

RAINFALL VARIABILITY OF VIRUDHUNAGAR DISTRICT OF TAMIL NADU - A SPATIO-TEMPORAL ANALYSIS USING GIS

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Abstract

The knowledge and the awareness of climate variability is an important factor to understand the nature of different climatic systems and their impact on the environment and the human development far and wide. In particular to that the Rainfall variability is an important feature of semi-arid climates and climate change is on the rise with such variability in many of these regions. The spatial study on the rainfall variability helps in understanding the trends for vulnerable dryland agriculturalists and policymakers to address these climate variations for future. The goal of this paper is to examine this climatic phenomenon in semi-arid region of Virudhunagar District in Tamil Nadu, which includes the spatial distribution, variability through different seasons and precipitation ratio. This will enable us to understand the frequent occurrences in that particular region for future climate adaptation. To reach these goals, the paper determines rainfall variability, monthly and annual trends in that variability based on 30 years of the monthly rainfall data for 8 rain gauge stations and the results delineate to show the gradients in rainfall over the years from 1980 to 2010. The results also identify a trend towards decreased rainfall throughout the district in all stations, which is associated with decrease in the number of rainy days. Both the drying trend and decrease in rainy days agree with climate change for Virudhunagar District which is alarming the farmers of the region.

Keywords: *Climate Variability, Rainfall variability, Rainfall trends, Climate change, Semi-arid climates, Precipitation Ratio.*

Introduction

India a tropical country very much dependent on the rainfall pattern which delineates agricultural planning and utilization of water depending on monsoon. So much to say that more than 75% of rainfall accruing during the monsoon season alone; but monsoon is uneven both in time and space, and it is important to evolve a rainfall analysis for such situation for semi-arid regions in India and as well in the regional level. The rainfall process can be viewed as a spatio-temporal phenomenon as Alak Gadgil (1986), analysed rainfall as a crucial agro-climatological factor in the seasonally arid parts of the world and its analysis an important pre-requisite for agricultural planning in India, Akinsanola A. A & Ogunjobi K. O., (2014), found that the analysis of long time trends and decadal trends of the precipitation and temperature suggest decreasing and increasing trends in mean annual precipitation and air temperature in Nigeria. Sawant Sushant, *et.al.*, (2013) has analysed the spatio-temporal analysis of Rainfall distribution and variability in Cauvery Basin with an overall observation of insignificant decrease in annual rainfall in the twentieth century. Jagannadha Sarma (2005) analysed the rainfall pattern of the coastal zone of Krishna-Godavari River Basin of Andhra Pradesh with the annual, monsoon and Non-monsoon rainfall and spatial and frequency distribution of rainfall intensity. Considering all these cases, A. Balachandran (2009) analysed the district groundwater condition of Virudhunagar district, Tamil Nadu, as that one block is over-exploited and other block is under "critical" Category. Very particularly as per the National Climate Change (NCC) Report 2010, Indian Meteorological Department Pune, by P.G. Gore Thakur Prasad and H.R. Hatwar, (2010) mapped the Drought areas of India in which alarming results are found in the Peninsular region where Tamil Nadu and

Pudhucherry at the Moderate & severe Drought experiences. However, under this condition the Rainfall variability of the Virudhunagar district is studied with a focus on spatial variation, distribution in different seasons having a statistical method of Precipitation Ratio for the scarcity water management in the near future.

Study Area Profile

Virudhunagar District is situated in the South western part of Tamil Nadu occupying an area of 4243km² and lies between 9°10'0"N to 9°50'0"N latitude and 77°20'0"E to 78°20'0"E longitude. It is bounded by Madurai District on the north, Sivagangai District on the northeast, Ramanathapuram District on the southeast, Thoothukudi District to the south, Tirunelveli District to the southwest, Kerala state to the extreme west, and Theni District to the northwest. The District has a population of 19,43,309 (as of 2011) census and the Head-Quarters of the district being Virudhunagar and the district is divided into two revenue divisions - Sivakasi and Aruppukottai (Fig.1). The district comprises nine taluks namely: Arupukottai, Kariapatti, Rajapalayam, Sattur, Sivakasi, Srivilliputtur, Trichuli, Vembakottai and VirudhuNagar. There are 11 blocks and 600 revenue villages in this district and the main market economy of the district being oil, chicory, coffee seeds, dry chilies and pluses.

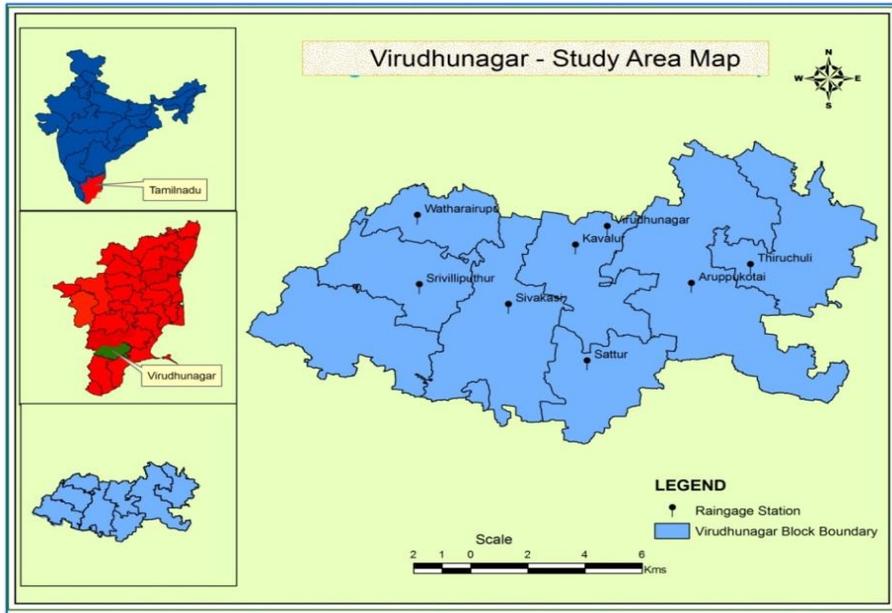


Figure 1. The Location of the Study Area of Virudhunagar District, Tamil Nadu

Physiographical Structure

Geologically, Virudhunagar comprised of Archaean Charnockite, Unclassified genesis and Pleistocene Laterite. These rock types are available in Rajapalayam, Srivilliputtur, Sivakasi and Sattur Taluks. Geomorphologically, Major physiographic Units of the Virudhunagar District are with Structural hills, Deep Burried, Pediments, Shallow Burried Pediments, Bazada and Flood Plain. The Western Ghats are represented in Rajapalayam and Srivilliputtur Taluks and other parts of the district are plain. The district is also drained by rivers such as Arjuna, Vaippar, Kowsika and Gundar. The major soil types are Deep red

loam, Black soil and Red sandy soil. The majority of the study area is covered by Black soil. Ferruginous red soils are also seen at places. Black soils are deep to very deep and generally occur in the depressions adjacent to hilly areas, in the western and central part of district. Alluvial soils occur along the river courses. Red sandy soil is seen all around the Sattur, Kariyapatti, Aruppukotai and Thiruchuli blocks. The Land Use pattern as per (2005-06) statistics as follows: i) Forest area, ii) Net area sown and iii) Cultivable waste with the area coverage of 264.66, 1428.82 and 96.63 Sq.kms respectively. The forests are found on the eastern slopes of the Western Ghats. Only 6.3% of the total geographical area of the district is under forests. Many rare and endemic varieties of flora and fauna are found along the mountain slopes. A wildlife sanctuary spread over 480 sq.kms at Shenbagathopu and Srivilliputtur taluk. The forests of Alagarkoil valley in Srivilliputtur taluk and Saduragiri are known for rare medicinal plants. The medicinal value of 275 plants has been recorded and reported. The forests host a rich variety of orchids and ferns which are part of the physiography of this important district.

Materials and Methodology

The base map of Virudhunagar district has been prepared from Survey of India Toposheet on 1:50000 scale. Monthly rainfall data for the period of 30 years from 1980 to 2010 has been collected from Indian Meteorological Department Pune, and Economics and Statistical Department Chennai. The acquisition of the rainfall data has been taken from eight rainfall stations namely: Srivilliputtur, **Watrap [Watharairupu]**, Sivakasi, Virudhunagar, Sattur, Aruppukottai, Kovaloor [Kavalur], Thiruchuli for analyzing long term mean, seasonal and annual rainfall pattern. (Table.1) After which the Mean Annual, Seasonal and Standard Deviation has been calculated and at the end coefficient of variability computed to derive at a particular conclusion. The collected computed data has been processed and analyzed by preparing various maps using GIS software i.e., ArcGIS 9.3 version.

Table 1. The Following Table shows the Annual Value, Mean, Winter, Summer, South West Monsoon and North East Monsoon in MM.

MEAN						
STATION	Annual value	Annual Average	WIN	SUM	SWM	NEM
Srivilliputtur	27313.8	910.46	252.40	701.00	480.20	770.60
Watrap	28493.9	949.80	251.00	446.40	224.70	813.00
Sivakasi	23399.8	779.99	198.30	428.90	334.90	731.00
Virudhunagar	25261.7	842.06	334.00	371.00	373.00	636.50
Sattur	20442.8	681.43	217.20	340.80	361.20	485.40
Aruppukottai	24577.9	819.26	303.80	306.20	380.90	808.00
Kovaloor(w.s)[Kavalur]	23527.00	784.23	303.30	322.90	249.90	635.40
Thiruchuli	19535.0	697.68	277.90	296.80	433.40	525.70
Mean	24068.98	808.11	267.23	401.75	354.77	675.7

Results and Discussion

Rainfall and climate

As the district experiences the subtropical climate, the rainfall pattern of the district as follows. It receives the rain under the influence of both southwest and northeast monsoons. The northeast monsoon chiefly contributes to the rainfall in the district. Most of the

precipitation occurs in the form of cyclonic storms caused due to the depressions in Bay of Bengal. The southwest monsoon rainfall is highly erratic and summer rains are negligible. Rainfall data from eight stations over the period 1980-2010 i.e., 30 years were utilized for analysis. The Average Annual Rainfall over the district varies between Sattur and **Watrap** stations as 681.43 mm and 949.80 mm respectively. This shows Sattur receives the minimum amount and **Watrap** receiving the maximum. This variation divides the District into two blocks as Sattur is in the southeastern part of the district and gradually increases towards the western, northwest part where it reaches at **Watrap** with the highest. This variation also shown in the Precipitation Ratio where Sattur receiving the lowest with 81.18% annually (Table.1).

Mean Annual Rainfall

Understanding the mean Annual Rainfall is an important factor as the district is characterized with varied and unique topography as it is discussed in the physiographic divisions. The quantum of the rainfall is purely influenced by the Western Ghats on the north, northwestern side of the district where **Watrap** and Srivilliputtur lies. As also the landscape, geomorphologically slopes eastward towards the Sattur station where the rainfall decreases. The long term mean annual rainfall of the Virudhunagar district is 808.11 mm (24068.98 mm). The average annual rainfall is recorded maximum at **Watrap** (949.80 mm), Srivilliputtur (910.46 mm), Virudhunagar (842.06 mm), Aruppukottai (819.26 mm), Kavalur (784.23 mm), Sivakasi (779.99 mm), Thiruchuli (697.68 mm) and Sattur recording (681.43 mm). But the mean annual average showing Sattur as the lowest. Therefore, the two blocks can be delineated as maximum rainfall region / windward side and the region towards the east as leeward or rain shadow region which experiences the lowest rainfall in the district (Fig.2). Thus, the regions can be classified as following zones. Very High Rainfall zone (above 896 mm) : **Watrap**, Rajapalayam and Srivilliputtur Taluks. High Rainfall Zone (842-896 mm) : Aruppukottai and Virudhunagar. Medium Rainfall Zone (788-842 mm) : The inter-regions between the Very High rainfall zone and the High Rainfall Zone. Moderate Rainfall zone (735-788 mm) : Sivakasi and towards the eastern region and Kavalur in particular. Low Rainfall Zone (less than 735 mm) : Sattur and Thiruchuli.

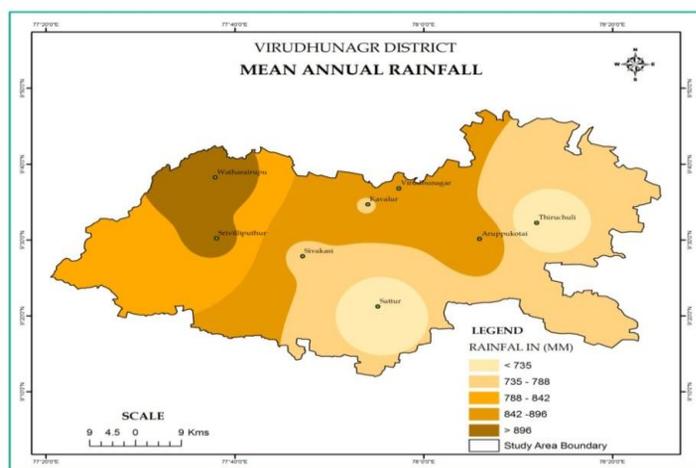


Figure 2. Mean Annual rainfall.

Mean Summer Rainfall

During the summer season as it is known the rainfall occurrence is due to the convection phenomena by which the region receives the rainfall. The mean summer rainfall of the district records to 401.75mm. The district receives the maximum amount of rainfall in the location of Srivilliputtur and towards the extreme of its west and north-south recorded 701.00mm, **Watrap** (446.40mm), Sivakasi (428.90mm), Virudhunagar (371.00mm), Sattur (340.80mm), Kavalur (322.90mm), Aruppukottai (306.20mm), and the lowest being Thiruchuli (296.80mm)(Table.1). This shows that the eastern regions of the district being very dry and hot and experiences less rainfall whereas the north (except Virudhunagar) and Western part of the district receives sufficiently due to the Western Ghat influence even during summer

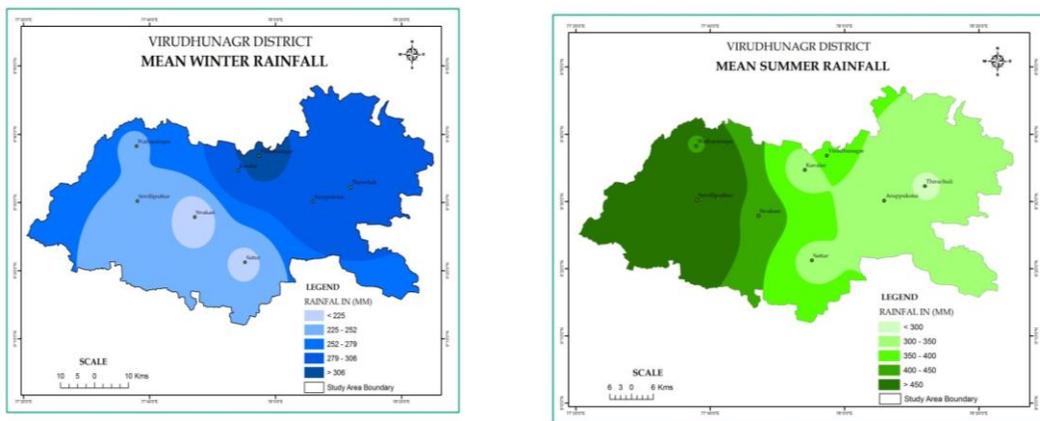


Figure 3 & 4. Mean Winter & Summer rainfall.

Mean South West Monsoon

There is a drastic change that is found in this season with the highest rainfall received in Srivilliputtur and Thiruchuli with 480.20mm and 433.40mm respectively. The Average rainfall of this season is 354.77mm. The southern part of the district in particular receive the better rainfall and the north, north-west receive erratic rainfall (Fig.5). The high rainfall sequence after Srivilliputtur and Thiruchuli as follows: Aruppukottai(380.90mm), Virudhunagar(373.00mm), Sattur(361.20mm), Sivakasi(334.90mm), Kavalur(249.90mm) and **Watrap** in the north receiving the lowest rainfall with 224.70mm only. The two locations one in the east i.e., Thiruchuli and Srivilliputtur in the western block shows a difference especially during this season during this season which needs to be noted.

Mean North East Monsoon

The North East Monsoon season is a major period for the appropriate rainfall for the district as well as for Tamil Nadu at large compared to South West Monsoon. The Mean average of North East Monsoon of the district accounts to 675.7mm. During the months of October, November and December, not only the district but also the whole of Tamil Nadu receives huge amount of rainfall and the same variability is noticed here. The highest seasonal rainfall recorded in **Watrap**(813.00mm), followed by Aruppukottai(808.00mm), Srivilliputtur(770.60mm), Sivakasi(731.00mm), Virudhunagar(636.50mm), Kavalur(635.40mm), Thiruchuli(525.70mm) and the lowest rainfall received by Sattur

(485.40mm). Most of the regions in the district is recorded with heavy rainfall except two stations Sattur and Thiruchuli in particular.

The reason for this particular rainfall phenomenon especially in the west and northwest of the district is due to the influence of the Western Ghats where the North East monsoon is arrested by the available forest cover. Whereas the regions which are slope towards the eastern side receives lesser compared to the western blocks for the reason that these are plain regions sloping towards the east without much of forest cover. In this connection the wettest and the driest regions can be noted: as **Watrap**, Srivilliputtur and its surroundings as wettest and Sattur, Thiruchuli as driest regions.

Variability of Rainfall

The definition of Variability is the extent to which data points in a statistical distribution or data set diverge from the average, or mean, value as well as the extent to which these data points differ from each other. There are four commonly used measures of variability: range, mean, variance and standard deviation. In other words it is the "ratio of the standard deviation to the mean rainfall" or coefficient of variation.

Annual Variability of Rainfall

The Annual rainfall variability of the district ranges from 4.33% to 31.57% of the regions of Watrap and Aruppukottai and its surroundings respectively (Table.2). The next variability locations as follows: Srivilliputtur of the western region and its surroundings with 30.71% , Thiruchuli recorded with 7.84%, Kavalur 5.56%, Virudhunagar 5.34%, Sattur 5.20%, and the lowest regions of variability being Sivakasi 4.73% and **Watrap** 4.33% as the shows clearly about the annual variability in the north western region **Watrap** with lowest and in the central region locating Sivakasi which experiences the rain scanty areas.

Table 2. The Following Table showing the Annual Rainfall Variability, Winter, Summer, South West Monsoon and North East Monsoon in %.

PRECIPITATION RATIO in %					
STATION	WIN	SUM	SWM	NEM	ANNUAL
Srivilliputtur	452.33	733.95	285.43	161.64	156.73
Watrap	380.88	233.35	124.90	158.57	100.72
Sivakasi	541.42	249.29	206.67	178.59	102.05
Virudhunagar	770.18	227.86	162.74	156.52	113.00
Sattur	589.20	228.68	237.75	141.27	81.18
Aruppukottai	840.15	214.98	180.83	187.89	143.28
Kovaloor(w.s.) [Kavalur]	802.38	208.70	125.16	162.09	147.83
Thiruchuli	802.43	250.15	227.17	148.66	121.46

Winter Season Rainfall Variability

The winter season rainfall variability as shown in the Fig.8 depicts higher variability compared to the other seasons (Table.2). In this season, the variability is seen with the same locations as high and low as it is in the annual variability i.e., Aruppukottai being the highest with 184.05% and Watrap and its adjacent regions being the lowest with 7.43%. The regions can be divided into two blocks as east and west where the eastern block of Aruppukottai and its adjacent areas experience better rainfall variability and the north west

part of the district i.e., **Watrap** and its surroundings experience low rainfall variability which is to be observed clearly.

Summer Season Rainfall Variability

The variability during this hot season between the months of March to May which is recorded shows that two locations at the two blocks i.e., eastern and western blocks of the district divides the region. The highest variability being recorded at Srivilliputtur (67.72%) and the lowest being at Sivakasi (21.92%). The second highest variabilities are found as the following: Aruppukottai (54.01%), Thiruchuli (30.45%), Virudhunagar (26.14%), Kavalur (25.36%), Sattur (25.10%), **Watrap** (22.84%), Sivakasi being the lowest (21.92%). The image indicates the regions adjacent to Srivilliputtur are at the highest variability on the western block of the region and Aruppukottai and its surroundings. The regions from north to south and the extreme east along with northwest in particular **Watrap**, experience the low rainfall variability as shown in the. This season causes low variability but the regions with high variability are due to the west influence and its pre-monsoon showers as well which needs to be understood.

South west Monsoon Rainfall Variability

The south west monsoon rainfall variability experiences more or less similar pattern of variability like that of the summer. The highest variability being recorded at Srivilliputtur (55.69%), followed by Aruppukottai (42.61%), Sattur (26.42%), **Watrap** (23.60%), Thiruchuli (21.79%), Sivakasi (20.53%), Virudhunagar (17.79%), and the lowest being Kavalur (13.73%). It indicates that the regions surrounding Srivilliputtur and adjoining areas of southern regions of the district and the eastern regions with Aruppukottai and its adjoining receive the highest variability whereas the northwest watrap region, Kavalur, Virudhunagar areas experience the lowest variability.

North East Monsoon Rainfall Variability

The North East Monsoon rainfall variability experienced by the district as indicated that the district experiences highest in the two blocks basically in the east Aruppukottai (47.32%) and its adjacent areas and Srivilliputtur (40.38%), and its surroundings. The rest of the regions as follows :Thiruchuli (14.44%), Kavalur (12.79%), Sivakasi (12.19%), Sattur (11.75%), Virudhunagar (11.40%), and the lowest being **Watrap** (8.87%). As the image indicates by analysis that from north to south location and its surrounding such as Virudhunagar, Kavalur, Sivakasi, Sattur and northwest location **Watrap** to be noted for the future study. The same condition is found in the summer rainfall variability image as well. The two East and west blocks with highest rainfall variability is influenced by season as well as the Western Ghata influence in the west.

Precipitation Ratio Analysis

The abnormalities of the rainfall at any location can be brought out by the simple ratio called the Precipitation Ratio. The method studies the overall difference between the maximum and minimum rainfall over the series of years which is denoted in terms of mean. The Formula as follows:

Precipitation Ratio = $\frac{P_x - P_n}{P_m} \times 100$

Where P_x and P_n , represent the maximum and the minimum of the rainfall over the series of year and P_m is the mean annual rainfall. This ratio is important as it gives the stability of

rainfall with special reference to its relationship. Higher the ratio, higher in abnormality of rainfall and lower the ratio, lower in abnormality of rainfall. As per the Table.3. The lowest annual precipitation rainfall ratio found in Sattur which is a clear indication with 8.18% and the highest being at Srivilliputtur with 156.73%. The higher rainfall abnormalities can be demarcated in two extreme blocks i.e., western region Srivilliputtur and its extreme surroundings and eastern region where Aruppukottai and its adjacent areas are in extreme rainfall abnormalities and it is not in good relationship with the rainfall pattern in these regions. Whereas the north, central, south, and northwest regions have the lowest rainfall abnormalities whereby the gradient of the rainfall gradually reduces in these regions i.e., Virudhunagar, Sivakasi, Sattur and **Watrap** where this relationship is good to the rainfall pattern as it is constant when studied by the analysis.

Table 3. The Following Table shows the Annual Precipitation Ratio Rainfall along with,

RAINFAL VARIABILITY in %					
STATION	WIN	SUM	SWM	NEM	ANNUAL
Srivilliputtur	130.91	67.72	55.69	40.38	30.71
Watrap	78.43	22.84	23.60	8.87	4.33
Sivakasi	138.38	21.92	20.53	12.19	4.73
Virudhunagar	157.13	26.14	17.79	11.40	5.34
Sattur	144.45	25.10	26.42	11.75	5.20
Aruppukottai	184.05	54.01	42.61	47.32	31.57
Kovaloor(w.s.)(Kavalur)	173.41	25.36	13.73	12.79	5.56
Thiruchuli	168.92	30.45	21.79	14.44	7.84
MEAN	146.96	34.19	27.77	19.89	11.91

Winter, Summer, South West Monsoon and North East Monsoon in %

Conclusion

This study provides valuable insight on the spatial and temporal patterns of rainfall variability in Virudhunagar District of Tamil Nadu. The results revealed that there is significant imbalance in the precipitation level seasonally and temporally. The presence of the Western Ghats in Rajapalayam and Srivilliputhuraluks divides the district into two major blocks i.e., the west and extreme west of Srivilliputtur as windward and the east and extreme east of Aruppukottai region as rainshadow regions. Normal rainfall of region during 1980-2010 is 24068.98 mm and the maximum recorded at **Watrap** 28493.9 mm and the minimum recorded at Thiruchuli 19535.0 mm but the actual station lowest being Sattur in the analysis findings. The rainfall anomaly over all the stations revealed that there was a composite nature in which some of dry years were mixed with wet years and vice versa and this occurred in all seasons in all stations. However, the decreased rainfall stations to be noted in this analysis are Sattur, **Watrap** and Sivakasi being the lowest annual precipitation ratio with 81.18%, 100.72% and 102.05% respectively. Similarly, the same locations are found in the rainfall variability analysis as well which is to be seriously noted for any socio-economic development and very particularly for the agriculture in these regions. Based on these the government could adopt sustainable policies of agricultural water management to help its farmers adapt to these changes as the region of Tamil Nadu is under the experience of moderate drought and probabilities of severe drought with 8-27% and 1-18% respectively.

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