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Prediction of water deficit by probability models for Coimbatore region, India

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ABSTRACT

Maximum daily rainfall is important for economical planning and designing of small and medium hydraulic structure. Maximum weekly water deficit of different return periods is important in crop planning in rainfed areas to apply supplementary irrigations or to predict the drought in terms of water deficit. There is no widely accepted procedure to predict the weekly water deficit. Hydrological frequency analysis has an application for predicting the future events on probability basis. An attempt has been made in this analysis to estimate the weekly water deficit values for various return periods for Coimbatore district by four distributions and to select the best one.

Key words : *Probability models, Gumbel, Log-normal, Normal, Log-Pearson*

Introduction

Evaporation involves the transformation of water from its liquid state into a gas and the subsequent diffusion of water vapour into the atmosphere. However, the measurement of evaporation in the open environment is difficult and is usually done by proxy. Potential evaporation is the variable most often used. Potential evaporationis a measure of the ability of the atmosphere to remove water from a surface assuming no limit to water availability, whereas actual evaporation is the quantity of water that is removed from that surface by evaporation. Therefore, actual evaporation is only equal to potential evaporation when a given surface is saturated. The most widespread measurement method for potential evaporation uses a pan evaporimeter, which quantifies water loss from the instrument itself and not from the surrounding environment. The standard US Class A pan is the most commonly used instrument. It consists of a metal container usually covered by an open wire birdguard that is 1,207 mm across and 254 mm high. Evaporation is the amount of loss (gain) in mm depth with rainfall from an adjacent rain-gauge subtracted. More accurate estimates of potential evaporation can be obtained by applying other meteorological data to empirical, water budget, energy budget, and combination approaches.

The empirical relationships account for many local conditions. Therefore, most models may give reliable results when applied to climatic conditions similar to those for which they were developed. Without some local or regional calibration, the use of such models for climatic conditions that are greatly different may give results that may differ considerably.

Annual actual evapotranspiration (AET) and annual climatic water deficit can be used to predict vegetation presence (Stephenson, 1998; McKenzie *et al.*, 2003) and growth rates.

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Need for water deficit prediction

Maximum daily rainfall is important for economical planning and designing of small and medium hydraulic structure. Maximum weekly water deficit of different return periods is important in crop planning in rainfed areas to apply supplementary irrigations or to predict the drought in terms of water deficit. There is no widely accepted procedure to predict the weekly water deficit.

Hydrological frequency analysis has an application for predicting the future events on probability basis. An attempt has been made in this analysis to estimate the weekly water deficit values for various return periods for Coimbatore district by four distributions and to select the best one.

Study Area

The region selected for the study is the Coimbatore district (10°12'to11°24' N, 76°39'to 77°30' E) of Tamil Nadu State in Southern Peninsular India. Of the district's 746,800 hectares, 43% is cultivated. The region's climate is classified as hot semi-arid. The dominant soils are red (Alfisols) and black (Vertisols). Lack of irrigation water results in 20% of arable land left fallow in any year.

The major agricultural crops in this region are sorghum, maize, rice, pulses, sugarcane, peanut and cotton. Tanks, canals and wells are major sources of irrigation water. The temperature ranges between 18.32 °C in the month of January and 36.42 °C in the month of April. The annual rainfall is around 714 mm. Of this 70% of rainfall occurs during south-west monsoon season and the remaining in the rest of the seasons.

Methodology

Daily meteorological data were collected for Coimbatore station for a period of 18 years (1995-2013 for the study. Potential Evapotranspiration (PET) data were collected for the study area. Evapotranspiration (P.E.) introduced the concept of PET defined it as the total water loss Potential from a large homogeneous vegetation covered area, which never suffers from lack of water. This is a function of climate only and does not depend on any biotic and edaphic controls as does Actual Evapotranspiration (A.E.). Time series data including solar radiation, precipitation, maximum and minimum temperature, and relative humidity for the study area were collected.

Table contains crop factors for the most commonly crops grown under water harvesting.

Calculation of Etcrop

While conventional irrigation strives to maximize the crop yields by applying the optimal amount of water required by the crops at well determined intervals, this is not possible with water harvesting techniques. As already discussed, the farmer or agropastoralist has no influence on the occurrence of the rains neither in time nor in the amount of rainfall.

Bearing the above in mind, it is therefore a common practice to only determine the total amount of water which the crop requires over the whole growing season. The crop water requirement for a given crop is calculated according to the formula:

$$ET_{crop} = Kc \times ETo$$

Since the values for ETo are normally measured or calculated on a daily basis (mm/day), an average value for the total growing season has to be determined and then multiplied with the average seasonal crop factor Kc as given in the last column.

The readings taken from the pan (Epan) however do not give ETo directly, but have to be multiplied by a "Pan Coefficient" (Kpan).

thus: ETo = Epan x Kpan

For the Class A evaporation pan, Kpan varies

Table 1. Crop factors (Kc)

Crop	Initial stage	(days)	Crop dev. stage	(days)	Mid-season stage	(days)	Late season	(days)	Season average.
Cotton	0.45	(30)	0.75	(50)	1.15	(55)	0.75	(45)	0.82
Maize	0.40	(20)	0.80	(35)	1.15	(40)	0.70	(30)	0.82
Millet	0.35	(15)	0.70	(25)	1.10	(40)	0.65	(25)	0.79
Sorghum	0.35	(20)	0.75	(30)	1.10	(40)	0.65	(30)	0.78
Grain/small	0.35	(20)	0.75	(30)	1.10	(60)	0.65	(40)	0.78
Legumes	0.45	(15)	0.75	(25)	1.10	(35)	0.50	(15)	0.79
Groundnuts	0.45	(25)	0.75	(35)	1.05	(45)	0.70	(25)	0,79

between 0.35 and 0.85, with an average of 0.70. If the precise pan factor is not known, the average value (0.70) can be used as an approximation.(The basis of water harvesting: History and perspectives http://www.fao.org/docrep/u3160e/u3160e05.htm). PET was estimated by Thornthwaite (TH).

Among the methods used to estimate PET, the one proposed by Thronthwaite (1948) is the simplest and the most used in Brazil.

$ETp = 16 * (10 * Tm/I)^a$ for $0 \leq Tm < 26.5\ ^oC$

$ETp = -415.85 + 32.24 * Tm - 0.43 * Tm^2$ for $Tm \geq 26.5\ ^oC$

$I = 12 * (0.2 * Ta)^{1,514}$

$a = 0.49239 + 1.7912*10^{-2} * I - 7.71*10^{-5} * I^2 + 6.75*10^{-7} * I^3$

where:

ETp is a standard evapotranspiration for a month of 30 days and with daylight period of 12h;

Tm the monthly temperature; *I* and *a* thermal indexes, function of annual average temperature (Ta). ETP, in mm per month, will be obtained by:

ETP = ETp * *fc* [5]

fc= N/12 * NDM/30

where:

N is the daylight period of the current month and NDM the number of days of the month. Average weekly Rainfall for 18 years were calculated and presented on weekly basis. Weekly water deficit values(DEF) were determined by the following expressions .

DEF = ETo –AET

Where

ETo=Weekly evapotranspiration, mm

AET=Weekly actual evapotranspiration, mm

The above graph represents the weekly rainfall average of 18 years and its variations over 52 weeks.

The computed weekly water balance is described in the following Table.

By computing the weekly water balance, we can know the week in which soil moisture deficit or surplus water is available.

The Weibull's method (1939) was used for computation of observed weekly maximum water deficit amounts at the return period of 2, 5, 10, 25, 50 and 100 years using below given equation

P=m/N+1

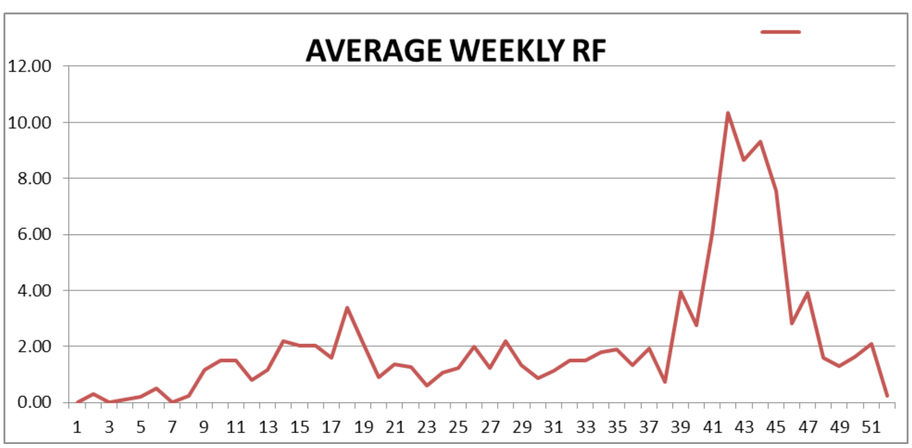
Where,

P is the return period (year), m is the rank number of water deficit events after arranging in descending order and N is the total number of years of record.

Frequency or probability distribution helps to relate the magnitude of extreme hydrologic events like floods, droughts and severe storms with their number of occurrences such that their chance of occurrence with time can be predicted successfully. Chow's general frequency formulaexpresses the frequency of occurrence of an event interms of a frequency factor, Kr , which depends upon the distribution of particular event investigated. Chow (1951) has shown that many frequency analyses can be reducedto the form

$$X = X_T + C_v K_T$$

Where, Xr is maximum value of event corresponding to return period T; X is mean of the annual maximum series of the data of length N years, Cv is the coefficient of variation and Kr is the frequency factor which depends upon the return period T and



Week	Weekly Mean Temp	Eto	AET	DEF	Surplus
1	47.50	145.37	157.00	-11.63	
2	50.73	113.08	122.13	-9.05	
3	51.83	99.97	107.97	-8.00	
4	54.13	69.43	74.99	-5.55	
5	53.12	83.36	90.03	-6.67	
6	52.65	89.61	96.78	-7.17	
7	54.15	69.05	74.57	-5.52	
8	56.06	40.17	43.38	-3.21	
9	52.39	93.03	100.47	-7.44	
10	52.60	90.26	97.48	-7.22	
11	53.09	83.80	90.51	-6.70	
12	54.58	62.87	67.90	-5.03	
13	54.52	63.73	68.83	-5.10	
14	54.14	69.26	74.80	-5.54	
15	54.87	58.63	63.32	-4.69	
16	52.24	94.84	102.43	-7.59	
17	54.49	64.13	69.26	-5.13	
18	53.32	80.67	87.13	-6.45	
19	53.97	71.70	77.44	-5.74	
20	49.64	124.97	134.97	-10.00	
21	52.33	93.76	101.26	-7.50	
22	47.69	143.73	155.23	-11.50	
23	50.61	114.39	123.54	-9.15	
24	54.27	67.32	72.70	-5.39	
25	52.27	94.48	102.03	-7.56	
26	47.53	145.11	156.71	-11.61	
27	51.48	104.32	112.67	-8.35	
28	51.82	100.15	108.17	-8.01	
29	53.08	83.96	90.68	-6.72	
30	48.99	131.53	142.06	-10.52	
31	50.35	117.29	126.67	-9.38	
32	50.06	120.50	130.14	-9.64	
33	50.62	114.33	123.48	-9.15	
34	50.48	115.92	125.19	-9.27	
35	50.92	110.90	119.77	-8.87	
36	49.82	123.07	132.92	-9.85	
37	48.37	137.55	148.55	-11.00	
38	46.87	150.59	162.64	-12.05	
39	50.68	113.68	122.77	-9.09	
40	54.99	56.70	40.83		15.88
41	48.24	138.71	99.87		38.84
42	50.17	119.35	85.93		33.42
43	46.23	155.61	112.04		43.57
44	47.70	143.58	103.38		40.20
45	47.56	144.86	104.30		40.56
46	50.14	119.62	86.13		33.49
47	44.88	164.99	118.80		46.20
48	50.62	114.36	82.34		32.02
49	52.43	92.50	66.60		25.90
50	50.46	116.08	125.37	-9.29	
51	53.10	83.60	90.29	-6.69	
52	51.80	100.36	108.39	-8.03	

the assumed frequency distribution. The expected value of annual weekly water deficit for the same return periods were computed for determining the best probability distributions. Calculations of frequency factor of the four distributions namely normal, log-normal, log-Pearson type-III and Gumbel.

The above graph shows the weekly rainfall of consecutive 18 years of daily rainfall mean and the water deficit (DEF) and Surplus computed over the weekly rainfall data.

The predicted values of annual maximum water deficit for the same return periods were computed by Gumbel, Lognormal, Normal and Pearson Type III distributions. The probability distribution with lowest Chi-squared (X^2) is selected as the best probability distribution for predicting the weekly maximum water deficit.

The chi-square test statistic is given by the Equation

$$X^2 = \frac{(O-E)^2}{E}$$

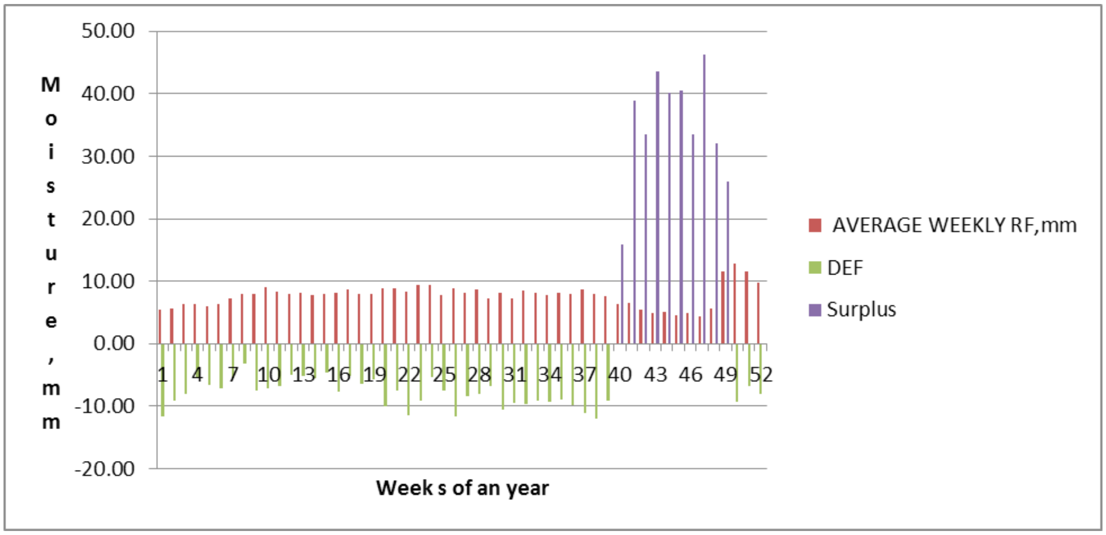
Where, Oi is the observed rainfall and Ei is the expected rainfall and will have chi-square distribution with (N - k -1) degree of freedom (d.f.). The best probability distribution function was determined by comparing Chisquare values obtained from each distribution and selecting the function that gives smallest chi-square value.

Results and Discussion

The weekly Potential Evapotranspiration of the study area was computed. The actual evapotranspiration of the study area was computed and the weekly water deficit and surplus of the study area were derived from the above data. The observed data of water deficit was compared with the four distributions predicted values namely Gumbel, Lonormal, Normal and Log Pearson III distributions for the return period of 5,7,10,17,26,53 years. The predicted values of Lognormal was found to be closer to the observed water deficit data.

The above table shows the observed and predicted water deficit of the study area for the return periods of 5, 7, 10, 17, 26, 53 respectively. Log Normal distribution gave the lowest calculated chi-square value among the four probability distributions. Hence, lognorma I has been found the best probability distribution for predicting water deficit for Coimbatore region.

Return period	Observed	Gumbel	Lognormal	Normal	Log pearson III
5	15.87	13.86	16	10.24	34.88
7	33.41	18.92	34	21.41	36.76
10	38.84	23.83	40	24.86	37.17
17	40.56	31.12	42	25.96	39.88
26	43.57	36.83	45.14	27.88	41.4
53	46.19	46.83	46.43	29.57	43.99



References

Paulo C. Sentelhas, 2008. Water deficit and water surplus maps for Brazil, based on FAO Penman-Monteith potential evapotranspiration (doi:10.4136/ambi-agua.59) ISSN = 1980-993X – doi:10.4136/1980-993X

Bhim Singh, 2012. Probability Analysis for Estimation Of Annual One Day Maximum Rainfall of Jhalarapatan Area of Rajasthan. *India Plant Archives.* 12 (2) : 1093-1100

Chow, V. T. 1951. A general formula for hydrologic frequency analysis. *Transactions American Geophysical Union.* 32 : 231237.

James A. Lutz, 2010. Climatic water deficit, tree species ranges, and climate change in Yosemite National Park. *Journal of Biogeography. (J.Biogeogr.)* 37 : 936-950.

Stephenson, N.L. 1998. Actual evapotranspiration and deficit: biologically meaningful correlates of vegetation distribution across spatial scales. *Journal of Biogeography.* 25 : 855-870.

McKenzie, D., Peterson, D. W., Peterson, D.L. and Thornton, P.E. 2003. Climatic and biophysical controls on conifer species distributions in mountain forests of Washington State, USA. *Journal of Biogeography.* 30 : 1093-1108.