An indirect method for forecasting the annual food production of India

The green revolution which increased the annual food production of India drastically was made possible by the application of science and technology to agriculture. The annual food production of India depends on the type of seeds used, the annual rainfall over the country, especially during the south-west (SW) monsoon season, the crop area, availability of irrigation facilities, fertilizers, pesticides and also on the government incentives to the farming sector during a year. The total technological inputs to the farming sector has been growing steadily and is difficult to quantify. Therefore, to simplify the forecasting models of food production in India, the total technological inputs to the agricultural sector is assumed to increase by unit amount every year.

The growth and fluctuations of annual food production (consisting of rice, wheat, coarse grains, and also grams and pulses) have been examined recently by Gadgil *et al.*[1]. Parthasarathy *et al.*[2] had earlier obtained a correlation coefficient of 0.61 between the rice production anomaly of India and the Indian SW monsoon rainfall. Chowdhury and Das[3] made a multiple regression model for forecasting the kharif food production of India, using Indian SW monsoon rainfall as one of the parameters of the model.

Two indirect but slightly different models to forecast the annual food production of India are presented in this note. Both the models use yearly variations in SW monsoon rainfall in different forms as one of the parameters.

Data on annual food production of India and average crop area of sub-divisions were obtained from reports of Indian Agricultural Ministry or other Government of India publications such as *India, 1998*. Data on SW monsoon rainfall are from reports of India Meteorological Department such as *Mausam*. The all India rainfall anomaly values are computed from the sub-divisional rainfall data following the method of Mooley and Parthasarathy[4]. For the computation of rainfall index used in the second model, the average crop area of the sub-divisions is considered. The computation is based on the monthly rainfall data. The rainfall index is a measure of the percentage area which receives excess or deficit 10 to 25% rainfall, after equating the nearly equal plus or minus rainfall percentage areas. The mean of the four monthly values is taken as the seasonal index. Since the index values during the period show a rising trend during 1989 to 1998, the values have been standardized by subtracting the mean value from the yearly values.

The annual Indian food production has been growing at a linear rate since 1980. This increase in food production is due to the increased use of technology in agriculture, assumed to increase linearly since 1980. As has been explained by Chowdhury and Das[3], a dummy variable, X_1, has been chosen for representing the increasing technological input to agriculture by unit amount every year. They have also noticed a significant rise (fall) in the kharif food production of India in good (bad) SW monsoon rainfall years. Since most of the annual rainfall over India occurs during the SW monsoon season, the SW monsoon rainfall anomaly has been included as another parameter in the forecast model.

In the first model, the data for 16 years from 1982 are considered. The food production is assumed to increase every year because of technological advances which are represented by one of the parameters (X_1). The fluctuations in yearly food production from the mean line in different years are attributed to the variation in seasonal SW monsoon rainfall anomaly (X_2). A multiple regression equation of the form $Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2$ makes the model. Here β_0, β_1, β_2 are constants and X_1 is the serial number of the years starting from 1982 = 1, 1983 = 2, etc., X_2 is the seasonal SW monsoon rainfall anomaly, and Y is the annual food production of India. The actual equation fitted to the 16 years of data is $Y_a = 136.89 + 3.64 X_1 + 0.684 X_2$. For the agricultural year 1999–2000, $X_1 = 18$ and $X_2 = -5\%$ and so the computed value of the food production is 199 million tonnes, 4.5 million tonnes less than that for the year 1998–99. The standard error of the estimate is 4.0 million tonnes. The correlation coefficient of the multiple regression equation is 0.98 and is significant at 1% levels of significance.

Examination of the residuals has indicated that their mean is nearly zero. The observations used are from normal distribution with a zero mean. There is no long term variation on the residuals with time.

The residual analysis has indicated that 4 out of 16 observations have negative residuals of about 6, which is more than standard error of 4. Comparatively low residuals are mainly due to increased incentives given to the agriculture sector during those years.

The second model is a combination of two linear models. It also uses a shorter data set from 1989 to 1998. A least square linear fit is made for the data of the food production and the years from 1989 to 1998. The correlation coefficient between the two is 0.89 and significant at 1% level. The residuals obtained after fitting a straight line are found to be related to the data of the seasonal index of rainfall. The relationship between these two parameters has a correlation coefficient of 0.85 and is significant at 1% level.

The equation that fits data of food production and years is given by $Y_2 = 165.233 + 3.447X_3$, where Y_2 is the yearly food production and X_3 is the serial order of the year from 1 to 10. The relation between the residual values of food production and the seasonal rainfall index (X_4) is given by $Y_3 = 0.601X_4 - 3.499$, where X_3 for the year 1989 is 1 and so on.

Combining the two equations, we have the yearly food production Y_b given by

$$Y_b = 161.734 + 3.447X_3 + 0.601X_4.$$

For the year 1999–2000, $X_3 = 11$ and $X_4 = -4.5$, substituting in the equation, we get the value of food production 197.0 million tonnes. The standard error of the estimate is 3 million tonnes corresponding to population standard error of estimates of 3.35 million tonnes.

The estimations of yearly food production by two similar models are not very different. Both results are below 200 million tonnes.

There are a number of limitations to the models. The models are indirect means of the measurement of food production. They do not take into account the likely variation in the north-east monsoon rainfall. The inputs into the farming methods, total area of crop land and government incentives are assumed not to vary substantially from year to year.

In spite of these limitations, the model's forecast error is about 4 million tonnes. We may use the models with caution, until better models for prediction of the annual food production are developed.

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Palynodebris accumulation characteristics of a sediment core from the eastern part of Lower Bengal Fan

In the investigation of the Quaternary, the botanical parameter concerns itself with the building up of the history of the flora, reconstruction and alteration in the past forest communities in response to climatic and biotic factors. In this respect the botanical parameter becomes interdependent upon the other diverse disciplines and like them it has its own technicalities and limitations. Hence palynological study coupled with sediment dynamics will give the accumulation characteristics of the palynodebris in the Lower Bengal Fan.

Marine processes play a major role in segregating pollen according to the size and morphology. Larger and more diverse assemblages occur nearest to the coast

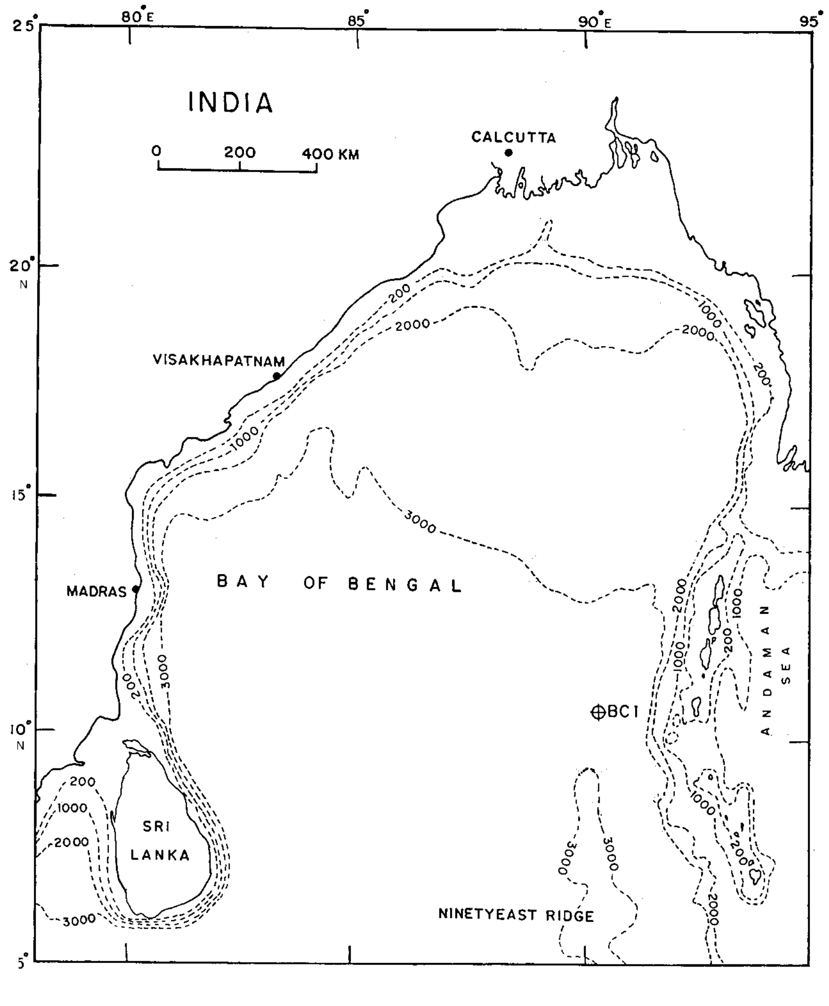

Figure 1. Map showing location of the core sample (BC-1) collected from the Lower Bengal Fan.

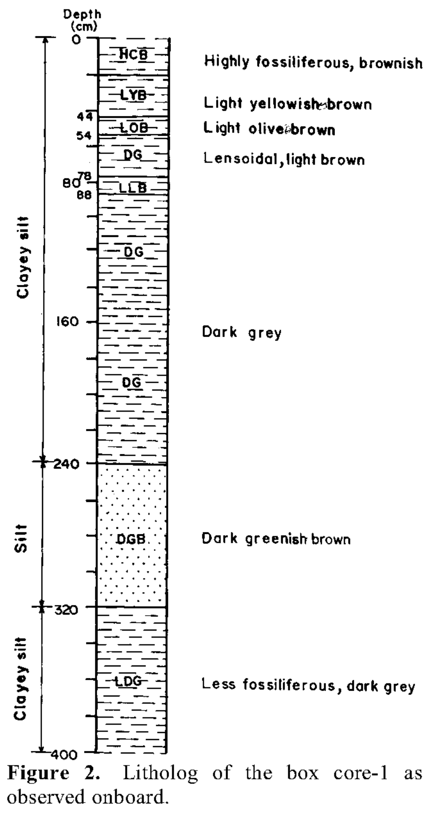

Figure 2. Litholog of the box core-1 as observed onboard.