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Rainfall Modelling For Trichy and Perambalur Districts in India

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Abstract

The main objective of this research was to select a suitable model for the rainfall data of Trichy and Perambalur districts; to predicts the nature of rainfall for the next 16 years for each district; and to get the average amount of rainfall in the four seasons.

Data was collected from the district statistical office of Trichy and Perambalur districts. The data is collected month wise rainfall in mm from 2000 to 2013.

The following Statistical tools are used for the analysis of data.

1. **Seasonal variations,**
2. **Markov Chain analysis,**
3. **ARIMA Model.**

Keywords

Rainfall, Rainfall Modelling, Trichy, Perambalur, India

Introduction

Water is a major concern for life, any development and planning activities. There is an increase in water use due to economic and industrial developments. India is a tropical country. It mainly depends on rainfall for its water resources to get replenished regularly. Groundwater is the readily available fresh water resource used for drinking, agricultural and industrial purposes. Its availability depends on rainfall and recharge conditions. As India is a monsoon reliant country for its major portion of rainfall, it is necessary to analyze the occurrence and distribution of rainfall.

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Importance of rainfall

Rainwater is an important part of how water cycles itself on earth, water from oceans travels around and is evaporated into the atmosphere. After enough water is stored in the sky, it eventually comes back down to earth as rain, feeding plants, animals and people.

Fresh water: Rainfall provides as environment with fresh water. Rain is necessary to around keep water moving around, replenishing lakes, river and oceans and moving nutrients along via run off. Rain becomes parts of ground water that keeps ecosystems in check.

Water conservation: According to the united nations environments program me, many countries suffering from water shortage benefit from rain water harvesting projects. Rainwater is harvested to provides people with water for drinking and agricultures uses.

Effective Rainfall

Introduction: When rain water falls on the soil surface, some of it infiltrates into the soil, some stagnates on the surface, while some flows over the surface as runoff.
When the rainfall stops, some of the water stagnating on the surface evaporates to the atmosphere, while the rest slowly infiltrates into the soil. From all the water that infiltrates into the soil and some percolates below the root zone, while the rest remains stored in the root zone. In other words, the effective rainfall is the total rainfall minus runoff minus evaporation and minus deep percolation; only the water retained in the root zone can be used by the plants, and represents what is called the effective part of the rainwater. The term effective rainfall is used to define this fraction of the total amount of rainwater useful for meeting the water need of the crops.

Factors influencing effective rainfall: Many factors influence the amount of the effective rainfall. There are factors which the farmer cannot influence (e.g. the climate and the soil texture) and those which the farmer can influence (e.g. the soil structure).

a) **Climate:** The climate determines the amount, intensity and distribution of rainfall which have direct influence on the effective rainfall.

b) **Soil texture:** In coarse textured soil, water infiltrates quickly but a large part of it percolates below the root zone. In fine textured soil, the water infiltrates slowly, but much more water is kept in the root zone than in coarse textured soil.

c) **Soil structure:** The condition of the soil structure greatly influences the infiltration rate and therefore the effective rainfall. A favorable soil structure can be obtained by cultural practices (e.g. ploughing, mulching, ridging, etc.).

d) **Depth of the root zone:** Soil water stored in deep layers can be used by the plants only when roots penetrate to that depth. The depth of root penetration is primarily dependent on the type of crop, but also on the type of soil. The thicker the root zone, the more water available to the plant.

e) **Initial soil moisture content:** This means that for a rain shower occurring shortly after a previous shower or irrigation, the infiltration rate is lower and the surface runoff higher.

Irrigation methods: There are different methods of irrigation each method has a specific influence on the effective rainfall. In basin irrigation there is no surface runoff. All the rainwater is trapped in the basin and has time to infiltrate. In inclined border and furrow irrigation, the runoff is relatively large. At the lower end of the field the runoff water is collected in a field drain and carried away. Thus the effective rainfall under border or furrow irrigation is lower than under basin irrigation.

In contour furrow irrigation there is very little or no slope in the direction of the furrow and thus runoff is limited; the runoff over the cross slope is also limited as the water is caught by the ridges. This results in a relatively high effective rainfall, compared to inclined border or furrow irrigation.

Review of Literature

Extensive survey has been conducted to collect literature in all the aspects of study. Literature on climate change climate variability has been collected relevant to the objectives of the study undertaken.

Temperature Variability

Pant and Kumar (1997) have shown that there has been an increasing trend of mean annual temperature over India at the rate of 0.57°C/100 years. The trend and magnitude of global warming over India / Indian sub continent over last century is broadly consistent with the global trend and magnitude. They have further reported that in India, warming was found to be mainly contributed by the post monsoon and winter seasons. The monsoon temperatures do not show a significant trend in any part of country except for significant negative trend over northwest India.

Samra *et al (*2004) have observed that crop yield loss varied between 10 and 100% in the case of horticultural and seasonal crops when there was a cold wave from December 2002 to January 2003 in some parts of Jammu, Punjab, Haryana, Himachal Pradesh, Bihar, Uttar Pradesh and north Eastern States. The occurrences of high maximum temperature in March 2004 adversely affected the crops like wheat, apple, mustard, rapeseed, linseed, potato, vegetables, pea and tea across the state of Himachal Pradesh in India. The yield loss was estimated between 20% and 60%, depending upon the crop (Prasad and Rana, 2006). Such heat and cold waves are not uncommon in northern States.

Hingane *et al.,* (1985); Kumar and Hingane (1988); Pant and Hingane (1988); Kumar and Parikh (1998); Sanghi *et al.,* (1998); Kumar *et al.,* (2002); Gadgil and Dhorde (2005); Kothawala and Kumar (2005); Ramakrishna (2007) studied from time to time on temperature variability across the country. It is inferred from the above studies that the rate of increase in temperature varied depending upon the data set, location, region and season. Overall, the warming trend is evident across the country and the rate of increase in temperature was high in recent years though some locations showed cooling trend. The trend is visible in the case of maximum temperature while not so in the case of minimum temperature. The temporal and spatial variations in temperature are significant depending upon the season and the region. The spatial patterns of maximum temperature indicated that the Central India experiences more than 45°C while 35-40°C along the West Coast and above 25°C in Himachal Pradesh in north India (NATCOM Report, 2004). Some stations of the Indian Peninsular Plains also showed a falling trend in temperature. Several models indicated that the increase in temperature is likely to be around 3°C over the Country by 2100A.D.

Statistical Analysis

MARKOV CHAIN ANALYSIS

Prediction of rainfall for the next 16 years:

The rainfall pattern is classified as follows:

The rainfall is low when it is below 800mm per annum. The normal rainfall range from 800-1200 and it is high when the rainfall is greater than 1200mm based on above classification we have the following tables.

Rainfall	Low	Normal	High	Total
Low	4	2	1	7
Normal	2	2	1	5
High	2	0	0	2
Total	8	4	2	14

In order to predict the pattern of rainfall we make the markov chain analysis and we find the transition probability matrix based on the previous year, the rainfall is compared .thus we obtain the following transition probability matrix.

Rainfall	Low	Normal	High	Total
Low	4/7	2/7	1/7	7/7
Normal	2/5	2/5	1/5	5/5
High	2/2	0/2	0	2/2
Total	8/14	4/14	2/14	14/14

Using the above transition probability matrix, we predict the rainfall pattern for the next five years (2,4,8.16 years).

$$P = \begin{bmatrix} 4/7 & 2/7 & 1/7 \\ 2/5 & 2/5 & 1/5 \\ 1 & 0 & 0 \end{bmatrix}$$

$$p^2 = \begin{bmatrix} 0.58 & 0.28 & .14 \\ 0.59 & 0.27 & .14 \\ 0.57 & .29 & .14 \end{bmatrix}$$

$$p^4 = \begin{bmatrix} 0.59 & 0.28 & 0.14 \\ 0.59 & 0.26 & 0.14 \\ 0.59 & 0.28 & 0.14 \end{bmatrix}$$

$$p^{16} = \begin{array}{c} \begin{matrix} L & M & H \end{matrix} \\ \begin{bmatrix} 0.59 & 0.28 & 0.14 \\ 0.58 & 0.27 & 0.14 \\ 0.59 & 0.28 & 0.14 \end{bmatrix} \end{array}$$

Based on the above Markov Chain analysis for the next 16 years, will be as follows the rainfall pattern for the next 10 the rainfall level will be low then for next 4 years will be medium and for 2 years will be high.

PERAMBALUR DISTRICT:

Prediction of rainfall for the next 16 years:

The rainfall pattern is classified as follows:

The rainfall is low when it is below 800mm per annum. The normal rainfall range from 800-1200 and it is high when the rainfall is greater than 1200mm based on above classification we have the following tables.

Rainfall	Low	Normal	High	Total
Low	3	2	1	6
Normal	2	0	1	3
High	2	2	1	5
Total	7	4	3	14

In order to predict the pattern of rainfall we make the markov chain analysis and we find the transition probability matrix based on the previous year, the rainfall is compared .thus we obtain the following transition probability matrix.

Rainfall	Low	Normal	High	Total
Low	3/6	2/6	1/6	6/6
Normal	2/3	0	1/3	3/3
High	2/5	2/5	1/5	5/5
Total	7/14	4/14	3/14	14/14

Using the above transition probability matrix, we predict the rainfall pattern for the next five years (2,4,8.16 years).

$$P = \begin{bmatrix} \mathbf{3/6} & \mathbf{2/6} & \mathbf{1/6} \\ \mathbf{2/3} & \mathbf{0} & \mathbf{1/3} \\ \mathbf{2/5} & \mathbf{2/5} & \mathbf{1/5} \end{bmatrix}$$

$$p^{2} = \begin{bmatrix} 0.54 & 0.23 & 0.23 \\ 0.47 & 0.36 & 0.18 \\ 0.55 & 0.21 & 0.24 \end{bmatrix}$$

$$p^{4} = \begin{bmatrix} 0.53 & 0.25 & 0.22 \\ 0.54 & 0.28 & 0.21 \\ 0.53 & 0.26 & 0.23 \end{bmatrix}$$

$$p^{16} = \begin{array}{c} \begin{matrix} L & M & H \end{matrix} \\ \begin{bmatrix} 0.51 & 0.26 & 0.27 \\ 0.55 & 0.27 & 0.23 \\ 0.55 & 0.26 & 0.22 \end{bmatrix} \end{array}$$

Based on the above Markov Chain analysis for the next 16 years, will be as follows the rainfall pattern for the next 9 years the rainfall level will be low then for next 4 years will be medium and for 3 years will be high.

Seasonal index:

YEARS	QUARTER I	QUARTER2	QUARTER3	QUARTER4
2000	-	-	167.07	167.05
2001	10.23	48.81	138.07	191.42
2002	61.75	40.53	201.50	180.38
2003	0.40	67.27	152.67	170.85
2004	0.15	109.81	144.25	147.43
2005	0.33	76.99	265.41	1.01
2006	35.21	94.04	207.62	0
2007	62.61	120.87	212.97	46.87
2008	77.68	97.66	209.42	1.8
2009	23.02	51.91	300.56	5.52
2010	78.39	122.69	224.64	2.30
2011	44.84	122.55	225.56	7.65
2012	41.44	0.32	318.49	6.45
2013	46.63	198.49	-	-
TOTAL	405.36	953.13	2311.67	737.31

Modified mean:

Winter	405.36/11	36.85
Summer	953.13/11	86.65
South west monsoon	2311.67/11	210.15
North east monsoon	737.31/11	67.03
	Total	400.68

Demonstration

Quarters	**Unadjusted indices*adjusted constant**	**Seasonal index**
Winter	36.85*.9994	36.8
Summer	86.65*.9994	86.6
North east monsoon	207.52*.9994	207.4
South west monsoon	69.24*.9994	69.2
Total		400

Mean of the seasonal indices=100

North east monsoon has the highest rainfall 107%.

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To determine the monthly averages for the following data :

Months	Total	Monthly averages (M.A)	Seasonal index=(M.A/A of A)*100
January	150.57	10.76	16.54
February	120.64	8.62	13.25
March	200.03	14.29	21.96
April	410.74	29.34	45.09
May	1029.23	73.52	112.99
June	327.95	23.43	36.01
July	554.85	39.63	60.90
August	978.64	69.90	107.42
September	1407.28	100.52	154.48
October	2407.94	171.99	264.32
November	2515.18	179.66	276.10
December	828.84	59.2	90.98
Total		780.86	1200.04

Result: Compare to the normal season the rainfall in Trichy district is having 107.4 percentage higher during the rainy season compare to other season.

PERAMBALUR:

COMPUTING A SEASONAL INDEX

YEAR	QUARTER-1	QUARTER-2	QUARTER-3	QUARTER-4
2000	-	-	183.43	12.13
2001	58.12	182.25	159.19	6.64
2002	74.07	105.84	164.72	0.0
2003	52.003	194.82	187.56	0.0
2004	156.66	83.49	181.67	0.0
2005	83.6	73.89	221.65	2.68
2006	45.94	91.67	198.12	0.0
2007	57.91	148.63	204.87	19.10
2008	69.74	77.73	254.39	4.03
2009	38.43	98.43	229.66	16.99
2010	40.08	143.85	215.86	0.54
2011	78.40	110.97	197.39	0.0
2012	43.77	91.21	186.39	10.63
2013	40.60	209.53	-	-
TOTAL	644.233	1401.16	2171.32	53.64

Modified mean :

QUARTER-1	644.233/11	58.567
QUARTER-2	1401.16/11	127.38
QUARTER-3	2171.32/11	197.39
QUARTER-4	53.64/11	4.87
TOTAL		388.21

Demonstration of indices:

QUARTERS	**Unadjusted indices*adjusted constant**	**Seasonal indix**
Winter	58.57*1.03	60.4
Summer	127.38*1.03	131.2
South westmonsoon	197.39*1.03	203.3
North eastmonsoon	4.87*1.03	5.05
TOTAL		400

Mean of the season indices=100

To determine the monthly averages for the following data :

Months	Total	Monthly average	Seasonal index
January	103.4	7.39	5.32
February	83.74	5.98	4.31
March	184.08	13.15	9.47
April	579.07	41.36	29.79
May	1128.56	80.61	58.06
June	498.56	34.97	25.19
July	1028.56	73.47	52.92
August	1220.74	87.19	62.80
September	1463.9	104.56	75.31
October	2126.39	151.89	109.40
November	2753.42	196.67	141.65
December	1163.32	83.09	59.85
Total		1666.046	634.07

Result: Compare to the normal season the rainfall in Perambalur district is having 103.3 percentage higher during the rainy season compare to other season.

Arima Modal for the Rainfall Data in Trichy District

In order to choose a proper modal to understand the pattern of rainfall, we choose the ARIMA model of the from Trichy district.

The result of the ARIMA model is given below:
Fifth order:

The hypotheses used for this test are

H0 : A5= 0

H1 : A5 ≠ 0

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Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1263.505	2272.753		.556	.617
	lag1	.057	.772	.053	.074	.946
	lag2	-.281	.833	-.212	-.337	.758
	lag3	.109	.794	.091	.138	.899
	lag4	-.403	.672	-.339	-.600	.591
	lag5	-.035	.838	-.028	-.042	.969

The fitted ARIMA model is

$\hat{Y}_i$=1263.505-0.057 Y_{i-1}-0.281 Y_{i-2} -0.109 Y_{i-3}-0.403 Y_{i-4}-0.035 Y_{i-5}

Here we take 5th order coefficient and test for significance.

The hypotheses used for this test are,

Test statistic t $= \frac{a5-A5}{Sa5}$

Interpretation:

Here lag5 is not significant, since the value 0.969 greater then 0.05 level of significance. So we consider up to lag4 and test for significance.

Fourth order:

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1251.926	1023.772		1.223	.276
	lag1	.066	.474	.062	.140	.894
	lag2	-.299	.528	-.246	-.566	.596
	lag3	.105	.518	.088	.203	.847
	lag4	-.408	.508	-.341	-.804	.458

The fitted ARIMA model is

$\hat{Y}_i$= 1251.926+0.066 Y_{i-1}-0.299Y_{i-2} +0.105 Y_{i-3} -Y_{i-4}

Here we take 4th order coefficient and test for significance.

The hypotheses used for this test are,

H0 : A4= 0

H1 : A4 ≠ 0

Test statistic t $= \frac{a4-A4}{Sa4}$

Interpretation:

here lag4 is not significant, since the value is 0.458greater then 0.05 level of significance. So we consider up to lag3 and test for significance.

Third order :

The hypotheses used for this test are

H0 : A3= 0

H1 : A3 ≠ 0

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	842.487	733.506		1.149	.288
	lag1	.017	.390	.017	.045	.966
	lag2	-.230	.449	-.193	-.514	.623
	lag3	.169	.450	.142	.376	.718

The fifed ARIMA model is
$\hat{Y}_i$= 842.487+0.017 Y_{i-1}-0.230 Y_{i-2} +0.169 Y_{i-3}

Here we take 3th order coefficient and test for significance.

The hypotheses used for this test are,

H0 : A3= 0

H1 : A3 ≠ 0

Test statistic t $= \frac{a3-A3}{Sa3}$

Interpretation:

Here lag3 is not significant, since the value is 0.718 greater then 0.05level of significance. So we consider up to lag2 and test for significance.

THE SECOND ORDER AUTO REGRESSIVE:

Model	Unstandardized coefficients		Standardized coefficients	t	Sig
	B	Std.Error	Beta		
1(Constant)	956.361	473.756	-0.23	2.019	.074
Lag1	0.024	0.348	-0.185	-0.69	.946
Lag2	-0.0227	0.405		0.560	.589

The fitted ARIMA model is

$\hat{Y}_i$ =956.361+0.024 Y_{i-1}-0.0227 Y_{i-2}

Here we take 2nd order coefficient and test for significance.

The hypotheses used for this test are,

H0 : A2 = 0

H1 : A2 ≠ 0

Test statistic t = $\frac{a2-A2}{Sa2}$

Interpretation:

Here lag2 is not significant, since the value is 0.589 greater then 0.05 level of significance. We conclude that the second order is not significant and can be deleted. Thus ARIMA model is not a suitable model for the Trichy rainfall data.

ARIMA MODAL; PERAMBALUR

Fifth order Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2098.625	1375.743		1.525	.225
	LAG1	-.081	.569	-.085	-.143	.895
	LAG2	-.679	.620	-.588	-1.096	.353
	LAG3	-.014	.555	-.015	-.025	.982
	LAG4	-.353	.506	-.386	-.697	.536
	LAG5	-.230	.498	-.253	-.462	.676

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The fitted ARIMA model is

$\hat{Y}_i$=2098.625-0.081 Y_{i-1}-0.679 Y_{i-2} -0.014 Y_{i-3}-0.353 Y_{i-4}-0.230 Y_{i-5}
Here we take 5order coefficient and test for significance.

The hypotheses used for this test are,

H0 : A5= 0

H1 : A5 ≠0

Test statistic t = $\frac{a5-A5}{Sa5}$

Interpretation:

Here lag5 is not significant, since the value is 0.676 greater then 0.05 level of significance, so we consider up to lag4 and test for significance.

Fourth order:
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	1521.153	666.581		2.282	.071
	LAG1	.076	.396	.079	.193	.855
	LAG2	-.558	.372	-.579	-1.499	.194
	LAG3	.113	.402	.118	.282	.790
	LAG4	-.347	.362	-.369	-.959	.381

The fitted ARIMA model is

$\hat{Y}_i$=1521.153- 0.076 Y_{i-1}-0.558 Y_{i-2} +0.113 Y_{i-3}-0.347 Y_{i-4}

Here we take 4th order coefficient and test for significance.

The hypotheses used for this test are,

H0 : A4= 0

H1 : A4 ≠ 0

Test statistic t = $\frac{a4-A4}{Sa4}$

Interpretation:

Here lag4 is not significant, since the value is 0.381 greater then 0.05 the level of significance, So we consider up to lag3 and test for significance.

Third order:

Model	Unstandardized coefficients		Standardized coefficients	t	Sig
	B	Std.Error	Beta		
1(Constant)					
Lag1	1026.804	480.939	0.199	2.135	0.070
Lag2	-0.175	0.310	-0.464	0.565	0.590
Lag3	-0.459	0.341	0.128	-1.345	0.221
	0.124	0.343		0.362	0.728

The fitted ARIMA model is

$\hat{Y}_i$=1026.804 + 0.175 Y_{i-1}-0.459 Y_{i-2} -0.124 Y_{i-3}

The hypotheses used for this test are

H0 : A3= 0

H1 : A3 ≠ 0

Test statistic t = $\frac{a3-A3}{Sa3}$

Interpretation:

Here lag3 is not significant, since the value is 0.728 greater then 0.05,the level of significance So we consider up to lag2 and test for significance.

THE SECOND ORDER AUTOREGRESSIVE MODEL:

H0 : A2 = 0

H1 : A2 ≠ 0

Test statistic t $\frac{a2-A2}{Sa2}$

Interpretation:

Here lag2 is not significant, since the value is 0.405 greater then 0.05,the level of significant. We conclude that the second order is not significant and can be deleted. thus ARIMA model is not a suitable model for the Perambalur district rainfall data.

CONCLUSION:

1. Based on the statistical analysis of selecting a proper model for the rainfall model Trichy and Perambalur districts no model such as linear, quadratic, qubic etc, is suitable for the rainfall data. The main reason for this is rainfall depends upon many parameters such as climate ,temperature, soil texture, soil structure, depth of the root zone, initial soil moisture consent, irrigation methods.The rainfall data for all the above set parameters are not available from the district statistical office.

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2. Compare to the normal season the rainfall in Trichy district is having 107.4 percent higher during the rainy season. Monthly wise rainfall level, the November month is high.

3. Compare to the normal season the rainfall in Perambalur district is having 103.3 percent higher during the rainy season. Monthly wise rainfall level, the November month is high.

4. ARIMA model for the Trichy district : Here lag2 is not significant, since the value is 0.589 greater than 0.05 level of significance. We conclude that the second order is not significant and can be deleted. T hus ARIMA model is not a suitable model for the Trichy rainfall data.

5. ARIMA model for the Perambalur district : Here lag2 is not significant, since the value is 0.405greater then 0.05 level of significance. We conclude that the second order is not significant and can be deleted. Thus ARIMA model is not a suitable model for the Perambalur rainfall data.

6. Markov chain analysis results from Trichy district :Based on the Markov Chain analysis for the next 16 years, Rainfall pattern
   - First 10 years the rainfall level will be low
   - Next 4 years the rainfall level will be medium
   - Last 2 years the rainfall level will be high

7. Markov chain analysis results from Perambalur district :Based on the Markov Chain analysis for the next 16 years Rainfall pattern
   - First 9 years the rainfall level will be low
   - Next 4 years the rainfall level will be medium
   - Last 3 years the rainfall level will be high

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