MARKOV CHAIN PROBABILITIES OF RAINFALL AND SOIL MOISTURE AT IMACULADA– PB, BRAZIL

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ABSTRACT – Daily values of soil moisture at Imaculada (PB) for the period 1931-1978 have been evaluated using precipitation and temperature data. A first order Markov chain model was applied to the soil moisture data and the initial and conditional probabilities obtained were compared with corresponding probabilities based on daily precipitation data for the same period of study. Results of this study indicate significant differences between Markov chain probabilities for rainfall and soil moisture and suggest that studies based on rainfall probabilities may lead to erroneous calculations.

INTRODUCTION

For many aspects of agricultural and hydrological planning knowledge of possible adverse weather conditions is essential. Since long-range weather forecasts are not yet available such knowledge is usually derived from an analysis of historical weather data. For agricultural purposes in arid and semi-arid regions occurrence of dry weather conditions is of much concern and the risk of such conditions is often estimated using rainfall totals or averages based on long term data. However, rainfall totals or averages can lead to erroneous conclusions. Robertson (1976) has suggested that Markov chain probabilities of daily rainfall can provide more reliable results than rainfall averages and presented results of rainfall and soil moisture studies based on Markov chain model (Robertson 1976,1989). Agroclimatological studies based on soil moisture data are more useful than those based only on rainfall since soil moisture conditions affect crops more directly than rainfall.

In the present study a first order Markov chain model is applied to daily values of rainfall and estimated soil moisture data at Imaculada-PB, Brazil (37^{o} 30' W, 07^{o} 23' S) and the differences between the results are discussed.

MATERIAL AND METHODS

Daily rainfall at Imaculada during the period 1931-1978 was used in this study. A first order Markov chain model was applied and the initial and conditional probabilities of dry and wet days were derived. A dry day was defined as that one with no rainfall.

Using daily temperature and precipitation data daily values of available soil moisture were obtained at the station for the same study period. The falling rate soil moisture model (Thornthwaite and Mather, 1957) was used to evaluate the soil moisture values. The available moisture capacity was considered as 100 mm and a dry day was defined as one with available soil moisture less than 50 mm. Initial and conditional probabilities were derived using the daily soil moisture data.

Each month was divided into three 10-day periods with the last ten-day period having 8, 9, 10 or 11 days depending on the month. The initial and conditional probabilities were computed for all the 36 ten-day periods of the year. The optimum crop growing period at Imaculada extends from March to July (Karuna Kumar, et al., 1999). The Markov chain probabilities based on rainfall and soil moisture data for the ten-day periods of 7 to 21 are given in Tables 1 and 2.

RESULTS AND DISCUSSION

The distribution during the year of soil moisture is different from that of rainfall. The three ten-day periods with highest rainfall were the 7th, 8th and the 9th while the soil moisture has the maximum values in the 9th to 11th ten-day periods.

Multiplying the values of P(D) (probability of the day being wet) by ten we obtained the expected number of dry days in each ten-day period. The 3rd ten-day period of July was the period with the greatest expected number of dry days based both on rainfall and soil moisture data. The largest number of rainy days is expected in the 9th ten-day period while the 13th ten-day period has the highest number of wet days. This is not the period with the maximum soil moisture content.

During the ten-day period with the maximum rainfall (9th period) the probability of a rainy day being followed by another rainy day (P(W/W)) is only about 50%. In the case of the 13th ten-day period (with the maximum number of wet days) the odds of a wet day being followed by another wet day are 99 %.

A simple way of estimating rainfall persistency is to compare the values of P(W) and P(W/W) for individual decades. If it is raining on a day in the 9th ten-day period (period with the largest number of rainy days) the probability of rain on the following day is 31% while the observed value of P(W/W) is 54%.The higher values of P(W/W) compared with values of P(W) during the 15 periods studied suggests that there is some degree of persistency in daily rainfall during the period March-July at this place. From Table 2 we can see that the value of P(W/W) during the fifteen periods is very nearly 100%. This is due to the fact that during most of these ten-day periods the soil moisture content is much higher than 50 mm. From Table 1 it can be seen that persistence in dry weather from day to day occurred only during the months of March and April and not during the other three months of the study period. It is interesting to note that March and April are the months when rainfall is the heaviest (165 and 140 mm respectively).

The probability of a spell of five consecutive wet days P(5W) is computed using the initial and transitional probabilities. Table 2 shows that during the periods 8-14 this probability is 70% or more. This parameter, which varies with the AWC value considered in the estimation of available soil moisture is very useful in the evaluation of optimum crop growing periods (Robertson, 1987; Karuna Kumar,

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1999). Table 1 on the other hand shows that P(5W) was zero for all the fifteen periods though during the 7th to 9th periods the mean rainfall was between 50-65 mm.

The occurrence of dry spells is of importance in agriculture. From Table 1 we can see that the probability of a ten day dry spell P(10D) is 66% for the third period of July and 7% for the third period of March. In the case of soil moisture data the lowest value of P(10D) occurs twice during the 8-14 ten-day periods which have high value of P(5W).

Table 1. Markov chain probabilities for daily rainfall at Imaculada.

Decade	P(D)	P(W)	P(D/D)	P(W/W)	P(5W)	P(10D)
7	0.73	0.27	0.82	0.48	0.01	0.12
8	0.74	0.26	0.80	0.41	0.01	0.10
9	0.69	0.31	0.78	0.54	0.03	0.07
10	0.78	0.22	0.82	0.41	0.01	0.12
11	0.74	0.26	0.80	0.41	0.01	0.10
12	0.78	0.22	0.85	0.48	0.01	0.17
13	0.81	0.19	0.85	0.35	0.00	0.19
14	0.84	0.16	0.87	0.30	0.00	0.23
15	0.87	0.13	0.88	0.24	0.00	0.28
16	0.84	0.16	0.88	0.24	0.00	0.26
17	0.88	0.12	0.89	0.33	0.00	0.31
18	0.89	0.11	0.93	0.32	0.00	0.46
19	0.90	0.10	0.91	0.29	0.00	0.39
20	0.92	0.08	0.94	0.26	0.00	0.50
21	0.95	0.05	0.96	0.28	0.00	0.66

Table 2. Markov chain probabilities for daily soil moisture at Imaculada.

Decade	P(D)	P(W)	P(D/D)	P(W/W)	P(5W)	P(10D)
7	0.36	0.64	0.99	0.97	0.56	0.32
8	0.27	0.73	0.96	0.98	0.67	0.20
9	0.20	0.80	0.97	0.99	0.76	0.15
10	0.20	0.80	0.94	0.99	0.76	0.11
11	0.22	0.78	0.97	0.99	0.76	0.16
12	0.18	0.82	0.96	0.99	0.77	0.13
13	0.17	0.83	0.97	1.00	0.82	0.13
14	0.26	0.74	0.91	0.99	0.70	0.11
15	0.37	0.63	0.97	0.99	0.60	0.27
16	0.38	0.62	0.98	0.99	0.59	0.32
17	0.38	0.62	0.97	0.99	0.59	0.30
18	0.44	0.56	0.97	0.99	0.53	0.34
19	0.52	0.48	0.95	0.98	0.44	0.34
20	0.59	0.41	0.98	0.98	0.38	0.47
21	0.72	0.28	0.98	0.98	0.26	0.57

REFERENCES

Kumar, K. K., Dantas.P.R.C. and Braga.C.C. 1999. A study of soil moisture conditions in Paraíba State. XI Cong. Bras. de Agrometeorologia. CD Rom.

Robertson, G.W. Application of calculated crop-available soil water in semi-arid areas. An International Symposium on Applied Soil Physics in Stress Environments. Islamabad, Pakistan, 22-29, 1989. 45 pages.

Robertson, G. W. 1976. Dry and wet spells. Project report A-6, MAL/71/529 UNDP/FAO, Pahang, Malaysia.

Thornthwaite, C. W. & Mather, J. R. Instructions and tables for computing potential evapotranspiration and the water balance. Publication in Climatology, Laboratory of Climatology, Vol. 8, no. 1, pp. 104, 1955.