

Chapter 5

Analysis of Rainfall Trends

5.0 Introduction

Climate change is no longer something to happen in future but rather an ongoing occurrence. It is presently clearly confirmed that climate change is realism, and the threats of climate changes pose of the supreme challenges facing humanity today (IUCN, 2011). The Intergovernmental Panel on Climate Change (IPCC) states climate change as “a variation in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that continues for a long era, typically decades or longer”. The changing climatic condition has been endorsed to rainfall (Adger et al, 2003; Obot et al, 2010).

Rainfall changeability is key factor affecting farming efficiency and sustainable in tropics (Tupe et al, 2010). Rainfall pattern and quantity decides cropping system in the developing country since amount, distribution and intensity can affect economical sector like agriculture. (Timme et al, 2015). Recent readings (Khan et al, 2000; Mirza, 2002; Shrestha et al,2000; Min et al, 2003; Goswami et al, 2006; Dash et al, 2007) demonstrations that in general the frequency of more extreme rainfall events in many portions of Asia has enlarged, while the number of rainy days and total amount of precipitation has weakened.

In India monsoon rainfall play very vital role in economic progress and hydrological planning (Mangalekar, 2015). Some earlier study (Mooley and Parthasarthy,1984) over India have concluded that there are no clear trends in average annual rainfall over country (Thapliyal and Kulshetrshtha, 1991; Kumar et al, 2010). Parthasarthy and Dhar (1974) found that the annual rainfall for the period of 1901-1960 had positive trends over central India and adjoining part of peninsula. Ray and Srivastav, (2000) attempted trends investigation of heavy rainfall events over certain stations located all over India and reported some decreasing trends over most part of the country.

There is high spatial variability of rainfall over districts of Maharashtra. It has been reported by many researchers (Guhathakurta et al. 2011; Sinha ray and Srivastav, 2000) about increasing trends of heavy rainfall events and also in total rainfall over Madhya Maharashtra and Konkan and Goa. Deshmukh and Lunge (2013) concluded same increasing result over Buldana district.

5.1 Analysis of Rainfall Trends of Parbhani and Nanded of Nanded

To investigate the changes in rainfall, rainfall analysis was carried for years, for different season, for all months and daily basis separately. A year is divided into four seasons winter (January-February), summer (March, April, and May), monsoon (June, July, August, and September), and post monsoon (October, November, and December). For trend analysis, daily rainfall series were used to form monthly, seasonal and annual rainfall series of these variables.

5.1.1 Analysis of Total Annual Rainfall Trends of Parbhani and Nanded

From figure 5.3 and Annexure 5.1A, 5.4B it can be specified that long term annual rainfall over Parbhani displayed significantly growing trends. Rise of about 0.5529 mm/year was observed and total rise in annual rainfall was 23.22 mm. The mean of annual rainfall for Parbhani was 940.60 mm. Near about 56% years showed annual rainfall less than that of mean annual rainfall and 44% years show annual rainfall more than that of mean annual rainfall. The maximum rainfall of 1783.00 mm was observed in 1988 and minimum annual rainfall of about 440.70mm was observed in the year 1982.

The mean of annual rainfall for 1st half years (1969-1989) was 964.90 mm. Annual rainfall of 1st half years (1969-1989) presented growing trends (Figure 5.1). For those 21 years annual rainfall enlarged by 20.74 mm/year and total rise observed was 871 mm. The average annual rainfall of 2nd half was 929.20 mm. Annual rainfalls of 2nd half (1990-2010) showed decreasing trends (figure 5.2). Annual rainfall of later 21 years showed decreasing trends of 8.60 mm/year and total decrease observed was 359.70 mm. The COV of 1st half was 37.55% and for 2nd half it was 26.59% that means rainfall was more varied in 1st half than that of 2nd half.

Long-term linear annual rainfall trends over Nanded revealed decreasing trends (figure 5.1). Decrease of about 0.3545 mm/year was

observed and total decrease was 14.90 mm. mean annual rainfall for Nanded was 877 mm.

Figure 5.1 Annual Analysis of 1st Half Period Rainfall Trends in Nanded and Parbhani Cities

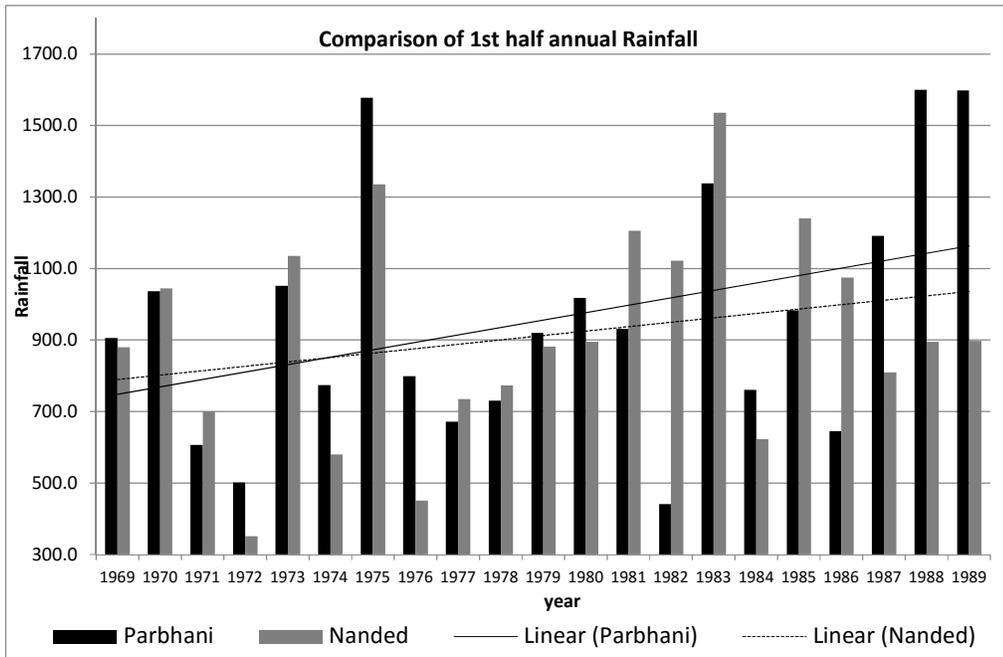
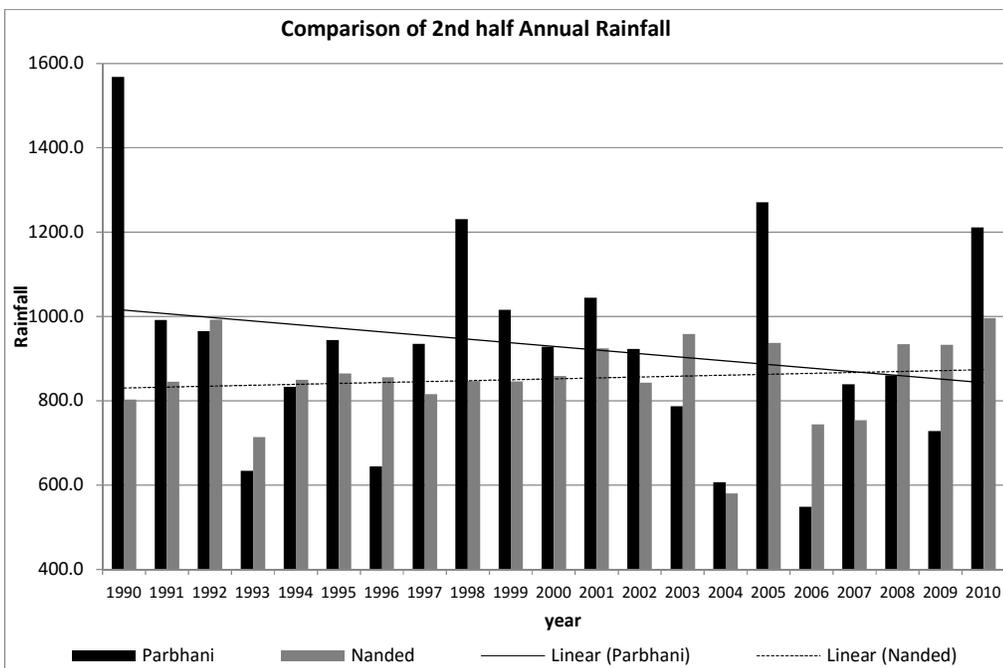
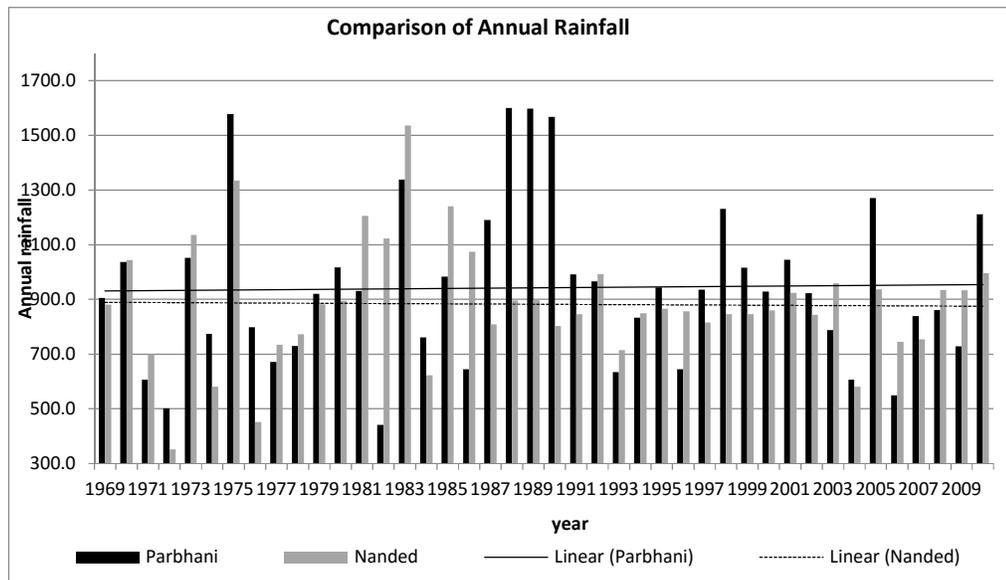


Figure 5.2 Annual Analysis of 1st Half Rainfall Trends in Nanded and Parbhani Cities



Near about 71.80% years show annual rainfall less than that of mean annual rainfall and 28.20% years show annual rainfall more that of mean annual rainfall. The maximum rainfall of 1583.00mm was observed in 1983 and minimum annual rainfall of about 350.9mm was observed in the year 1972.

Figure 5.3 Comparison of Annual Rainfall Trends in Nanded and Parbhani Cities

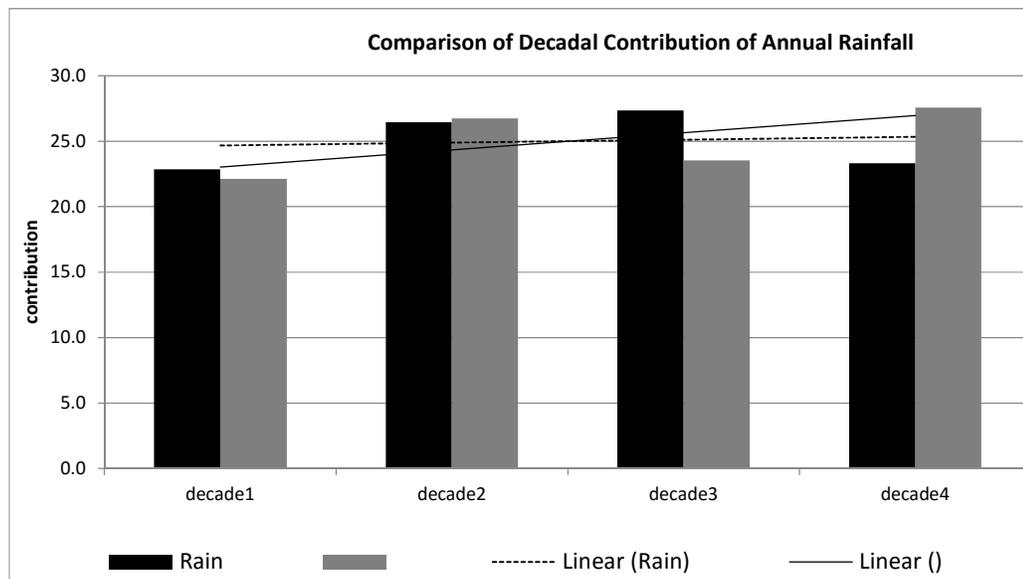


The mean of annual rainfall for 1st half years (1969-1989) was 913.60 mm. Annual rainfall of 1st half years (1969-1989) displayed increasing trends. For 1st half period (21) year's annual rainfall increased by 12.35 mm/year and total increase observed was 518.10 mm. The average annual rainfall of 2nd half (1990-2010) was 838.50 mm. Annual rainfalls of 2nd half (1990-2009) showed decreasing trends. Annual rainfall of later 20 years decreased by 2.16 mm mm/year and total decrease observed was 90.80 mm. The COV of 1st half was 33.0 and for 2nd half it was 11.20 that means rainfall was more varied in 1st half and more stable in 2nd half.

5.2.2 Analysis of Decade-wise Annual Rainfall Trends of Parbhani and Nanded

For decade-wise study of annual rainfall of Parbhani and Nanded total period is divided into four decades. 1st decades 1969-1978, decade 2 1979-1988, decade-3 1989-1998, decade 4 1999-2010. Decadal analysis of annual rainfall of Parbhani revealed upward trends. The maximum rainfall was witnessed in third decade and it was 10345.23 mm and it contributed about 27.34% of total period. While minimum decade-wise annual rainfall was observed in 1st decade and it was 8653.7 mm and contributed 22.87% of total period of 42 years. Total rainfall 37836.10 mm was observed.

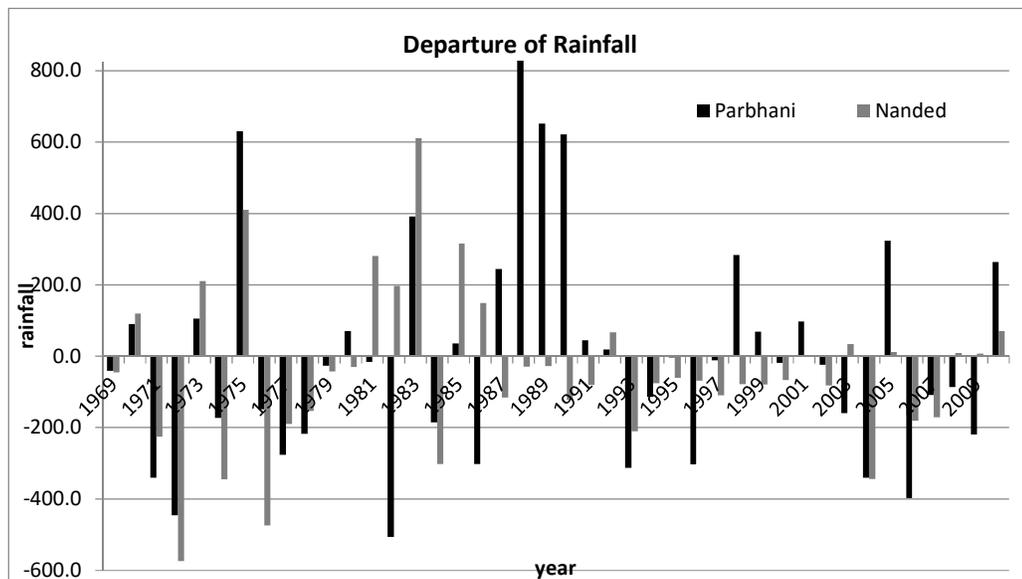
Figure 5.4 Comparison of Decade-wise Contribution of Rainfall Trends in Nanded and Parbhani Cities



Linear trends of Decadal analysis of annual rainfall of Nanded show slightly increasing trends. The decade-wise rainfall increases by 218.01/decade and total increase for four decades was 872.04 mm rainfall. Maximum rainfall was observed in 4th decade and it was 10309.9 mm and it contributed about 27.52% of total period. While minimum decadal annual rainfall was observed in 1st decade and it was 7986 mm and contributed 22.14% of total period of 42 years. Total rainfall 36068.5 mm for Nanded was observed.

For Parbhani there were 25 years with below average annual rainfall, only 17 years with above average annual rainfall (Figure 5.5). The maximum negative departure of about -506.3 mm was observed in 1982. The maximum positive departure was witnessed in 1989 and it was 651.10 mm. from normal. For Nanded there were 28 years with below normal rainfall, only 14 years with above normal rainfall. The maximum negative departure was detected in 1976 which was -474 mm and. The maximum positive departure was observed in 1975 and it was 411 mm. from normal.

Figure 5.5 Departure of Annual Rainfall from Normal of Nanded and Parbhani Cities



5.2.3 Analysis of seasonal Rainfall Trends of Parbhani and Nanded

For seasonal rainfall analysis, year is separated into four seasons- winters- January, February. Summer- March, April, May. Monsoon June, July, August, September. The trends of seasonal rainfall over different years were obtained using linear regression best fit lines. The linear regression equation and COV and coefficient of determination for all four-season represented in Figure 5.6, 5.8, 5.10, 5.12 and Table 5.2A, 5.2 B.

A) Analysis of Winter Rainfall Trends

Slightly growing trends of winter rainfalls trends were observed for Parbhani. The total rainfall enlarged by 0.0454 mm/year and total rise was 1.90 mm. (Annexure 5.2A, 5.2B and Figure 5.6). The average winter rainfall for Parbhani was 15.00 mm. The maximum winter rainfall was detected in the year 1982 and it was 113.80 mm. Near about 631.40 mm rainfall was observed in winter and it contributed 1.6% to the annual.

Figure 5.6 Comparison of Winter Rainfall of Nanded and Parbhani Cities

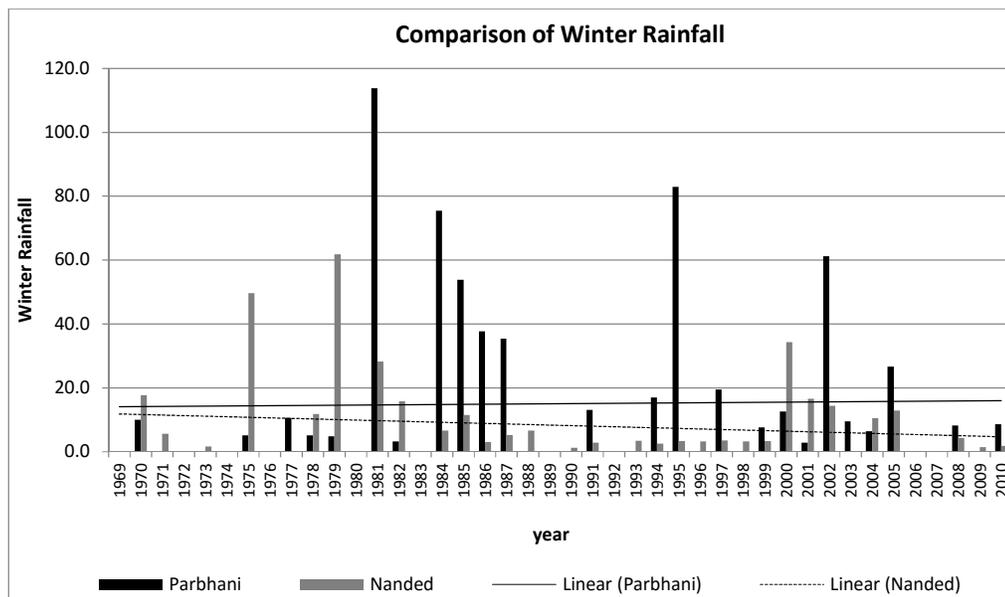
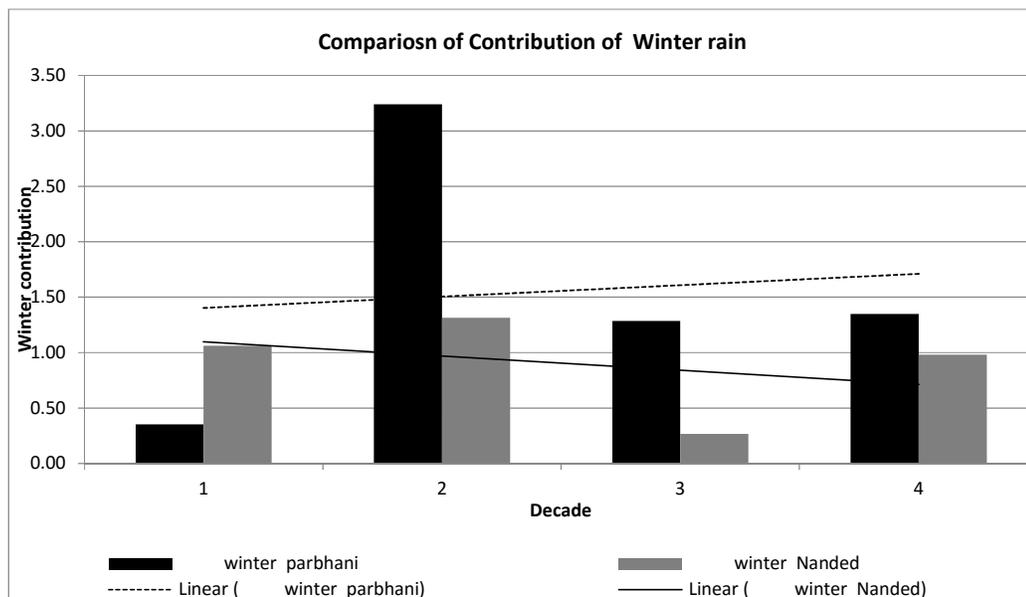


Figure 5.7 Comparison of Decade-wise Contribution of Winter Rainfall Trends of Nanded and Parbhani Cities



Decade-wise study of winter showed increasing trends (figure 5.7). Winter rainfall increased by 14.60 mm/decade and total increase was 58.20 mm. The maximum winter rainfall was observed in the 2nd decade and it was 324.10mm. While minimum winter rainfall was observed in 1st decade and it was 31.10 mm.

The average winter rainfall for Nanded was 8.72 mm. long term seasonal rainfalls of winter showed decreasing trends. The total rainfall decreased by 0.1743 mm/year and total decrease was 7.30 mm. The Maximum winter rainfall was observed in the year 1979 and it was 61.80 mm. About 340.40 mm rainfall was observed in winter and winter contributed 0.93% to the annual rainfall.

Decade-wise study of winter showed decreasing trends. Winter rainfall decreased by 9.85 mm/decade and total decrease was 39.40 mm. The maximum winter rainfall was observed in the 2nd decade and it was 138.90 mm. While minimum winter rainfall was observed in third decade and it was 23.30 mm.

B. Analysis of Summer Rainfall Trends of Parbhani and Nanded

It was apparent from Annexure 5.2A, 5.2B and Figure 5.8 that the average of summer rainfall over Parbhani was 54.60 mm. The long term seasonal rainfalls of summer showed slightly upward trends. The total rainfall enlarged by 0.5733 mm/year and total rise was 24.08 mm. The maximum summer rainfall was observed in the year 1991 and it was 456.20 mm. Near about 2291.50 mm rainfall was observed in summer and it contributed 5.80% to the annual rainfall.

Decade-wise study of Parbhani of summer showed increasing trends (figure 5.9). Summer rainfall increased by 129.40 mm/decade and total increase was 517.60 mm. The maximum summer rainfall was observed in the third decade and it was 1020 mm. While minimum summer rainfall was observed in 1st decade and it was 316 mm.

Figure 5.8 Comparison and of Summer Rainfall Trends of Nanded and Parbhani Cities

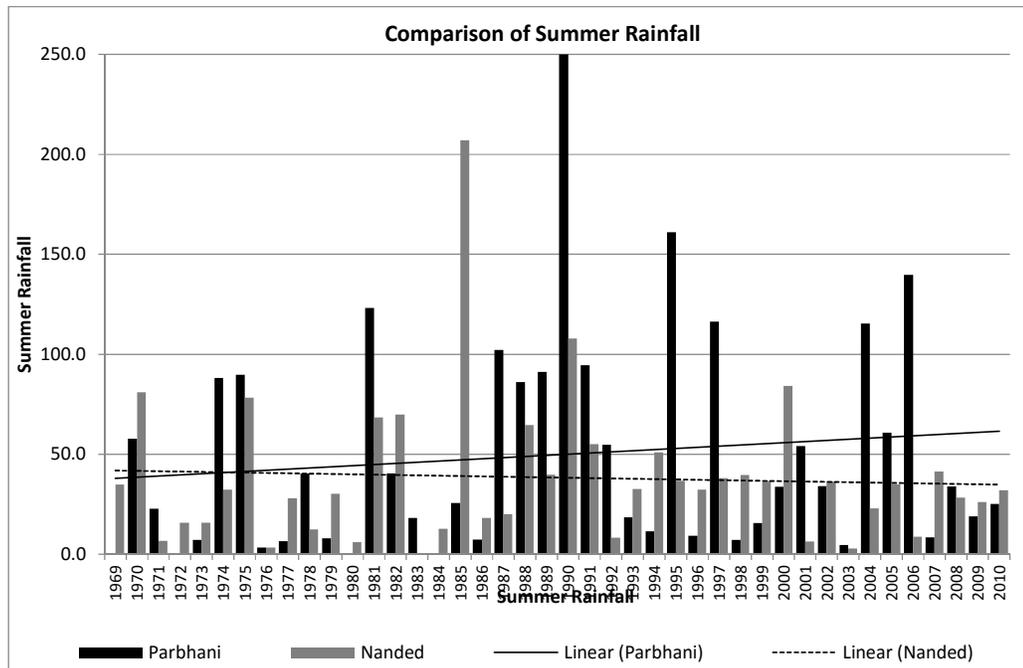
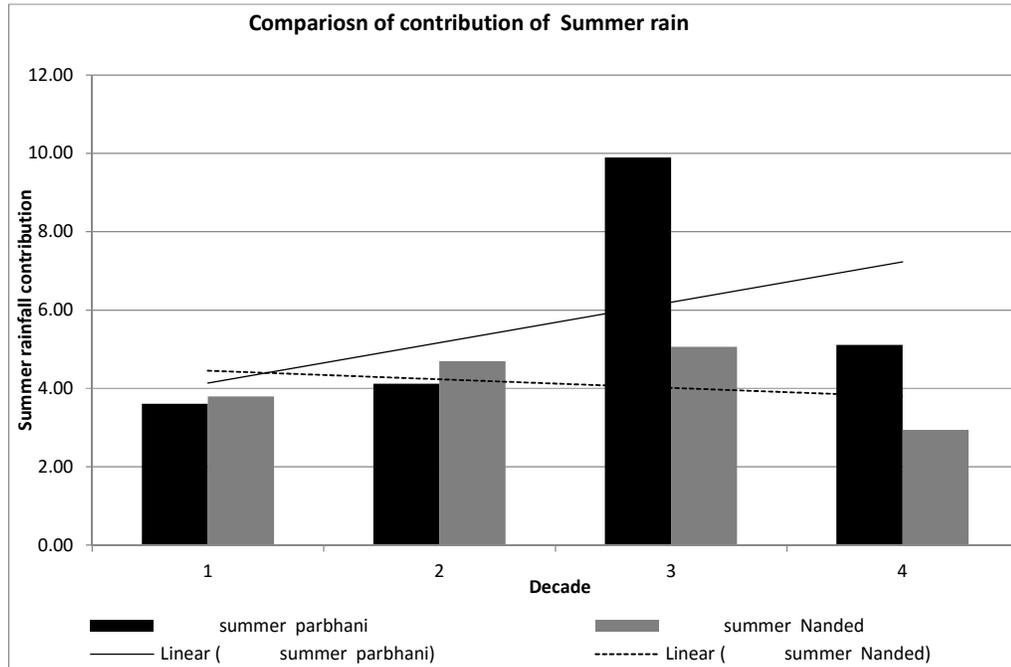


Figure 5.9 Comparisons and Decade-wise Contribution of Summer Rainfall Trends of Nanded and Parbhani Cities



The average summer rainfall for Nanded was 39.00 mm. long term seasonal rainfalls of summer showed slightly declining trends (figure 5.8). The total rainfall declined by 0.173 mm/year and total decline was 7.30 mm. The maximum Summer rainfall was observed in the year 1985 and it was 61.80 mm. About 207.10 mm rainfall was observed in summer and it contributed 4.14 % to the annual rainfall.

Long-term linear trends of decade-wise summer trends (Figure 5.9) showed decreasing trends. Summer rainfall decreased by 15.66 mm/decade and total decrease was 62.30 mm. The maximum summer rainfall was observed in the 2nd decade and it was 497 mm. While minimum summer rainfall was observed in 4th decade and it was 274.70 mm.

C. Analysis of Monsoon Rainfall Trends

The average of monsoon rainfall over Parbhani was 782.20 mm. long term seasonal rainfalls of monsoon displayed slightly declining trends (figure 5.10). The total rainfall declined by 0.462 mm/year and total decline was 19.404 mm. The maximum monsoon rainfall was witnessed in the year 1989 and it was 1673.50 mm. Near about 32854.20 mm rainfall was detected in monsoon and it contributed 82.80% to the annual.

Decade-wise study of monsoon for Parbhani disclosed increasing trends (figure 5.11). Monsoon rainfall increased by 387.20 mm/decade and total increase was 1548.90 mm. The maximum monsoon rainfall was observed in the 4th decade and it was 8865.60 mm, while minimum monsoon rainfall was observed in 1st decade and it was 7436.50 mm.

The average monsoon rainfall for Nanded was 774.40 mm. long term seasonal rainfalls of monsoon showed increasing trends. The total rainfall increased by 2.5535 mm/year and total increase was 107.20 mm. The maximum monsoon rainfall was observed in the year 1983 and it was 1344.40 mm. About 30202 mm rainfall was observed in monsoon and it contributed 82.16% to the annual rainfall.

The linear trends of decade-wise monsoon study over Nanded showed decreasing trends. The Monsoon rainfall decreased by 133.05 mm/decade and total decrease was 552.16 mm. The maximum monsoon rainfall was observed in the 2nd decade and it was 8932.30 mm. While minimum of monsoon rainfall was observed in 4th decade and it was 6881.80 mm.

Figure 5.10 Comparison of Monsoon Rainfall of Nanded and Parbhani Cities

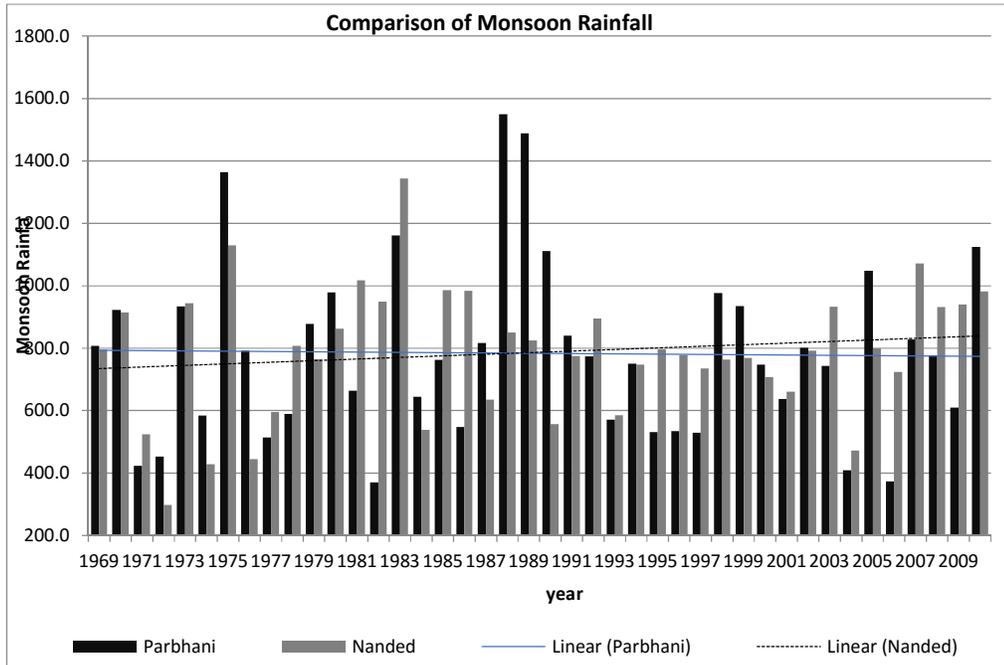
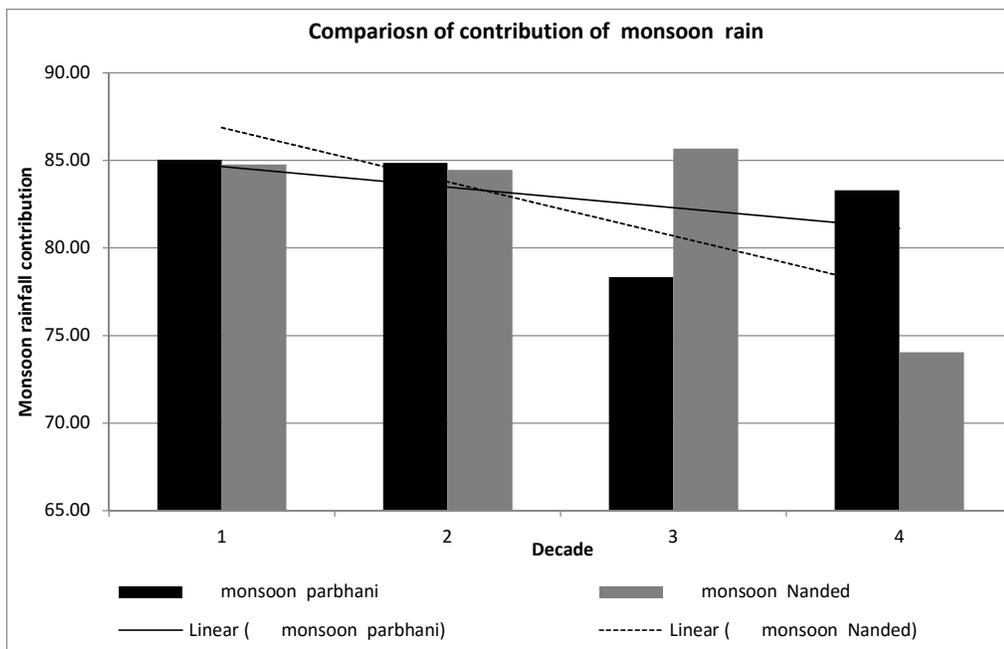


Figure 5.11 Comparison of Decade-wise Contribution of Monsoon Rainfall Trends of Nanded and Parbhani Cities



D. Analysis of Post Monsoon Rainfall Trends

The mean of post monsoon rainfall for Parbhani was 93.20 mm. long term seasonal rainfalls of post monsoon (Figure 5.12) revealed upward trends. The total post monsoon rainfall improved by 0.3564 mm/year and total rise was 14.90 mm. The maximum post monsoon rainfall was witnessed in the year 2002 and it was 349.40 mm. Near about 3911 mm rainfall was detected in post monsoon and it contributed 9.9% to the annual rainfall.

Decade-wise study of post monsoon (Figure 5.13) showed increasing trends. Post monsoon rainfall increased by 68.70 mm/decade and total increase s was 274.80 mm. The maximum post monsoon rainfall was observed in the 4th decade and it was 1090 mm. While minimum post monsoon rainfall was observed in 2nd decade and it was 779 mm.

The average post monsoon rainfall for Nanded was 120.38 mm. long term seasonal rainfalls of post monsoon (Figure 5.12) showed decreasing trends.

Figure 5.12 Comparison of Post Monsoon Rainfall of Nanded and Parbhani Cities

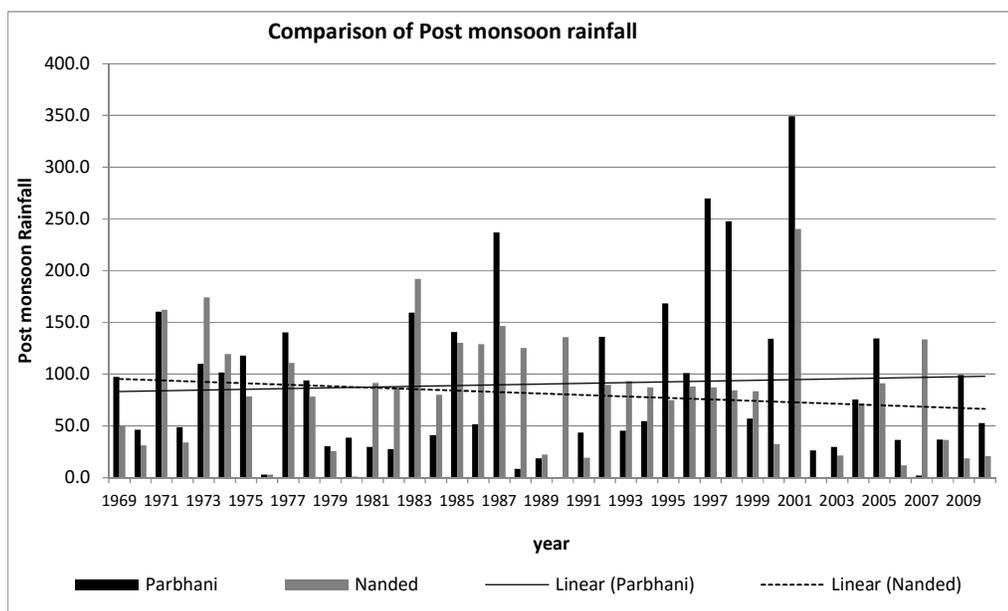
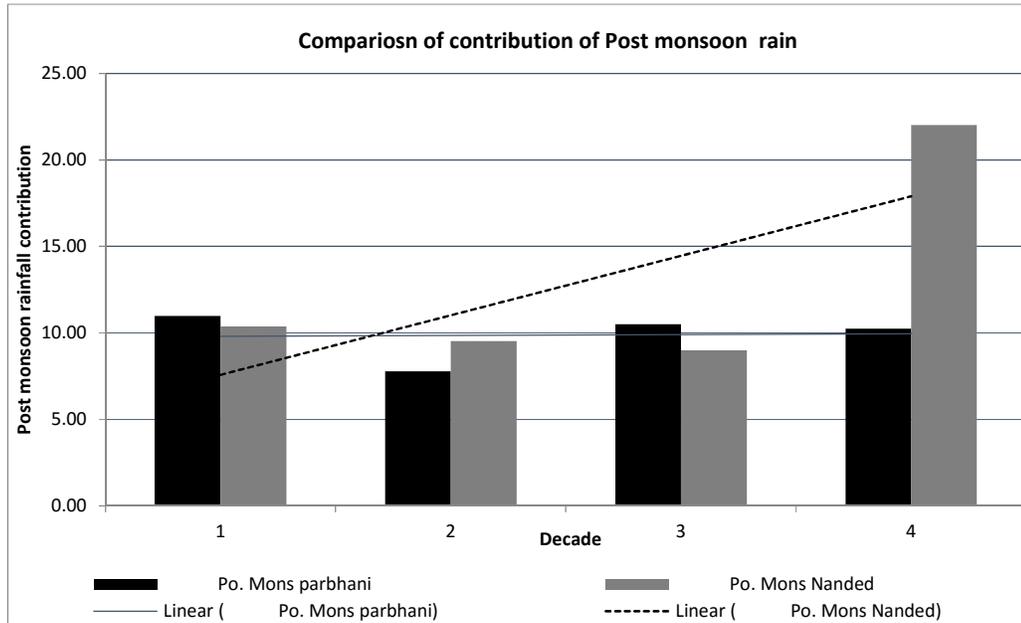


Figure 5.13 Comparisons of Decade-wise Post Monsoon Rainfall Trends of Nanded and Parbhani Cities



The post monsoon rainfall increased by 0.7097 mm/year and total increase was 29.70 mm. The maximum post monsoon rainfall was observed in the year 2001 and it was 240.50 mm. About 4695 mm rainfall was observed in post monsoon and it contributed 12.78% to the annual rainfall.

Decade-wise study of post monsoon (Figure 5.13) exposed rising trends. Post monsoon rainfall increased by 342.80 mm/decade and total decrease was 1371.20 mm. The maximum post monsoon rainfall was observed in the 4th decade and it was 2060.60 mm. While minimum post monsoon rainfall was observed in third decade and it was 782.80 mm.

Analysis of seasonal rainfall trends of Parbhani reveals that Maximum seasonal rainfall was observed in monsoon (Annexure 5.2 C). Monsoon contributed 83.30% and minimum seasonal rainfall of about 01.35% was contributed by winter. The maximum seasonal mean was observed in Monsoon and it was 782.40 mm. downward trends were perceived for monsoon rainfall and upward trends were seen for winter, summer and post monsoon season. Minimum mean rainfall was observed for winter which was 15.0 mm.

Study of seasonal rainfall trends of Nanded exposed that Maximum seasonal rainfall was detected in monsoon. Monsoon contributed 82.20% and minimum seasonal rainfall of about 0.93% was contributed by winter. The maximum seasonal mean was observed in Monsoon and it was 774.40 mm. Increasing trends were seen for monsoon rainfall. Minimum mean rainfall detected for winter which was 8.73 mm falling trends were detected for winter, summer, post monsoon.

5.3 Analysis of Monthly Rainfall Trends of Parbhani and Nanded Cities

The trends of monthly rainfall of Parbhani and Nanded for the period of 1969 to 2010 were acquired using linear regression best fit lines. The linear regression trends with their linear regression equations and coefficient of determination and COV for monthly rainfall are summarized in Annexure 5.3A, 5.3B and from below Figures and explained below.

For decade-wise study of month, months are divided into four decades decade.1st decade 1969-1978, decade 2 1979-1988, decade 3 1989-1998, decade 4 1999-2010.

A. Monthly Rainfall Trends of January

The average rainfall of January for Parbhani was 9.60 mm. linear trends of The long term rainfall trends of January (Figure 5.14) displayed growing trends. The total January rainfall enlarged by 0.1583/year and total rise was 6.60 mm. The maximum January rainfall was detected in the year 1995 and it was 82.90 mm. Near about 402.9 mm rainfall was recorded in January and it contributed 1.02 % to the annual rainfall.

The linear trends of decade-wise analysis of January (Figure 5.15) disclosed rising trends. January rainfall increased by 22.25 mm/decade and total increase was 89.20mm. The maximum January rainfall was observed in the 2nd decade and it was 166 mm. While minimum January rainfall was observed in 1st decade and it was 11.6 mm.

Figure 5.14
Comparison of January Rainfall of Nanded and Parbhani Cities

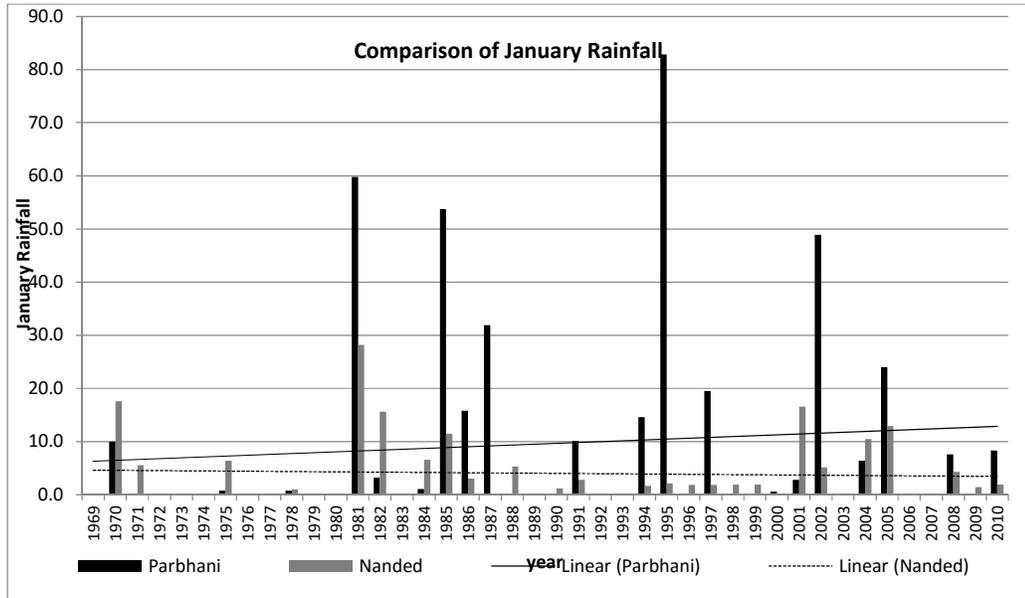
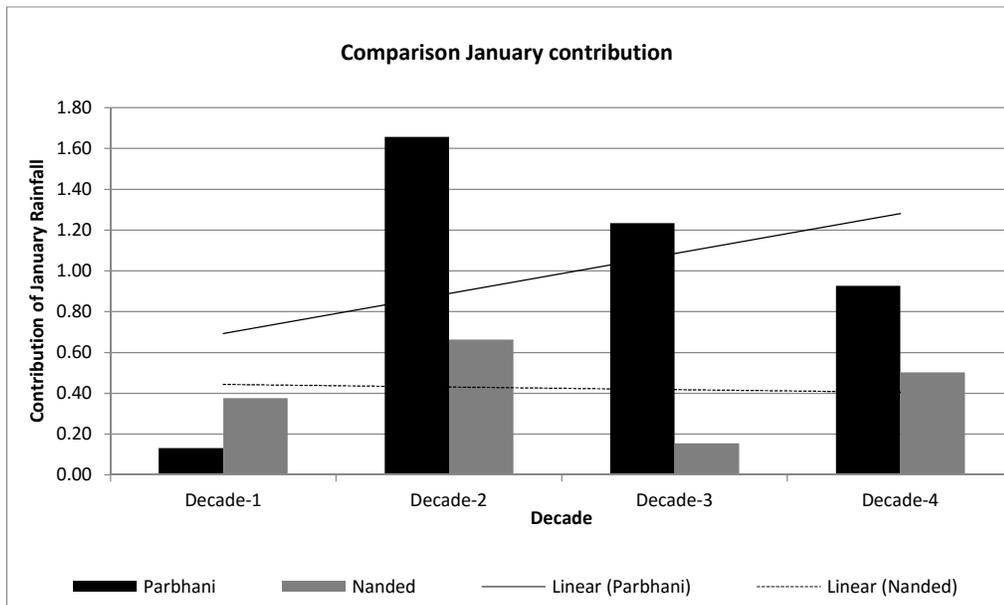


Figure 5.15 Comparison of Decade-wise Contribution of January Rainfall Trends of Nanded and Parbhani Cities



The average rainfall of January for Nanded was 4.14 mm. The long term rainfall trends of January (Figure 5.14) showed slightly decreasing trends. The total January rainfall decreased by 0.0285mm/year and total decrease was 1.20 mm. Maximum January

rainfall was observed in the year 1981 and it was 28.20 mm. near about 161.40 mm rainfall was observed in January and it contributed 0.44% to the annual rainfall.

Decade-wise study of January show slightly decreasing trends. January rainfall decreased by 0.7387 mm/decade and total increase was 2.950mm. The maximum January rainfall was observed in the 2nd decade and it was 70.20 mm. While minimum January rainfall was observed in third decade and it was 13.50 mm.

B. Monthly Rainfall Trends of February

The average rainfall of February for Parbhani was 5.40 mm. long term monthly rainfall trends during February presented falling trends (Figure 5.16). The total February rainfall reduced by 0.1130 mm /year and total reduction was 4.741 mm. The maximum February rainfall was noticed in the year 1985 and it was 74.30 mm. Near about 228.5 mm rainfall was detected in February and it contributed 0.58% to the annual rainfall.

Decade-wise study of February (Figure 5.17) of Parbhani reveals dropping trends. February rainfall cut by 7.645 mm/decade and total decrease was 30.40 mm. The maximum February rainfall was observed in the 2nd decade and it was 158.5 mm. While minimum February rainfall was detected in the third decade and it was 5.4 mm.

The average rainfall of February for Nanded was 4.60 mm. The long term rainfall trends of February revealed decreased trends. The total February rainfall decreased by 0.1458 mm/year and total decrease was 6.1 mm. The maximum February rainfall was observed in the year 1979 and it was 61.80mm. Near about 179 mm rainfall was observed in February and it contributed 0.49 % to the annual rainfall.

Figure 5.16
Comparison of February Rainfall of Nanded and Parbhani Cities

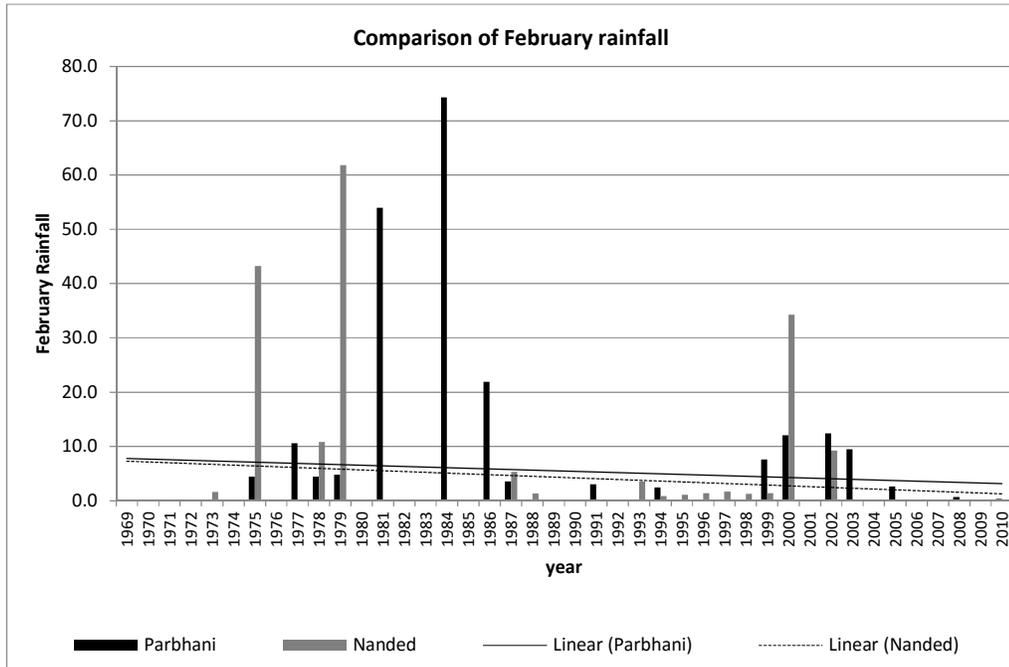
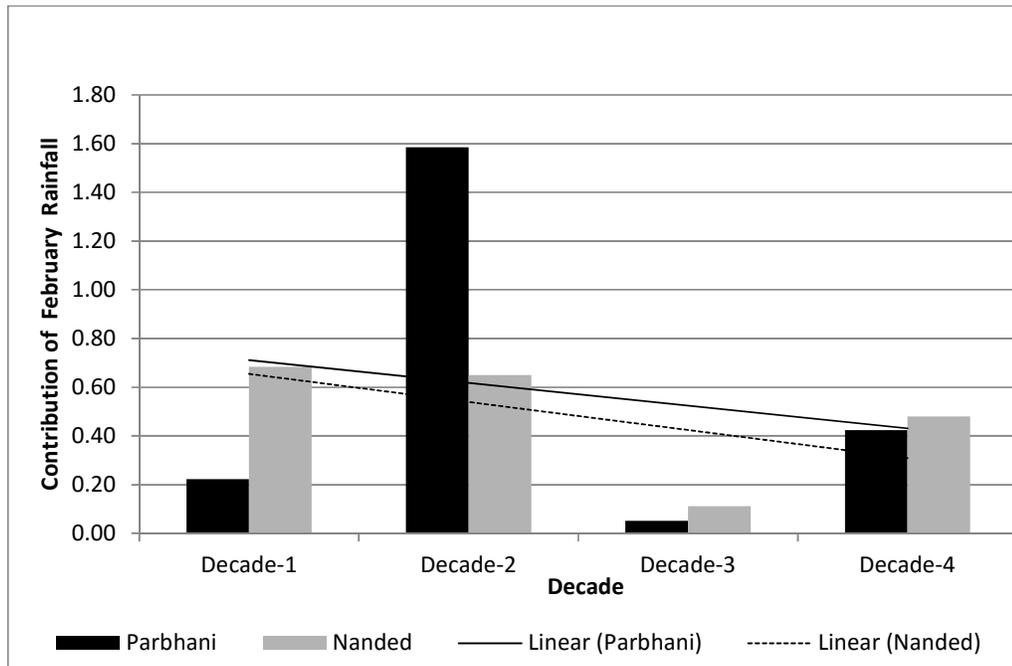


Figure 5.17 Comparison of Decade-wise Contribution of Rainfall of February of Nanded and Parbhani Cities



The linear trends of decade wise study of February contribution of rainfall showed declining trends. February rainfall decreased by 9.102 mm/decade and total increase was 36.40 mm. The maximum February rainfall was observed in the 2nd decade and it was 68.70 mm. While minimum February rainfall was observed in third decade and it was 9.8 mm.

C. Monthly Rainfall Trends of March

The average rainfall of March for Parbhani was 12.60 mm. The March rainfall trends revealed upward trends (Figure 5.18). The total March rainfall increased by 0.3639/year and total rise was 15.30 mm. The maximum March rainfall was detected in the year 1996 and it was 88.40 mm. Near about 528.80 mm rainfall was observed in March and it contributed 1.33 % to the annual rainfall.

Decade-wise study of March showed growing trends (Figure 5.19). March rainfall increased by 41.00 mm/decade and total increase was 164 mm. The maximum March rainfall was observed in the third decade and it was 192.10 mm. While minimum March rainfall was observed in 1st decade and it was 50.10 mm.

The average rainfall of March for Nanded was 7.00 mm. The long term rainfall trends trends of March showed decreasing trends. The March rainfall decreased by 0.2271 mm/year and total decrease was 9.50 mm. The maximum March rainfall was observed in the year 1981 and it was 50 mm. Near about 272.9 mm rainfall was observed in March and it contributed 0.74% to the annual rainfall.

Decade-wise study of March rainfall showed decreasing trends. March rainfall decreased by 19.49 mm /decade and total decrease was 77.02 mm. The maximum March rainfall was observed in the third decade and it was 86.20mm. While minimum March rainfall was observed in 4th decade and it was 18.40 mm.

Figure 5.18
Comparison of March Rainfall of Nanded and Parbhani Cities

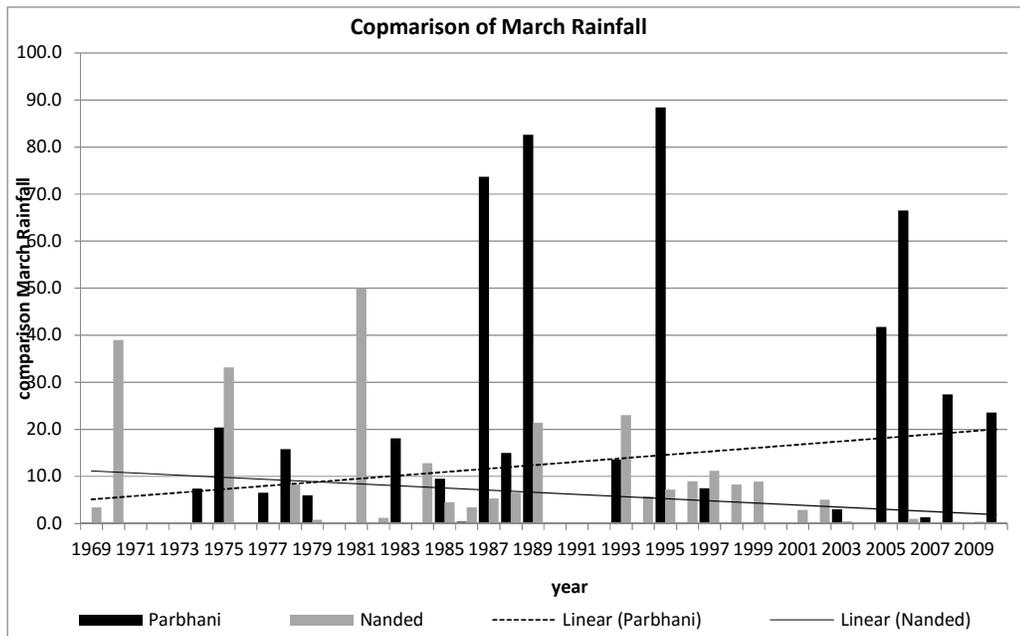
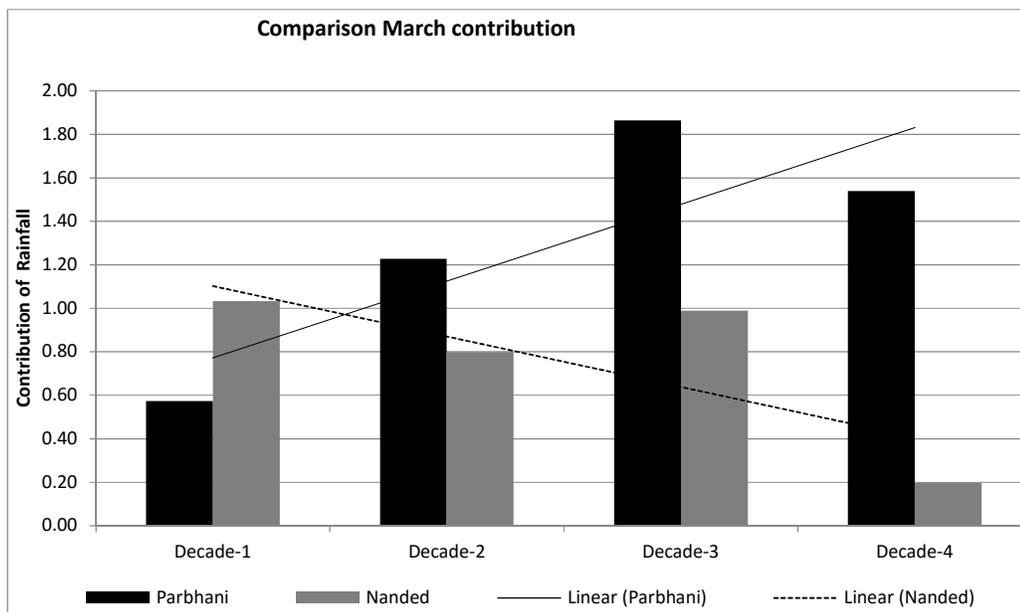


Figure 5.19 Comparison of Decade-wise Contribution of March Rainfall of Nanded and Parbhani Cities



D. Monthly Rainfall Trends of April

The average rainfall of April for Parbhani was 12.20 mm. The long term rainfall trends of April revealed rising trends (Figure 5.20). The total April rainfall enlarged by 0.2603 mm/year and total rise was 10.93 mm. The maximum April rainfall was witnessed in the year 1991 and it was 152.70 mm. Near about 513.85 mm rainfall was observed in April and it contributed 1.33 % to the annual rainfall.

Decade-wise study of April showed increasing trends (Figure 5.21). April rainfall increased by 49.20 mm/decade and total increase was 196.80 mm. The maximum April rainfall was observed in the third decade and it was 290.90 mm. While minimum April rainfall was observed in 1st decade and it was 50.10 mm.

The average rainfall of April for Nanded was 6.30 mm. The long term rainfall trends of April showed increasing trends. The total April rainfall increased by 0.3492 mm/year and total decrease was 14.70 mm. The maximum April rainfall was observed in the year 2007 and it was 40.90mm. Near about 244.50 mm rainfall was observed in April and it contributed 0.67 % to the annual rainfall

Decade-wise study of monthly rainfall of April of Nanded show increasing trends. April rainfall increased by 14.48 mm/decade and total decrease was 57.92 mm. The maximum April rainfall was observed in the 4th decade and it was 88.40 mm. While minimum April rainfall was observed in 1st decade and it was 36.80 mm.

Figure 5.20
Comparison of April Rainfall of Nanded and Parbhani Cities

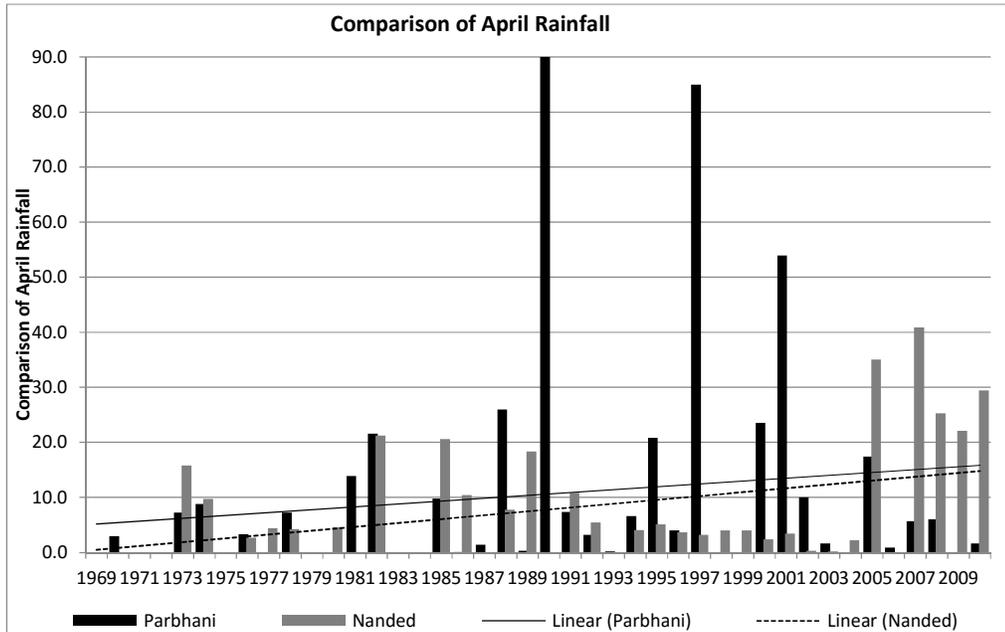
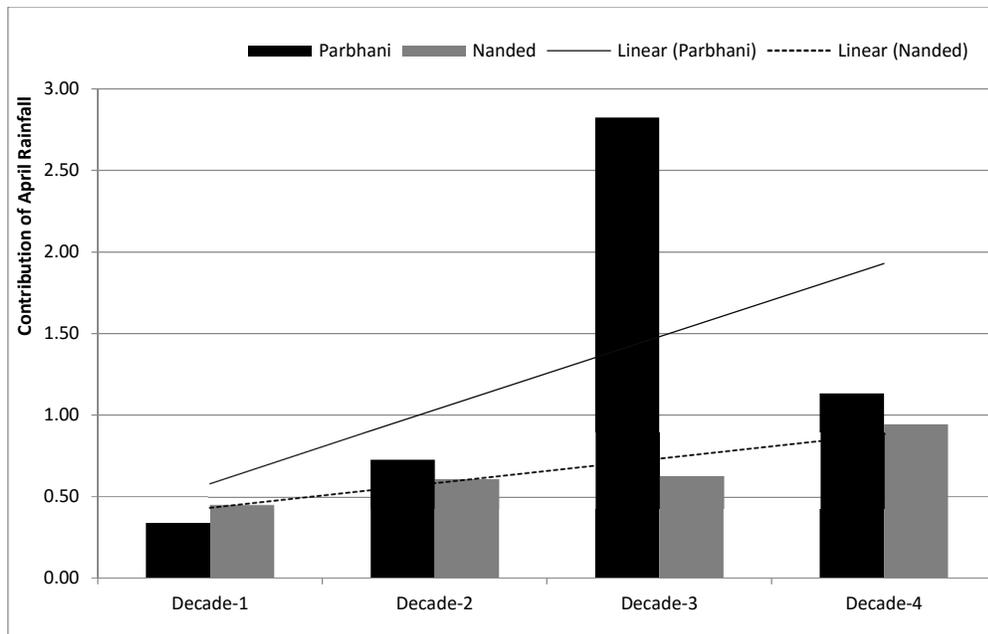


Figure 5.21 Comparison of Decade-wise Contribution of April Rainfall Trends of Nanded and Parbhani Cities



E. Monthly Rainfall Trends of May

The average rainfall of May for Parbhani was 29.70 mm. long term rainfall trends over May displayed slightly declining trends (Figure 5.22). The total May rainfall declined by 0.0606 mm/year and total decline was 2.55 mm. The maximum May rainfall was detected in the year 1991 and it was 303.10 mm. Near about 1248.82 mm rainfall was observed in May and it contributed 3.15 % to the annual rainfall.

Decade-wise study of May showed upward trends (Figure 5.23). May rainfall increased by 39.20 mm/decade and total increase was 156.80 mm. The maximum May rainfall was observed in the third decade and it was 536.90 mm. While minimum May rainfall was observed in 2nd decade and it was 259.70 mm.

The average rainfall of May for Nanded was 25.74 mm. The long term rainfall trends of May showed increasing trends (Figure 5.22). The total May rainfall increased by 0.2952 mm/year and total increase was 12.40 mm. The maximum May rainfall was observed in the year 1985 and it was 182 mm. Near about 1003.80 mm rainfall was observed in May and it contributed 2.73% to the annual rainfall.

Decade-wise study of May showed decreasing trends (Figure 5.23). May rainfall decreased by 10.65 mm/decade and total decrease was 42.60 mm. The maximum May rainfall was observed in the 2nd decade and it was 347.90mm. While minimum May rainfall was observed in 4th decade and it was 167.90mm.

Figure 5.22
Comparison of May Rainfall of Nanded and Parbhani Cities

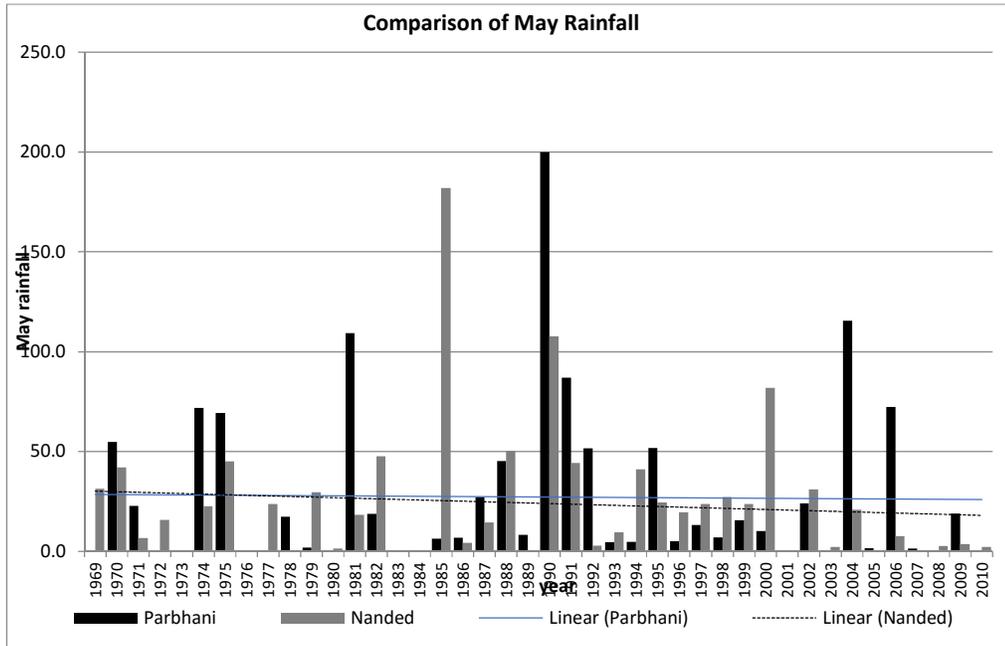
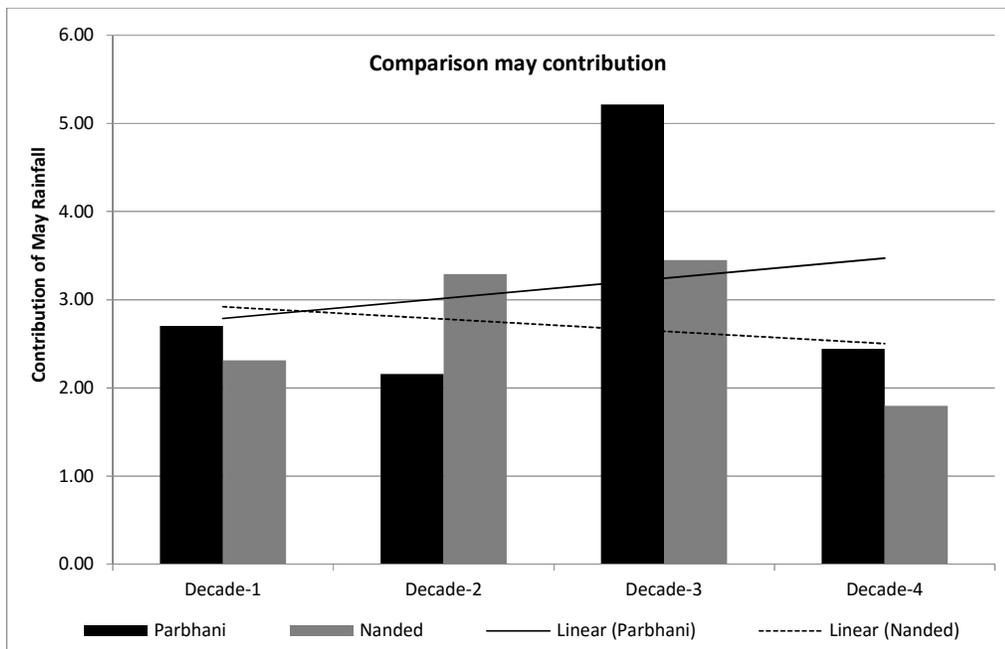


Figure 5.23 Comparison of Decade-wise Contribution of May Rainfall Trends of Nanded and Parbhani Cities



F. Monthly Rainfall Trends of June

The average rainfall of June over Parbhani was 165.80 mm. long term rainfall trends of June showed decreasing trends (Figure 5.24). The total June rainfall decreased by 0.4649/year and total decrease was 19.50 mm. The maximum June rainfall was observed in the year 1990 and it was 405. mm. Near about 6964.10 mm rainfall was observed in June and it contributed 17.55% to the annual rainfall.

Decade-wise study of June show increasing trends (Figure 5.25). June rainfall increased by 107.52 mm/decade and total increase was 430 mm. he maximum June rainfall was observed in the third decade and it was 2747.9 mm. While minimum June rainfall was observed in 1st decade and it was 1389.10 mm.

The average rainfall of June for Nanded was 154.03 mm. The long term rainfall trends of June exhibited rising trends (Figure 5.24). June rainfall enlarged by 1.2579 mm/year and total increase was 52.80 mm. The maximum June rainfall was observed in the year 1985 and it was 182 mm. Near about 6007.0 mm rainfall was observed in June and it contributed 16.34% to the annual rainfall.

Decade-wise analysis of June showed increasing trends (Figure 5.24). June rainfall increased by 111.73 mm/decade and total decrease was 446.92 mm. The maximum June rainfall was observed in the third decade and it was 2137.0 mm. While minimum June rainfall was observed in 1st decade and it was 1921.30 mm.

Figure 5.24

Comparison of Jun Rainfall of Nanded and Parbhani Cities

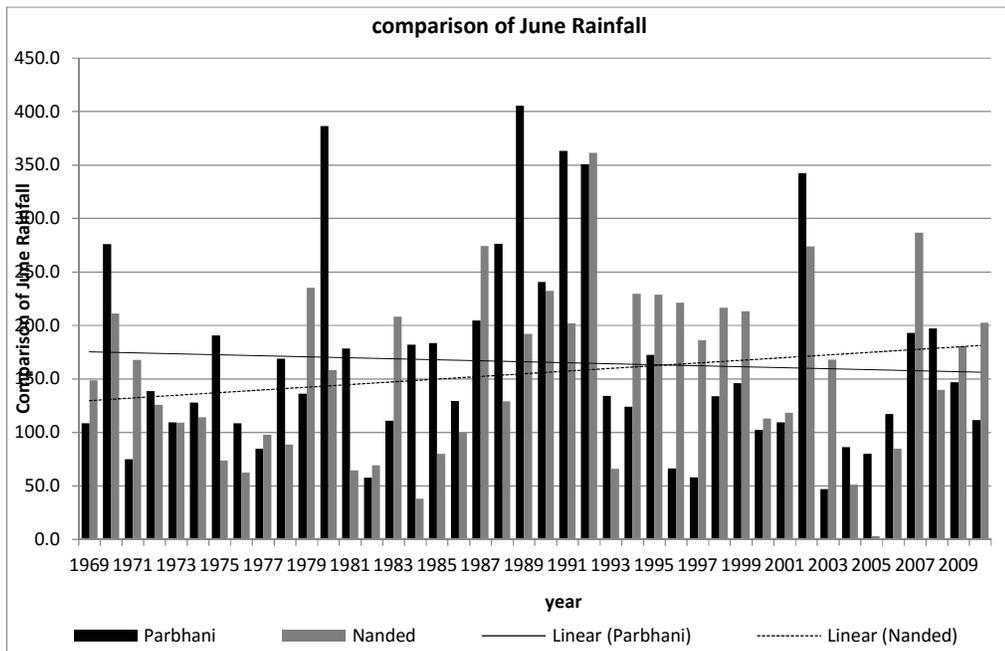
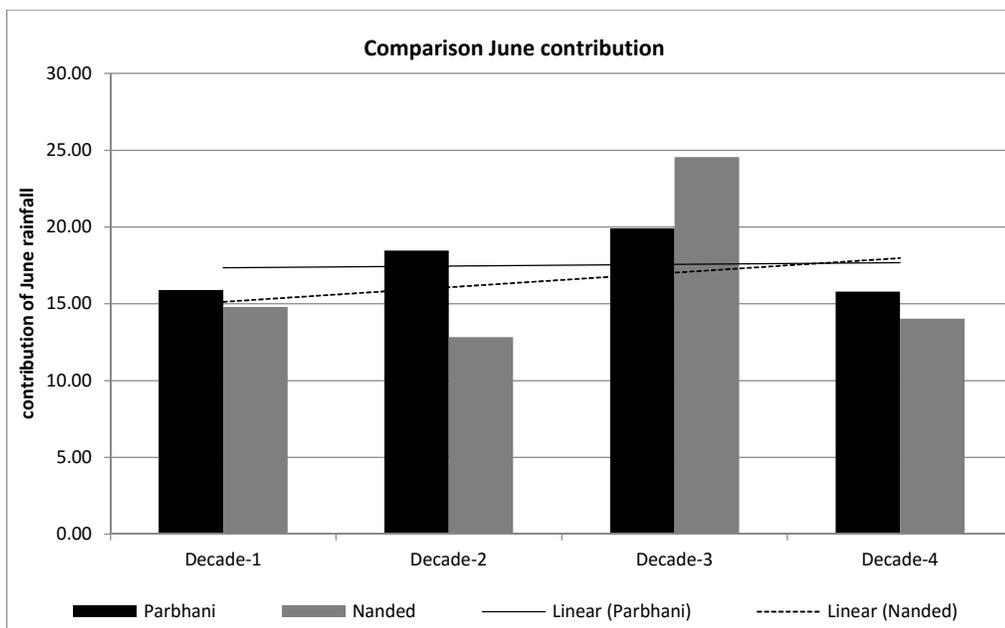


Figure 5.25 Comparison of Decade-wise Contribution of Rainfall June Trends of Nanded and Parbhani Cities



G. Monthly Rainfall Trends of July

The average rainfall of July for Parbhani was 250.60 mm. The long-term rainfall of July revealed growing trends (Figure 5.26). The total July rainfall improved by 2.831mm/year and total growth was 118.90 mm. The maximum July rainfall was detected in the year 2006 and it was 755 mm. Near about 10523.70 mm rainfall was observed in July and it contributed 26.52 % to the annual rainfall.

Decade-wise study of July rainfall showed upward trends (Figure 5.27). July rainfall enlarged by 457.99 mm/decade and total upsurge was 1831 mm. The maximum July rainfall was experienced in the 4th decade and it was 2624.80 mm. While minimum July rainfall was observed in 1st decade and it was 1955.50 mm.

The average rainfall of July for Nanded was 232.81 mm. The long-term rainfall of July showed increasing trends (Figure 5.26). The total July rainfall increased by 2.309 mm/year and total increase was 97.00 mm. The maximum July rainfall was observed in the year 2005 and it was 636.20mm. Near about 9079.4 mm rainfall was observed in July and it contributed 24.70% to the total annual rainfall.

Figure 5.26

Comparison of July Rainfall of Nanded and Parbhani Cities

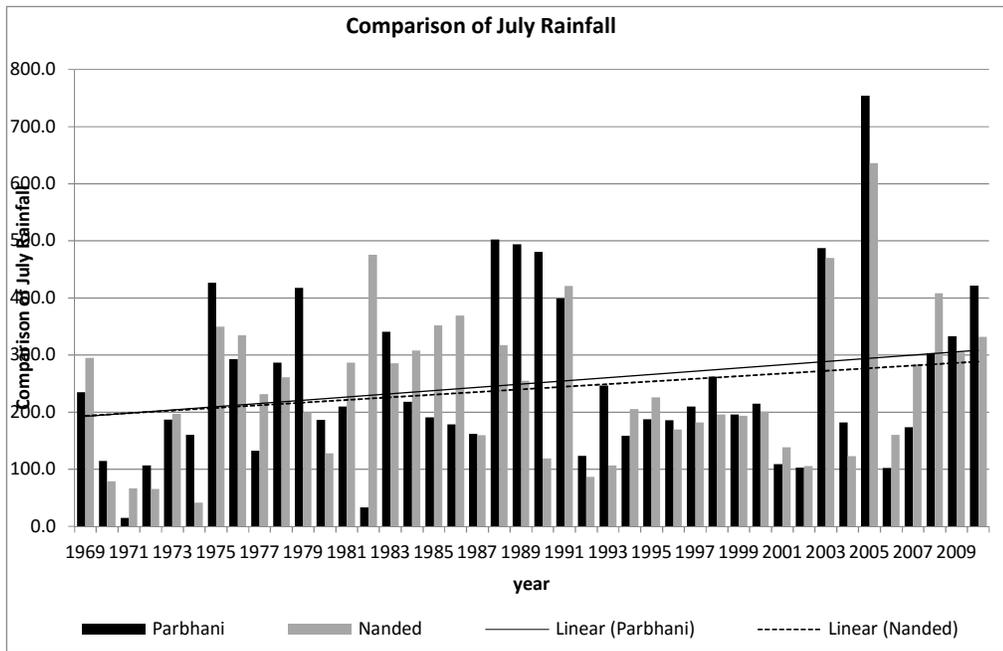
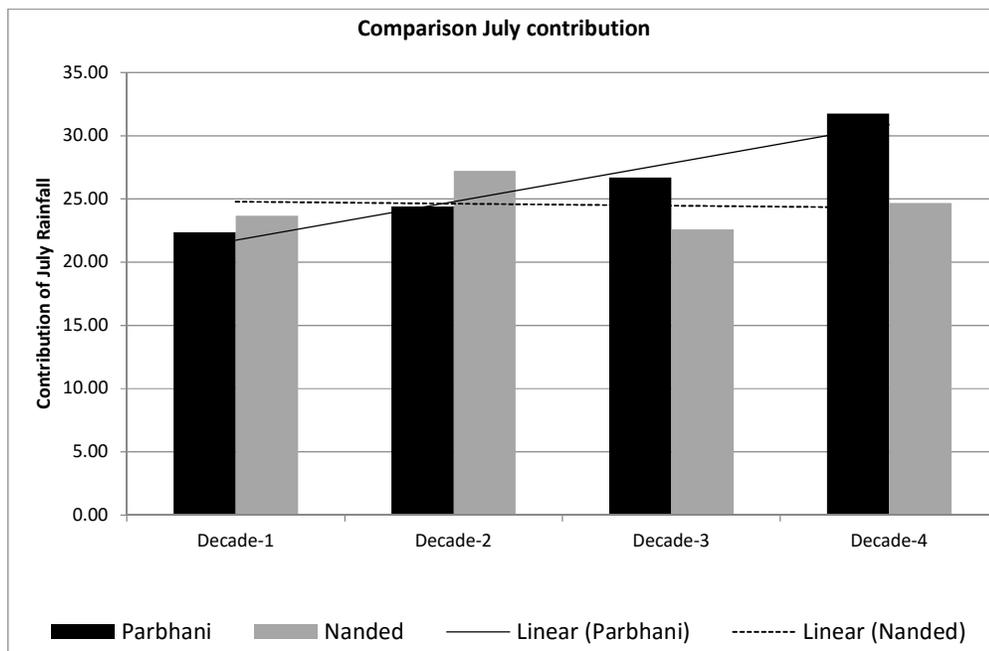


Figure 5.27 Comparison of Decade-wise Contribution of July Rainfall Trends of Nanded and Parbhani Cities



Decade-wise study of July showed increasing trends (Figure 5.27). July rainfall increased by 25.28mm/decade and total decrease was 101.12 mm. The maximum July rainfall was observed in the 2nd decade and it was 2881.0mm. While minimum July rainfall was observed in 1st decade and it was 1921.30 mm.

H. Monthly Rainfall Trends of August

The average rainfall of August for Parbhani was 210.60 mm. long term rainfall trends over August displayed declining trends (Figure 5.28). The total August rainfall declined by 2.868 mm/year and total decrease was 120.40 mm. The maximum August rainfall was observed in the year 1974 and it was 495.80 mm. Near about 8845.90 mm rainfall was detected in August and it contributed 22.29% to the annual rainfall.

Decade-wise study of August showed declining trends (Figure 5.29). August rainfall reduced by 208.65 mm/decade and total reduction was 836 mm. The maximum August rainfall was detected in the 2nd decade and it was 2587.9 mm. While minimum August rainfall was observed in 1st decade and it was 1729 mm.

The average rainfall of August for Nanded was 224.50 mm. The long-term rainfall trends of August showed increasing trends (Figure 5.28). The total August rainfall increased by 0.5744 mm/year and total increase was 24.10 mm. The maximum August rainfalls was observed in the year 1983 and it was 593.90mm. Near about 8755.30mm rainfall was observed in August and it contributed 23.82% to the annual rainfall.

Decade-wise study of August show increasing trends (Figure 5.29). August rainfall increased by 21.83mm/decade and total decrease was 85.12 mm. he maximum August rainfall was observed in the 2nd decade and it was 2595.10mm. While minimum August rainfall was observed in 1st decade and it was 1914.30 mm.

Figure 5.28
Comparison of August Rainfall of Nanded and Parbhani Cities

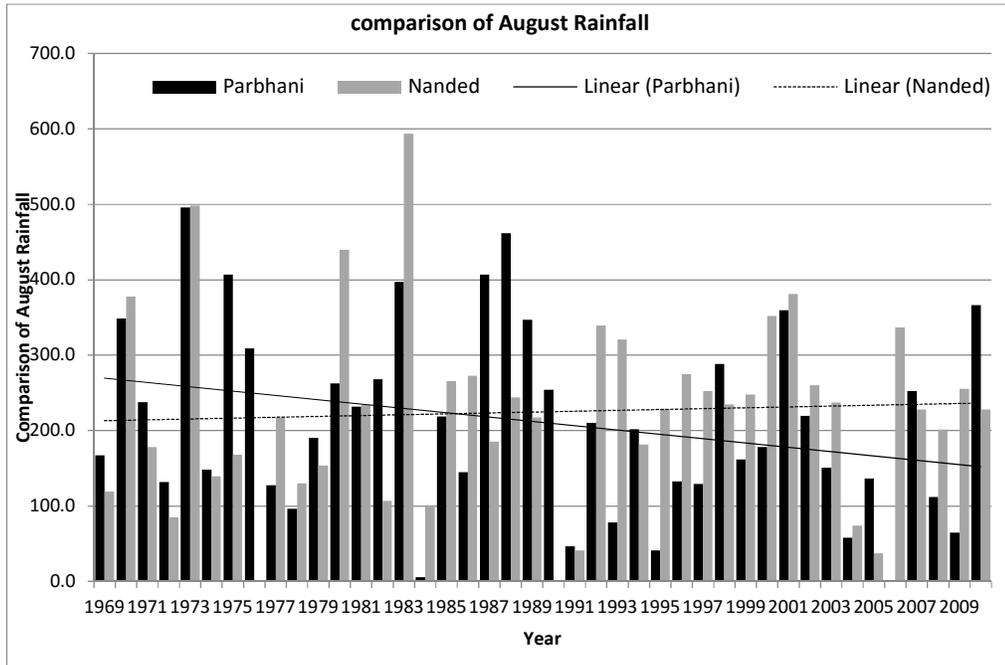
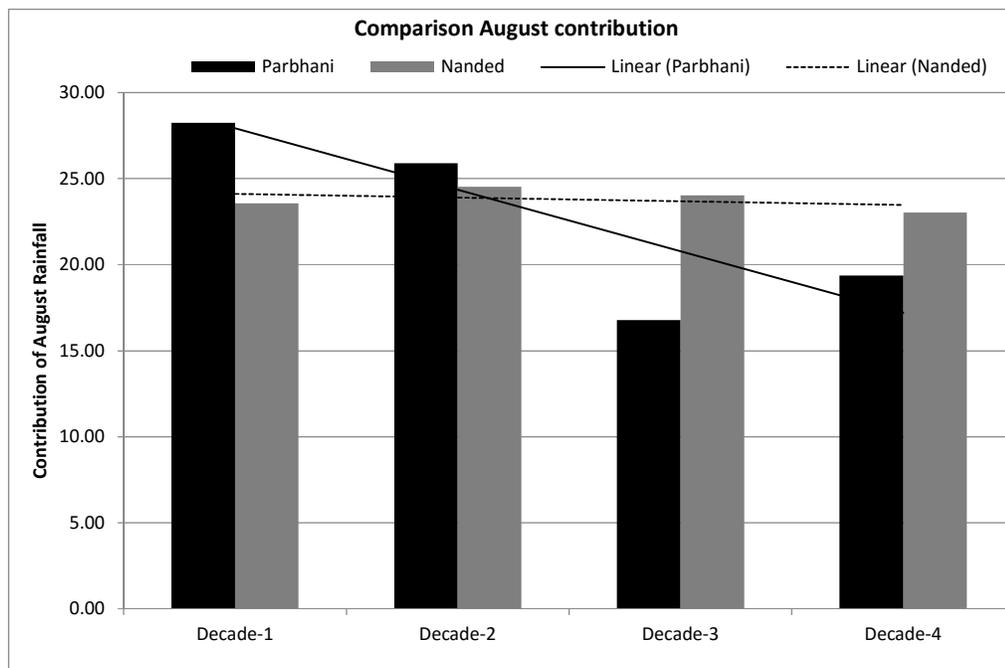


Figure 5.29 Comparison of Decade-wise Contribution of August Rainfall Trends of Nanded and Parbhani Cities



I. Monthly Rainfall Trends of September

The average rainfall of September for Parbhani was 155.30 mm. The long-term rainfall trends of September showed decreasing trends (Figure 5.30). The total September rainfall decreased by 0.4831mm/year and total decrease was 20.30 mm. The maximum September rainfall was observed in the year 1989 and it was 432.6 mm. Near about 6520.30 mm rainfall was observed in September and it contributed 16.43 % to the annual rainfall.

Decade-wise study of September show increasing trends (Figure 5.31). September rainfall increased by 30.31 mm/decade and total increase was 121.20 mm. The maximum September rainfall was observed in the 4th decade and it was 1746.60 mm. While minimum September rainfall was observed in third decade and it was 1541.30 mm.

The average rainfall of September for Nanded was 163.08 mm. The long-term rainfall of September displayed falling trends (Figure 5.30). The total September rainfall lessened by 1.5877 mm/year and total decline was 66.70 mm. The maximum September rainfall was observed in the year 1975 and it was 537.50 mm. Near about 8755.30 mm rainfall was observed in September and it contributed 17.30% to the annual rainfall.

Decade-wise study of September show decreasing trends (Figure 5.31). September rainfall decreased by 291.90mm/decade and total decrease was 1167mm. The maximum September rainfall was observed in the 2nd decade and it was 2099.10mm. While minimum September rainfall was observed in 4th decade and it was 1152.10 mm.

Figure 5.30
Comparison of September Rainfall of Nanded and Parbhani Cities

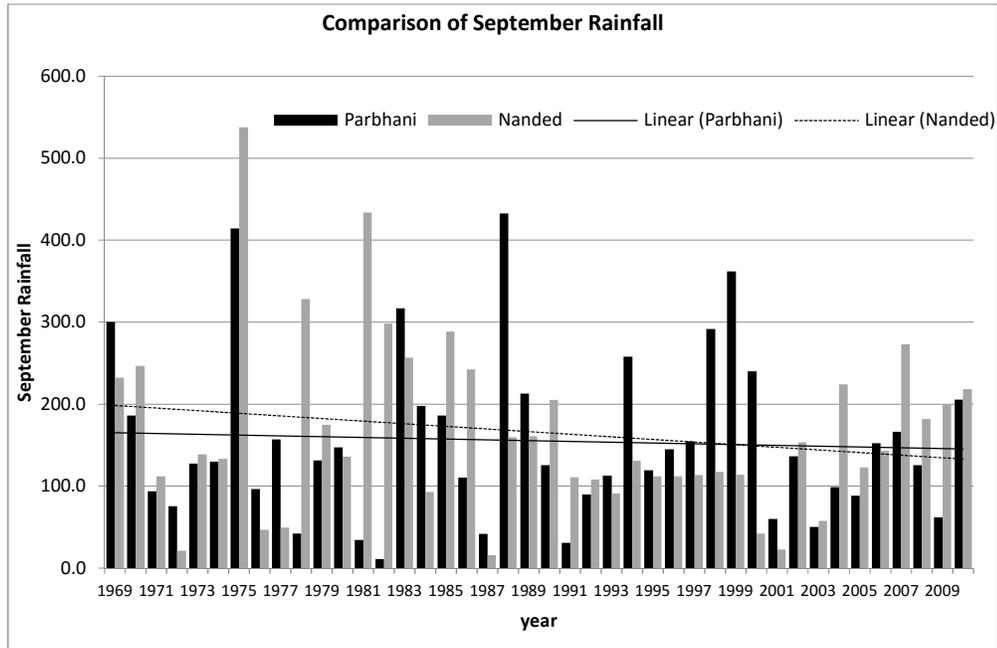
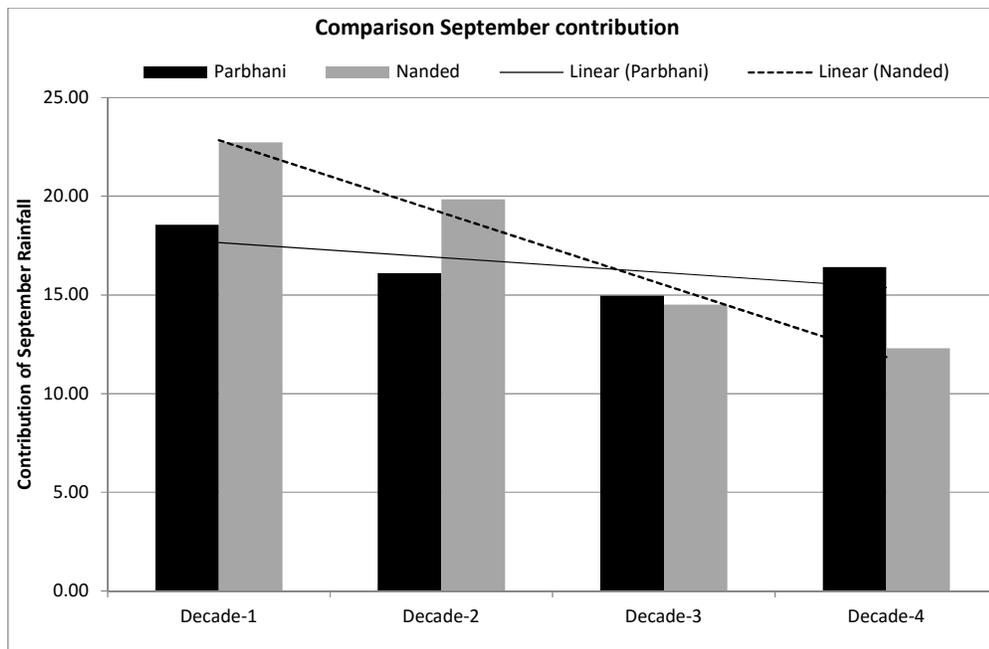


Figure 5.31 Comparison of Decade-wise Contribution of September Rainfall Trends of Nanded and Parbhani Cities



J. Monthly Rainfall Trends of October

The average rainfall of October for Parbhani was 68.70 mm. The long-term rainfall trends of October exposed growing trends (Figure 5.32). The total October rainfall enlarged by 0.3280 mm/year and total increase was 13.80 mm. The maximum October rainfall was observed in the year 2002 and it was 349.40 mm. Near about 2885.70 mm rainfall was observed in October and it contributed 7.27% to the annual rainfall.

Decade-wise study of October showed growing trends. October rainfall increased by 70.60 mm/decade and total increase was 282.40 mm (Figure 5.33). The maximum October rainfall was detected in the 4th decade and it was 889.90 mm. While minimum October rainfall was observed in 2nd decade and it was 526 mm.

The average rainfall of October for Nanded was 63.61 mm. The long-term rainfall of October showed decreasing trends (Figure 5.32). The total October rainfall decreased by 0.8549 mm/year and total decrease was 35.90 mm. The maximum October rainfall was observed in the year 2001 and it was 240.50 mm. Near about 2480.80mm rainfall was observed in October and it contributed 6.75 % to the annual rainfall.

Figure 5.32
Comparison of October Rainfall of Nanded and Parbhani Cities

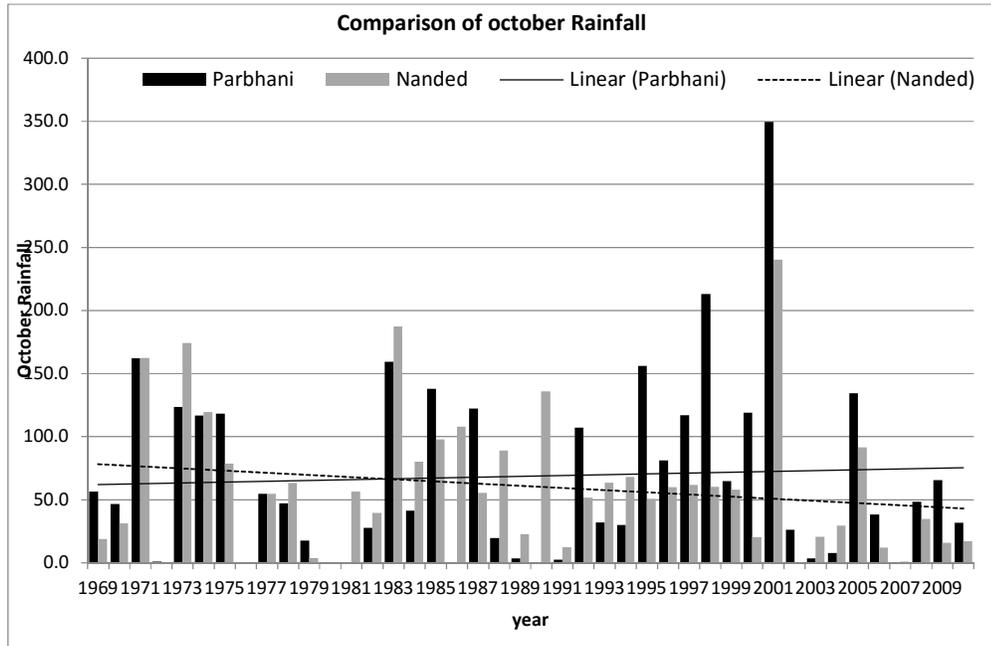
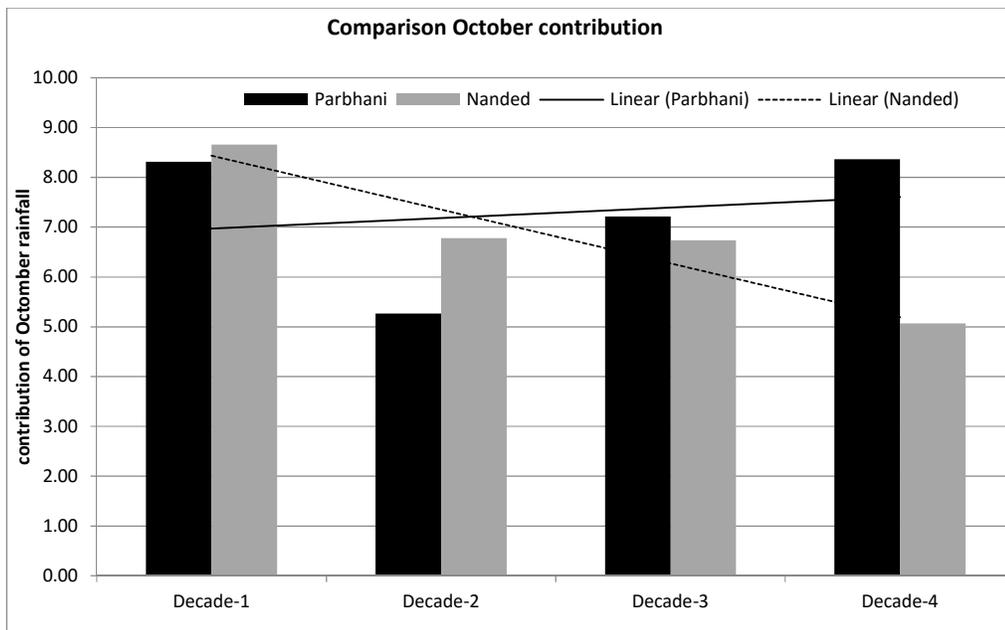


Figure 5.33 Comparison of Decade-wise Contribution of October Rainfall Trends of Nanded and Parbhani Cities



Decade-wise study of October show reducing trends (Figure 5.33). October rainfall decreased by 81.66mm/decade and total decrease was 326.60mm. The maximum October rainfall was observed in the 2nd decade and it was 717.20mm. While minimum October rainfall was observed in 4th decade and it was 474.10mm.

K. Monthly Rainfall Trends of November

The average rainfall of November for Parbhani was 18.20 mm. The long-term rainfall trends of November revealed rising trends (Figure 5.34). The total November rainfall raised by 0.0476 mm/year and total increase was 1.99 mm. Maximum November rainfall was observed in the year 1978 and it was 93.40 mm. near about 764.90 mm rainfall was observed in November and it contributed 1.93% to the annual rainfall.

Decade-wise study of November do not show any trends (Figure 5.35). The maximum November rainfall was observed in the 4th decade and it was 226.50 mm. While minimum November rainfall was observed in 1st decade and it was 126.5 mm decrease was 9.10 mm. The maximum November rainfall was observed in the year 1987 and it was 84.30mm. Near about 535.90mm rainfall was observed in November and it contributed 1.46% to the annual rainfall.

Decade-wise study of November shows decreasing trends (Figure 5.35). November rainfall decreased by 28.656 mm/decade and total decrease was 114.64 mm. The maximum November rainfall was observed in the 2nd decade and it was 246.30 mm. While minimum November rainfall was observed in 4th decade and it was 62.80mm.

Figure 5.34
Comparison of November Rainfall of Nanded and Parbhani Cities

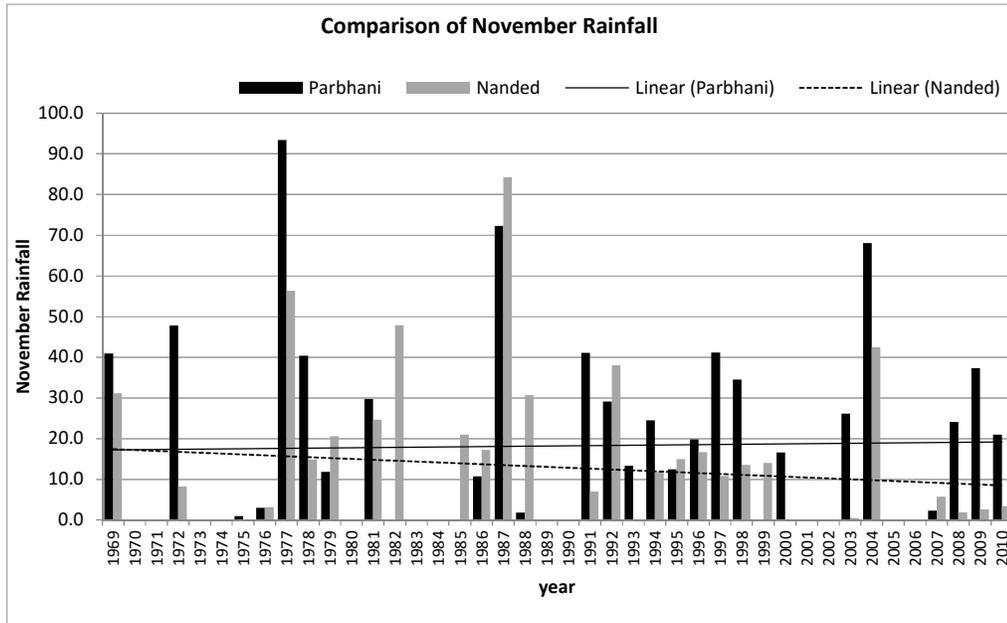
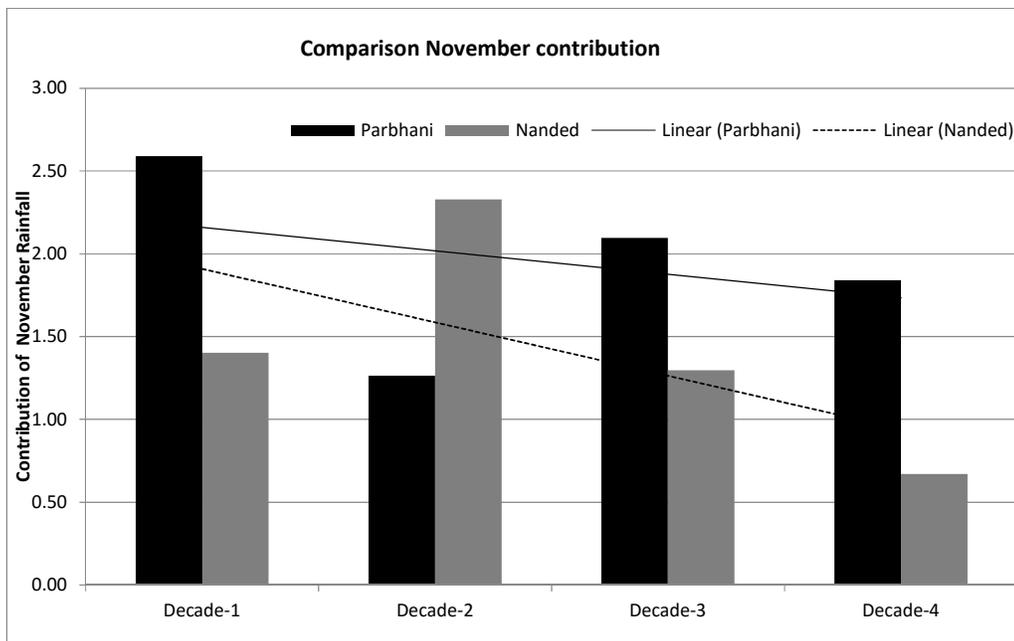


Figure 5.35 Comparison of Decade-wise Contribution of November Rainfall Trends of Nanded and Parbhani Cities



The average rainfall of November for Nanded was 13.74 mm. The long-term rainfall of November showed decreasing trends (Figure 5.34). The total November rainfall decreased by 0.2169 mm/year and total

L. Monthly Rainfall Trends of December

The average rainfall of December for Parbhani was 6.20 mm. The long-term rainfall trends of December presented slightly growing trends (Figure 5.36). The total December rainfall enlarged by 0.2820 mm/year and total increase was 1.1844 mm. The maximum December rainfall was detected in the year 1998 and it was 111.8 mm. Near about 261.20 mm rainfall was detected in December and it contributed 0.66% to the annual rainfall.

Decade-wise study of December showed decreasing trends (Figure 5.37). December rainfall decreased by 1.589 mm/decade and total increase was 6.4 mm. The maximum December rainfall was observed in the 2nd decade and it was 126.5 mm. While minimum December rainfall was detected in 4th decade and it was 8.2 mm.

The average rainfall of December for Nanded was 43.03 mm. The long-term rainfall of December showed increasing trends (Figure 5.36). The total December rainfall increased by 0.5694 mm/year and total increase was 23.91 mm. The maximum December rainfall was observed in the year 2007 and it was 126.90 mm. Near about 535.90mm rainfall was observed in December and it contributed 4.57% to the annual rainfall.

Decade-wise study of December show increasing trends (Figure 5.37). December rainfall increased by 453.10mm/decade and total increase was 1638.32 mm. The maximum December rainfall was observed in the 4th decade and it was 1523.60mm. While minimum December rainfall was observed in 1st decade and it was 25.80 mm.

Figure 5.36
Comparison of December Rainfall of Nanded and Parbhani Cities

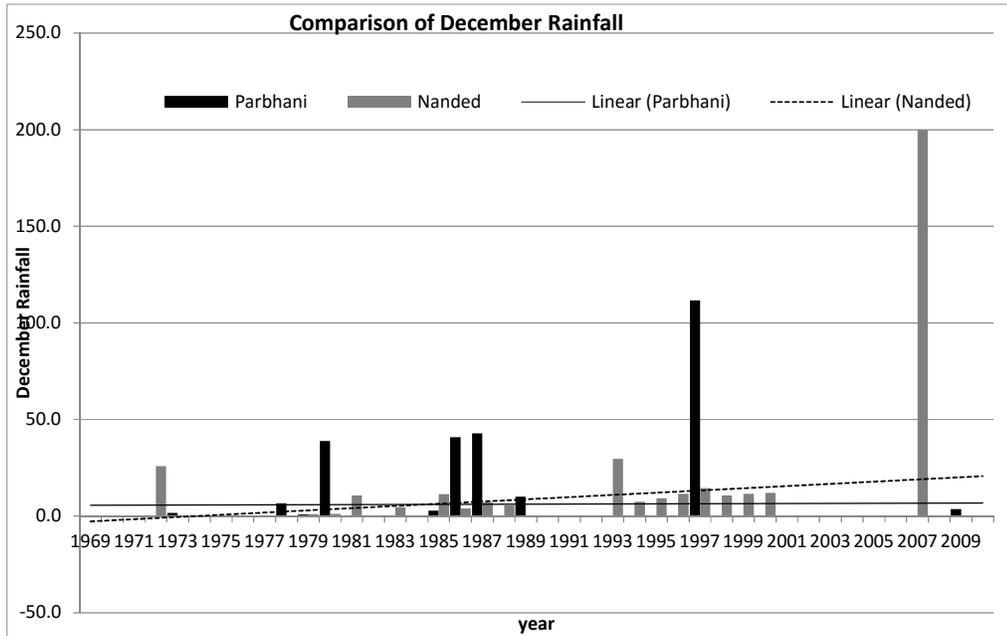
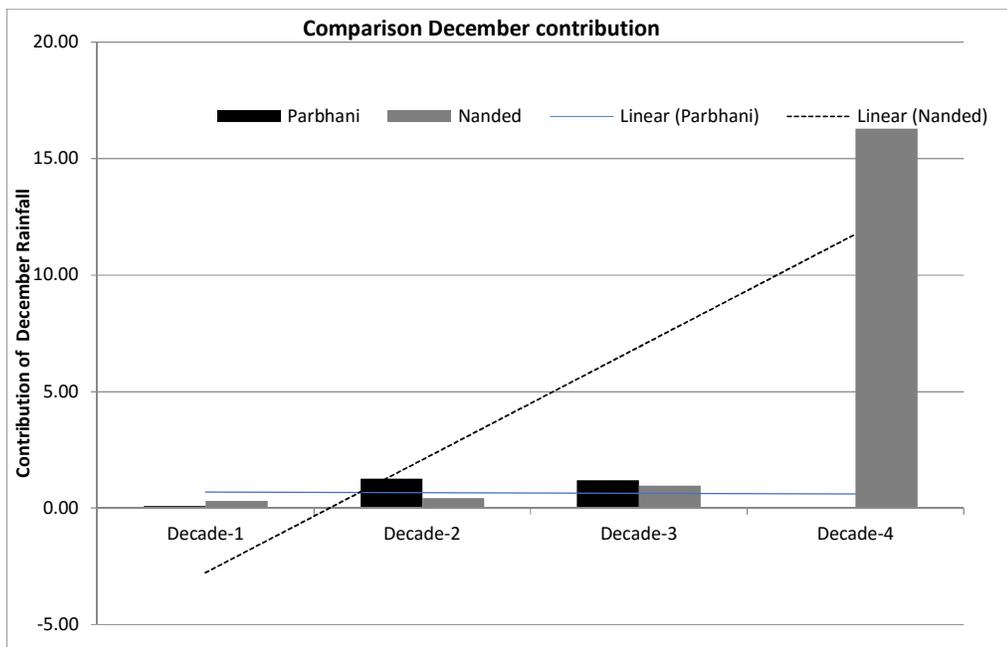


Figure 5.37 Comparison of Decade-wise Contribution of December Rainfall Trends of Nanded and Parbhani Cities



Behavior of monthly rainfall had been calculated for individual months by subjecting them to the linear trends. The results are presented in above tables 5.3A, 5.2B and from above Figures. It is evident from above Figures and table 5.3A, 5.2B that maximum monthly rainfall for Parbhani was observed for July, August, June and September and it was 250.60 mm, 210.60 mm, 165.80 mm, and 155.20 mm respectively. January, March, April, July, October, November, December showed growing monthly rainfall trends. The maximum growth was seen for July and it was 2.80 mm/year and total increase was 118.90 mm.

For Parbhani February, May, June, August, September show decreasing trends. The maximum fall was seen for the month of August and it was 2.86 mm/year and total fall was 120.40 mm. For monthly rainfall, maximum COV was observed for December and February and it was 318.15% and 262.02% respectively and minimum COV was observed for June, August and September and it was 56.12%, 59.45%, and 56.87% respectively. This means that monthly rainfall was more variable in December and February and it is more stable in June, August and September.

Study of Decade-wise monthly rainfall trends of Parbhani most of months revealed increasing trends which includes January, March, April, May, June, July, September, October and. The maximum increase was noticed for July and it was 458 mm/year and total increase over the given period was 1832 mm. February, August and December showed decreasing trends maximum decrease was observed for the month of August and it was 204 mm/decade and total decrease over given period was 836mm. While monthly rainfall of November showed no trends.

For Nanded in an annual rainfall, maximum contribution was done by July, August, June and September and they contribute 26.52%, 22.29%, 17.55%, and 16.43% respectively, while least contribution was done by February, December, January and April. They contribute 0.58%, 0.66%, 1.02% and 1.29% respectively.

It is evident from above Figures and table that maximum monthly rainfall over Nanded was observed for July, August, September and June and it was 2532.81 mm, 224.50 mm, 163.10 mm, and 154.00 mm respectively. 56% (7) months showed decreasing monthly rainfall trends while 44% (5) months showed increasing monthly rainfall trends. January, February March, May, September, October, November, showed decreasing monthly rainfall trends.

For Nanded Maximum decrease was seen for September and it was 2.4253 mm/year and total decrease was 94.59 mm. April, June, July, August, and December displayed growing rainfall trends. The maximum rise was seen for the month of December and it was 5.8261 mm/year and total rise was 227.22 mm. For monthly rainfall, maximum COV was observed for December and February and it was 556.69 and 280.51 respectively and minimum COV was observed for June, July and August and it was 52.69%, 55.53% and 58.18% respectively. This means that monthly rainfall was more variable in December and February and it is more stable in June, July and August

Study of Decade-wise monthly rainfall trends reveal most of months displayed decreasing trends which includes January, February, March, May, September, October and November. The maximum decrease was noticed for September and it was 291.90 mm/decade and total decrease over the given period was 1167.60 mm. April, June, July August and December showed increasing trends maximum increase was observed for the month of December and it was 453.10 mm/decade and total increase over given period was 1812 mm.

In an annual rainfall of Nanded maximum contribution was done by July, August, September and June and they contribute 24.70%, 23.82%, 17.30% and 16.34% respectively, while least contribution was done by January, February, April, March. They contribute 0.44%, 0.49%, 0.67 % and 0.74% respectively.

5.4 Analysis of Daily Rainfall Trends of Parbhani and Nanded

For analysis of daily rainfall trends over Parbhani and Nanded monsoon season (June, July, August, and September) has been considered. From Figure 5.36, 5.37 and Table 5.4A, 5.4B it was plain that In June Maximum mean of daily rainfall for Parbhani was observed on 21th and 26th June and it was 10.3 mm and 8.6 mm. Minimum of mean daily rainfall was seen on 1st and 7th June and it was 1.4 mm and 1.8 mm. The maximum COV was observed on 18th June and it was 463.316%. Minimum COV was observed on 28th June and it was 148.146%. It means that daily rainfall was more variable on 18th June and it was more stable on 28th June.

Linear trends of daily rainfall of 12th June showed Maximum increase of 0.185 mm/year and total increase in rainfall in June was 7.77 mm and 2nd June displayed maximum fall of 0.249 mm/year and total fall detected was 10.458 mm in daily rainfall in June. Rainfall amount realized in a day is 2.5 mm or more is called as rainy day. The maximum rainy days were observed on 23rd and 28th June and it was 20. Minimum rainy days were observed on 1st June and it was 6.

In July, Maximum mean of daily rainfall of Parbhani was observed on 25th July and it was 19.10 mm. Minimum of mean daily rainfall was seen on 17th July and it was 2.6 mm. The maximum COV was observed on 30th July and it was 279.054. Minimum COV was observed on 2nd July and it was 151.440. It means that daily rainfall was more variable on 30th July and it was more stable on 2nd July.

Linear trends of daily rainfall of 25th July presented Maximum rise in July of 1.373 mm/year and total increase in daily rainfall in July was 57.666 mm. Linear trends of daily rainfall of 6th July showed maximum fall in July of 0.320 mm/year and total fall observed was 13.44 mm in daily rainfall in July. Maximum rainy days were observed on 26th July and it was 25. Minimum rainy days were observed on 12st, 17th, 31st July and it was 10.

In August Maximum of mean of daily rainfall of Parbhani was observed on 25th August and it was 19.10 mm. Minimum of mean daily rainfall was seen on 17th August and it was 2.6mm mm. The maximum COV was observed on 30th August and it was 279.054. Minimum COV was observed on 2nd August and it was 151.44%. It means that daily rainfall was more variable on 30th August and it was more stable on 2nd August. Linear trends of daily rainfall of 5th August showed Maximum increase in August of 0.293 mm/year and total increase in daily rainfall in August was 12.306mm.

Linear trends of daily rainfall of 20th August showed maximum fall in August of 0.503mm/year and total fall observed was 21.126 mm in daily rainfall in August. Maximum rainy days were observed on 26th August and it was 25. Minimum rainy days were observed on 12st, 17th, 31st August and it was 10.

In September Maximum of mean of daily rainfall of Parbhani was observed on 7th September and it was 11.20 mm. Minimum of mean daily rainfall was seen on 11th September and it was 1.0 mm. The maximum COV was observed on 29^h September and it was 503.049. Minimum COV was observed on 1st September and it was 181.536. It means that daily rainfall was more variable on 29th September and it was more stable on 1st September.

Linear trends of daily rainfall of 21th September showed Maximum increase in September of 0.280mm/year and total increase in daily rainfall for 21th September was 11.76mm. Linear trends of daily rainfall of 1st September showed maximum fall in September of 0.539mm/year and total fall observed was 22.638 mm in daily rainfall in September. The maximum 15 rainy days were observed on 1st, 6th, 20th September. Minimum 5 rainy days were observed on 29th September.

Maximum of mean daily rainfall of Parbhani was seen on 25th July and 24th July and it was 19.10 mm and 15.40 mm respectively. Minimum of daily rainfall was observed on 11th September and 1st June and it was 1.00 mm and 1.40 mm respectively. Out of 122 day of monsoon season near about (61) 50.15 % days show upward daily rainfall trends and 60

(49.18%) show downward trends. The maximum increasing trends of daily rainfall was observed for 25th July.

For this day rainfall has increased 1.3732 mm/year and total rise was 57.67 mm. The maximum fall was seen for 1st September daily rainfall decreased by 0.5399 mm/year total fall of 22.64 mm was noticed. While linear trends of daily rainfall of 4th June does not show any trends.

Maximum COV was seen for 29th September, 18th June and this was 503.049% and 463.316% respectively and minimum COV was seen for 26th July and 26th August and it was 130.081% and 145.014% respectively. This means daily rainfall was more variable on 29th September and 18th July and daily rainfall was more stable on 26th July and 26th August.

In June, Maximum mean of daily rainfall of Nanded was detected on 24th and 30th June and it was 14.80 mm and 13.90 mm. Minimum of mean daily rainfall was seen on 8th and 1st June and it was 1.0 mm and 1.7 mm. The maximum COV was observed on 1st and 5th June and it was 368.240% and 344.529% respectively. Minimum COV was observed on 16th and 12th June and it was 135.452% and 141.776% respectively.

It means that daily rainfall was more variable on 1st and 5th June and it was more stable on 16th and 12th June. A linear trend of daily rainfall of 24th June over Nanded showed Maximum increase of 0.713 mm/year and total increase in rainfall in June was 27.807 mm. 25th June showed maximum fall of 0.341 mm/year and total fall observed was 13.299 mm.

Maximum rainy days were detected on 15th and 11th June and it was 21 and 20 respectively. Minimum rainy days were observed on 1st June and 8th June and it was 3 and 5 respectively

Figure 5.38 Showing Number of Daily Rainfall Trends of Nanded and Parbhani Cities

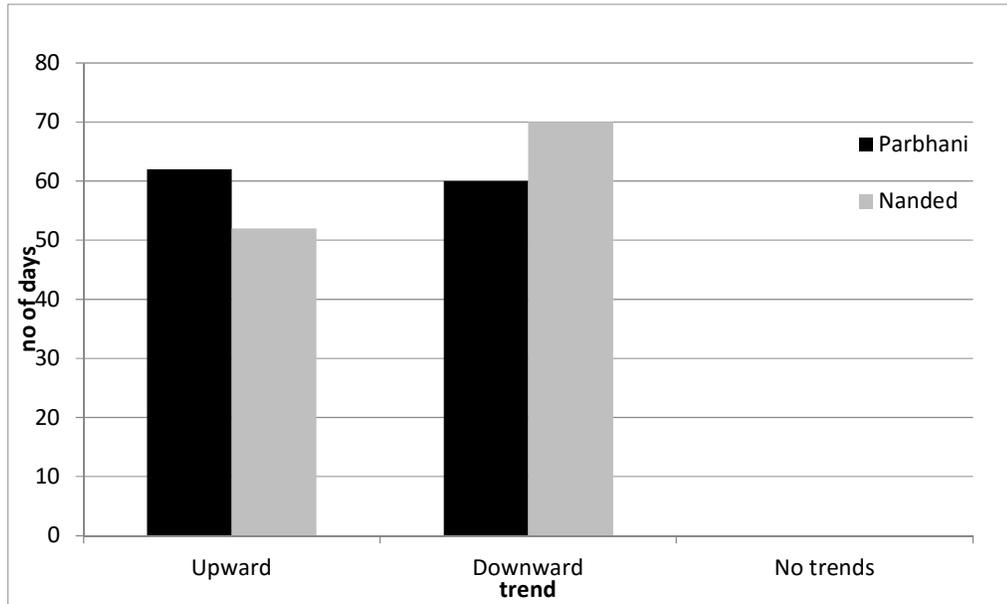
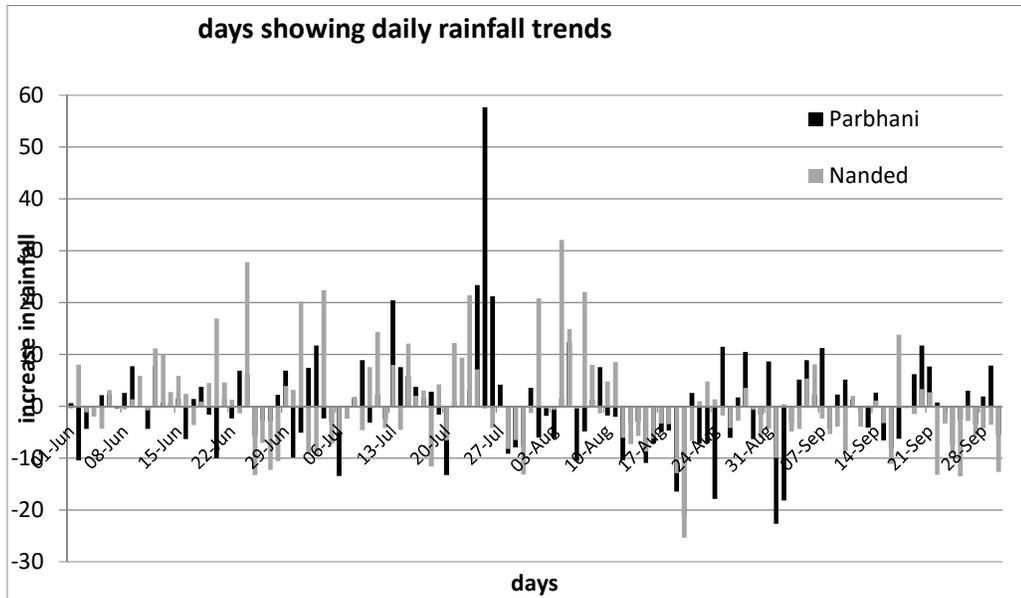


Figure 5.39 Comparison of Daily Rainfall Trends of Nanded and Parbhani Cities



In July, Maximum mean of daily rainfall of Nanded was observed on 12th July and it was 13.50 mm. Minimum of mean daily rainfall was seen on 29th July and it was 3.30 mm. The maximum COV was observed on 23rd July and it was 363.295%. Minimum COV was observed on 12th July and it was 119.156%. It means that daily rainfall was more variable on 23rd July and it was more stable on 12th July.

A linear trend of daily rainfall of 4th July displayed Maximum surge in July of 0.573 mm/year and total increase in daily rainfall in July was 22.347 mm. A linear trend of daily rainfall of 30th July showed maximum fall in July of 0.168 mm/year and total fall observed was 13.104 mm in daily rainfall in July. Maximum rainy days were observed on 12th July and it was 26. Minimum rainy days were observed on 19th July and it was 05.

In August Maximum of mean of daily rainfall of Nanded was perceived on 11th August and it was 21.10 mm. Minimum of mean daily rainfall was seen on 26th August and it was 2.2 mm. The maximum COV was observed on 19th August and it was 317.442%. Minimum COV was observed on 8nd August and it was 112.032%. It means that daily rainfall was more variable on 19th August and it was more stable on 8th August.

Linear trends of daily rainfall of 4th August showed Maximum increase in August of 0.0.823 mm/year and total increase in daily rainfall in August s was 32.097 mm. linear trends of daily rainfall of 20th August showed maximum fall in August of 0.651 mm/year and total fall observed was 25.389 mm rainfall in August. The maximum rainy days were observed on 23rd August and it was 24. Minimum rainy days were observed on 25th August and it was 07.

In September Maximum of mean of daily rainfall of Nanded was observed on 2nd September and it was 13.90 mm. Minimum of mean daily rainfall was seen on 13th September and it was 0.40 mm/year and total fall observed was 0.195 mm Maximum COV was observed on 8^h September and it was 354.508%. Minimum COV was observed on 3rd

September and it was 141.245%. It means that daily rainfall was more variable on 8th September and it was more stable on 3rd September.

A linear trend of daily rainfall of 17th September showed Maximum increase in September of 0.354 mm/year and total increase in daily rainfall in September was 13.806 mm. A linear trend of daily rainfall of 25th September showed maximum fall in September of 0.347 mm/year and total fall observed was 13.553 mm in daily rainfall in September. Maximum 27 rainy days were observed on 4th September. Minimum 02 rainy days were observed on 13th September.

Maximum of mean daily rainfall was seen on 11th August and it was 21.10 mm. Minimum of daily rainfall was observed on 13th September and it was 1.00 mm and 0.40 mm respectively. Out of 122 day of monsoon season near about (50 days) 41% days displayed upward daily rainfall trends and (72 days) 59% days show descending trends. The maximum increasing trends for daily rainfall was observed on 4th August. And it was 0.548 mm/year and total rise was 32.097 mm. The maximum fall was seen for 20th August daily rainfall decreased by 0.651 mm/year and total fall of 25.389 mm was noticed.

Maximum COV was seen for 23rd July and this was 363.295% and minimum COV was seen 8th August and it was 112.032% and. This means daily rainfall was more variable on 23rd August and daily rainfall was more stable on 8th August.

5.5 Analysis of extreme events of rainfall of Parbhani and Nanded Cities

One of the most significant concerns of global warming due to increase in greenhouse gases would be rise in magnitude and frequency of extreme rainfall events. Climate model imitations (Hennessey et al, 1997) and observed signs confirm that warmer climates, owing to increased water vapor, lead to more extreme rainfall events and therefore raise threats of floods [Intergovernmental Panel on Climate Change (IPCC), 2007].

Any positive or increasing trend in extreme rainfall events is a serious concern. The fresh extreme heavy rainfall event (94.4 cm in 24 hours) occurred over Mumbai on 26 July 2005 reminds us to think whether there is any significant trend in extreme rainfall events over India. The recent realistic studies have shown that worldwide there is a growing trend of extreme precipitation events (Groisman et al, 2001; Haylock and Nicholls, 2000; Alexander et al, 2006; Klein Tank et al, 2006; Guhathakurta and Rajeevan, 2007; Sen Roy and Balling, 2004).

Study of some researchers like Goswami et al, (2006)., Rajeevan et al, (2006) showed that there is significant increase in magnitude and frequency of extreme rainfall events. At the same time, some researcher put forward exactly the opposite results thus leading to

1. Frequency of rainy days. A day is called rainy day according to India Meteorological Department if the rainfall of that is 2.5mm or more.
2. Frequency of heavy rainfall days (including very heavy and extremely heavy). A day is called heavy rainfall day according to India Meteorological Department if the rainfall of that is 64.5mm or more. This includes very heavy (i.e. 124.5mm to 244.5mm) and extremely heavy (i.e. greater than 244.5mm) rainfall cases.
3. Annual one-day Extreme rainfall series

A. Analysis of Trends of Rainy Days of Parbhani and Nanded Cities

Rainfall amount realized in a day is 2.5 mm or more is called as rainy day. Analysis of rainy days carried out considering three periods 1. Total months 2. for monsoon season 3. Season other than monsoon.

From Annexure 5.9A and 5.12, below Figure 5.38 it is obvious that the mean of Annual rainy days for Parbhani was 49. The maximum 92 rainy days were detected in 2000. Minimum 27 rainy days were observed in 1972. The linear trends of total rainy days showed increasing trends of 0.2311 days/year and total increase was 9.70.

The mean of 1st half (1969-1989) of annual rainy days was 46.75. The linear trends of 1st half of total rainy days showed increasing trends

of about 0.7974 days/ year and total increase observed was 15.948. The mean of 2nd half of total rainy days was 51.30. The linear trends of 2nd half (1990-2010) of total rainy days show slightly decreasing trends of 0.0636 days / year, total decrease was 1.272.

From Annexure 5.6A and 5.6B and Figure 5.40 it is evident that the mean of monsoon rainy days for Parbhani was 40.10. Maximum 70 rainy days were seen in 2000. Minimum 23 rainy days were observed in 1982 and 2006. The linear trends of monsoon rainy days displayed growing trends of 0.1657 days/year and total increase was 6.96.

The mean of 1st half (1990-2010) of monsoon rainy days was 38.85. The linear trends of 1st half (1990-2010) of monsoon rainy days showed upward trends of 0.539 days/year and total rise was 10.78. The linear trends of 2nd half of monsoon rainy days also showed rising trends of about 0.3935 days/year and total rise observed was 7.87 which is less than that of 1st half.

From Annexure 5.7A and 5.7B, and Figure 5.41 it is evident that the mean of non-monsoonal rainy days was 9.10. The maximum rainy days were observed in 1997 and it was 25. Minimum 2 rainy days were experienced on 2007. The linear trends of non-monsoon rainy days show upward trends of 0.0654 days/year and total rise was 2.75.

The mean of 1st half (1969-1989) of non- monsoon rainy days was 7.90. The linear trends of 1st half (1969-1989) of non-monsoon rainy days revealed rising trends of 0.3278 days/year and total rise was 6.556. The mean of 2nd half of non-monsoon rainy days was 10.10. The linear trends of 2nd half of non-monsoon rainy days showed decreasing trends of about 0.3461 days/year total decrease observed was 6.576.

During the study period of 42 years 2325 rainy days were witnessed over Parbhani . Out of 2325 rainy days 1921 (82.62%) rainy days were witnessed in monsoon season and only 404 (17.38%) rainy days witnessed in summer and winter and post monsoon season.

Figure 5.40 Comparison of Monsoon RD of rainfall from Nanded and Parbhani Cities

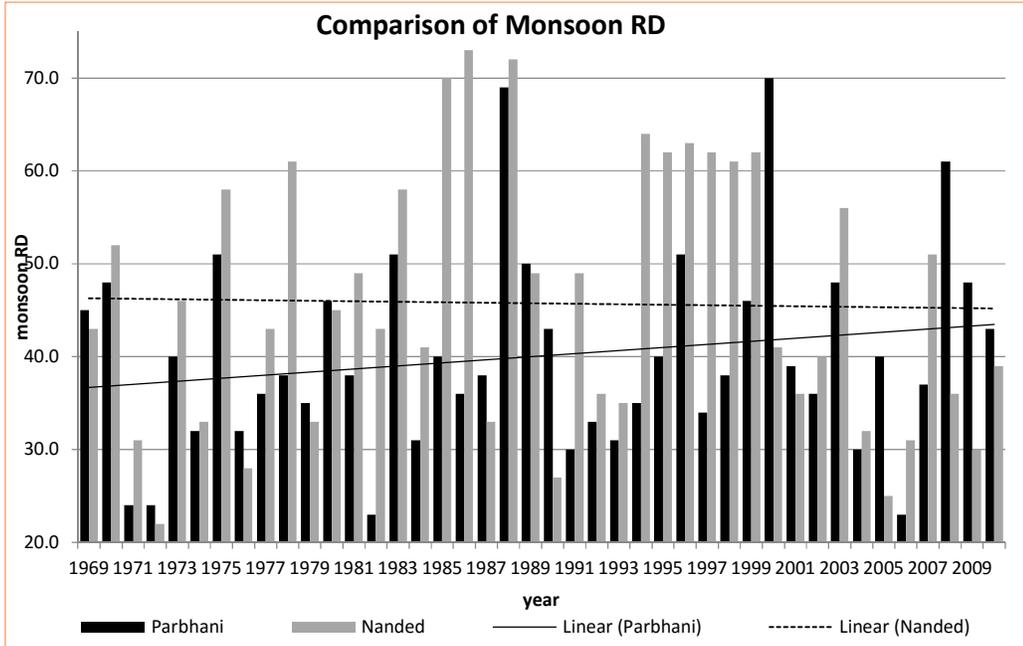


Figure 5.41 Comparison of Non-Monsoon RD of Rainfall of Nanded and Parbhani Cities

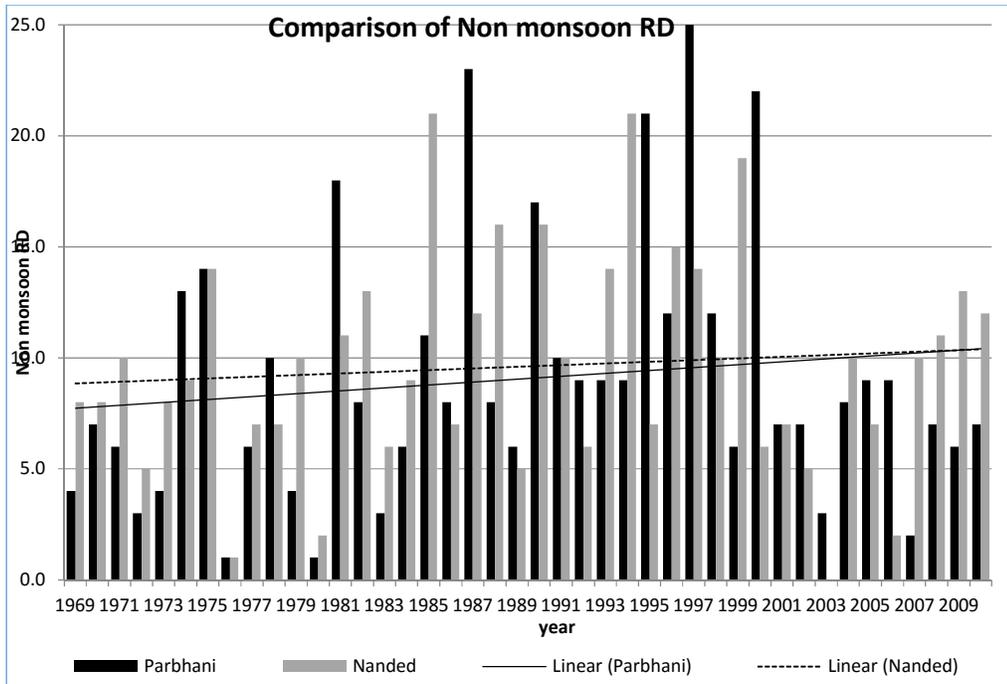
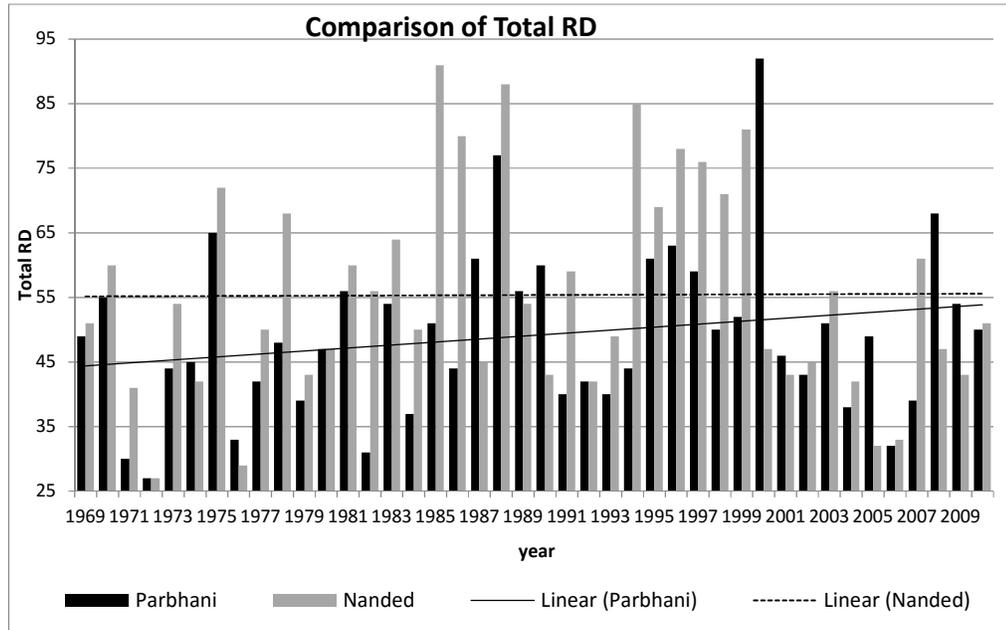


Figure 5.42 Comparison of Total RD of Rainfall of Nanded and Parbhani Cities



From Annexure 5.6B, Figure 5.42 it is evident that the For Nanded the mean of Annual (total) rainy days was 56. The maximum 91 rainy days were observed in 1985. Minimum 27 rainy days were observed in 1972. The linear trends of total rainy days showed increasing trends of 0.1188 days/year and total increase was 4.63. The mean of 1st half (1969-1989) of annual rainy days was 55.90. The linear trends of 1st half of total rainy days showed increasing trends of about 1.525 days/year and total increase observed was 30.50. The mean of 2nd half of total rainy days was 56.11. The linear trends of 2nd half (1990-2010) of total rainy days showed decreasing trends of 0.8175 days/year and total decrease was 15.53.

From Annexure 5.6B and 5.12, Figure 5.40, it is evident that the mean of monsoon rainy days of Nanded was 46.56. The maximum rainy days were observed in 2000 and it was 70. Minimum rainy days were observed in 1972 and it were 22. The linear trends of monsoon rainy days show increasing trends of 0.1026 days/year and total increase was 4.0014. The mean of 1st half (1969-88) of monsoon rainy days was 46.70. The linear trends of 1st half (1969-88) of monsoon rainy days

showed increasing trends of 0.1.2256 days/year and total increase was 24.52. The linear trends of 2nd half (1989-2010) of monsoon rainy days showed decreased trends of about 0.4474 days/year and total decrease observed was 8.5006.

From Annexure 5.7B and 5.12, Figure 5.41 it is evident that the mean of non-monsoon rainy days of Nanded was 9.44. The maximum rainy days were observed in 1985 and in 1995 and it was 21. Minimum rainy days were observed in 1976 and it was 01. The linear trends of non-monsoon rainy days show slightly increasing trends of 0.0162 days/year and total increase was 0.6318. The mean of 1st half (1969-88) of non-monsoon rainy days was 9.2. The linear trends of 1st half (1969-88) of non-monsoon rainy days showed increasing trends of 0.2992 days/year and total increase was 5.984. The linear trends of 2nd half (1989-2010) of non-monsoon rainy days show decreasing trends of about 0.3702 days/year and total decrease observed was 7.033 days.

During the study period of 42 years 2184 rainy days were witnessed over Nanded. Out of 2184 rainy days 1816 (83.15%) rainy days were seen in monsoon season and 368 (16.85%) rainy days viewed in summer and winter and post monsoon season.

5.6 Occurrences of Extreme Rainfall Events in A Day

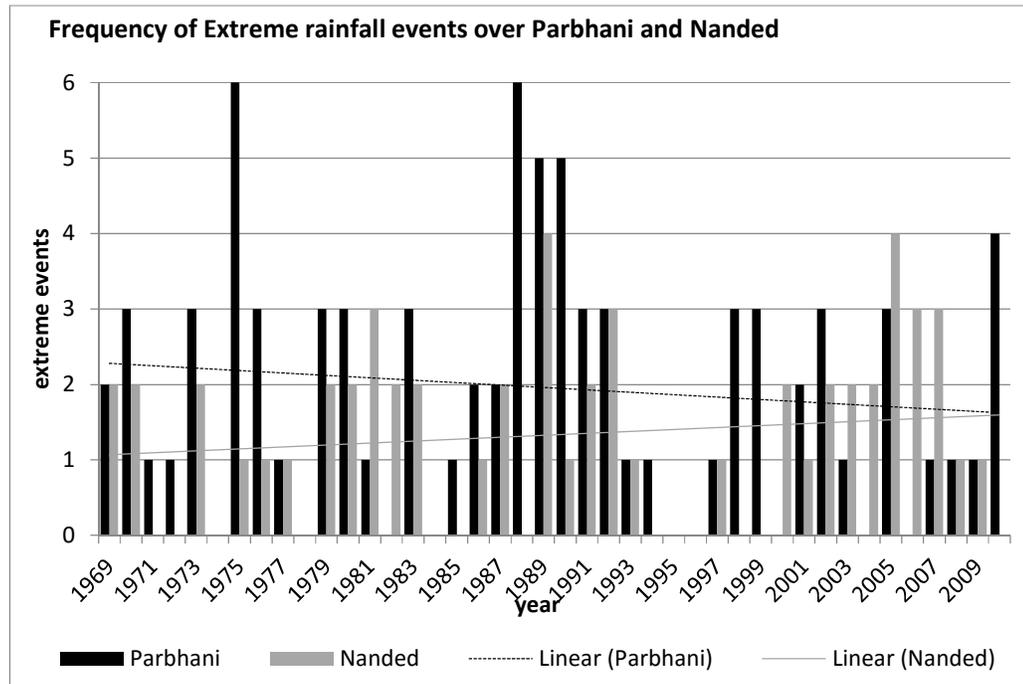
While discussing extreme events yearly extreme events based on simple statistics such as very high and very low daily temperature or daily rainfall is considered. As concluded by Goswami et al, (2006), we have reflected the rainfall events between 5 and 100 mm/day as moderate events and rainfall events between 100 and 150 mm/day as heavy rain (HR) events. Rainfall events equal or greater than 150 mm/day are categorized as very heavy rain (VHR) events.

As concluded by Guhathakurta (2006), we have reflected the rainfall events. Frequency of heavy rainy days (including very heavy and extremely heavy). A day is called heavy rainfall day according to India Meteorological Department if the rainfall of that particular day is 64.5

mm or more. This includes very heavy (i.e. 124.5 mm to 244.5 mm) and extremely heavy (i.e. greater than 244.5mm) rainfall cases.

Figure 5.43

Comparison of heavy rainfall days of Nanded and Parbhani Cities



Above Figure 5.43 exposed temporal variation of frequency of very heavy rainfall events ($R > 64.50$ mm/day) over Parbhani and Nanded. Figure 5.43 presented the frequency of extreme rainfall events (heavy rainfall < 64.5 mm) over Parbhani and Nanded. From Figure, it clear that Parbhani revealed total 82 extreme rainfall events for given period of 42 years. The maximum 6 heavy rainfall days were noticed in the year 1975 and 1988.

For Parbhani linear trends of frequency of extreme rainfall events showed decreased trends. From below table 5.1, it obvious that for Parbhani 09 days were detected showing very heavy rainfall (i.e. rainfall 124.5mm to 244.5mm).and 1 day showing very extreme heavy rainfall (i.e. greater than 244.5mm). For Parbhani Maximum one-day rainfall was observed on 30th July 2005 and it was 264 mm.

Table 5.1 Occurrences of one-day Extreme rainfall series

| Year | Parbhani | | Nanded | |
|------|-----------------|---------------------|-----------------|---------------------|
| | 1-Day rain (mm) | Date of Occurrences | 1-Day rain (mm) | Date of Occurrences |
| 1969 | 88 | 03-Jul | 70.8 | 31-Jul |
| 1970 | 69.9 | 04-Jun | 73.4 | 17-Aug |
| 1971 | 101 | 26-Aug | 61.2 | 23-Jun |
| 1972 | 64.6 | 12-Aug | 37.8 | 12-Aug |
| 1973 | 114.8 | 22-Aug | 156 | 23-Aug |
| 1974 | 56.6 | 16-Oct | 37.4 | 25-Sep |
| 1975 | 93.6 | 02-Aug | 151.2 | 03-Sep |
| 1976 | 132.2 | 24-Aug | 109.2 | 21-Jul |
| 1977 | 104.6 | 01-Sep | 109.6 | 22-Jul |
| 1978 | 57.2 | 18-Jun | 38 | 13-Sep |
| 1979 | 164.2 | 29-Jul | 80.2 | 20-Jun |
| 1980 | 91 | 04-Sep | 71.6 | 03-Aug |
| 1981 | 90.6 | 25-Aug | 77.6 | 20-Sep |
| 1982 | 49.2 | 24-Sep | 115.6 | 11-Jul |
| 1983 | 126.6 | 12-Aug | 252.6 | 12-Aug |
| 1984 | 60.6 | 01-Aug | 58 | 01-Aug |
| 1985 | 98 | 15-Aug | 64.4 | 13-Aug |
| 1986 | 86.3 | 18-Jul | 80.5 | 10-Aug |
| 1987 | 75.5 | 16-Jun | 128.4 | 16-Jun |
| 1988 | 108.5 | 22-Jul | 39.2 | 05-Jun |
| 1989 | 254.4 | 24-Jul | 131.5 | 24-Jul |
| 1990 | 98.5 | 30-Aug | 67.6 | 17-Jun |
| 1991 | 130 | 10-Jun | 94.8 | 12-Jul |
| 1992 | 176.1 | 20-Jun | 117.5 | 20-Jun |
| 1993 | 109.8 | 30-Jul | 144.5 | 30-Jul |
| 1994 | 204.9 | 12-Sep | 39.2 | 24-Jun |
| 1995 | 69.6 | 25-Oct | 52.2 | 24-Jun |

| | | | | |
|------|-------|--------|-------|----------|
| 1996 | 51.2 | 12-Sep | 56.5 | 07-Aug |
| 1997 | 67.5 | 04-Jul | 70.6 | 07-Aug |
| 1998 | 91.6 | 29-Jul | 52.1 | 07-Aug |
| 1999 | 82.3 | 08-Sep | 56.1 | 07-Aug |
| 2000 | 38.2 | 12-Sep | 82 | 11-Aug |
| 2001 | 171.3 | 01-Oct | 126.3 | 01-Oct |
| 2002 | 118.7 | 26-Jun | 138.1 | 26-Jun |
| 2003 | 66 | 15-Jul | 68 | 05-Jul |
| 2004 | 65 | 11-Sep | 68 | 11-Sep |
| 2005 | 264 | 30-Jul | 144 | 27-Jul |
| 2006 | 47.8 | 07-May | 206 | 05-Aug |
| 2007 | 111.6 | 22-Aug | 300 | 27-31DEC |
| 2008 | 87.5 | 30-Jul | 85.4 | 05-Aug |
| 2009 | 102.3 | 30-Jul | 113.8 | 05-Aug |
| 2010 | 166.2 | 07-Aug | 83.1 | 05-Aug |

Nanded rainfall presented total only 60 heavy rainfall days for given period of 42 years (From Figure 5.43). The maximum 7 heavy rainfall days were noticed in the year 2007. For Nanded linear trends of frequency of extreme rainfall events showed increasing trends.

From below table, it evident that for Nanded 15 days were observed showing very heavy rainfall ((i.e. 124.5 mm to 244.5 mm) and 6 day showing very extreme heavy rainfall (i.e. greater than 244.5 mm). for Nanded Maximum one-day rainfall was observed on 27th, 28th, 29th, 30th, and 31st December and it was 300 mm.

5.5 Resume

The present chapter is mainly deals with trends analysis of annual, seasonal, monthly, daily rainfall, rainy days, decade-wise rainfall trends, contribution of monthly, seasonal rainfall and extreme rainfall events like occurrence of one-day extreme rainfall, severe rainy day, heavy rainfall days, occurrences of one-day extreme rainfall over Parbhani and Nanded cities. The chapter includes introduction, statistical investigation and techniques etc. In addition to these, arrangement of text been discussed in brief.

While 6th chapter deals with the local reasons like population, land use and land cover (LULC) and vehicular burden caused for change in temperature and rainfall trends of Parbhani and Nanded, temporal dependency of temperature and rainfall, climatological characteristic of study area and prediction model of temperature and rainfall by using simple moving average method is thoroughly discussed in detail in the 6th chapters.

