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Research Article

CLIMATE RISK ANALYSIS IN TAMIL NADU: DISTRICT LEVEL MONTHLY RAINFALL PANEL DATA ANALYSIS

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Abstract: The present study attempts to estimate the climate risk as measured by monthly rainfall deviation from the normal rainfall in different agricultural production risk zones of Tamil Nadu as followed under PMFBY insurance programme (G.O(M.S).No.227). The study has employed panel data covering 45 years district wise monthly rainfall and measured the trend in actual and normal rainfall. Based on the results, the occurrence of extreme weather events was accounted and interpreted. The finding reveals that the ongoing process of climatic change will lead to increase the extreme events occurrence in High risk zones by 53 percent. North East and south west monsoon which arethe important rainfall source for Tamil Nadu, fluctuating more compared to other seasons. These changes will affect the sowing and harvesting of crops. This study suggests that suitable technologies and policies should be developed to reduce the effects and to overcome the climate extremes.

Keywords: *Climate Change, Extreme Events, Rainfall, Tamil Nadu*

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Introduction

Climate change refers to any changes in the climate of a particular area or location over a period of time. Climate changes occur either by the human actions and / or naturally. Climate changes include increasing temperature i.e. global warming, decreasing rainfall or changing the distribution of rainfall which leads to rising the sea levels, occurrence of extreme events and affecting the agriculture. As the Indian agriculture already faces many challenges, the real challenge lies in climate change. One of the major challenge due to this climate change is changing the rainfall pattern which leads to flood and drought, that causes decrease in area and production of agricultural crops. Many studies have reported [1, 2] that precipitation variability within the growing season has a negative effect on yields of sorghum, maize and rice yields in Tanzania. During the last 10 decades, India has experienced moderate decrease in rainfall, number of wet days and enhanced level of relative humidity [3]. India has also noticed a marked changes in the rainfall pattern as indicated by the drought years 1972, 1979, 1987, 2002 and 2009 [4]. Similar reports were also noticed in the state of Tamil Nadu which experienced the marked changes in rainfall during the years 1980, 1982, 1983, 1987 and 1989 which denoted as drought years. Among all 1987 drought crippled the state's economy when the state incurred expenditures of 106.2 crores [5]. Tamil Nadu which is situated in the southeast corner of Indian peninsular with geographical area around four percent of the nation's geographical area (130.33 lakh hectare (lha)). Historically, Tamil Nadu is an agricultural state, which presently accounts 15 percent of the state's GDP in 2018. The state receives 945 mm (37.2 inches) through distinct bimodal rainfall patterns one from Northeast monsoon (NE) which accounts about 48 percent benefitted through Northeast trade winds and another by Southwest trade winds which brings 32 percent of the state annual rainfall in Southwest monsoon (SW). The temporal and spatial changes in distribution of rainfall woes the cropping pattern. The state is entirely dependent on both monsoon rains for recharging its water resources and thereby there is a chance of water scarcity if monsoon fails. The state located in the rain shadow region of Western Ghats. So, it is underprivileged of rains by Southwest monsoon which is an important monsoon season for the rest of the country.

Any deviation in the quantity and distribution of rainfall not only alter the cropping pattern but also affect the productivity and production of the major agricultural crops and bring problems in achieving the food security of the state. Hence, the district wise rainfall deviation analysis will help to assess the potential risk in rainfall and guide to alter the sowing dates and crop choice. Wilson *et al*. (1979) have used coefficient of variation in their study on rainfall variability over the years [6]. Machiwal *et al*. (2018) have used the t test and F test to measure the differences in variance and mean between the measured and gridded rainfall datasets of Indian arid regions from 1979 to 2013 [7]. Considering the spatial variability, the present study has been taken up with the specific objectives:
To assess the rainfall risk in different agricultural production risk zones and
To study the occurrence of extreme events indifferent risk zones and for Tamil Nadu.

Materials and methods

The study was conducted in Tamil Nadu state of India which is located at southern peninsular region of the country. 'Tamil Nadu Agricultural Department Policy Note 2017-18', reported that the state received average rainfall of 921mm which is lesser than the national average of 1200 mm. Northeast monsoon accounted 48 percent during October-December, alike the contribution of Southwest monsoon (June-September), Summer (March-May) and Winter (January-February) monsoons were 35 percent, 14 percent and 3 percent, respectively. The present study uses the district wise seasonal and monthly rainfall for the period from 1970-71 to 2015-16 of Tamil Nadu. Based on the climate risk level, the state agricultural production districts were classified into low, medium and high risk districts based on the Tamil Nadu G.O. (Ms). No. 227, for crop insurance scheme for paddy production system which account 31 percent of gross cropped area of the state. Climate risk was measured in terms of percentage deviation from the normal rainfall. In order to account the changes in the geographical area of the district during the study period, the geographical area was used as weights to estimate the weighted averages monthly rainfall for the different risk zones.

Climate risk zone of Tamil Nadu

SN	Risk level	Districts covered	No. of district	% of geographical	% of GCA
1	Low	Kanyakumari, Kancheepuram, Theni, Dindigul, Karur, Erode, Ariyalur, Perambalur, Nilgris, Tiruvallur, Tirupur, Krishnagiri, Dharmapuri, Villupuram and Vellore	14	45.58	42.02
2	Medium	Trichy, Tirunelveli, Thanjavur, Madurai, Salem, Coimatore and Virudhunagar	7	24.95	23.30
3	High	Ramanathapuram, Sivagangai, Pudukottai, Tiruvarur, Cuddalore, Nagapattinam, Thiruvannamalai, Namakkal and Thoothukudi	10	29.47	34.68
		Tmil Nadu Area (lakh ha)	31	100.00 130.06	100.00 60.74

The percentage deviation of weighted average actual rainfall over normal were estimated for each district from 1971-72 to 2015-16 and the monthly rainfall risk was analyzed under different production risk zones. The distribution of districts ineach risk zone and the state extend of geographical area and gross cropped area are presented in Table 2.1. Out of the 31 districts in the state, ten districts classified under the high-risk zone which account 29.47 percent of the state geographical area and 34.68 percent of the cropped area in 2015-16. Hence, assessing the climate risk and relevant coping strategies were attempted in this study.

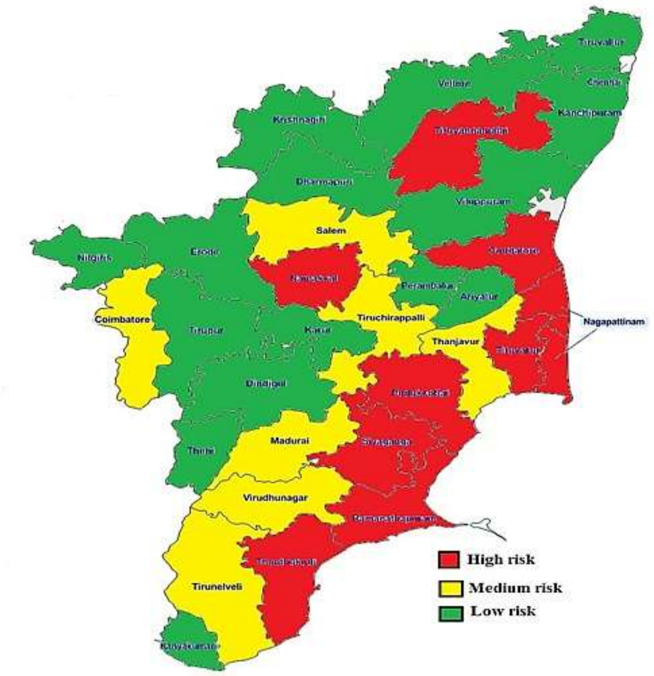

Fig-1 Climate risk zones of Tamil Nadu

Coefficient of Variation

Coefficient of variation is usually used to measure the dispersion of data around the mean. The CV is therefore a standardization of the SD that allows comparison of variability [8, 9]. The extent of variability of rainfall in relation to the mean rainfall is considered as climate risk in the study. Coefficient of variation was used to measure the variability in rainfall over the years for different risk zones and Tamil Nadu.

$$CV = \frac{\sigma}{x} \times 100$$

Where σ =standard deviation

x = Arithmetic Mean

t test for similar means

The simple t test was used to examine the null hypothesis of similar means of two datasets when their standard deviations are also the similar to each other. The test statistic is defined as [10]:

$$ts = \frac{|\bar{X}_2 - \bar{X}_1\ |}{S\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

where $\bar{X}_1$, $\bar{X}_2$, s_1^2 and $s_2^2$are the estimated means and variances of the first and second datasets. Critical value of this test statistic was taken from standard tables of the Student's t distribution at $\propto$ = 0.05 for "n-2" degrees of freedom. To compare the significant difference in annual and seasonal rainfall between risk zones, this test was applied.

F test for similar variances

The F test is used to compare the variances of the two datasets. The test – statistic is defined as follows [10]:

$$F\ = \frac{s_1^2}{s_2^2}$$

where s1 > s2

Critical value was taken from the F distribution table at $\propto$ = 0.05 for the sample size of two datasets defined by n_1 and n_2. To analyze the trend in monthly, seasonal and annual rainfall charts were drawn using the deviation, actual and normal rainfall in risk zones and State by using time series plotting and graph feature in STATA 13.

Analytic weights: were used to analyse rainfall data with respect to geographical area of particular districts. These were estimated by using STATA 13 software. In STATA 'aweights', or analytic weights, are inversely proportional to the variance of an observation; that is, the variance of the j^{th} observation is assumed to be σ^2=wj, where w_j are the weights [11].

Results and Discussion

Significant differences between the risk zones

t test was used to know the significant difference between the risk zones classification.

Table-1 *t test between different risk zone*

Variables	v1	v2	diff	t value	p value
Low vs Medium	959.08	852.47	106.61	2.99	0.00
Low vs High	959.08	999.67	-40.59	-1.05	0.29
Medium vs High	852.47	999.67	-147.20	-3.97	0.00

Table-1 concludes that there is no significant difference between the three climatic risk zones *i.e.* they exhibits more or less same pattern in rainfall variation. We can clearly say that the classification of risk zones for crop insurance does not depended on rainfall only. F test was performed to analyze the rainfall variation among different risk zones. The ratio between 2 risk zones and their standard deviation were used to test the significant differences in coefficient of variation. If the ratio is equal to one, it indicates that there is no significant difference among the risk zones. Hence more than one indicates numerator risk zone has higher variation than the denominator risk zone.

Table-2 *F test between different risk zones*

Variable	Ratio	P value
Low vs Medium	>1	0.0074**
Low vs High	<1	0.0751*
Medium vs High	<=1	0.0001***

From the table we can conclude that there exists significant difference in variation among different risk zones. Hence the analysis should be done separately.

Mean monthly rainfall

The mean monthly rainfall and its coefficient of variation for all the months were estimated using the formula. The below table clearly indicates that high variation was observed in most of the months especially winter season i.e. January and February months. While seeing the SWM and NEM months which are important for Tamil Nadu agriculture, South West monsoon season months viz., August, June and July exhibits high variation which will affect the sowing of *kharif* season crops especially in rainfed areas. The high deviation in November month will affect the harvesting stage of the crop. The variation among different risk zone were depicted as cycle plot in [Fig-1] which clearly indicated that in June, - September months received comparatively more rainfall in low risk zone districts while in October- march months relatively received highest rainfall than other risk zones along with more variability. While considering the months October, November and December they exhibit high variation in high risk zones which will affect the harvesting of the crops.

Table-3 *Mean monthly rainfall in risk zones and its coefficient of variation*

Month	Low	Medium	High	Mean	CV (%)
June	54.74	34.60	47.34	44.12	44.82
July	74.21	46.91	67.64	60.07	42.72
August	101.75	71.13	93.64	86.87	45.67
September	141.56	102.98	112.57	118.91	29.61
October	185.12	174.72	194.99	183.66	33.84
November	182.86	181.75	217.92	191.87	49.83
December	77.00	77.85	114.41	88.04	79.91
January	7.81	10.25	15.36	10.71	156.39
February	10.27	14.72	19.32	14.29	168.26
March	14.26	23.48	21.97	19.74	153.82
April	34.13	46.07	34.57	38.88	69.22
May	75.37	68.01	59.94	68.71	58.67
Annual	959.08	852.47	999.67	925.86	17.98
Month	Low	Medium	High	Mean	CV (%)

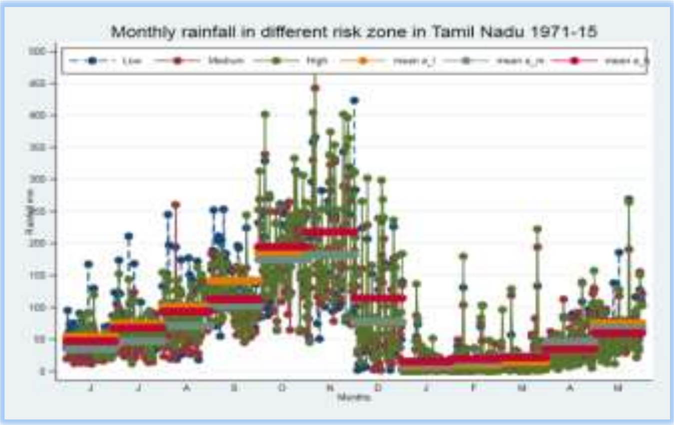

Fig-1 Monthly Rainfall in different risk zones of Tamil Nadu

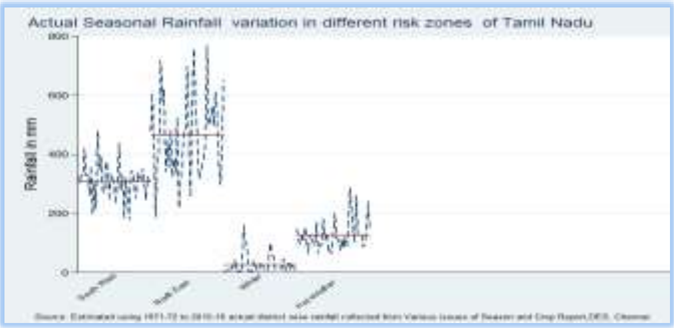

Fig-2 Variation in Actual Seasonal Rainfall of Tamil Nadu

[Fig-2] indicates that the high variation from the mean in observed actual rainfall was more in North East monsoon season which is harvesting time for most of the crops. This is followed by South West Monsoon season which is important season for sowing of *kharif* crops. These variations mayleads to affect in the sowing area, yield and quality of major agricultural produces.

Rainfall deviation in Actual and Normal monthly Rainfall

The climate risk as measured as coefficient of variation of rainfall over the 45 years for the three risk zones and Tamil Nadu were estimated and the result are present in [Table-4]. It could be inferred from table that the variation in south west monsoon rainfall was high in low and medium risk districts. The highest variation was noticed in December in NEM in all risk zone particularly high in districts under low risk zones where, most of the *rabi* crops at maturity or early harvesting stage which may cause more losses in low and medium risk districts. While considering the whole Tamil Nadu, the climate risk was high in NEM than South West monsoon particularly 80 per cent variation in December rainfall. Though the winter season months also exhibit higher variation in all risk regions, their role in Tamil Nadu agriculture is limited to cause major effects in crop production.

Table-4 *Climate risk (CV) in Monthly, Seasonal and Annual Rainfall in Different risk zones of Tamil Nadu*

Month/ Season	Low (n=367)	Medium (n=301)	High (n=328)	TN (n=996)
June	52.4	52.1	41.0	44.8
July	55.4	50.2	39.7	42.7
August	50.4	60.5	35.6	45.7
September	34.8	34.0	33.4	29.6
October	33.9	36.3	37.6	33.8
November	54.2	49.4	48.4	49.8
December	95.8	80.2	76.7	79.9
January	173.9	154.7	159.6	156.4
February	221.9	149.9	181.1	168.3
March	160.5	146.6	179.0	153.8
April	79.4	64.4	79.4	69.2
May	58.6	53.1	77.4	58.7
South West	25.8	24.1	19.8	20.0
North East	31.6	30.1	29.8	29.8
Winter	154.5	121.7	136.1	130.7
Summer	42.9	39.0	51.1	40.6
Annual	18.3	18.9	18.9	18.0

Source: 1. Estimated weighted average using 1971-72 to 2015-16 actual district wise rainfall data collected from various issues of Season and Crop Reports, DES, Chennai

2. Geographical area of the district was used as weight for that year

3. Coefficient of variation were estimated as climate risk of respective variables

Trend in monthly rainfall in different risk zone

The actual and normal annual rainfall non-linear trend were estimated and presented in Figures-3 and 4 respectively.

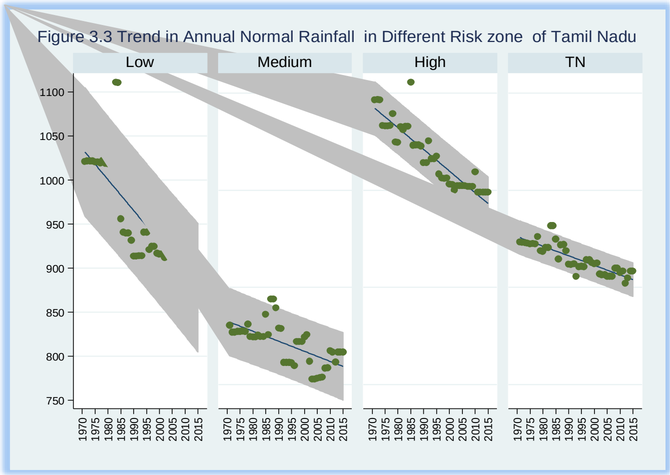

Fig-3 Trend in Annual Normal Rainfall in Different Risk zones of Tamil Nadu

[Fig-3] illustrates the declining trend of normal annual rainfall in Tamil Nadu. The declining slope is more in low and high risk zone districts than that of medium risk zone which exhibits that there is high rate of reduction in average annual, normalannual rainfall of high risk districts i.e. in Ramanathapuram, Sivagangai, Pudukottai, Tiruvarur, Cuddalore, Nagapattinam, Thiruvannamalai, Namakkal and Thoothukudi. While considering the state as a whole, also there was decreasing trend in normal annual rainfall.

[Fig-4] indicates the trend in actual annual rainfall in different risk regions and Tamil Nadu. Here we can see that, all plots exhibit increasing trend in annual actual rainfall except SWM. Comparing with [Fig-3], we can conclude that the increasing trend may be due to the change in distribution of rainfall under SW and NE monsoon months different risk zone.

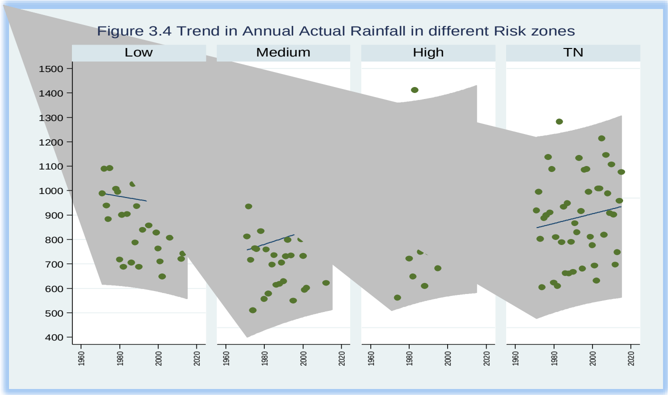

Fig-4 Trend in Annual Actual Rainfall in Different Risk zones of Tamil Nadu

Fig-5 Trend of SW and NE monsoons months in low risk zone

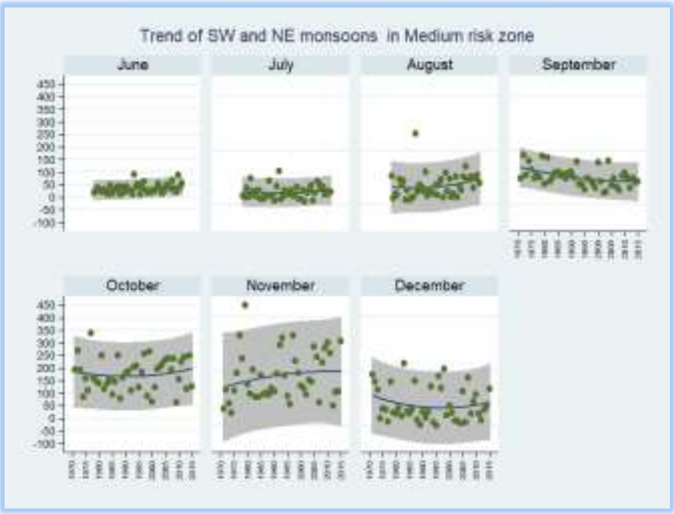

Fig-6 Trend of SW and NE monsoons in Medium Risk zone

[Fig-5] clearly indicates that there is a decrease in rainfall during the South West monsoon season months *viz*, June, July, September and October. Also, we can conclude that in low risk zone, the rainfall has increased during the months of October, November and December. These changes may affect the sowing and harvesting time of most of the *kharif* crops especially in rainfed areas.

[Fig-6] shows that there is an increase in October and December months' rainfall and decrease in July and September month's rainfall. Here also we can conclude that there is a decrease in sowing moth rainfall in SWMand increase in harvesting months in NEM rainfall which will surely affect the area and yield of most crops.
[Fig-7] also concludes that there is a decreasing trend in sowing month's rainfall *i.e*. June, July and September and increase in harvesting season rainfall during October and December. This will affect the sowing area, quality and yield of harvested crops.

Fig-7 Trend of SW and NE monsoons in high risk zone

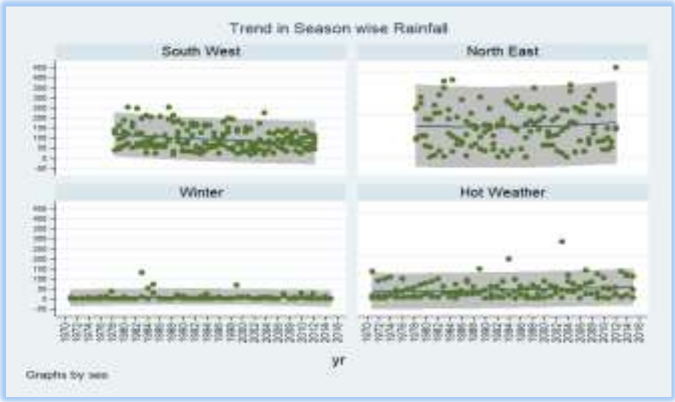

Fig-8 Trend in Season wise actual rainfall

[Fig-8] also shows that there is an increase in North East monsoon rainfall and decrease in South West monsoon rainfall. So we can clearly say that, this current trend in rainfall will affect the sowing and harvesting of the crops invariably in all the risk zones. The effects will be more in rainfed areas that depends merely on rainfall.

Occurrence of Extreme events

Extreme events occurrences were studied by classifying the months based on rainfall deviations. Large deficit of rainfall denotes drought and Large Excess denotes heavy rainfall which will leads to floods. The rainfall categories were classified based on IMD classification based on the percent deviation in monthly rainfall over normal rainfall. The occurrence of particular rainfall categories (no rain, large deficit, deficit, excess and large excess) in last 45 years were classified base on deviation and the results are presented in [Table-5]. [Table-5] indicates that only one fourth of the times all risk zones and state has received normal rainfall. About one fifth of the times, all the zones received more than 60percent deficit rainfall over normal rainfall in all the risk zones and the state. It is also interesting to note that once in 10 years flood (Large excess) may occur while once in five years, drought (Large Deficit in 20 percent months) will occur in all risk zones. In other words, Tamil Nadu rainfall pattern clearly confirmed that the drought occurrence was 20 percent and the flood occurrence was 12 percent irrespective of the risk zone classification. And there was no rain for 1 to 2 percent. From the table we can conclude that the extreme event occurrence became more frequent.

Conclusion

There is a drop in sowing month and increase in harvesting month rainfall of *kharif* crops, the important season of agriculture in Tamil Nadu which may lead to area and yield reduction respectively. Extreme events occurrence became frequent in recent years. Hence suitable policies need to be framed to cope up with these climate changes.

Application of research: Study of district wise monthly rainfall can be used to study the effects of rainfall in sowing and harvesting time of crops.

Table-5 *Occurrence of extreme events based on the deviation from the normal rainfall*

Rainfall Categories	ID	% rainfall deviation from normal	Low		Medium		High		TN	
			No. of months	%	No. of months	%	No of months	%	No of months	%
No Rain	NO	-100	12	2.22	6	1.11	6	1.11	4	0.74
Large Deficit	LD	-99 to -60	106	19.63	105	19.44	110	20.37	99	18.33
Deficit	DF	-20 to -59	152	28.15	149	27.59	170	31.48	168	31.11
Normal	NR	-19 to 19	125	23.15	131	24.26	132	24.44	127	23.52
Excess	EX	20 to 59	75	13.89	75	13.89	63	11.67	76	14.07
Large Excess	LE	>60	70	12.96	74	13.70	59	10.93	66	12.22
Total			540	100.0	540	100.0	540	100.0	540	100.0

It will be useful to formulate suitable policies to overcome the effect of climate change in agriculture.

Research Category: Agricultural Economics- Climate change

Abbreviations:
SWM: South West Monsoon, NEM: North East Monsoon, IMD: Indian Meteorological Department, GO: Government Order, CV: Coefficient of Variation, PMFBY: Pradhan Mantri FasalBima Yojana.

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Research project name or number: MSc Thesis, or Project, Research station trials, Frontline Demonstration, Clinical case study

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Study area / Sample Collection: Tamil Nadu state of India

Cultivar / Variety name: Nil

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
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