Probability models for weekly rainfall at Thrissur

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Received 14 March 2014; received in revised form 16 April 2015; accepted 6 June 2015

Abstract

Probability distributions were fitted for rainfall in the different standard meteorological weeks (SMWs) at Thrissur, using daily rainfall data for 31 years from 1980 to 2010, recorded at Agromet observatory, Vellanikkara. Exponential distribution was suitable for 16 SMWs, normal distribution for 10 SMWs and lognormal for 8 SMWs. The probabilities for more than 10, 20, 30 and 40 mm rainfall in the different standard weeks were estimated based on the distributions. Heavy rainfall is obtained from 23rd to 31st SMWs during 4th June to 5th August as indicated by the probabilities. The excess rainfall during this period should be harvested and stored for irrigation in the SMWs with less than 75 percent probability for even 10 mm rainfall. In northeast monsoon season (October-November), more than 75 percent probability for 30 mm rainfall is only during 15th to 21st October. Hence supplementary irrigation is needed for rabi crops raised in this season. The assured rainfall amounts at 75 and 90 percent probabilities in the different SMWs were computed based on the probability distributions fitted. The dependable rainfall is found to be more than 40 mm during 4th June to 5th August. 11th to 17th June is the rainiest week at Thrissur. From 35th to 39th SMWs coming in September, assured rainfall is less than 20 mm. During 1st October to 11th November of northeast monsoon season, dependable rainfall is in the range 12-32 mm. The probabilities for different amounts of rainfall along with assured rainfall amounts in the different SMWs serve as a guide for planning various agricultural activities in Thrissur.

Key words: Southwest monsoon, Northeast monsoon, Assured rainfall, Dependable rainfall

Introduction

Weather plays an important role in agriculture of a country and rainfall is the most important of all the weather variables. Amount and distribution of rainfall varies from place to place and from year to year at the same location. Although the deviation in the annual rainfall received in Kerala in any year from the long term average is very small, there is considerable variation in the rainfall availability during the different seasons. Thrissur, which represents central zone of Kerala, features a tropical monsoon climate. Summer lasts from March to May and is followed by the south-west monsoon from June to September. October and November form the post monsoon and winter from December through February. More than 90 percent of annual rainfall is confined to a six-month monsoon period between June and November, leaving the remaining six months as practically dry. Even in the years of normal rainfall, summer water scarcity problems are severe. Rainfall data are usually published as monthly mean over a number of years. This provides only an idea about the pattern of rainfall received in different months over the years and will not be of much use for planning of agricultural operations. Several reports are available for analysis of location specific seasonal, monthly or weekly rainfall data. Seasonal rainfall data (Deka et al., 1999; Jadhav et al.,1999; Sudhishri et al.,

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2002), monthly rainfall data (Sen and Eljadid, 1999; Pimpale et al., 2003) and weekly rainfall data (Kumari et al., 2000; Deka and Nath, 2000; Das et al., 2006). Seasonal and monthly rainfall analysis is not adequate for rainfed farming. Large variation is observed in the weekly rainfall received over years. Farmers as well as crop planners require the dependable rainfall in different SMWs. Knowledge of probability of getting a given amount of rainfall in different weeks of the crop season is very useful for planning various agricultural operations like sowing, fertilizer application, spraying against pest and diseases, etc. The present study was undertaken to identify the probability distribution of rainfall in different SMWs and to estimate the probabilities for getting different amounts of rainfall along with assured rainfall in different SMWs at Thrissur.

Materials and Methods

Daily rainfall data for 31 years from 1980 to 2010 recorded at Agromet observatory, Vellanikkara were collected. Each year was classified into 52 standard meteorological weeks (SMWs) according to the definition given by India Meteorological Department, Pune. Details of this classification are presented in Table 1.

For all the years from 1980 to 2010, total rainfall in each of the 52 standard meteorological weeks was computed from the daily rainfall data. The years from 1980 to 2010 were allotted serial numbers from 1 to 31.

Let Y_{ij} be the total rainfall for i^{th} standard meteorological week in j^{th} year; i = 1,2,....., 52; j=1,2,3, ...31. For i^{th} standard week, Y_{ij}, j = 1,2,….31 constituted the data for fitting theoretical distribution of rainfall of that week. Probability distributions were fitted for rainfall during 14^{th} to 47^{th} SMWs during 2^{nd} April to 25^{th} November, since the total rainfall during the other weeks (1-13 and 48-52) was insignificant.

Different probability models *viz*., normal, exponential, lognormal and gamma were tried for the rainfall data in each SMW and the best among them was selected using Kolmogorov-Smirnov one sample test. Either of the three probability distributions *viz*., normal, lognormal and

Table 1. Classification of Standard Meteorological Weeks (SMWs)

SMW	Period		SMW	Period		SMW	Period	
	From	To		From	To		From	To
1	1st January	7th January	19	7th May	13th May	35	27th August	2nd September
2	8th "	14th "	20	14th "	20th "	36	3rd September	9th "
3	15th "	21st "	21	21st "	27th "	37	10th"	16th "
4	22nd "	28th "	22	28th "	3rd June	38	17th "	23rd "
5	29th "	4th February	23	4th June	10th "	39	24th "	30th "
6	5th February	11th "	24	11th "	17th "	40	1st October	7th October
7	12th "	18th "	25	18th "	24th "	41	8th "	14th "
8	19th "	25th	26	25th "	1st July	42	15th "	21st "
9	26th "	4th March	27	2nd July	8th July	43	22nd "	28th "
10	5th March	11th "	28	9th "	15th "	44	29th "	4th November
11	12th "	18th "	29	16th July	22nd July	45	5th November	11th "
12	19th "	25th "	30	23rd "	29th "	46	12th "	18th "
13	26th "	1st April	31	30th "	5th August	47	19th "	25th "
14	2nd April	8th "	32	6th August	12th "	48	26th "	2nd December
15	9th "	15th "	33	13th "	19th "	49	3rd December	9th "
16	16th "	22nd "	34	20th "	26th "	50	10th "	16th "
17	23rd "	29th "	35	27th "	2nd September	51	17th "	23rd "
18	30th "	6th May				52	24th "	31st "

SMW- Standard Meteorological Week

exponential distributions could be fitted for the different standard weeks. The main characteristics of these distributions are given below:

Normal distribution

A continuous random variable X is said to follow normal distribution if its probability density function (p.d.f.) is:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-1}{2\sigma^2}(x-\mu)^2}$$

where $-\infty < x < \infty$ $-\infty < \mu < \infty$ and $\sigma > 0$.

μ = mean and σ= standard deviation are the parameters of the distribution.

π is the constant Pi (3.1415…) and *e* is Euler's constant (2.718…).

Lognormal distribution

A continuous random variable X is said to follow lognormal distribution if its p.d.f. is:

$$f(x) = \frac{1}{x\sigma\sqrt{2\Pi}} e^{\frac{-(\ln(x)-\mu)^2}{2\sigma^2}},$$

where $x>0$, $-\infty < \mu < \infty$ and μ = mean and σ= standard deviation are the parameters of the distribution.

Exponential distribution

A continuous random variable X has an exponential distribution if it has a p.d.f. of the form,

$f(x) = \lambda e^{-\lambda x}$, $0 \le x < \infty$ and $\lambda > 0$, where λ is an exponential function parameter, *e* is Euler's constant (2.718…).

Kolmogorov – Smirnov one sample test

The null hypothesis of the test is that the observed data follow the hypothesized distribution. This test is found to be very powerful if the observations are made on an ordinal scale. Relative cumulative frequencies form the basis of the test. Let $F_0(x)$ be the observed relative cumulative frequency of x and $F_X(x)$ be the expected relative cumulative frequency of x. Then the test criterion is

$$D = \text{Max} \mid F_0(x) - F_X(x) \mid$$

The hypothesis regarding the distributional form is rejected if the test statistic D is greater than the critical value for a specified level of significance. Among the fitted distributions, the distribution with the least non-significant D value was identified as the best fitted distribution for the respective SMW.

Rainfall Probabilities

Based on the distributions fitted, the probabilities for getting more than 10, 20, 30 and 40 mm rainfall in the different SMWs were obtained.

Assured rainfall

In rainfed agriculture, the amount of rainfall that can be expected at least in three out of four years is more important than the mean rainfall. This is termed as the assured rainfall or dependable rainfall, *i.e.*, rainfall received at 75 per cent probability level. Assured rainfall at 75 percent probability is the rainfall received in three out of four years and assured rainfall at 90 percent probability is the rainfall received in nine out of ten years. The amount of rainfall received in the different standard weeks at 75 and 90 percent probability levels were computed based on the distribution fitted.

STATISTICA 8 (2007) was used for fitting the distribution, for computation of rainfall probabilities and the amount of rainfall assured at different probability levels.

Results and Discussion

The total annual rainfall during 1980 to 2010 is depicted in Figure 1. The mean annual rainfall over the 31 years from 1980 to 2010 is 2798 mm with 18 per cent coefficient of variation (CV), lowest of 2189 mm being received in 2000 and maximum of 3962 mm in 2007. During the study period, southwest monsoon rainfall ranged from 1501 mm in 2002 to 3243.6 mm in 2007 with average of 2067 mm and CV 22.17%. Mean northeast monsoon

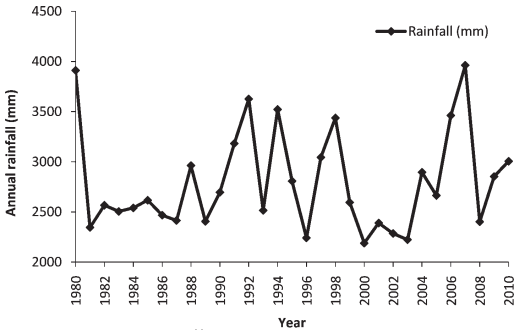

Figure 1. Annual rainfall at Thrissur during 1980-2010

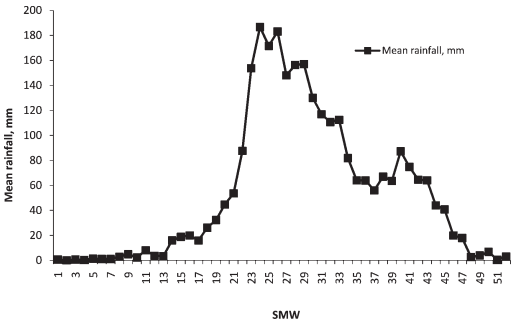

Figure 2. Mean rainfall in the different standard meteorological weeks

rainfall was 414.8 mm with a CV of 41.67%, the maximum of 950.4 mm being in 2010 and minimum of 127.6 mm in 1988. 74 per cent of the total annual rainfall is received during southwest monsoon season and 19% during northeast monsoon and the remaining 9 % is received during summer and winter seasons. Rice is the staple food of Kerala and rice cultivation depends on the distribution of monsoon rainfall. Kharif and rabi crop seasons coincide with the southwest and northeast monsoon periods respectively. Land preparation, sowing and other cultural operations depends on the onset of monsoon and other activities like pest control measures, fertilizer application and irrigation scheduling depends on the distribution of rainfall in different weeks of the year.

Mean weekly rainfall

The weekly rainfall pattern is given in Figure 2. Highest mean weekly rainfall of 186.67 mm is during 24th SMW (June 11th-17th). Second week of January had the lowest mean rainfall of 0.04 mm, since rainfall was obtained only in 1990 during this period. It is to be noted that from 23rd to 33rd SMWs, variability in rainfall over the years was low. This is true as these weeks come under southwest monsoon season.

Probability distributions for weekly rainfall

Best fitted distributions for the different SMWs along with the parameters of the respective distribution are laid out in Table 2. Lognormal distribution was the best fit for rainfall from 14th(2nd-8th April) to 19th (7th-13th May), 46th(12th-18th November) and 47th(19th-25th November) SMWs. Normal distribution was found to fit the rainfall well during 23rd (4th-10th June) to 31st (30th July - 5th August) and 42nd (15th -21st October) SMWs. Exponential distribution most fitted the rainfall for 20th (14th-20th May) to 22nd (28th May - 3rd June), 32nd (6th -12th August) to 41st(1st-7th October), 43rd (22nd -28th October) to 45th (5th-11th November) SMWs. Out of 34 SMWs 8 had lognormal distribution, 16, exponential and 10 had normal distribution.

Rainfall probabilities

The probabilities for getting more than 10, 20, 30 and 40 mm rainfall for each SMW were determined from the fitted distributions and are given in Table 3. Heavy rainfall is obtained from 23rd to 31st SMWs during 4th June to 5th August as indicated by the probabilities. The excess rainfall during this period should be harvested and stored for irrigation during 35th to 39th standard weeks (27th August to 30th September), where the probability is high only for 10 mm rainfall. In northeast monsoon season (October-November), more than 75 percent probability for 30 mm rainfall is only during 15th to 21st October. In the 40th and 41st SMWs during 1st to 14th October, there is high probability for 20 mm rainfall. From 43rd to 45th SMWs, probability is more than 75 percent for 10 mm rainfall only. Standard meteorological weeks having more than 10, 20, 30 and 40 mm rainfall with more than 75 per cent probability are plotted in Figure 3.

In Figure 3, for all SMWs which do not have any

Table 2. Best fitted distribution for different standard weeks

SMW	SMW period	Best fitted distribution	Parameters estimated 1	2	Kolmogorov - Smirnov -D value
14	2-8th April	Log-normal	μ = 1.792	σ = 1.624	0.1136
15	9-15th "	Log-normal	μ= 1.624	σ = 1.650	0.1583
16	16-22nd "	Log-normal	μ=2.044	σ = 1.637	0.1066
17	23-29th "	Log-normal	μ= 2.063	σ = 1.181	0.0788
18	Apr. 30-6th May	Log-normal	μ= 2.144	σ =1.293	0.065
19	7-13th "	Log-normal	μ= 2.270	σ = 1.295	0.0745
20	14-20th "	Exponential	λ = 0.022		0.0685
21	21-27th "	Exponential	λ= 0.019		0.0532
22	May 28-3rd June	Exponential	λ= 0.0113		0.0327
23	4-10th "	Normal	μ=153.671	σ = 112.749	0.104
24	11-17th "	Normal	μ= 186.668	σ = 82.121	0.0634
25	18-24th "	Normal	μ= 171.529	σ = 94.611	0.0778
26	June 25-1st July	Normal	μ= 183.106	σ = 115.008	0.0655
27	2-8th "	Normal	μ= 148.058	σ = 92.072	0.0764
28	9-15th "	Normal	μ= 156.316	σ = 83.995	0.0614
29	16-22nd "	Normal	μ= 157.013	σ = 95.931	0.0424
30	23-29th "	Normal	μ= 130.042	σ = 92.695	0.0572
31	July 30-5th Aug.	Normal	μ=116.848	σ = 83.265	0.1082
32	6-12th "	Exponential	λ= 0.009		0.0545
33	13-19th "	Exponential	λ= 0.009		0.0974
34	20-26th "	Exponential	λ= 0.012		0.0468
35	Aug. 27-2nd Sept.	Exponential	λ= 0.016		0.0624
36	3-9th "	Exponential	λ= 0.016		0.0984
37	10-16th "	Exponential	λ= 0.018		0.1087
38	17-23rd "	Exponential	λ= 0.015		0.1001
39	24-30th "	Exponential	λ= 0.016		0.1072
40	1-7th Oct.	Exponential	λ= 0.011		0.0292
41	8-14th "	Exponential	λ= 0.013		0.0198
42	15-21st "	Normal	ì= 64.503	σ =48.228	0.0951
43	22-28th "	Exponential	λ= 0.016		0.0443
44	Oct. 29-4th Nov.	Exponential	λ= 0.023		0.0789
45	5-11th "	Exponential	λ= 0.025		0.0609
46	12-18th "	Log-normal	μ= 1.705	σ = 1.661	0.0451
47	19-25th "	Log-normal	μ= 1.321	σ = 1.733	0.0998

Critical value for Kolmogorov- Smirnov D=0.286 ($p<0.01$) and 0.238 ($p<0.05$)

marking, the probability of getting even 10 mm rainfall is less than 75 per cent. More than 40 mm rainfall occurs between 4th June and 5th August. Harvest and store the excess rainfall during this period. 30-40 mm rainfall can be expected during 6th -19th August and 15th -21st October; 20-30 mm rainfall is expected during 28th May -3rd June, 20th - 26th August and 1st -14th October. 10-20 mm rainfall is expected during 14th – 27th May, 27th August – 30th September and 22nd October -11th November. Remaining weeks can be identified as dry weeks and hence give supplementary irrigation during these weeks. Rainwater stored can be used

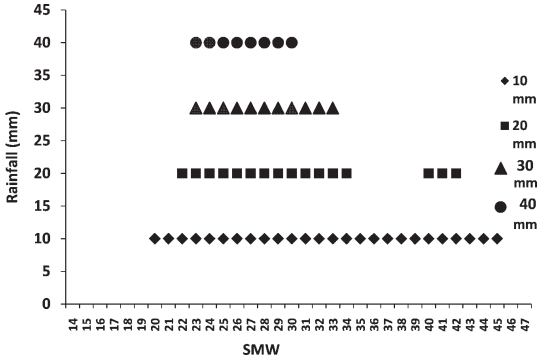

Figure 3. Dependable rainfalls in different standard meteorological weeks

Table 3. Probability for different amounts of rainfall

SMW	Period	Probability(%) for rainfall more than			
		10mm	20mm	30mm	40mm
14	2-8th April	33.79	19.9	13.68	10.17
15	9-15th ''	34.04	20.29	14.07	10.54
16	16-22nd ''	43.73	28.05	20.36	15.75
17	23-29th ''	43.18	25.18	16.87	12.19
18	30-6th May	46.22	30.52	22.61	17.8
19	7-13th ''	49.21	33.26	25.01	19.89
20	14-20th ''	79.95	63.92	51.1	40.86
21	21-27th ''	82.98	68.86	57.14	47.42
22	28-3rd June	89.21	79.58	70.99	63.33
23	4-10th ''	89.97	88.21	86.36	84.35
24	11-17th ''	98.43	97.88	97.17	96.3
25	18-24th ''	95.61	94.53	93.27	91.78
26	25-1st July	93.39	92.19	90.85	89.33
27	2-8th ''	93.31	91.79	90.01	87.92
28	9-15th ''	95.92	94.77	93.77	91.7
29	16-22nd ''	93.73	92.34	90.72	88.87
30	23-29th ''	90.36	88.38	86.12	83.57
31	30-5thAug.	90.02	87.76	85.15	82.2
32	6-12th ''	91.36	83.46	76.24	69.65
33	13-19th ''	91.49	83.7	76.58	70.06
34	20-26th ''	88.49	78.31	69.29	31.32
35	27 -2nd Sep.	85.53	73.16	62.57	53.51
36	3-9th ''	85.52	73.13	62.54	53.48
37	10-16th ''	83.64	69.96	58.52	48.95
38	17-23rd ''	86.13	74.19	63.9	55.03
39	24-30th ''	85.43	72.98	62.35	53.26
40	1-7th Oct.	89.17	79.51	70.89	63.21
41	8-14th ''	87.48	76.53	66.95	58.57
42	15-21st ''	87.08	82.19	76.28	64.3
43	22-28th ''	85.54	73.16	62.58	53.53
44	29-4th Nov.	76.65	63.44	50.53	40.25
45	5-11th ''	78.25	61.22	47.91	37.48
46	12-18th ''	35.95	21.86	15.36	11.62
47	19-25th ''	28.56	16.69	11.5	8.59

for this purpose. First showers of southwest monsoon are expected by 2nd week of May. Start land preparation during 2nd week of May. Sowing can be done in 3rd week of May. The information from Figure 3 can be used as a ready reckoner for planning various agricultural operations like time of sowing, transplanting, irrigation scheduling, fertilizer application, pesticide application etc.

Assured weekly rainfall at different probability levels

The assured rainfall at 75 per cent and 90 per cent probabilities for the different SMWs calculated

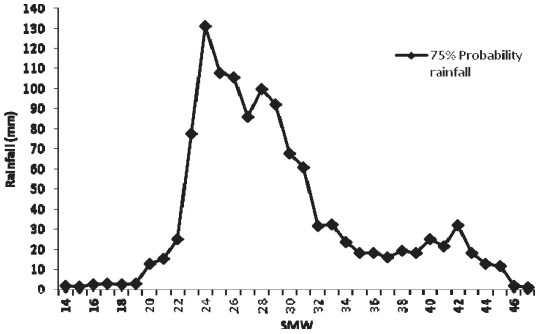

Figure 4(a). Assured rainfall at 75 per cent probability

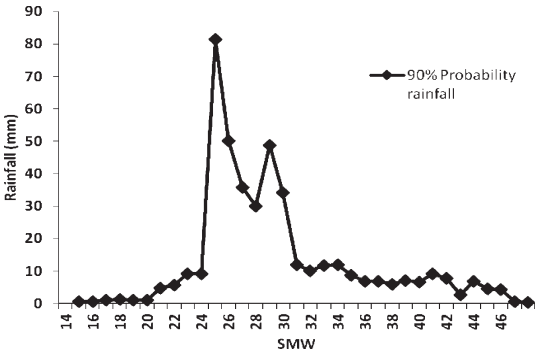

Figure 4(b). Assured rainfall at 90 per cent probability

based on the fitted distribution are depicted in Figures 4(a) and 4(b) respectively. Assured rainfall at 75 percent probability is the rainfall that can be expected in three out of four years and can be considered for planning various agricultural activities. 75 percent probability rainfall ranged from 61 to 131 mm during 24th to 31st SMWs (4th June to 5th August). At 90 percent probability also, this is the heavy rainfall period. From May 14th to 27th, 75 percent assured rainfall is 13-15 mm. The maximum of 90 per cent assured rainfall is during the week from 11th - 17th June (81.43 mm). Summer rainfall is very low at Thrissur.

Southwest monsoon arrives by last week of May at Thrissur, which is in agreement with Ajith (1999). 11th to 17th June is the rainiest week. The dependable rainfall is found to be more than 40 mm during 4th June to 5th August. Harvest and store

the excess rainfall during this period. During 1st October to 11th November of northeast monsoon season, dependable rainfall is in the range 12-32 mm. Thus, rainfed crops can successfully be grown during kharif season while rabi crops grown in winter season should be provided supplementary irrigation. Table 3 and Figure 3 can be taken as ready reckoner for planning various agricultural operations. Crop calendar can be prepared with respect to the results obtained.

References

Ajith, K. 1999. Agroclimatology in crop planning for central zone of Kerala. M.Sc. (Ag.) thesis, Kerala Agricultural University, Trichur, p.79.

Das, P. K., Subash, N., Sikka, A. K., Sharda, V. N. and Sharma, N. K. 2006. Modelling weekly rainfall using gamma probability distribution and Markov chain for crop planning in a sub-humid (dry) climate of central Bihar. Indian J. agric. Sci., 76: 358-361.

Deka, R.L., Nath, K.K. and Hussain, R. 1999. Seasonal and monthly rainfall analysis of Jorhat. J. agric. Sci. Soc. N. E. India, 12: 244-247.

Deka, R.L. and Nath, K.K. 2000. Rainfall analysis for rainfed crop planning in the Upper Brahmaputra Valley Zone of Assam. J. Agromet., 2: 47-53.

Jadhav, J.D., Mokashi, D.D., Shewale, M.R. and Patil, J.D. 1999. Rainfall probability analysis for crop planning in scarcity zone of Maharashtra. J. Agromet., 1: 59-64.

Kumari, P., Sastri, C.V.S. and Srivastava, A.K. 2000. Variation of weekly rainfall probability during rice and wheat growing seasons in Bihar. Ann. agric. Res., 21: 504-511.

Pimpale, A.R., Gawande, P.A., Hiwase, S.S. and Miskin, R.B. 2003. Probability analysis of rainfall at Nagpur, Maharashtra. J. Soils and Crops, 13: 248-253.

Sen, Z. and Eljadid, A.G. 1999. Rainfall distribution function for Libya and rainfall prediction. Hydrol. Sci. J., 44: 665-680.

STATISTICA 8, 2007. http//www.StatSoft.com

Sudhishri, S., Patnaik, U.S., Dass, A. and Dash, B.K. 2002. Seasonal rainfall probability for Eastern Ghat High Land Zone of Orissa. Indian J. Dryland agric. Res. Development, 17: 89-94.