of June to September there is a significant increase in Rainy days in stations in North East Delhi district. While remaining districts did not show any significant change.

Figure 30 shows that in the month of during the entire year there is a significant increase in Rainy days in stations in North East Delhi district While remaining districts did not show any significant change.

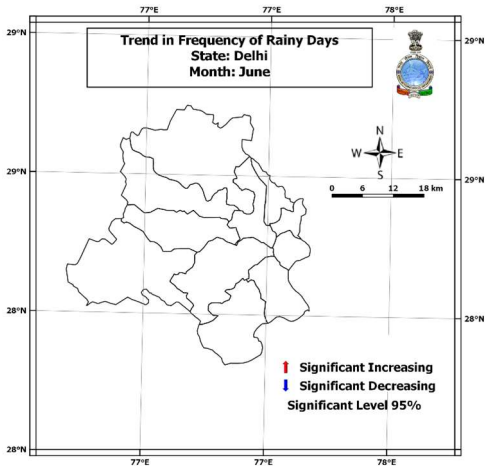

Fig. 25 Trend in frequency of rainy days: June

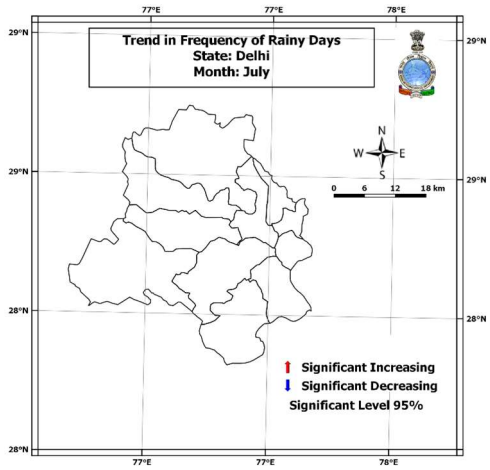

Fig. 26Trend in frequency of rainy days: July

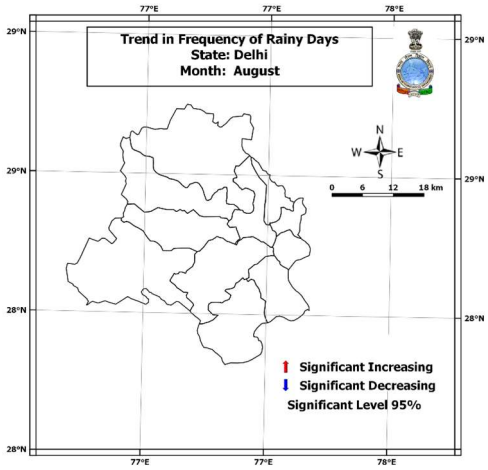

Fig. 27Trend in frequency of rainy days: August

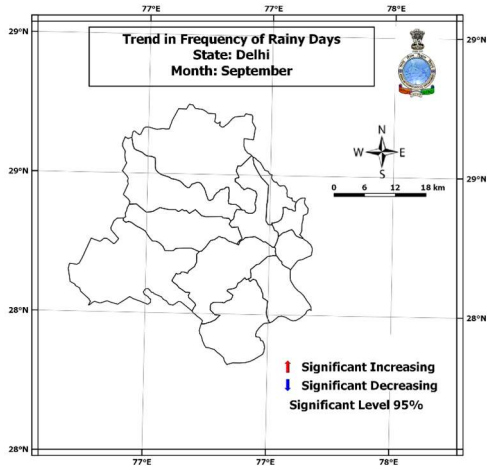

Fig. 28Trend in frequency of rainy days: September

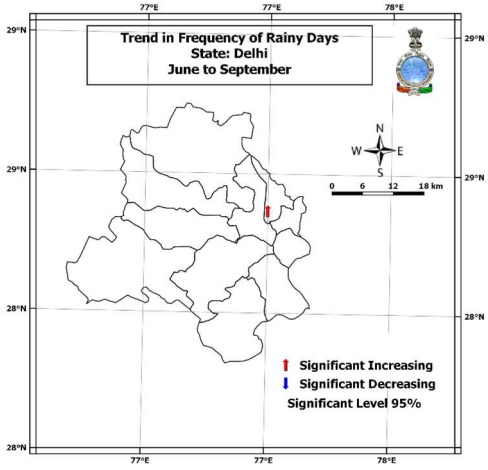

Fig. 29 Trend in frequency of rainy days: JJAS

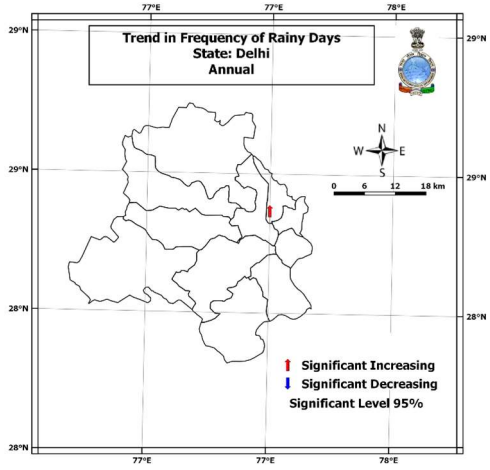

Fig. 30 Trend in frequency of rainy days: Annual

6.2 Trend in frequency of Heavy rainfall days

The Trend in frequency of Heavy rainfall days is calculated for Delhi NCR for June, July, August, September, June to September and Annual. Figure 31-34 shows that in the monthwise trend in frequency of Heavy rainfall days of June, July, August, September month respectively there is no significant increase or decrease in Heavy rainfall days in all stations of all districts of Delhi state i.e. not show any significant change.

Figure 35 shows that during June to September there is no significant increase or decrease in Heavy rainfall days in all stations of all districts of Delhi state i.e. not show any significant change.

Figure 36 shows that during the entire year there is no significant increase or decrease in Heavy rainfall days in all stations of all districts of Delhi state i.e. not show any significant change.

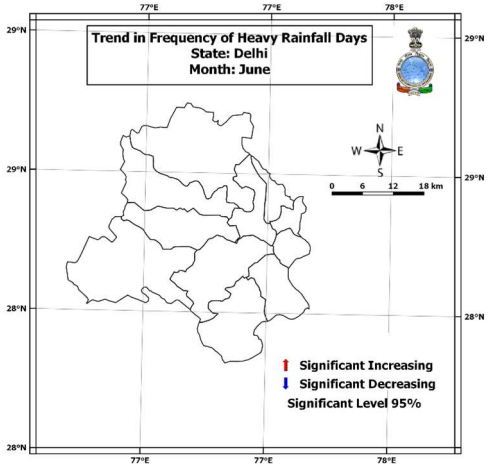

Fig.31 Trend in frequency of heavy rainfall days: June

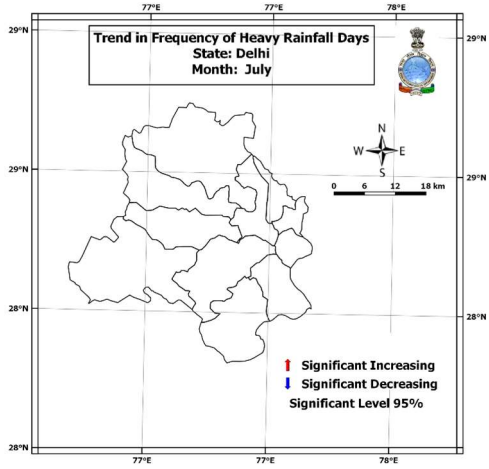

Fig. 32 Trend in frequency of heavy rainfall days: July

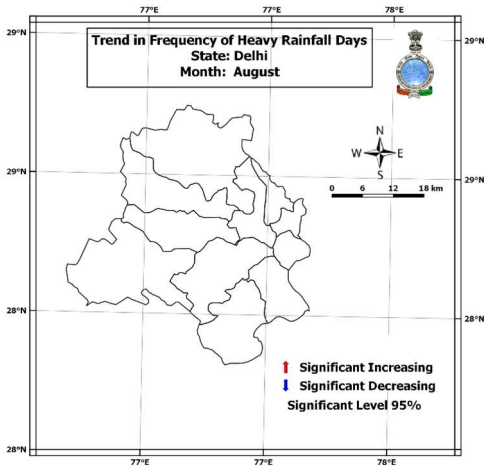

Fig. 33 Trend in frequency of heavy rainfall days: August

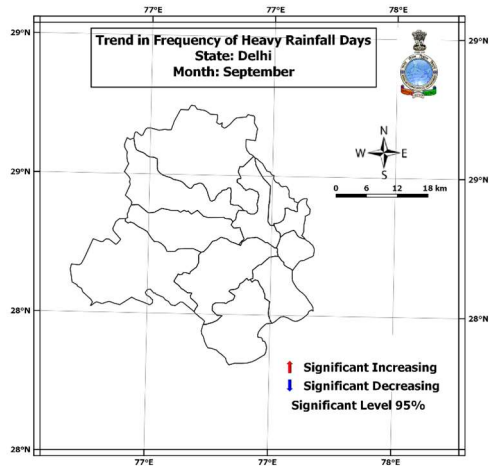

Fig. 34 Trend in frequency of heavy rainfall days: September

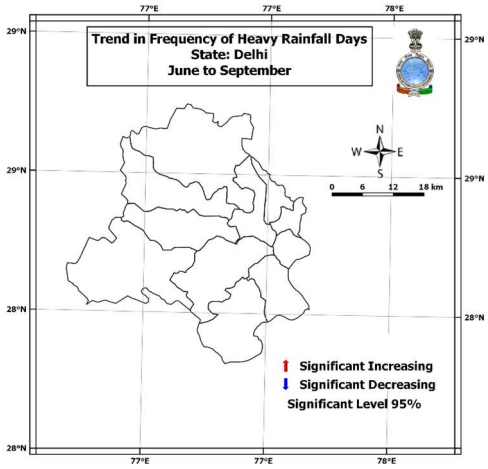

Fig. 35 Trend in frequency of heavy rainfall days: JJAS

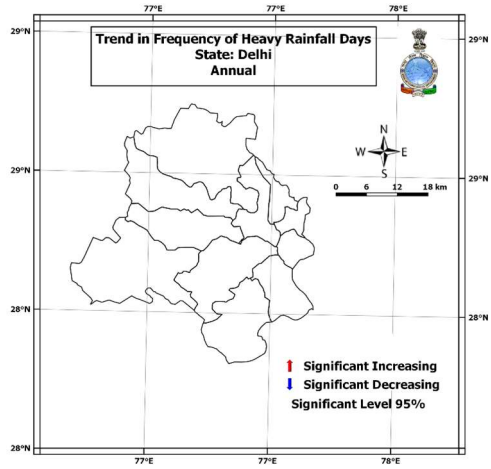

Fig. 36 Trend in frequency of heavy rainfall days: Annual

6.3 Trend in frequency of Dry days

The Trend in frequency of dry days is calculated for Delhi NCR for June, July, August, September, June to September and Annual. Figure 37 shows that in the month of June there is no significant increase or decrease in dry days in all districts of state of Delhi, i.e. did not show any significant change in trend in frequency of dry days.

Figure 38 shows that in the month of July there is no significant increase or decrease in dry days in all districts of state of Delhi, i.e. did not show any significant change in trend in frequency of dry days.

Figure 39 shows that in the month of August there is a significant decrease in dry days in New Delhi and North East Delhi districts. While remaining districts did not show any significant change.

Figure 40 shows that in the month of September there is no significant increase or decrease in dry days in all districts of state of Delhi, i.e. did not show any significant change in trend in frequency of dry days.

Figure 41 shows that in the month of June to September there is a significantly decreasing trend in dry days in North eastern parts of New Delhi district. While remaining districts did not show any significant change.

Figure 42 shows that during the entire year there is a significant decreasing trend in dry days in western parts of New Delhi district. While remaining districts did not show any significant change.

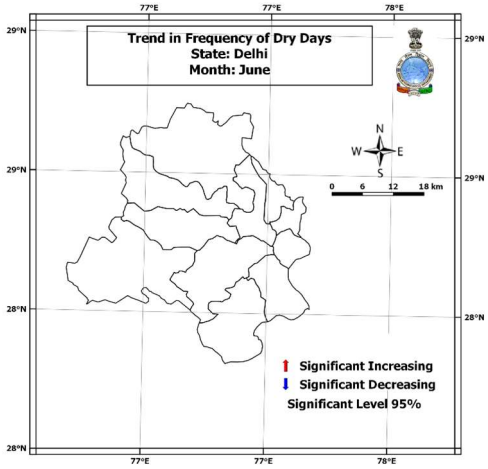

Fig. 37 Trend in frequency of dry days: June

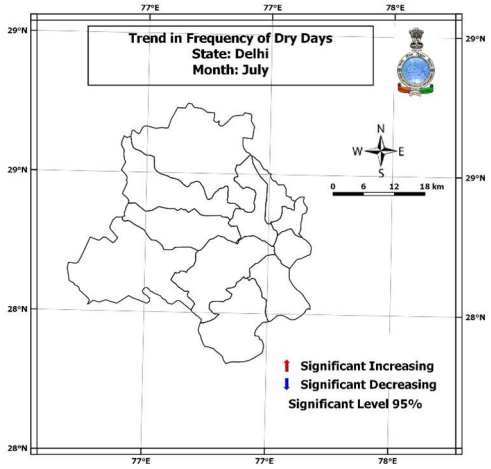

Fig. 38Trend in frequency of dry days: July

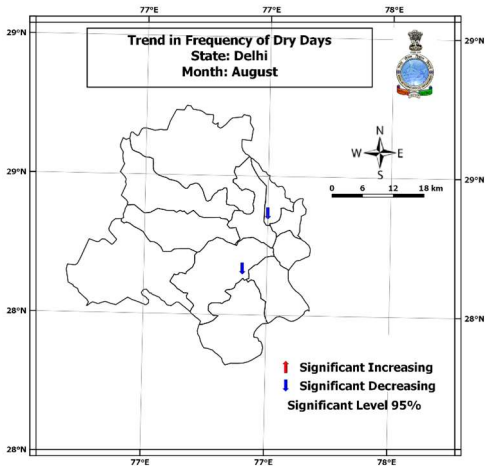

Fig. 39 Trend in frequency of dry days: August

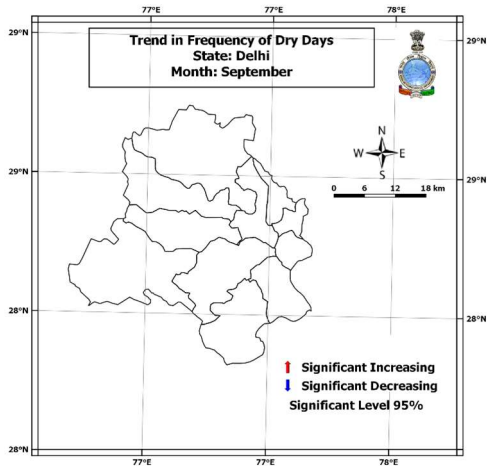

Fig. 40 Trend in frequency of dry days: September

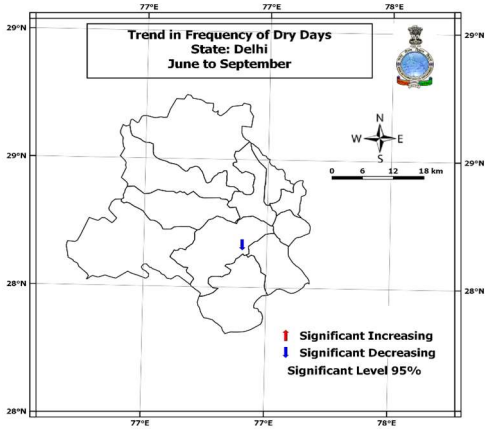

Fig. 41 Trend in frequency of dry days: JJAS

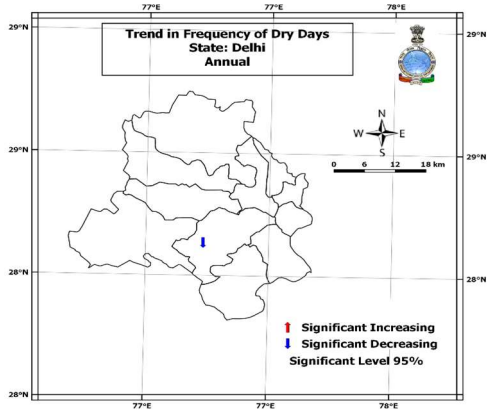

Fig. 42 Trend in frequency of dry days: Annual

7. Conclusions

In the present study we have investigated the rainfall pattern and it its variability and also changes based on recent 30 years data. In the analysis we have considered monsoon months, the monsoon season and annual scale. The spatial scale has been considered from state to district for study of rainfall total and stations are being considered for seeing intensities of rainfall. The analysis brought many significant features of rainfall pattern and can be used for water agricultural managements. Some of the important results can be summarized as:

- Delhi NCR gets maximum rainfall in August (34% of SW monsoon rainfall) followed by July (31 % of SW monsoon rainfall).
- 83% of annual rainfall receives during southwest monsoon rainfall (June –September).
- North East Delhi and North West Delhi receive 87-88% of annual rainfall in SW monsoon season while South, South West and Central Delhi districts receive 82-83% of annual rainfall in SW monsoon season.

- Significant increasing trends in June observed in case of South Delhi District only, in case of August rainfall shows significantly decreasing trend in monthly rainfall in East, North West Delhi and North East Delhi, September month shows significantly decreasing trend in monthly rainfall in East and North East Delhi. Month of July rainfall doesn't show any change in trend.
- Maximum rainfall receive during the SW monsoon season over the districts in Central Delhi and New Delhi (580mm -610mm) while East Delhi and North East Delhi receive lowest rainfall (419-440mm). East Delhi district receives lowest rainfall of 419.2mm.
- Maximum rainfall receive during the year over the districts in Central Delhi and New Delhi (712mm -732mm) while North East Delhi receives lowest annual rainfall of 495.3mm.
- Significant increasing trend in SW monsoon rainfall has been noticed in South Delhi district while North West Delhi, North East Delhi , East Delhi district show significant decreasing trend.
- In annual rainfall shows no significant increasing trend while belt runnig from North West Delhi to North East Delhi and Shahadara passing through Central Delhi show significant decreasing trend.
- Eastern regions receive on an average 25-26 rainy days (daily rainfall >=2.5mm) out of 122 days of SW monsoon season while western region gets lowest 21-22 rainy days .
- For heavy to extremely heavy rainfall (daily rainfall >=6.5mm) South Western and North Eastern region gets 1.45-2 days during the SW monsoon season, western parts of Delhi NCR get lowest around 1.25-1.30 heavy to extremely heavy rainfall days in Southwest Monsoon and Annual Rainfall days.
- Number of dry days is maximum over central parts of the state (70-79 dry days out of 122 days during the SW monsoon season while on an average 289-300 dry days in 365 days have been noticed in many parts of northern districts of Delhi NCR.

Acknowledgement:

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3. Guhathakurta P and Rajeevan M, 2008 "Trends in rainfall pattern over India" International J. of Climatology, 28: 1453–1469.

The report brings out observed rainfall variability and trends over the state as an impact of climate change based on recent 30 years of data (1981 - 2018)

Rainfall pattern of monsoon months, south west monsoon season and annual of the state and it's districts as well as extreme rainfall event of different intensity of stations are analysed.

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