



Forecasting of *Kharif* Rice and Jute Yield in North Bengal through Statistical Model

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Authors' contributions

This work was carried out in collaboration among all authors. Author KN designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AR, KN and SM also performed some statistical analysis. Authors SB and DSG wrote some part of introduction and material method of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Crop yield forecasting under the present climate change scenario needs an effective model and its parameter that how crop respond to the weather variable. A number of weather based models have been developed to estimate the crop yield for the various crops at block, district and state level. Among the different model statistical model is more popular and commonly used. The current study was undertaken to evaluate the performance of statistical model for rice and jute yield forecast of four different district viz. Cooch Behar, Jalpaiguri, Uttar Dinajpur and Dakhin Dinajpur. Among the four districts Cooch Behar district found superior for *kharif* rice yield prediction (1.46% error with RMSE 177.68 kg/ha) whereas in case of jute crop its performance was the best in the Jalpaiguri district (-0.44% error with RMSE 217.50 kg/ha).

Keywords: Yield forecasting model; weather variable; RMSE; *kharif* rice; jute.

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1. INTRODUCTION

Rice being one of the most important crop of India, as it is the backbone of livelihood for millions of rural households and plays a dynamic role in the country's food security, so the term "rice is life" is most applicable in Indian context. Jute is an important fiber crop of South Asia and most specifically it is cultivated in the country of Bangladesh and India [1,2]. Cultivation of jute crop is a matter of culture and mainly grown by the resource poor and marginal farmers of Bengal. According to the second advanced assessment by the Department of Agriculture, Cooperation and Farmers Welfare for the year 2017-18, the total food grain production is 275.11 million tonnes out of this rice contributes 111 million tonnes which is higher by 4.71 million tonnes than the average production of last five years'. However, in case of Jute and mesta it is estimated about 10.51 million bales (1 bale = 180 kg) which is lower than their production of the year 2016-17.

The crop acreage estimation, precise and timely forecasting of crop yield before harvest of the crop is vital in policy planning, strategic planning and decision making in agricultural sector of the country. This helps in reducing the undesirable effects on price and distress public policy. Crop yield estimation at regional level is the basis for planning crop production prospects at national level. The estimates of production is come by long after the crop season is over as traditional crop production estimation approach is based on crop cutting experiments (CCE) for crop yield forecasting [3]. So, the government needs advance tool for production estimation for different policy making decision related to marketing, pricing, storage, distribution, import/export which is very much vital for economy of the country. Weather is one of the most crucial parameters affecting the yield of crops as the adverse weather conditions during the cropping season results in the reduction in the production of crops. Models based on weather parameter can provide reliable crop yield forecast in advance of crop harvest [4]. These statistical models are not location specific; location specific weather data is used in these statistical models to forecast the yield of that location. Tripathi et al. [5] used the above said modified model and forecasted the yield of sugarcane and paddy at pre-harvest stage satisfactorily. Similarly, Rajegowda et al. [6] used the model for pre-harvest forecasting of ragi and groundnut yield in Karnataka. In different linear

and nonlinear models Das et al. [7] used 14 years of total monthly rainfall and monthly average value of other weather parameter for west coast of India to develop weather indices which were used to forecast coconut yield for the same region.

As the weather parameters plays a vital role in crop production, an attempt has been made to develop the statistical equations using modified Hendrick and Scholl [8] method to investigate the feasibility of estimating the yield of *kharif* rice and jute crops in advance based on weather variables using past weather and crop yield records of North Bengal districts.

2. MATERIALS AND METHODS

ICAR-Indian Agricultural Statistics Research Institute (ICAR-IASRI) has modified the Hendrick and Scholl model by expressing effect of change in weather variables on yield in the given week relating yield and weather. Yield is the dependent variable and weekly weather parameters viz. mean maximum temperature, mean minimum temperature, total rainfall, mean relative humidity at morning (RHI) and mean relative humidity at afternoon (RHII) forms the independent variables in the study. Yield forecasted at mid-crop stage is termed as F_2 forecast and forecast issued at pre-harvest stage are identified as F_3 forecast [9].

Rice and jute crop yield data for the period of 28 years and the daily data of weather parameters for the same period were used to develop the forecasting model. Sowing and transplanting weeks and growing periods were generated based on district wise area sown in different years which is obtained from State Agricultural Department. The weather variables collected from SMC, Kolkata, used in this study were standard meteorological weekly mean maximum temperature (T_{max} , Z1) and mean minimum temperature (T_{min} , Z2), total rainfall (Z3) and mean relative humidity {RH I (Z4) and RHII (Z5)}.

With these data sets and actual crop yield, forecast models were developed to predict the yield of *kharif* rice and jute. The model developed for *kharif* rice at pre-harvest stage (F_2 forecast) has been tested for two consecutive years *i.e.* 2017 and 2018 for four districts of North Bengal *viz.* Cooch Behar, Jalpaiguri, Uttar Dinajpur and Dakshin Dinajpur, respectively. The forecast models to predict the yield of jute at mid-crop stage (F_3 forecast) developed for the four districts of North Bengal were also tested for two consecutive year's *i.e.* 2016 and 2017. The

weighted and un-weighted weather indices were calculated as per the method given by Ghosh et al. [3].

Stepwise regression procedure was adopted for selecting the best regression equation among the numbers of independent variables. Statistical Package for Social Sciences (SPSS) was used to generate the correlation coefficients among the different variables with probability level of 0.05 to enter and 0.1 to remove the variables. When the individual effect of different weather parameters was considered, the notation of the variable was Z_{ij} ; where i range from 1 to 5 and j ranges from 0 to 1. The i value of 1 stands for weekly average maximum temperature, 2 stands for weekly average minimum temperature, 3 is for weekly total rainfall, 4 is used for weekly average of morning relative humidity and 5 is for afternoon relative humidity. The j value 0 stands for sum of the meteorological parameters for different weeks and 1 stands for sum product of the meteorological parameters and the correlation coefficients between yield and weather parameters. Also some variables were formed in Z_{ijk} format for understanding that the variables were used to show the combined effect of these weather parameters. After generating these variables, statistical analysis was done with yearly yield data, time as dummy variable and other weather variables. By this manner one equation was developed to predict the *kharif* rice and jute yield for districts of North Bengal, India. A regression model was fitted considering the entered variables obtained from individual stepwise regression analysis to predict the yield of *kharif* rice and jute crop for the subsequent years. The multiple linear stepwise regression models developed has been evaluated on the basis of examination of coefficients of determination (R^2), standard error (SE) of estimates values resulted from different weather variables.

The model evaluation strategy was based on the comparison of the statistical characteristics of forecasted data with that of the observed data. For model evaluation, model efficiency (ME), the mean absolute errors (MAE), the root mean square error (RMSE) and normalized root mean square error (NRMSE) were calculated

$$ME = 1 - [(C_{sr} - C_{oi})^2 / (C_{or} - \bar{O})^2] \quad (1)$$

$$MAE = \left| \frac{1}{N} \sum_{i=1}^N (C_{si} - C_{oi}) \right| \quad (2)$$

$$RMSE = \left[\frac{1}{N} \sum_{i=1}^N (C_{si} - C_{oi})^2 \right]^{0.5} \quad (3)$$

$$NRMSE = \frac{RMSE}{\bar{O}} * 100 \quad (4)$$

Where N is the total number of data, C_{si} the simulated data, C_{oi} the observed data and \bar{O} is mean of observed data.

3. RESULTS AND DISCUSSION

3.1 Forecasting of *Kharif* Rice Yield

The yield variation explained by *kharif* rice models along with standard errors are presented in the Table 1.

The coefficient of determination (R^2) was significant at 5% level of probability for rice in all the four districts of North Bengal. The R^2 ranged between 0.837 (Cooch Behar) to 0.912 (Dakshin Dinajpur). The R^2 values which are more than 0.6 indicates good agreement between the observed and the predicted yield and also the weather parameters plays a major role in predicting good yield. The model performance was evaluated in terms of ME, MAE, RMSE and NRMSE Table 1. The model efficiency ranged between 0.84 (Cooch Behar) to 0.91 (Dakshin Dinajpur), mean absolute error ranged between 133.26 (Uttar Dinajpur) to 140.88 (Cooch Behar) and RMSE ranged between 143.51 (Dakshin Dinajpur) to 177.68 (Cooch Behar). It can be seen from Table 1 that the developed *kharif* rice models predicted well with NRMSE values ranging between 8.43 (Dakshin Dinajpur) to 10.47 (Cooch Behar). The best agrometeorological indices to incorporate in the *kharif* rice model were Tmax (Z11) and Rainfall (Z30) for Cooch Behar district, RHII (Z51) for Uttar Dinajpur district and Tmin × RHI (Z341) for Dakshin Dinajpur district.

The validation of model for *kharif* rice yield for the year 2017 and 2018 are shown in Table 2. Results revealed that in the year 2017, the models for Cooch Behar (1.46%) and Jalpaiguri (4.33%) districts overestimated the yield while under estimation was observed in Uttar Dinajpur (-4.02%) and Dakshin Dinajpur (-2.68%) districts. Whereas, during the year 2018, the models overestimated the *kharif* rice yield for CoochBehar (4.42%), Jalpaiguri (12.25%), Uttar Dinajpur (5.06%) and Dakshin Dinajpur (1.34%).

Table 1. Yield forecast models of rice and jute for different districts of North Bengal

Crops	Districts		R ²	Standard Error	ME	MAE	RMSE	NRMSE
Kharif rice	Cooch Behar	Y=412.923+Time*49.481+Z11*52.68+Z30*-0.167	0.837	184.65	0.84	140.88	177.68	10.47
	Jalpaiguri	Y=985.51+Time*52.368	0.838	179.69	0.84	135.91	172.64	10.2
	Uttar Dinajpur	Y=2387.611+Time*51.487+Z51*6.888	0.856	173.11	0.86	133.26	166.58	8.88
	Dakshin Dinajpur	Y=1325.819+Time*59.107+Z341*0.1747	0.912	149.14	0.91	115.10	143.51	8.43
Jute	Cooch Behar	Y= 2633.7+Time*46.120+Z151*0.191+Z231*0.039	0.851	150.56	0.92	129.95	147.74	8.54
	Jalpaiguri	Y=2149.83+Time*48.071+Z351*0.024+Z241*0.096	0.776	224.64	0.78	175.19	217.50	12.61
	Uttar Dinajpur	Y=292.33+Time*47.653+Z11*20.697+Z141*0.769+Z140*(-0.042)	0.857	177.73	0.86	130.90	171.02	9.29
	Dakshin Dinajpur	Y= 992.5329+Time*54.217+Z131*0.0929	0.905	142.35	0.90	114.29	136.98	7.11

Table 2. Validation of model for forecasting of kharif rice and jute yield for different districts of North Bengal

Districts	Rice yield						Jute yield					
	2017			2018			2016			2017		
	Forecasted yield (kg ha ⁻¹)	Observed Yield (kg ha ⁻¹)	Error (%)	Forecasted yield (kg ha ⁻¹)	Observed yield (kg ha ⁻¹)	Error (%)	Forecasted yield (kg ha ⁻¹)	Observed yield (kg ha ⁻¹)	Error (%)	Forecasted yield (kg ha ⁻¹)	Observed Yield (kg ha ⁻¹)	Error (%)
Cooch Behar	2434	2470	1.46	2621	2742	4.42	2423	2434	0.46	2471	2385	-3.61
Jalpaiguri	2399	2508	4.33	2452	2794	12.25	2400	2259	-6.23	2473	2462	-0.44
Uttar Dinajpur	2632	2030	-4.02	2694	2838	5.06	2596	2444	-6.22	2597	2405	-7.98
Dakshin Dinajpur	2988	2910	-2.68	3008	3049	1.34	2605	2551	-2.10	2640	2608	-1.22

Models were having less than $\pm 10\%$ error in *kharif* rice yield prediction for all districts during both the years, except for Jalpaiguri district during the year 2018. This has indicated that the model can be used for prediction of *kharif* rice yield in the above districts.

3.2 Forecasting of Jute Yield

The yield variation explained by jute crop models along with standard errors is presented in the Table 1.

The coefficient of determination (R^2) was significant at 5% level of probability for jute in all the four districts of North Bengal. The R^2 , ME, MAE, RMSE, n RMSE ranged between 0.776 (Jalpaiguri) to 0.905 (Dakshin Dinajpur), 0.78 (Jalpaiguri) to 0.92 (Cooch Behar), 114.29 (Dakshin Dinajpur), to 175.19 (Jalpaiguri), 136.98 (Dakshin Dinajpur) to 217.50 (Jalpaiguri), 7.11 (Dakshin Dinajpur) to 12.61 (Jalpaiguri), respectively. The best agrometeorological indices to incorporate in the jute model was selected as $T_{max} \times RH_{II}$ (Z151) and $T_{min} \times Rainfall$ (Z231) for CoochBehar district, $Rainfall \times RH_{II}$ (Z351) and $T_{min} \times RHI$ (Z241) for Jalpaiguri district, T_{max} (Z11) and $T_{max} \times RHI$ (Z140 & Z141) for Uttar Dinajpur district and $T_{max} \times Rainfall$ (Z131) for Dakshin Dinajpur district.

The validation of model for jute crop yield for the year 2016 and 2017 are shown in Table 2. Results revealed that in the year 2016, the models for Cooch Behar (0.46%) district overestimated the yield while under estimation was observed in Uttar Dinajpur (-6.23%), Dakshin Dinajpur (-6.22%) and Jalpaiguri (-2.10%) districts whereas, during the year 2017, the models underestimated the jute yield for all the districts of North Bengal. Results also revealed that the models had less than $\pm 10\%$ error in jute yield prediction for all districts during both the years. As the variation in predicted and observed jute yield was close, therefore the developed models can be used for forecasting of crop yield.

4. CONCLUSION

Yield forecasting was done for *kharif* rice and jute crop for the districts of North Bengal. The developed model performance predict the yield very efficiently as most of the districts accuracy is under the 10%. Therefore, the developed models could be used for yield forecasting

satisfactorily for both crops and for districts of North Bengal.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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