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CHARACTERIZATION OF THE PATTERN OF RAINFALL IN NORTHERN KERALA

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Weather plays an important role in the agriculture of a country, especially of India. Rainfall, which is one of the most important of the weather parameters is highly variable in nature in our country. In Kerala, year-round cultivation mainly depends on south-west and north-east monsoons. But the distribution of rainfall in Jong and short spells over the past several years has been marginal and erratic. The northern districts of Kerala are worst affected by the vagaries of monsoons. In these districts, the north-east monsoon is not at all strong and exerts no significant impact on water availability. It is therefore necessary to know the pattern of rainfall occurrence for efficient agricultural planning in this region.

Simple criteria related to sequential phenomena like dry and wet spells could be used for analysing rainfall data to obtain specific information needed for crop planning and for carrying out agricultural operation. As synoptic systems inducing rainfall or wet spells have been found to persist for a few days over a region, it is useful to ascertain the probability of sequential events like a wet day following another wet day or a dry day following a wet or dry day during the crop growing season. Markov Chain probability model has been found suitable to describe the long term frequency behaviour of wet or dry weather spells (Gabriel and Neumann 1962, Hopkins and Robillard 1964, Bhargava *et* /. 1972, Krishnan and Kushwaha 1973, Rao 1684). The study of rainfall probabilities is an approach to sound planning against the hardship caused by large variation in rainfall. The probability of a fixed amount of rainfall to be expected could be computed by fitting appropriate probability distribution of rainfall. It was found by Chow (1954) that log-normal probability law could be applied to model monthly and daily rainfall amounts. Singh and Pavate (1968) observed that monthly precipitation amounts at Amravati and Coimbatore followed the normal probability law when the data were transformed to the square root scale. Thorn (1968) recommended the fitting of incomplete gamma function to skew distributions such as those of rainfall having zero as lower bound.

Materials and Methods

Daily rainfall data of the past 30 years were used to characterize fortnightly rainfall pattern at the selected centres of northern districts of Kerala viz., Irikkur, Cannanore, Kozhikode, Quilandy and Mananthody. Each month in an year is divided into two fortnights of 15 or 18 days duration. However, February is divided into two fortnights each with 14 days duration.

Using daily rainfall data of the whole year, a classification of days are made based on the amount of rainfall received on each day. Following Gabriel and Neumann 1962, wet day can be defined as a day on which the amount of rainfall received is greater than or equal to 2.5 mm. Similarly, a dry day is defined as a day which receives an amount of rainfall which is lass than 2.5 mm. By this classification, a sequence of wet and dry days are obtained. One of the following four possibilities may occur while classifying each day of such a sequence.

1) A dry day preceeded by a dry day. 2) A wet day preceeded by a dry day. 3) A dry day preceeded by a wet day. 4) A wet day preceeded by a wet day.

The number of days for the above four possibilities are counted for each fortnight. The process is repeated each year and the total number of days are obtained for all the fortnights separately. Let these frequencies be denoted by n_{11}, n_{12}, n_{21} and n_{22} respectively with $n_{11}+n_{12}=n_1$ and $n_{21}+n_{22}=n_2$.
previous day is dry, let the probabilities of a day being dry and wet I
p_{11} and p_{12} with $p_{11}+p_{12}=1$ where $p_{11} = n_{11}/n_1$ and $p_{12} = n_{12}/n$
likelihood estimates. Similarly, given that the previous day
ties of a day being dry and wet be respectively p_{21} and p_{22} with $p_{21}+p_{22}=1$

It is assumed that the probability of rainfall on any day depends only on whether the previous day was wet or dry. Givan the event on the previous day, then, the probability of rainfall is assumed independent of events of further preceding days. Such a probability model is the Markov Chain whose parameters are the two conditional probabilities p_{12} and p_{22}.

In order to test whether the Markov Chain is of first order, the normal deviate test can be applied.

The tost statistic

$$Z = \frac{|p_{12}-p_{22}|}{SE(p_{12}-p_{22})} \longrightarrow N(0,1)$$

SE $(p_{12}-p_{22})$ is estimated by pq $(1/n_1+1/n_2)$ where

$p=(n_1p_{12}+n_2p_{22})/(n_1+n_2)$

$q=1-p$

A significant value of Z reveals that the occurrence of rainfall on a particular day depends on the immediately preceeding days, rainfall which is evidently the property of the first order Markov Chain. In such cases, the sequence of wet and dry days over a given period strictly follows a two state Markov Chain model. The transition probability matrix can be put as

P -,-⌉
1 p_{22} J

It is seen that after a sufficiently long period of time, the system settles down to a condition of statistical equillibrium in which the state occupation probabilities are independent of initial conditions. If this is so, then there is an equilibrium probability distribution $\pi = (\pi_0, \pi_1)$.

It can be easily verified that

$$\pi_0 = \frac{1-p_{22}}{1-p_{22}+p_{12}} \quad \text{and} \quad \pi_1 = \frac{p_{12}}{1-p_{22}+p_{12}}$$

A wet spell of length k is defind as a sequence of k wet days preceded and followed by dry days. Similarly a day spell of length m is defind as a sequence of m dry days preceded and followed by wet days. Weather cycles are defined as combination of a wet spell and an adjacent dry spell. The distribution of spells by length is found to be geometric with the probability of a wet spell of length k $(1-p_{22})^{k-1}p_{22}$ and the probability of a dry spell of length m being

The expected length of a wet spell of length k is given by $\frac{1}{1-p_{22}}$ and that of a dry spell of length m is given by $\frac{1}{p_{12}}$

The expected length of a weather cycle is then $\frac{1}{1-p_{22}} + \frac{1}{p_{12}}$

Fortnightly rainfall data are also used to evolve appropriate probability distributions of best fit. The values of β_1 (coefficient of skewness) and β_2 (coefficient of kurtosis) which determine the shape of the curve are calculated and tested for significance by the normal deviate test. In large samples $(n>24)$' Pearson and Hartley (Buck, 1975) have shown that Z_1 = [illegible]

is approximately normally distributed with mean zero and SD= unity.

Similarly Z_2 =

is approximately normally distributed with mean zero and SD = unity.

In case of any significant deviation from normality, the square root and logarithmic transformations are applied to restore normality. When both these transformations fail to normalize the data, gamma distribution is tried.

The forms of the distributions with parameters are as follows.

1. Normal distribution

$$f(x) = (1/\sqrt{2\pi}\,\sigma)\exp\left(-1/2\right)(x-\mu)^2/\sigma^2, \quad -\infty < x < \infty$$

μ = mean and σ^2 = variance are the parameters of the distribution.

2. Root normal distribution

$$f(x) = (1/2\sqrt{x}\,\sqrt{2\pi}\,\sigma_y)\exp\left[(-1/2)(\sqrt{x}-\mu_y)^2/\sigma^2_y\right], \quad x>0$$

where $Y = \sqrt{X}$

This gives the distribution of X as the root normal distribution with parameters

This is the distribution of X as the log normal distribution with parameters μ_y and σ_y. The estimates of the parameters μ_y and σ_y are $\bar{y} = (1/n) \Sigma y_i$ and $s^2_y = (1/n) \Sigma y^2_i - \bar{y}^2$ respectively which can bs obtained by transforming all X_i's to Y_i's by the transformation $y_i = \log_e X_i$

4. Gamma distribution

$$f(X) = X^{n-1} \exp(-px) \, p^n / \sqrt{n}, \quad x, p, n > 0$$

Where $\sqrt{n} = \int_0^{\infty} t^{n-1} \exp(-t)\, dt$ for $n > 0$

n is the shade parameter and p is the scale parameter

The parameters can be estimated from the relations

$\hat{p} = \hat{n} / \bar{X}$ and $\hat{n} = (-1 - \sqrt{1-(4/3) \log_e (G/\bar{X})}) / 4 \log_e (G/\bar{X})$

Where X is the arithmetic mean and g is the geometric mean

The probabilities of receiving a minimum amount of assured rainfall was computed by utilising the properties of the corresponding distribution in various fortnights.

Results and Discussion

The transition probabilities p_{12} and p_{22} were estimated for every fortnight and for each centre and the test for the first order Markove Chain was done. Such a model was fitted to all fortnights in which the basic assumption of the model was justified py the normal diviate test. The state occupation probabilities at equillibrium and the number of days required for the system to achieve the state of equillibrium were worked out and are presented in Table 1. However, equillibrium state probabilities could not be found out in certain fortnights in which p_{22} was found to be zero. Equillibrium could not be attained in 15 days in the 18th fortnight at the Cannanore Station.

The study revealed that first order Markov Chain model is an adequate representation of wet and dry days except in a few fort nights. The equilibrium probability of occurrence of wet day (π_1) showed increasing trend up to the 12th 13th or 14th fortnights and thereafter showed a steady decline. A significant difference between any two earliest consecutive values of π_1 (or π_0) in the anticipated time scale indicates the probable start of monsoon rains. Hence it could be seen that at all centres, the likely commencement of south-west monsoon was in the 11th fortnight.

Appropriate probability distributions were fitted to fortnightly amounts of rainfall to estimate rainfall probabilities. No probability distribution was found to fit the rainfall amounts in the fortnights numbered 1-7, 23 and 24 for Irikkur centre, fortnights 1-6, 9 and 24 for the Cannanore Station, fortnights 1-5 and 24 for Kozhikode, fortnight 1-6, and 24 for Quilandy and fortnights 1-5 and 24 for Mananthody centres, since most of the data were zeros. The mean rainfall and the

Table 1
Properties of Markov Chain model

Fort-night	Irikkur: Equillibrium state pro-babilities π_0	π_1	Irikkur: No. of days to equilli-brium	Cannanore: Equillibrium state pro-babilities π_0	π_1	Cannanore: No. of days to equilli-brium	Kozhikode: Equillibrium state pro-babilities π_0	π_1	Kozhikode: No. of days to equilli-brium	Quilandy: Equillibrium state pro-babilities π_0	π_1	Quilandy: No. of days to equilli-brium	Mananthody: Equillibrium state pro-bablities π_0	π_1	Mananthody: No. of days to equilli-brium
1	0.99	0.01	7	1.00	0	15				0.99	0.01	11	1.00	0	2
2	0.99	0.01	12				0.98	0.02	16	0.99	0.01	12	0.99	0.01	6
3															
4							0.97	0.03	7	0.98	0.02	6	0.97	0.03	9
6				0.99	0.01	8				0.98	0.02	9	0.97	0.03	10
6	0.98	0.02	1	0.98	0.02	6	0.94	0.06	10	0.96	0.04	R	0.93	0.07	12
7	0.91	0.09	7	0.91	0.09	7	0.85	0.15	5	0.87	0.13	9	0.78	0.22	8
S	0.80	0.20	9	0.88	0.12	6				0.84	0.16	6	0.74	0.26	8
9	0.77	0.23	0	0.82	0.18	9	0.73	0.27	7	0.79	0.21	8	0.74	0.26	g
10	0.59	0.41	14	0.66	0.34	13	0.56	0.44	16	0.55	0.45	11	0.68	0.32	9
11	0.26	0.74	15	0.28	0.72	15	0.27	0.73	13	0.29	0.71	15	0.42	0.58	13
12	0.12	0.88	15	0.16	0.84	10	0.17	0.83	10	0.20	0.80	14	0.21	0.79	12
13	0.08	0.92	•10	0.16	0.84	15	0.16	0.84	12	0.18	0.82	14	0.15	0.85	12
14	0.09	0.91	13	0.19	0.81	14	0.19	0.81	11	0.17	0.83	11	0.15	0.85	10
15	0.20	0.80	11	0.26	0.74	13	0.28	0.72	10	0.31	0.69	12	0.20	0.80	12
16	0.34	0.66	16	0.40	0.60	16	0.42	0.58	15	0.41	0.59	16	0.31	0.69	14
17	0.47	0.53	15	0.60	0.40	14	0.36	0.44	13	0.60	0.40	14	0.54	0.46	14
18	0.53	0.47	12	-	*		0.60	0.40	15	0.61	0.39	15	0.62	0.38	13
19	0.60	0.40	12	0.74	0.26	11	0.66	0 34	7	0.63	0.37	10	0.63	0.32	11
20	0.56	0.44	11	0.70	0.30	9	0.67	0.33	9	0.66	0.34	11	0.67	0.33	12
21	0.76	0.24	11	0.84	0.16	"2.	0.77	0.24	8	0.81	0.19	7	0.78	0.22	8
22	0.86	0.14	15	0.93	0.07	7	0.90	0.10	10	0.88	0.12	12	0.90	0.10	10
23	0.95	0.05	15	0.95	0.05	12	0.89	0.11	11	0.91	0.09	13	0.92	0.08	10
24	0.98	0.02	15	0.99	0.01	13				0.98	0.02	7	0.99	0.01	15

Equillibrium could not be attained in 15 days

Table 2

Rainfall probabilities

	Irrikkur			
Fort-night	Distri-bution fitted	Mean rainfall (mm)	Rainfall amounts (x mm)	Probability of receiving x mm or less rainfall
6				
8	Gamma	66.2	52.9	0.49
			79.4	0.63
9	Root normal	57.5	46.0	0.33
			69.0	0.67
10	Root normal	146.9	117.5	0.34
			176.3	0.66
11	Root normal	265.4	212.3	0.31
			318.5	0.69
12	Normal	473.1	378.5	0.35
			567.8	0.65
13	Normal	661.3	529.0	0.35
			793.5	0.65
14	Root normal	555.7	444.5	0.22
			666.8	0.78
15	Root normal	307.6	246.1	0.25
			369.1	0.75
16	Normal	238.3	190.6	0.38
			285.9	0.62
17	Normal	132.7	106.2	0.39
			159.3	0.61
18	Normal	116.3	93.0	0.39
			139.6	0.61
19	Root normal	141.9	113.5	0.34
			170.3	0.66
20	Normal	142.4	114.0	0.38
			170.9	0.62
21	Normal	70.9	56.7	0.40
			85.1	0.60
22	Log-normal	8.9	7.2	0.40
			10.7	0.60
23				

Table **2 contd.**

Fort-night	Cannanore Distri-bution fitted	Mean rainfall (mm)	Rainfall amounts (x mm)	Probability of receiving x mm or less rainfall
6				
7	Gamma	26.4	21.1	0.69
			31.6	0.78
8	Root normal	23.6	18.9	0.36
			28.3	0.64
9				
10	Root normal	123.9	99.1	0.37
			148.7	0.63
11	Normal	359.6	287.7	0.38
			431.6	0.62
12	Root normal	444.9	356.0	0.19
			533.9	0.81
13	Normal	525.9	420.7	0.33
			631.1	0.67
14	Normal	477.3	381.8	0.34
			572.7	0.66
15	Root normal	264.8	211.9	0.26
			317.8	0.74
16	Root normal	182.1	145.7	0.29
			218.5	0.71
17	Root normal	87.8	70.2	0.35
			105.3	0.65
18	Root normal	92.2	73.8	0.36
			110.7	0.64
19	Normal	85.0	68.0	0.41
			102.0	0.59
20	Root normal	114.5	91.6	0.35
			137.4	0.65
21	Gamma	62.0	49.6	0.60
			74.4	0.70
22	Log-normal	6.0	4.8	0.40
			7.2	0.60
23	Log-normal	4.3	3.5	0.42
			5.2	0.58

Table 2 contd.

Fort-night	Kozhikode Distri-bution fitted	Mean rainfall (mm)	Rainfall amounts (x mm)	Probability of receiving x mm or less rainfall
6	Log-normal	4.8	3.8	0.41
			5.7	0.59
7	Gamma	51.0	40.8	0.58
			61.2	0.73
[illegible]	Root normal	36.6	29.3	0.32
			43.9	0.68
9	Root normal	65.9	52.7	0.33
			79.1	0.67
-10	Normal	228.6	182.9	0.40
			274.4	0.60
11	Normal	376.0	300.8	0.35
			451.2	0.65
12	Normal	445.2	356.2	0.33
			534.2	0.67
13	Normal	472.7	378.2	0.33
			567.3	0.67
14	Normal	420.0	336.0	0.35
			504.0	0.65
15	Normal	261.9	209.5	0.34
			314.3	0.66
16	Normal	182.1	145.7	0.34
			218.5	0.66
17	Normal	108.6	86.9	0.41
			130.3	0.59
18	Root normal	107.7	86.1	0.36
			129.2	0.64
19	Root normal	87.8	70.2	0.31
			105.4	0.69
20	Root normal	107.5	86.0	0.32
			128.9	0.68
21	Root normal	65.2	52.1	0.36
			78.2	0.64
22	Root normal	18.0	14.4	0.38
			21.5	0.62
23	Root normal	25.4	20.3	0.39
			30.5	0.61

Table 2 contd.

Fort-night	Quilandy			
	Distri-bution fitted	Mean rainfall (mm)	Rainfall amounts (*x* mm)	Probability of receiving x mm or less rainfall
6				
7	Root normal	33.9	27.1	0.37
			40.6	0.63
8	Root normal	36.7	29.4	0.33
			44.1	0.65
9	Root normal	57.5	46.0	0.33
			69.0	0.67
ID	Log-normal	164.3	131.5	0.19
			197.2	0.81
11	Root normal	363.8	291.0	0.32
			436.5	0.68
15	Normal	516.2	413.0	0.34
			619.4	0.66
13	Normal	488.6	390.8	0.34
			586.3	0.66
14	Root normal	475.3	380.2	0.21
			570.3	0.79
15	Root normal	272.4	217.9	0.31
			326.8	0.69
16	Normal	213.7	170.9	0.36
			256.4	0.64
17	Log-normal	66.3	53.0	0.25
			79.5	0.75
18				
19	Root normal	96.8	77.5	0.34
			116.2	0.66
20	Root normal	139.1	111.3	0.33
			166.9	0.67
21	Root normal	60.0	47.9	0.38
			72.0	0.62
22	Gamma	71.6	63 9	0.69
			85.9	0.74
23	Log-normal	7.6	6.1	0.41
			9.1	0.59

Table **2** contd.

	Mananthody			
Fort-night	Distri-bution fitted	Mean rainfall (mm)	Rainfall amounts (x mm)	Probability of receiving x mm or less rainfall
6	Root normal	11.9	9.5	0.38
			14.3	0.62
7	Root normal	38.3	30.6	0.33
			45.9	0.67
8	Root normal	43.0	34.4	0.33
			51.6	0.67
9	Log-normal	36.2	28.9	0.29
			43.4	071
10	Root normal	82.9	66.3	0.33
			99.5	0.67
11	Normal	169.3	135.4	0.37
			203.2	0.63
12	Root normal	292.2	233.8	0.29
			350.7	0.71
13	Normal	562.1	449.7	0.37
			674.6	0.63
14	Normal	421.0	336.8	0.35
			505.2	0.65
15	Root normal	269.9	215.9	0.25
			323.9	0.75
16	Log-normal	194.6	155.7	0.09
			233.6	0.91
17	Root normal	76.6	61.3	0.30
			91.9	0.70
18	Normal	76.2	60.9	0.40
			91.4	0.60
19	Root normal	61.3	49.0	0.29
			73.5	0.71
20	Normal	86.4	69.1	0.39
			103.6	0.61
21	Log-normal	21.5	17.2	0.32
			25.7	0.68
22	Log-normal	7.0	5.6	0.40
			8.5	0.60
23	Log-normal	5.3	4.2	0.40
			6.4	0.60

amounts of expected rainfall which ara 20% above and below the average observed rainfall together with the relevant probabilities are presented in Table 2. The probability estimates revealed that during earlier fortnights (8th and 9th) there was slightly higher chance at Irikkur and Mananthody for getting sufficiently high rainfall. In the case of later fortnights, Mananthody was likely to be more prone to drought conditions than the other centres.

Summary

A first order Markov Chain model was applied to daily rainfall data of five selected reporting stations of northern Kerala with a view to characterize the rainfall pattern in that tract. It was found that the model was [illegible] in representing the rainfall pattern in almost all fortnights except a few at the beginning and at the end of the year. The equillibrium probability of occurrence of wet day showed increasing trend in all centres upto 12th, 13th or 14th fortnights and then decreased. The results indicated that the likely commencement af south-west monsoon was in the 11th fortnight (June 1 to 15). Suitable probability distributions were fitted to estimate the rainfall probabilities. It was found that there was slightly higher chance at Irikkur and Mananthody to get sufficiently high rainfall during earlier fortnights (8th and 9th).

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