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Forecasting the yield of paddy at Chinsurah in West Bengal, using multiple regression technique

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सार — भारत के पश्चिम बंगाल में स्थित एक केन्द्र, चिन्सुराह में, धान की पैदावार के पूर्वानुमान के लिए मौसम सम्बन्धी आंकड़ों को स्वतन्त्र चर और पैदावार के आंकड़ों को आश्रित चर मानकर एक बहुलित समाश्रयण समीकरण व्युत्पित किया गया है। इसमें आंकड़े "समन्वित फसल मौसम परियोजना" के उपयोग किए गए हैं। जब मौसम के प्राचलों में प्रसामान्य मानों से पांच प्रतिशत तक परिवर्तन होते हैं उस स्थिति में अन्तिमरूप में उत्पादन में भिन्नता का प्राकलन किया गया है। अनुमानित और वास्तविक उत्पादन के बीच अच्छी संगति है। व्युत्पित समाश्रयण समीकरण की सहायता से सन् 1969 और 1972 के मौसम के आंकड़ों का उपयोग करके उत्पादन का पूर्वानुमान भी किया गया है। पूर्वानुमानित और वास्तविक उत्पादन के बीच अच्छी संगति पाई गई है।

ABSTRACT. Using the weather data as independent variables and yield data as dependent variable, multiple regression equation has been derived to forecast the yield of paddy at Chinsurah, a station in West Bengal, India. The data utilized is that of Coordinated Crop Weather Scheme. An estimate is also made of change in the final yield when the weather parameters change by five per cent from their normal value. The agreement between the estimated and actual yield is good. An yield forecast is also made using 1969 and 1972 weather data with the help of derived regression equation. The agreement between actual and forecast yield is found to be good.

1. Introduction

Weather has long been recognised as a major control over the growth and yield of crops. But the precise manner in which this influence is produced on crop is not very well understood. Weather affects crop growth differently at different phenological phases. Therefore, large variation in yield from year to year and place to place is dominantly due to the weather parameters.

A number of countries including Canada, USA, USSR, India, Japan, etc are involved in crop-weather studies for different crops (rice, wheat, soyabean, corn, sorghum, etc). The main workers are Thompsen (1969), Baier (1973), Lomas (1973), Haun (1982), Das *et al.* (1971), Appa Rao *et al.* (1977), Huda *et al.* (1975) and Subbaramayya *et al.* (1980).

Although there are numerous studies utilizing the linear, curvilinear and multiple regression techniques, our present knowledge is still insufficient and we do not know the exact manner in which various weather elements influence and control different crops, crop growth and resulting yield.

The present study is undertaken to investigate the feasibility of estimating paddy yield from combined effects of individual weather elements, *viz.*, temperature, sunshine, evaporation, rainfall and number of rainy days at Chinsurah, a station in West Bengal.

2. Method and material

Chinsurah is one of the stations under Coordinated Crop Weather Scheme. It is situated approximately 22 metres above sea level and is at a latitude of 22° 52'N and longitude of 88°24' E in West Bengal. West Bengal is one of the States where paddy is grown traditionally in vast area.

The actual and reliable meteorological and yield data used are taken from the Agricultural Meteorology Division of IMD, Pune, which has conducted experiments and collected data on the crop growth and yield of paddy at Chinsurah, West Bengal State Government's farm, under the All India Coordinated Crop Weather Scheme. Mean over 7 days (standard meteorological weekwise) of daily readings are used for the analysis of temperature and sunshine and total weekly value (7 days standard

meteorological weekwise) for rainfall, number of rainy days and evaporation. The paddy yield in kg/ha is used as dependent variable while weather elements are used as independent variables in multiple regression analysis. It is assumed that high level farm technology on paddy land is used, therefore, in this model, no technological term is included.

2.1. *Method of analysis*

In the present study, first of all, for all the weather elements nine points moving averages are calculated. Then the mean crop yield is linearly correlated with temperatures (maximum, minimum and mean), sunshine, evaporation, rainfall and number of rainy days for different overlapping periods, ranging from one week to nine weeks.

Those periods which give high correlations for a particular weather element called "sensitive periods", are selected for the analysis. The yield is assumed to be directly related to the weather elements. It is assumed that the effect of weather elements on paddy yield in each period is independent of the effect of weather elements in other time period. Different weather elements are selected and these periods are subjected to linear multiple regression analysis with yield as dependent and weather element as independent variables. The regression equation has the form :

$$Y = a + b_1x_1 + b_2x_2 + \ldots\ldots + b_kx_k\ldots\ldots \qquad (2.1)$$

where, $a, b_1, b_2, \ldots, b_k$ are all constants and $x_1, x_2, \ldots, x_k$ are the weather elements during different phenological periods of crop growth, Y is the yield. Numerous combinations and permutations are tried. The combination which gives significant and high multiple correlation coefficient, is selected.

3. Phenology of the paddy crop and distribution of climatic variables

3.1. *Phenology of the paddy crop*

The paddy growing season covers an approximate period of 175 days from 25 June to 15 December. This period is divided into 25, seven days periods for analysis purpose. The whole paddy growth season can be grouped into three phases :

(*i*) Establishment phase, (*ii*) Vegetative phase and (*iii*) Maturity phase.

These phases may be further subdivided into seven phenological stages :

(*a*) Sowing and emergence stage,

(*b*) Nursery stage,

(*c*) Transplantation stage,

(*d*) Tillering stage,

(*e*) Elongation stage,

(*f*) Flowering stage, and

(*g*) Harvesting stage.

3.2. *Distribution of climatic variables*

The crop at Chinsurah is rainfed of the autumn season characterized by monsoon rainfall. The period up to first week of October is of low water deficit because evapotranspiration losses are low and rainfall is high. This period is highly favourable for vegetative growth. The period after first week of October is of increasing water deficit, because evapotranspiration losses are more and rainfall is less. This period is good for flowering and some rainfall is quite useful. The distribution of climatic variables is discussed in the following lines.

3.2.1. *Maximum, minimum and mean temperatures*

The average maximum weekly temperature during the paddy growing season varied from 32°C to 26°C. The minimum temperature from 26°C to 12°C and mean temperature from 29°C to 19°C. The period covering 26th week to 43rd week is characterized by stable temperature. During the period from 44th week to 50th week the maximum temperature vary little while the minimum temperature decreases rapidly. The mean temperature during the season shows a decreasing trend.

3.2.2. *Rainfall and rainy days*

The total amount of rainfall fluctuates from year to year. The average weekly total rainfall during the period from 26th week to 40th week varies from 77 mm to 45 mm. The highest weekly rainfall of 77 mm is in 28th week. The average total number of rainy days is between 2 and 4 days per week.

3.2.3. *Sunshine and evaporation*

The average sunshine value during the paddy growing season varies from 5 hr/day to 9 hr/day. The rate of evaporation decreases from 26th week to 40th week and rising trend is observed in succeeding period.

4. Result and discussion

4.1. *Crop weather relationships of paddy based on correlation technique*

The object of the study of crop weather relationships using simple correlations is to get some idea as to how a particular weather element influences the final yield during different phenological periods of crop growth. It is an obvious expectation that the same weather element is not influencing the crop growth and the final yield uniformly in the same sense throughout the phenological phases of the crop growth. The present study very well confirms this obvious experience. The important partial correlation coefficients obtained during different phenological phases at Chinsurah have been summarized in Table 1 and details are given in the following lines.

At Chinsurah, the yield is negatively correlated with maximum temperature during flowering stage. The correlations are relatively larger and significant with minimum temperature in the vegetative phase. This clearly indicates that the decreasing temperature in the flowering stage and vegetative phase have a beneficial

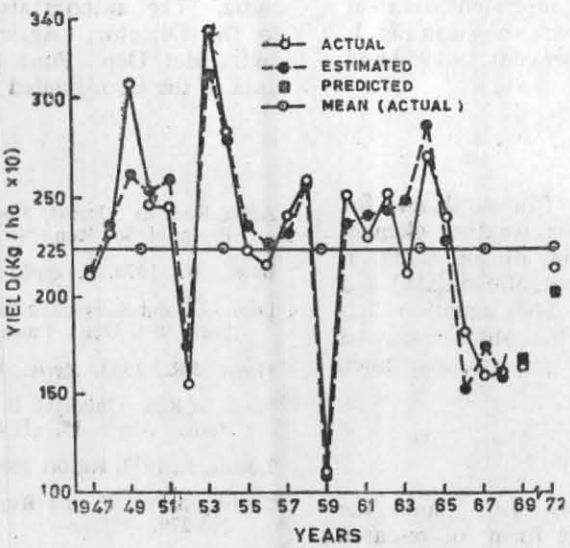

Fig. 1. Actual, estimated and predicted yields for different years at Chinsurah

TABLE 1

Coefficient of correlation between paddy yield and weather elements at Chinsurah

Weather elements	Phenological phases			
	Establishment phase	Vegetative phase: Tillering stage	Vegetative phase: Elongation stage	Maturity stage
Maximum temperature	0.30	0.26	0.31	—0.57
Minimum temperature	0.50	0.57	0.56	0.11
Mean temperature	0.23	0.42	0.43	—0.13
Sunshine	0.31	0.50	0.38	0.14
Evaporation	0.20	0.46	—0.18	0.39
Rainfall	—0.63	—0.42	—0.57	—0.26
Number of rainy days	—0.19	—0.31	—0.43	—0.18

effect on yield. The mean temperature has positive correlation with yield during vegetative phase. The negative correlation in the tillering stage between sunshine and yield is significant. Rainfall and rainy days are negatively correlated with sunshine. In this particular case the correlations are in the same sense, hence all of them add towards a better yield.

4.2. *Multiple regression equation*

The derived regression equation is :

$$Y = -775.05 + 41.17X_1 + 3.68X_2 - 8.82X_3 - 0.54X_4 - 0.18X_5 - 0.11X_6$$

where, Y is estimated yield,

X_1 is average minimum temperature during 10 September to 7 October,

X_2 is average mean temperature during 1 October to 14 October,

X_3 is average sunshine during 20-26 August,

X_4 is total rainfall during 8-14 October,

X_5 is total rainfall during 30 July to 19 August,

X_6 is total rainfall during 13 August to 14 October.

The equation accounts 86 per cent of the variation of the independent variables with multiple correlation coefficient of 0.93. All the partial correlation coefficients are significant at 5 per cent level, some of them are significant at one per cent level also. The final meteorological parameters included in the equation are given above and the brief discussion of the same is given below.

The beneficial effect of increasing minimum temperature during the vegetative growth stage (10 September to 7 October) is observed. If the minimum temperature is 5 per cent more than the normal value, the yield increase by 24 per cent.

An increase in rainfall by 5 per cent from normal value reduces the yield about 2 per cent. The yield increases by about one per cent with a decrease in the rainfall from normal value by 5 per cent during 8 October to 14 October.

With an increase in sunshine duration by 5 per cent from the normal value during the period 20 August to 26 August, the decrease in yield is less than 2 per cent.

If the average duration of sunshine decreases by 5 per cent of the normal value, the increase in yield is about one per cent.

The actual and estimated yields show a very good agreement as shown in Fig. 1. All the estimated yields are within $\pm$ 10 per cent of the actual yields in 86 per cent cases. The extreme departure of the estimated yield from actual yield is 18 per cent in 1963.

The equation is tested with an independent data set for the year 1969 & 1972 and results are shown in Fig. 1. It is observed that the errors are 3 per cent in 1969 and 6 per cent in 1972.

5. Conclusions

The equation derived is valid for Chinsurah and for the autumn paddy crop only. The weather element (rainfall) is useful for yield forecasting during establishment and vegetative phases. The actual estimated and forecasted yields agree very well. The equation has considerable forecasting value as the observations of weather elements required for the purpose, are much before the completion of the crop.

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