Mausam, (1981), 32, 4, 393-396

551.5 : 631

Estimation of rice yield through weather factors in a dry sub-humid region

A. CHOWDHURY and M. B. SARKAR

Meteorological Office, Pune

(Received 13 December 1980)

ABSTRACT. Rice is staple cereal for a vast population in the country. Naturally it is, therefore, grown in varied climates from per-humid to semi-arid areas. An attempt has been made in this paper to identify weather factors and their duration, which exert influence on the crop growth and the yield for rice grown in the southwestern parts of Madhya Pradesh, a typical dry sub-humid area. Correlation technique has been adopted for this purpose. Apart from routine meteorological parameters, extent to which monthly water need of the plant (*i.e.*, evapotranspiration) is met by monthly rainfall and called efficiency ratio has also been introduced in the analysis. This analysis thus brings out relationship between crop during its various growth phases with important weather parameters.

The parameters chosen are then utilised to obtain a linear multiple regression. The coefficient of determination obtained was 0.90 explaining 81 per cent of the yield variation.

1. Introduction

India is basically agricultural country. Its agricultural practices are as old as the nation. The soil, terrain and climate of the country vary widely, ranging from tropical to temperate conditions. The existence of such diverse climatic conditions has paved a way for cultivation of a large number of different crops, both annuals and perennial. Among these crops rice occupies an important position from the point of view of acreage, production and consumption. It is predominantly grown in varied climatic conditions from per-humid in the northeastern parts to the semi-arid regions in the northwest and the Peninsula. Though in some areas like Punjab, Haryana etc natural rainfall is supplemented by irrigation in the growth of this crop, in most of the remaining areas of the country it is raised purely on rainfed culture.

Because of its importance, several attempts have been made in the past to arrive at an estimation of the crop yield much ahead of actual harvesting. The oldest and most widely used method of forecasting crop yield is the eye estimate based on the reports of agricultural officials though it is a subjective method. Measures to improve this method have been advanced from time to time through the use of weather and other factors.

The National Sample Survey for example conducts crop cutting experiments for this purpose. Application of regression analysis to forecast crop yield was first initiated rather recently by Das *et al.* (1971) employing basic and computed meteorological parameters. Subsequently numerous other studies were undertaken in the India Meteorological Department covering different areas crops (*cf Das* 1970, *Bedekar et al.* 1977, Rao *et al.* 1978). Pilot studies to forecast yield of jute, cotton, rice etc from biometric characters were reported by Institute of Agricultural Research Statistics (1977).

In the present paper, an attempt has been made to develop a model for estimating rice crop yield for southwestern parts of Madhya Pradesh.

2. Physiography of the area

The area under study is situated south of the Satpura range of mountains. The general elevation is upto 500 m a.m.s.l. Climatologically it belongs to dry sub-humid regime (Rao *et al.* 1972). From ecological point of view, the general vegetation genera is dry and moist desiduous forest type (Chowdury and Sarwade 1980).

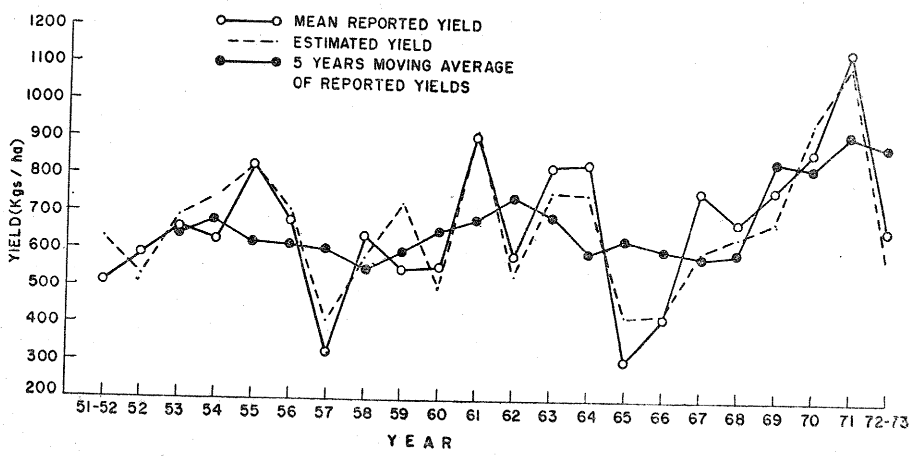

Fig. 1. Mean reported and estimated yield along with moving average yields

TABLE 1 (a)

Developed regression equation from weather parameters

Sub-division : Madhya Pradesh West, No. of years data used : 22

Mean yield (kg/ha)	Standard deviation (kg/ha)	Coefficient of variation (%)	Regression equation	R^2	Total % variation accounted for
674.59	192.05	28.47	$Y=-69.98+1.52X_1+48.03X_2+0.43X_3+7.80X_4$ (2.82) (3.68) (2.46) (2.56)	0.90	81

where,

Y=Estimated yield in kg/ha.,

X_1=Rainfall during 3/6 to 26/6 in mm (sowing),

X_2=Efficiency ratio during July, August, September (sowing, transplanting, tillering and elongation),

X_3=Rainfall during 30/6 to 14/8 in mm (sowing, transplanting and tillering),

X_4=Rainfall during 16/10 to 22/10 in mm (flowering and maturity)

NOTE — t-test value is shown below each partial regression coefficient.

It normally gets rains during southwest monsoon season (June to September) with seasonal rainfall about 100 cm. As it lies on the path of monsoon depressions, it receives very heavy falls, when being traversed by these rain bearing systems during the later half of July and August.

3. Data set

The study is based on data series of 22 years (1951-52 to 1972-73). The rice yield data for Betul, Chindwara, Domah, Seoni and Narsingpur districts of Madhya Pradesh was collected from the yearly season and Crop Reports published by Economic and Statistical Adviser, Ministry of Agriculture and Irrigation, Govt. of India. Where these reports were not available the data was collected from the Director of Agriculture, Madhya Pradesh. For each year, the rice production during the kharif season for each of these districts was added together. The value thus obtained was divided by the sum of the acreage under kharif rice cultivation during the year in these districts. This was the yield figure for the southwest Madhya Pradesh for the kharif rice in that year. Since no separate figures of the rice production under irrigation and non-irrigated areas were available for any of the districts the component of yield due to irrigation could not be separated and thus 'yield' represent effect due to both the natural and irrigated water.

So far as analysis of weather factors is concerned, to begin with all the weather elements, namely, daily rainfall amount, mean daily relative humidity, cloud amount and daily maximum and minimum temperatures were considered. For this purpose for each day of an year an arithmetic mean of a particular weather element was obtained from the observations of these stations for that day. This was done for all the days from 1 June to 31 October and for all the years. These set of mean daily values of the weather elements were analysed according to the methodology described in a subsequent paragraph. In this study, a new factor, known as 'efficiency-ratio' has also been introduced. This is the ratio of the precipitation to the potential evapotranspiration. The potential evapotranspiration computed by Rao *et al.* (1971) was utilised for this purpose. The efficiency-ratio was determined on a monthly basis for June to September months.

4. Crop growth phases

The crop is grown normally by transplanting the seedling from the nursery. Sowing in the nursery is normally done between 15 June to 21 July, depending upon the establishment and stabilization of the monsoon. Between middle of July to third week of August, transplantation is completed. The tillering phase is normally completed by middle of September, while by first week of October the elongation phase is over. Flowering takes place between middle of September to third week of October. By end of October the crop is fully matured and ready for harvest.

5. Method of analysis

In the technique the mean crop yield was first correlated linearly with various important weather parameters. These correlations were obtained for various successive overlapping periods of 7 to 60 days of the crop growing season. From these results, weather sensitive periods having significant correlation have been selected, which were then used in obtaining multiple correlation with yield. Multiple correlation of all combinations are calculated dropping one or more variables found less significant. Finally, that combination of weather parameters which gives high and significant multiple correlation, satisfying various multiple statistical tests (explained later) at the mandatory 5 per cent level, was chosen as the final equation.

6. Results and discussion

6.1. *Model developed*

The model developed along with the various statistical parameters are given in Table 1(a). It is worth mentioning that although all weather elements like rainfall, temperature, relative humidity and cloud amount were analysed, only rainfall has been noticed to have statistically significant influence on the yield. Thus rainfall in general during most parts of June is, as can be expected, helpful in increasing the yield. This weather parameter correspond generally to the sowing phase. Rainfall during July and first half of August, which cover phases from sowing to elongation also help in increasing the yield. Similarly rainfall for a brief period (*i.e.*, 3rd week) of October also exerts beneficial influence.

Monthly values of the efficiency ratio were not found to give large linear correlation for any of the 4 months considered. The study gives

TABLE 1 (b)

Analysis of variance

Variation due to	S. S.	D. F.	M. S.	'*F*' calculated	*F* (Table value at 0.1% level)
Regression	658239.00	4	164559.75	18.26	7.68
Residual	153181.69	17	9010.69		
Total	811420.69	21			

correlation of two month each, *e.g.*, June & July, and August etc did not yield encouraging results. However, the sum of the ratio for a three month period, *viz.*, July to September, was found to contain statistically significant influence on the rice yield.

The mean reported yield and those estimated from the model are depicted in Fig. 1. There appears a fairly good agreement between the two.

6.2. *Statistical tests of significance*

The significance of the individual parameter obtained was tested by *t*-test. The values are given in Table 1. It can be seen that all the parameters are significant at 5 per cent level.

The significance of the regression model is tested by the analysis of variance. The *F* value obtained is given in Table 1(b). The variance found highly significant at 0.1 per cent level.

The multiple correlation coefficient was 0.90 explaining 81 per cent variations in yield.

7. Impact of agricultural technology

In order to evaluate impact, if any, of the recent advances in the agricultural technology on the rice yield, like improved agronomic and better water management practices, large scale use of chemical fertilizers etc, this parameter was introduced in the analysis rather indirectly along with the other weather factors. This was accomplished by introducing a linear time scale dummy variable in the analysis. For this, the yearly yield fluctuations were first smoothened by a 5-year moving average (Fig. 1). A gradual increase in the yield is easily discernible from 1958 onwards in the figure. The upward trend was assumed to be due to the agricultural technology. The linear time-scale variable was, therefore, introduced from the year 1958 onwards alongwith the weather parameters identified earlier, with 1958 having a dummy value 1 for the technological parameter, 1959, a value 2 etc. The model thus developed is shown in Table 2.

As may be observed, the individual parameters as well as the regression remained significant. However, not much change was observed in the coefficients of the parameters. Also R^2

TABLE 2

Developed regression equation from weather parameters and technology

Sub-division : Madhya Pradesh West, No. of year data used : 22

Mean yield (kg/ha)	Standard deviation (kg/ha)	Coefficient of variation (%)	Regression equation
674.59	192.05	28.47	$Y = -83.99 + \underset{(2.76)}{1.40X_1} + \underset{(3.44)}{42.92X_2} + \underset{(2.85)}{0.47X_3} + \underset{(2.74)}{7.81X_4} + \underset{(1.87)}{7.24X_5}$

where,

Y =Estimated yield in kg/ha,

X_1=Rainfall during 3/6 to 26/6 in mm (sowing),

X_2=Efficiency ratio during July, August and September (sowing, transplanting, tillering and elongation),

X_3=Rainfall during 30/6 to 14/8 in mm (Sowing, transplanting and tillering),

X_4=Rainfall during 16/10 to 22/10 in mm (Flowering and maturity),

X_5=Agriculture technological parameter.

NOTE — t-test value is shown below each partial regression coefficients.

obtained was 0.92 which is a very marginal increase to the earlier model. Thus advances in agricultural technology, do not appear to have assumed a dominating influence so far on it. Perhaps there is much scope in introducing high doses of technology in the agriculture in the form of fertilisers, insecticide, land and water management etc.

8. Conclusion

It is a well recognised fact that weather exerts pronounced influence on agricultural production. At the same time, influence of biometric characters cannot be easily overlooked. For a more realistic and stable model, it is desirable that biometric factors are studied in conjunction with weather parameters.

It is also necessary to examine the stability of different coefficients in the regression of the predictant over a number of years. For want of sufficient data, these aspects could not be examined in the present paper.

This paper is an exploratory attempt to estimate objectively, the rice yield over southwest Madhya Pradesh from weather factors only. It has been possible to identify periods when rainfall has critical influence on the yield. Other weather factors do not appear to have significant effects on the growth of rice plant. From the impact of agricultural technology point of view, there appears enough scope to introduce high doses of modern technology to increase rice yield in the area.

The analysis carried out in the study describes the relationship between the yield and weather parameters and can be further utilised for studying the effects of weather on the crop growth and the yield.

Acknowledgement

The authors are thankful to Dr. R. P. Sarker, Dy. Director General of Meteorology, for encouragement and helpful suggestions. Help rendered by the staff of Drought Research Unit of the Department, in the preparation of this report is acknowledged.

References

Bedekar, V. C., Moray, P. E., Rao, G. A., Ramachandran G., Madnani, M. L., Vidhate, S. G., 1977, Forecasting the wheat yield in India from weather parameters, Met. Monogr. Agrimet. No. 8, 1977, India Met. Dep.

Chowdhury, A. and Sarwade, G. S., 1980, A simple approach towards climatic classification of India (in press), *Tropical Ecology,* Banaras Hindu Univ., U. P.

Das, J. C. *et al.*, 1971, *Indian J. Met. Geophys.*, **22**, pp. 47-58.

Das, J. C., 1970, Forecasting the yield of principal crops in India on the basis of weather : Paddy/Rice, Pre-publ. Sci. Rep. No. 120, India Met. Dep.

Institute of Agricultural Research Statistics, New Delhi, 1977, Proc. Seminar on 'Crop Forecasting Methodology, New Delhi.

Rao, G. A., Sarwade, G. S., Jaipal, Sarkar, M. B., Lowrence Joseph and Jangle, N. K., 1978, Forecasting rice yield in India from weather parameters : Marathwada, Rayalaseema, Gujarat Region and Himachal Pradesh, Pre-publ. Sci. Rep. No. 15/78, India Met. Dep.

Rao, K. N., George, C. J. and Ramasastri, K. S., 1971, Potential evapotranspiration over India, Pre-publ. Sci. Rep. No. 136, India Met. Dep.

Rao, K. N., George, C. J. and Ramasastri, K. S., 1972, Agro-climatic classification of India, Met. Monogr. Agrimet. No. 4, India Met. Dep.