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Short communication

Application of discriminant function analysis for forecasting wheat yield in Jaunpur district, Uttar Pradesh

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The crop yield forecasting faces significant challenges due to the complex interaction between weather variability and technological advancements. Recognizing that both biometrical characteristics and weather factors, such as maximum and minimum temperatures, rainfall, wind velocity, and sunshine hours, the intricate task lies in accurately predicting these yields amidst environmental uncertainties (Singh *et al.,* 2023). However, the dynamic nature of weather conditions and the technological changes impacting agricultural practices necessitate a more refined approach to modeling and forecasting (Ghosh *et al.,* 2014; Chaudhari *et al.,* 2010). There have been inherent limitations of over-fitting in multiple linear regression models when the predictor variables outnumber the observations and the challenge of multicollinearity within these predictors. Past research has extensively analyzed the impact of individual weather factors on wheat yields, leading to the use of discriminant function and principal component analysis to harness weekly weather data to develop robust forecast models (Agrawal *et al.,* 2012; Sisodia *et al.,* 2014; Kumar *et al.,* 2019).

The present study is aimed to use the discriminant function analysis to predict the wheat yield of Jaunpur district of Uttar Pradesh by gathering data from critical stages of the wheat growing season. The time series data on wheat crop yield for Jaunpur district in eastern Uttar Pradesh covering the period from 2000-01 to 2021-22 were obtained from the specified website http://updes.up.nic.in/spatrika/spatrika.htm. The time series weather data such as maximum and minimum temperatures, rainfall, wind velocity, and sunshine hours of Jaunpur were obtained from India Meteorological Department, Lucknow. The six models as described by Sisodia *et al.,* (2014) having different combinations of weighted and un-weighted weather indices were followed and six crop yield prediction equations using two discriminant scores (ds1, ds2) of the following forms were developed.

$$Y=\beta_0+\beta_1 ds_1+\beta_2 ds_2+\beta_3 T+\epsilon_y$$

Where, Y is wheat yield and T is a trend variable and (ϵ) is the error term.

Following six models were developed following Sisodia *et al.,* (2014) methodology.

Model 1 used five un-weighted weather indices

Model 2 used five weighted weather indices

Model 3 used 30 indices (both weighted and un-weighted, including interaction indices)

Model 4 used five weighted and five un-weighted weather indices

Model 5 used five un-weighted and 10 un-weighted interaction weather indices and

Model 6 used five weighted and 10 weighted weather indices

The weather data of five weather parameters (maximum and minimum temperatures, rainfall, wind velocity, and sunshine hours), from the 44th standard meteorological week (SMW) to the 7th SMW of the following year, for 15 years (2000-01 to 2014-15) were used for developing models. The best performing model was

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Table 1: Wheat yield forecast models

Model	Forecast regression equation	R^2	R^2adj
1	$Y = 20.314 + 1.651ds_1 + 1.651ds_2 + 0.677\ T$ (1.925) (0.514) (0.936 (0.214)	45.7	46.9
2	$Y = 23.425N + 1.784ds_1 + 0.529ds_2 + 0.329T$ (1.007) (0.324) (0.458) (0.111)	77.6	77.8
3	$Y = 23.425 + 1.784ds_1 + 0.529\ ds_1 + 0.329\ T$ (1.007) (0.324) (0.458) (0.111)	68.7	68.9
4	$Y = 24.903 - 1.170ds_1 + 0.593\ ds_2 + 0.159\ T$ (1.262) (0.224) (0.561) (0.145)	75.4	75.8
5	$Y = 23.437 + 0.870\ ds_1 - 0.949\ ds_2 + 0.343T$ (1.408) (0.298) (0.413) (0.156)	66.1	67.2
6	$Y = 24.168 + 0.830ds_1 - 0.730\ ds_2 + 0.246\ T$ (0.948) (0.129) (0.355) (0.104)	83.1	84.7

Table 2: Actual yield and the yield forecasted by Model 6 during 2015-16 to 2021-2022

Period	Actual yield (q ha^{-1})	Forecasted yield (q ha^{-1})	Deviation (%)	RMSE
2015-16	35.40	30.58	13.62	
2016-17	26.61	28.11	-5.64	
2017-18	32.30	29.38	9.04	3.35
2018-19	37.11	38.47	-3.66	
2019-20	35.95	39.45	-9.74	
2020-21	36.98	42.45	-14.79	
2021-22	40.10	39.23	2.17	

used to predict the wheat yield of Janupur for seven years (2015-16 to 2020-21). The coefficient of determination (R^2) and the adjusted coefficient of determination (R^2_{adj}) were computed to compare the six models' performance.

The models thus developed are presented in Table 1. The effectiveness of regression models for forecasting wheat yield using discriminant scores and a trend variable as predictors were evaluated based on their goodness of fit, represented by R^2 and adjusted R^2 values. Model 1 shows moderate fit, with R^2 and adjusted R^2 values of 45.7 and 46.9, respectively. Model 2 significantly improved, achieving the higher R^2 (77.6) and adjusted R^2 (77.8). Model 4 also achieves a high level of explanatory power, with R^2 and adjusted R^2 values of 75.4 and 75.8, respectively. Model 6 achieves the highest adjusted R^2 (84.7), suggesting that the predictors used comprehensively explain the variance in wheat yield, making it a strong candidate for practical forecasting applications. Models 6 performed the best, followed by model 4 and model 2 (Table 1). The analysis indicates that discriminant scores and the trend variable are valuable predictors for wheat yield forecasting.

Based on the performance criteria, the model 6 was selected to predict the wheat yield of Jaunpur for seven years (2015-16 to 2021-22). The RMSE of 3.35 reflects a generally good predictive accuracy, though with some notable errors in year 2015-16 and 2020-21. The varying accuracy across models and years underscores the challenge of capturing the complex and dynamic factors influencing agricultural production (Table 2).

This study demonstrates the utility of discriminant function analysis in forecasting wheat crop yields for the Jaunpur district of eastern Uttar Pradesh, India. By analyzing weather variables from 2000-01 to 2021-22, various regression models were developed and evaluated for their predictive accuracy. The results indicated that the best provided the most comprehensive explanation of yield variance, achieving the highest adjusted R^2 (84.7). These findings underscore the importance of accurate model specification and the effective use of discriminant scores and trend variables for reliable yield forecasting. Despite these advances, there are areas for improvement. The models showed variable performance across different years, suggesting the need for continuous refinement and validation of predictive tools. Additionally, integrating additional environmental, economic, and agronomic variables could enhance forecast accuracy and provide a more nuanced understanding of yield determinants

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Author's contribution: **P. K. Singh**: Conceptualized, data analysis, and drafted the manuscript; **P. Singh**: Data collection and interpretation of the analysis; **V. D. Chaturvedi:** Reviewing, editing and final manuscript.

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