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Evaluation of crop growing periods at some stations in northeast Brazil

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सार — उत्तरपूर्व ब्राज़ील के कुछ स्थानों में फसल की बढ़ोतरी की अवधियों के अध्ययन के परिणाम प्रस्तुत किए गए हैं। तापमान एवं वर्षण आँकड़ों का प्रयोग करते हुए एक मृदानमी साधारण निदर्श की सहायता से 25 वर्षों की न्यूनतम अवधि के दैनिक मृदानमी मानों का मूल्यांकन किया गया है। मृदानमी आँकड़ों के लिए एक उत्तम मार्कोव चेन निदर्श का अनुप्रयोग किया गया तथा आर्द्र एवं शुष्क मृदा वाले दिनों की प्रारम्भिक एवं आकस्मिक संभावनाओं का पता लगाया गया है। इन स्थानों में फसल बढ़ोतरी की अवधियों का मूल्यांकन करने के लिए औसत तथा सम्भावित मृदानमी का प्रयोग किया गया है। आकलित बढ़ोतरी अवधियों के दौरान निदर्श प्राचलों में अनिश्चितताओं के प्रभाव की भी इसमें जाँच की गई है।

ABSTRACT. Results of a study of crop growing periods at some stations in northeast Brazil are presented in this paper. Daily soil moisture values for a minimum period of 25 years are evaluated by means of a simple soil moisture model using temperature and precipitation data. A first order Markov chain model is applied to the soil moisture data and initial and conditional probabilities of wet and dry soil days are obtained. Soil moisture averages and probabilities are used to evaluate crop growing periods at the stations. The effect of uncertainties in the model parameters on the estimated growing periods is investigated.

Key words — Potential evapotranspiration, Soil moisture content, Maximum root zone moisture, Markov chain probabilities, Crop growing periods

1. Introduction

The semi-arid zone of northeast Brazil is 860000 km^2 in extent and contains nearly 10% of the country's population. The main climatic characteristics are: annual rainfall of 400-800mm with a coefficient of variability of upto 80%, high air temperatures and high potential evapotranspiration rates (averaging 2000 mm). The frequent incidence of droughts in the region is responsible for the extreme poverty that affects the majority of the population and various attempts are being made to reduce the impact of droughts on the region's economy. In the semi-arid zone the main constraint to crop production is rainfall and it's extreme variability.

Agroclimatic studies based on longterm soil moisture information would be superior to those using rainfall averages and probabilities since soil moisture information can be related to crop growth and production. Longterm soil water records are not often available. Models of varying degrees of complexity have been developed in the past for the evaluation of soil moisture conditions.

A simple water balance using longterm averages of monthly rainfall and potential evapotranspiration gives some indication of the availability of soil water and of water surplus (Thornthwaite 1948).

For agroclimatic purposes it seems preferable to use models and techniques which are simpler than the complex mathematical models and still yield better results than those based on longterm averages of rainfall and temperature. In the present study simple techniques are used to convert historical rainfall information to soil moisture data. These techniques integrate the knowledge of potential evapotranspiration, moisture holding capacity of the soil as well as daily rainfall data and provide an estimate of available soil water on a daily basis. The estimated daily soil moisture data is subjected to various types of analysis. The present paper deals with the evaluation of growing seasons at selected stations in northeast Brazil. Determination of irrigation requirements at the stations using soil moisture data is discussed elsewhere (Karuna Kumar and Silva 1995).

Fig. 1. Location of stations

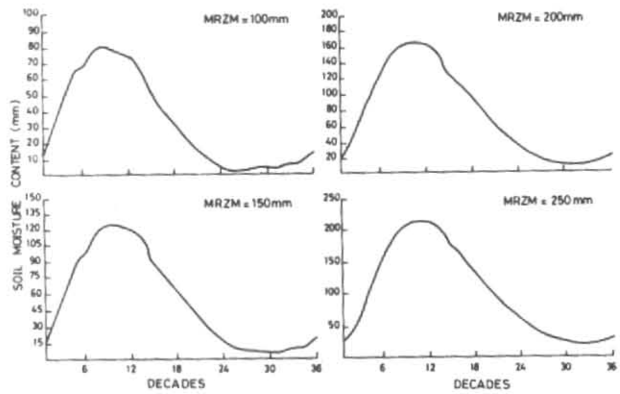

Fig. 2. Mean values of soil moisture content at Sao Goncalo for four MRZM values

2. Evaluation of soil moisture content and Markov chain probabilities

The evaluation of daily soil moisture values at the stations is based on the procedure suggested by Thornthwaite and Mather (1957). Mean monthly potential evapotranspiration (PE) values are computed using long term mean monthly temperature data. Fig. 1 shows the location of the stations selected for this study. Climatic formulae of the stations and periods of study are given in Table 1. The variation of PE during the year is used to obtain the PE values for each decade of the year. Each month is divided into three decades for this purpose, the last decade having 8, 9, 10 or 11 days depending on the month. From the decadal PE values, daily values are obtained and these together with the daily precipitation values are used to evaluate the daily soil moisture values. At each station, daily soil moisture content is evaluated for the entire study period for each of five assumed root zone moisture values (25, 100, 150, 200 and 250 mm).

A first order Markov chain model is applied to the estimated soil moisture data. Using the daily soil moisture values the initial and conditional probabilities P(D), P(W), P(D/D), and P(W/W) are determined for each decade of the year. Here P(D) is the probability of soil on a given day being dry, P(W) the probability of soil being wet, P(D/D) the probability of soil being dry given that soil on the previous day is dry and P(W/W) the probability of soil on a day being wet given that the previous day is wet. The threshold moisture content (VC) separating a dry from a wet day is 50% of the maximum root zone moisture (MRZM) adopted.

Mean soil moisture content in individual decades and the corresponding probabilities for different MRZM values are used to evaluate the growing periods at the stations.

3. Results and discussion

Results for Sao Goncalo are given below and a summary of the results for all the stations is presented in Table 3.

Decadal mean values of soil moisture at Sao Goncalo for different MRZM values are averaged over all the years of the study period (Fig. 2). The period with the maximum soil moisture content seems to vary with variation in the MRZM value adopted. For example, for $MRZM_{25}$ the three decades with the highest moisture content are the 7th, 8th and 9th decades while for $MRZM_{250}$ the three corresponding decades are the 10th, 11th and 12th decades.

A preliminary estimate of the growing season at Sao Goncalo can be obtained from Fig. 2 on the

TABLE 1

Details regarding stations, period and climatic formula

S. No.	Station	Geographical location		Period of study	Climatic formula*
1.	Campina Grande	7° 13′ S	35° 53′ W	1939-56	DB'_4 d a′
2.	Quixeramobim	5° 12′ S	39° 18′ W	1932-63	DA′ d a′
3.	Iguatu	6° 22′ S	39° 18′ W	1927-57	DA′ d a′
4.	Fortaleza	3° 45′ S	38° 28′ W	1925-57	C_1A' w a′
5.	Sao Goncalo	6° 45′ S	38° 13′ W	1943-80	DA′ d a′
6.	Umbuzeiro	7° 42′ S	35° 40′ W	1935-61	$C_1B'_4$ d a′
7.	Teresina	5° 5′ S	42° 49′ W	1932-57	C_1A' w a′

* According to Thornthwaite and Mather (1955)

assumption that moisture content must be atleast 50% of the MRZM for favourable crop growth.

Fig. 2 shows that growing season at Sao Goncalo has a duration of 110 days for MRZM values of 100 and 150 mm. If the MRZM values are increased to 200 and 250 mm (heavier soil/deeper root system) the length of the growing season increases to 130 and 150 days respectively.

The above information is based on mean soil moisture patterns. A better understanding of the soil moisture conditions can be obtained from the probabilities of sequences of days with dry or wet soil.

The initial and conditional probabilities for four MRZM values (100, 150, 200 and 250 mm) are evaluated and results for $MRZM_{100}$ are shown in Table 2. The probability of a day being wet, P(W), is very low (less than 10%) during the months August to December for all the four MRZM levels. For the remaining months, in general, P(W) increases as the MRZM increases. The probability of the occurrence of five consecutive wet days in each decade of the year is shown in Fig. 3 for different MRZM values. We now assume that a five day wet spell in each decade is sufficient for productive crop growth and that successful agriculture is based on good crops being produced in atleast seven out of ten years. From Fig. 3 we notice that growing season at Sao Goncalo extends from the 7th to 14th decades for $MRZM_{100}$ and 8th to 17th decades for $MRZM_{250}$. For $MRZM_{150}$ and $MRZM_{200}$ the growing season lies between 7th & 13th and 8th & 16th decades respectively.

We now assume that the seedbed holds 25 mm of moisture and that germination and early seedling growth requires atleast half of this moisture for atleast five days after sowing. We further assume that sowing is normally done after rain has sufficiently moistened the soil. From the mean decadal soil moisture content for $MRZM_{25}$ it is found that for decades 4-19 the mean moisture content is more than half the water holding capacity. Comparing these decades with the growing periods for $MRZM_{100}$ to $MRZM_{250}$ discussed above we observe that decades 4 to 9 can be considered for sowing purposes. For $MRZM_{25}$ the probability of five wet days succeeding a wet day is the highest for the second decade of February. There is about 90% probability of atleast one wet day occurring in this decade. This decade can, therefore, be considered appropriate for sowing. If sowing is done in this decade the growing seedling will enter a period when the expanding root system can tap moisture from greater depths (MRZM values varying between 100 mm and 250 mm).

The length of the growing period will be 90, 100, 110 and 130 days for MRZM values 100, 150, 200 and 250 mm respectively.

TABLE 2

Markov probabilities of daily soil moisture at São Gonçalo

MRZM : 100 mm

Month	Decade	Initial probabilities		Conditional probabilities				
		P(D)	P(W)	P(D/D)	P(D/W)	P(W/W)	P(W/D)	P(5W)
January	1	0.951	0.049	1.000	0.118	0.882	0.000	0.029
	2	0.835	0.165	0.977	0.219	0.781	0.023	0.061
	3	0.570	0.430	0.966	0.073	0.927	0.034	0.317
February	1	0.446	0.554	0.965	0.079	0.921	0.035	0.398
	2	0.290	0.710	0.944	0.015	0.985	0.056	0.668
	3	0.327	0.673	0.966	0.028	0.972	0.034	0.602
March	1	0.146	0.854	0.955	0.035	0.965	0.045	0.602
	2	0.084	0.916	0.906	0.003	0.997	0.094	0.906
	3	0.039	0.961	0.769	0.008	0.992	0.231	0.929
April	1	0.100	0.900	0.882	0.007	0.993	0.118	0.876
	2	0.135	0.865	0.900	0.016	0.984	0.100	0.812
	3	0.108	0.892	0.917	0.010	0.990	0.083	0.856
May	1	0.157	0.843	0.870	0.011	0.989	0.130	0.808
	2	0.319	0.681	0.926	0.008	0.992	0.074	0.659
	3	0.526	0.474	0.944	0.029	0.971	0.056	0.421
June	1	0.679	0.303	0.962	0.031	0.969	0.038	0.267
	2	0.769	0.231	0.979	0.047	0.953	0.021	0.190
	3	0.824	0.176	0.982	0.035	0.965	0.018	0.152
July	1	0.884	0.116	0.983	0.079	0.921	0.017	0.084
	2	0.921	0.079	0.991	0.034	0.966	0.009	0.068
	3	0.971	0.029	0.997	0.091	0.909	0.003	0.020
August	1	0.992	0.008	0.997	0.000	1.000	0.003	0.008
	2	1.000	0.000	1.000	1.000	0.000	0.000	0.000
	3	1.000	0.000	1.000	1.000	0.000	0.000	0.000
September	1	1.000	0.000	1.000	1.000	0.000	0.000	0.000
	2	0.990	0.010	1.000	0.250	0.750	0.000	0.003
	3	0.997	0.003	0.997	1.000	0.000	0.003	0.000
October	1	0.986	0.014	0.997	0.200	0.800	0.003	0.006
	2	1.000	0.000	1.000	1.000	0.000	0.000	0.000
	3	1.000	0.000	1.000	1.000	0.000	0.000	0.000
November	1	1.000	0.000	1.000	1.000	0.000	0.000	0.000
	2	0.990	0.010	1.000	0.250	0.750	0.000	0.003
	3	0.965	0.035	1.000	0.083	0.917	0.000	0.025
December	1	0.946	0.054	1.000	0.000	1.000	0.000	0.054
	2	0.934	0.066	0.991	0.200	0.800	0.009	0.027
	3	0.912	0.088	0.979	0.125	0.875	0.021	0.052

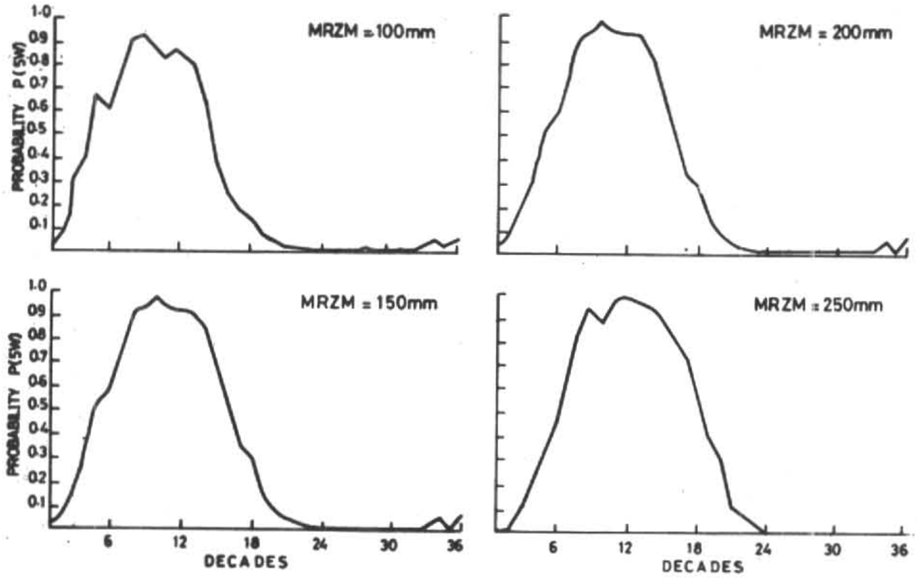

Fig. 3. Probability of occurrence of five consecutive wet days in each decade P (5W) at Sao Goncalo for different MRZM values

TABLE 3

Crop growing periods at selected stations in NE Brazil

Station	MRZM (mm)	Crop growing period		
		Start	End	Duration (days)
SAO GONGALO	100/250	10 Feb	10 May/20 Jun	90/130
FORTALEZA	100/250	1 Apr	20 Jun/20 Jul	80/110
UMBUZEIRO	100/250	20 May	30 Sep/30 Oct	130/160
IGUATU	100/250	1 Mar	10 May/30 May	70/90
TERESINA	100/250	10 Feb	20 May/10 Jun	100/120
QUIXARAMOBIM	100/250	10 Apr	20 May/20 Jun	40/70
CAMPINA GRANDE	100/250	10 Jun	30 Aug/10 Oct	80/120

TABLE 4

Effect of uncertainties in potential evapotranspiration MRZM and threshold moisture content on the length of the growing season

Potential evapotranspiration (mm)	MRZM (mm)	Threshold moisture content (mm)	Growing season (Days)
1.2 × PE (RS)			100
PE (RS)	100 (RS)	50 (RS)	130
0.8 × PE (RS)			135
	75	37.5	160
PE (RS)	100 (RS)	50 (RS)	130
	125	62.5	140
		40	140
PE (RS)	100 (RS)	50 (RS)	130
		60	115

RS : Reference state

The start and duration of the crop growing season at the selected stations for different water holding capacities are given in Table 3.

Some of the significant results of the analysis are as follows :

The period of the year with maximum moisture content and the moisture content expressed as a fraction of MRZM vary with the MRZM value assumed.

There is a significant phase difference between the variation during the year of mean decadal precipitation and soil moisture values. This suggests that crop growing periods determined on the basis of precipitation data alone may lead to erroneous conclusions.

The length of the growing period increases with increase in the MRZM value assumed. This implies that at a given station with a given soil type the growing period for deep rooted crops will be longer than for shallow rooted crops.

To evaluate the variation in crop growing periods due to uncertainties in PE. VC and MRZM results for Campina Grande for $MRZM_{100}$ are taken as reference and the computations are repeated assuming 20% variation in PE and VC and 25% variation in MRZM (Table 4). An increase of 20% in PE significantly decreases the crop growing period. while a decrease of 20% in PE slightly increases the growing period. When the reference state root zone moisture capacity is increased or decreased by 25%. the growing season increases.

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