EDITORIAL CSIC

Spanish Journal of Agricultural Research
24 (1) January-March 2026, 21542
ISSN-L: 1695-971X, eISSN: 2171-9292
https://doi.org/10.5424/sjar/2026241-21542

ARTICLE

RESEARCH ARTICLE

Forecasting of wheat yield through statistical models for different districts of Himachal Pradesh, India

Pronóstico del rendimiento del trigo mediante modelos estadísticos para diferentes distritos de Himachal Pradesh, India

Sangita Sharma
Regional Horticultural Research and Training Station, Dr. YS Parmar University of Horticulture & Forestry, Nauni, Solan. Mashobra, Shimla-171007(HP), India
Corresponding author: sangitasharmaento@gmail.com, https://orcid.org/0000-0001-7695-8408

Abstract: *Aim of study:* The objective was to construct weather-based forecasting models that can estimate wheat yield well in advance at pre-harvest stages. *Area of study:* This study primarily focused on diez wheat-growing areas in Himachal Pradesh, India. *Material and methods:* The forecast model was developed using long-term data on yield and meteorological parameters spanning from 1990 to 2020. The models were then validated using data from the remaining two years, 2021 and 2022. The yield projection for wheat was derived for ten districts at two growth stages, namely vegetative stage (F1) and pre-harvest stage (F2). The stepwise regression analysis was conducted using a trial and error strategy to determine the optimal combination of predictors that were statistically significant at a 5% level. Multiple regression techniques were employed to fit the model, with the best fit determined by the highest coefficient of determination (R2) value and the lowest percentage error. *Main results:* The findings indicated that the constructed forecast model successfully accounted for 43 to 93% of the variability in wheat output. The crop yield forecasting models provided accurate projections, with a percentage deviation ranging from 1.2 to 9.8 at the F1 stage and from 0.2 to -9.1 at the F2 stage. These deviations fell within the allowed limit of ±10%. Throughout both years of validation, the observed yield closely matched the anticipated wheat output for all ten districts. *Research highlights:* The characteristics that had the greatest impact on wheat yield were temperature and relative humidity. The crop forecasting models provided accurate estimates of wheat yield throughout all stages of the forecast for the majority of districts.

Keywords: climate indices; percent error; statistical model; wheat; yield forecasting.

Resumen: *Objetivo del estudio:* El objetivo fue construir modelos de pronóstico basados en el clima que puedan estimar el rendimiento del trigo con mucha antelación en las etapas previas a la cosecha. *Área del estudio:* Este estudio se centró principalmente en diez zonas de cultivo de trigo en Himachal Pradesh, India. *Material y métodos:* El modelo de pronóstico se desarrolló utilizando datos a largo plazo sobre rendimiento y parámetros meteorológicos, abarcando desde 1990 hasta 2020. Los modelos se validaron posteriormente utilizando datos de los dos años restantes, 2021 y 2022. La proyección de rendimiento para el trigo se derivó para diez distritos en dos etapas de crecimiento, a saber, la etapa vegetativa (F1) y la etapa de precosecha (F2). El análisis de regresión gradual se realizó mediante una estrategia de ensayo y error para determinar la combinación óptima de predictores estadísticamente significativos al 5%. Se emplearon técnicas de regresión múltiple para ajustar el modelo, con el mejor ajuste determinado por el valor más alto del coeficiente de determinación (R2) y el menor porcentaje de error. *Resultados principales:* Los resultados indicaron que el modelo de pronóstico construido representó con éxito entre el 43% y el 93% de la variabilidad en la producción de trigo. Los modelos de pronóstico del rendimiento del cultivo proporcionaron proyecciones precisas, con una desviación porcentual que osciló entre 1,2% y 9,8 % en la etapa F1 y entre 0,2% y -9,1% en la etapa F2. Estas desviaciones se mantuvieron dentro del límite permitido de ±10 %. Durante los dos años de validación, el rendimiento observado coincidió estrechamente con la producción de trigo prevista para los diez distritos. *Aspectos destacados de la investigación:* Las características que mayor impacto tuvieron en el rendimiento del trigo fueron la temperatura y la humedad relativa. Los modelos de pronóstico de cultivos proporcionaron estimaciones precisas del rendimiento del trigo en todas las etapas del pronóstico para la mayoría de los distritos.

Palabras clave: índices climáticos; modelo estadístico; trigo; porcentaje de error; previsión de rendimiento.

Recibido: 03-12-2024 / **Aceptado**: 15-09-2025 / **Publicado online**: 24-06-2026

Cómo citar: Sharma, S (2026). Forecasting of wheat yield through statistical models for different districts of Himachal Pradesh, India. Spanish Journal of Agricultural Research, Volume 24, Issue 1, 21542. https://doi.org/10.5424/sjar/2026241-21542

Supplementary information ↓

1. INTRODUCTION

Around 71% of the working population in the state of Himachal Pradesh, India is employed in the agricultural sector. Agriculture accounts for more than 45% of the net state domestic product. Wheat is the primary cereal crop grown during the *rabi s*eason in Himachal Pradesh (HP). It covers about 10% of the country's land and contributes to approximately 9% of the overall yield (Sati, 2023). The cultivation of this crop is primarily concentrated in sub-tropical regions and low hills, namely in districts of HP such as Una, Hamirpur, Bilaspur, Kangra, Chamba, Sirmaur, and Solan. The state suffers from insufficient and unevenly distributed precipitation during crucial phases of wheat development, leading to subpar germination and stunted growth of the crop. In addition to other biotic pressures, cereal crops are susceptible to a variety of insect pests (Nayak et al., 2023). Climatic parameters are the variables that determine the agricultural productivity of a place. Therefore, extensive research has traditionally been focused on the direct effects of climatic conditions on agricultural growth and development. Weather variables exert diverse impacts on crops at different phases of the growth season.

Data analysis facilitates the timely transmission of accurate information regarding the quality and quantity of crops, enabling the early identification of potential problems and the ability to strategize and execute suitable actions (Kumar et al., 2016). Historically, a range of statistical techniques including multiple regression, principal component analysis, and agro-meteorological models have been used to assess the influence of weather on crop growth. The methods described have been recorded in research conducted by Ravi Kiran & Bains (2007), Bazgeer et al. (2008), Munu et al. (2013), Singh et al. (2014) and Giri et al. (2017). Agrawal et al. (2012) developed predicted models for wheat yield in Kanpur district using discriminate function analysis on weekly meteorological variable data. Ghosh et al. (2014) discovered that their district-level yield forecast model, which used composite weather indices, successfully predicted yields for many significant crops in different states of the country at the district level. Gupta et al. (2018) developed statistical models to forecast the harvests of wheat and mustard crops in ten districts located in western Uttar Pradesh.

Farmers perceive agriculture as financially rewarding solely when a robust crop year yields a substantial output, therefore resulting in advantageous prices. Yield forecasting entails the examination of agricultural and meteorological data gathered over a prolonged duration for particular locations of interest. Precise forecasting of important agricultural commodities at different stages of growth is crucial for future strategic planning, policy development, and import/export decisions. The cultivation and assessment of agricultural production exert a substantial impact on the yearly economic outcomes at both national and international scales, and they also play a pivotal role in food administration. Crop yield in different years are affected due to technological change, system productivity and climate variability. These models are utilized to predict agricultural yield prior to the harvest. Notable contributors to this field include Baweja (2002), Sharma et al. (2017), Singh & Sharma (2017) and Verma et al. (2017). The objective of the present study was to investigate the feasibility of estimating the productivity of wheat crop based on weather variables using past weather and yield records of different districts of Himachal Pradesh. Such studies are useful in guiding agricultural policy in the prioritization of climate risks and will give a robust path to improving productivity (Kumar et al., 2023).

2. MATERIAL AND METHODS

The aim of this study was to develop prognostic models for the pre-harvest yield of wheat in 10 districts of Himachal Pradesh. The models were constructed using the stepwise multiple linear regression technique, which entailed examining both the yield and meteorological data. The objective was to analyze the impact of weather variables on wheat production during two distinct growth stages: Vegetative stage (F1 stage) and pre-harvest stage (F2 stage). The current investigation employed the wheat production data obtained from the Directorate of Agriculture, government of Himachal Pradesh, spanning duration of 32 years (1990-2022). The weather data i.e. maximum and minimum temperature, morning and evening relative humidity, and amount of rainfall was obtained from Met Centre, Shimla.

2.1. Data and variables used in the study

Yield forecast models for wheat have been developed for multiple districts in the state. These models utilize historical crop yield data and long-term weather data from the 48th to the 11th standard meteorological week for each district. The study employed weekly mean data on climatic variables, viz. maximum temperature (oC), minimum temperature (oC), morning relative humidity (%), evening relative humidity (%), and total rainfall (mm). The forecast model was constructed using data from 1990 to 2020. The model was then validated using data from 2020 to 2021 and 2021 to 2022. The data on the weekly weather variables from the 48th week to the 03rd week (F1 stage) and from the 48th to the 07th week (F2 stage) were used.

2.2. Yield forecast model

The operational yield projection was generated using composite weather indices and the modified Hendricks and Scholl Model, as developed by Agrawal et al. (1986). The preferred model, as proposed by Agrawal & Mehta (2007), had the following form:

$$Y = A_0 + \sum_{i=1}^{p}\sum_{j=0}^{1} a_{ij}Z_{ij} + \sum_{i=i'=1}^{p}\sum_{j=0}^{1} a_{ii',j'}Z_{ii'j} + cT + e$$

Where,

$$Z_{ij} = \sum_{w=1}^{m} r_{iw}^{j}X_{iw} \text{ and } Z_{ii'j} = \sum_{w=1}^{m} r_{ii'w}^{j}X_{iw}X_{ii'w}$$

are the simple and weighted weather indices, respectively.

Here Y: wheat yield (tones/ha)

A_0: model parameter.

r_{iw}: correlation coefficient of yield with ith weather variable in w^{th} period.

$r_{ii'w}$: correlation coefficient (adjusted for trend effect) of yield with product of i^{th} and i'^{th} weather variables in wth period.

X_{iw} and $X_{ii'w=}$values of the i^{th} weather variable in the w^{th} period.

a_{ij} and $a_{ii',j}$: regression coefficient of the model.

Z_{ij} and $Z_{ii'j}$: generated variable (un weighted and weighted)

m: number of meteorological weeks considered for forecast.

a, *b* and *c* are constants.

T: year number included to correct for the long term upward or downward trend in yield.

p: number of weather variables used =5

e: random error distributed as N (0, σ2)

Two variables were constructed for each weather variable: one representing the basic accumulation of the weather variable, and the other representing the weighted accumulation of weekly data on the weather variable. The weights used for the weighted accumulation were the correlation coefficients between the weather variables in each corresponding week and the yield. Similarly, to determine the combined impact of weather factors, weekly interaction variables were created by multiplying pairs of weather variables on a weekly basis. To study the joint effects, simple and weighted indices for interaction were calculated with products of weather variables taking two at a time (Tripathi et al., 2012). A total of 31 weather indices (simple or un-weighted and weighted) including time trend, T (year number) were taken as independent variables (Table 1). The stepwise regression technique was employed to determine the significant weather indices. The process of stepwise regression was employed to identify the statistically significant produced variables *Zij* and *Zii'j.* The model's performance was assessed by computing various statistical metrics, including the Standard Error (SE), correlation coefficient, and Root Mean Square Error (RMSE). The RMSE quantifies the average absolute difference between observed and simulated values. The accuracy of the model is determined by a smaller RMSE, as stated by Varshneya et al. (2010).

Table 1. Weather indices used in models using composite weather variables of five weather parameters

Weather variables	***Simple weather variables**					****Weighted weather variables**				
	T_{max}	**T_{min}**	**RF**	**RH_I**	**RH_{II}**	**T_{max}**	**T_{min}**	**RF**	**RH_I**	**RH_{II}**
T_{max}	Z10					Z11				
T_{min}	Z120	Z20				Z121	Z21			
RF	Z130	Z230	Z30			Z131	Z231	Z31		
RH_I	Z140	Z240	Z340	Z40		Z141	Z241	Z341	Z41	
RH_{II}	Z150	Z250	Z350	Z450	Z50	Z151	Z251	Z351	Z451	Z51

T_{max} (maximum temperature oC), T_{min} (minimum temperature oC), RF (cumulative rainfall mm), RH_I (morning humidity %), RH_{II} (evening humidity %).*Simple weather variable is sum of weather parameter; **Weighted weather variable is sum product of weather parameters (taken two at a time) and weight factor (correlation coefficients)

3. RESULTS

Crop yield forecast models were developed using crop weather research to estimate the yield of the wheat crop well in advance of the actual harvest. An analysis was conducted on the data pertaining to yield and weather conditions over a span of 32 years. The regression equations derived for various meteorological factors are presented in Table 2 and Table 3. The algorithm for predicting the ultimate yield, which incorporates significant weather variables, has been provided for the 2019-20 season. The function's R^2 and RMSE values, as well as the percentage error during the F1 and F2 stages, have also been included. The R^2 value, a measure of the quality of fit, indicated that the generated weather variables were able to account for 52 to 88% of the variation during the vegetative stage (F1) and 43.0 to 93.0% of the variation during the pre-harvest stage (F2). The remaining variation is attributed to unexplained factors that were not considered in this study. The simulated yield values for different districts of the state during the 2019-20 season, namely for the F1 growth stage, are shown in Table 2. Similarly, the simulated yield values for the F2 growth stage are shown in Table 3. The percentage variation between the observed value and the simulated value during the F1 stage varied from 1.2% to 9.8% (Fig. 1) and from 0.2% to -9.1% at F2 stage (Fig. 1). The Kangra district exhibited the lowest deviation at both growth stages, suggesting that the model performed exceptionally well for this district. The forecasted yield was nearly identical to the observed yield. The Bilaspur district also showed a relatively low deviation, indicating a satisfactory level of accuracy compared to other districts.

Table 2. Wheat yield forecast at vegetative stage (F1) for different districts of the state Himachal Pradesh, India

District	Equation	Predicted yield (kg/ha)	Average yield (Last 10 yrs) (kg/ha)	RMSE	R^2	S.E	*Error (%)	
							2020-21	2021-22
Bilaspur	Y=275.64+28.94*Time+0.432 *Z131+9.73*Z51	2009.3	1930.0	339.9	0.76	207.9	2.5	-3.1
Chamba	Y=2723.71+0.264*Z151	1965.8	1771.2	315.6	0.66	214.5	3.8	-8.1
Hamirpur	Y=1232.14+1.37*Z131+0.371*Z240 +2.27*Z251-0.348*Z351	1630.0	1517.3	235.4	0.75	139.1	-1.5	9.8
Kangra	Y=1660.15+55.54*Z11-0.025*Z350 +0.171*Z351+3.81*Z51	1770.6	1647.8	177.6	0.88	91.5	3.9	1.2
Kullu	Y=2705.91+57.43*Z11+0.185*Z451	1784.4	1646.1	225.0	0.52	153.2	8.9	5.3
Mandi	Y=626.39-17.65*Z50+53.96*Z51	1563.4	1500.6	249.6	0.58	183.7	8.1	5.8
Shimla	Y=1550.39+7.31*Z121+0.104*Z140 +0.281*Z451	1328.9	1620.7	223.0	0.79	156.6	6.1	-8.5
Sirmaur	Y=3728.47+0.326*Z141	2138.7	1969.1	326.9	0.54	325.3	7.9	7.6
Solan	Y=615.91+39.55*Time+9.171*Z41	2005.7	1900.1	208.6	0.66	216.8	9.7	-6.8
Una	Y=651.21+1.047+Z141+2.55*Z241 +31.105*Z51	1686.7	1832.0	283.9	0.58	227.9	3.1	-5.3

*Describes the percentage of deviations from actual yield = $\frac{(Predicted\ Yield - Observed\ Yield)}{Observed\ Yield} \times 100$

Table 3. Wheat yield forecast at pre-harvest stage (F2) for different districts of the state Himachal Pradesh, India

District	Equation	Predicted yield (kg/ha)	Average yield (Last 10 yrs) (kg/ha)	RMSE	R^2	S.E	*Error (%)	
							2020-21	2021-22
Bilaspur	Y=-377.84+2.59*Z121+19.46*Z51	1671.1	1930.0	339.9	0.75	195.6	-1.9	-4.0
Chamba	Y=2439.36+0.546*Z131+0.099 *Z141	1808.0	1771.2	315.6	0.71	203.9	2.9	-9.1
Hamirpur	Y=1291.92+1.24*Z251+0.086*Z341	1818.4	1517.3	235.4	0.67	148.2	-2.1	-5.8
Kangra	Y=1735.7+61.15*Z11-0.027 *Z350+0.172*Z351+4.05*Z51	1786.9	1647.8	177.6	0.86	89.1	2.0	0.2
Kullu	Y=2824.64-15.76*Time+16.04 *Z11+0.455*Z241+13.44*Z41	1523.8	1646.1	225.0	0.67	133.6	7.4	6.2
Mandi	Y=1457.58+0.80*Z131	1641.2	1500.6	249.6	0.43	207.8	8.6	6.4
Shimla	Y=685.83+0.291*Z141+6.69*Z51	1795.8	1620.7	223.0	0.77	150.5	5.8	-6.3
Sirmaur	Y=3806.8+0.227*Z141	2149.0	1969.1	326.9	0.54	317.4	9.1	6.5
Solan	Y=270.172+27.819*Time+0.734 *Z141+8.46*Z51	2075.0	1900.1	208.6	0.93	100.6	4.8	-4.1
Una	Y=1962.54+203.74*Z21	1612.1	1832.0	283.9	0.53	229.6	-7.7	-8.0

*Describes the percentage of deviations from actual yield = $\frac{(Predicted\ Yield - Observed\ Yield)}{Observed\ Yield} \times 100$

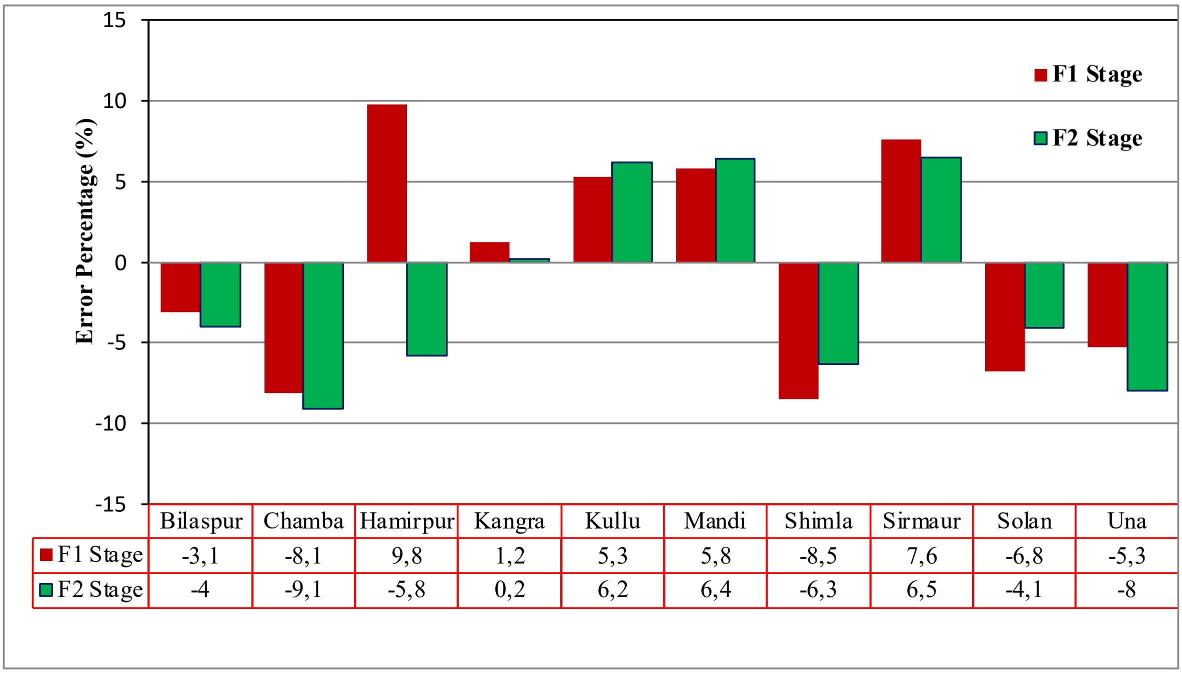

Figure 1. District wise validation of forecast models of wheat for the state Himachal Pradesh at vegetative (F1) & pre-harvest stages (F2)

Table 2 and Table 3 display the wheat yield forecasts and observed yields for different districts of Himachal Pradesh. Based on the average of the past 10 years, the district of Sirmaur demonstrated the highest production with a yield of 1969.1 kg/ha, followed by Bilaspur with a yield of 1930.0 kg/ha. Forecast models for the ten primary wheat producing regions have been created, and their accuracy has been confirmed by comparing them to the actual yield for the 2021-22 seasons. The Kangra district had the highest correlation coefficient (cc=0.88) and a relatively lower Root Mean Square Error value (RMSE) i.e. 177.6 kg/ha, making it the most accurate prediction. The Shimla district had a correlation of 0.79 and an RMSE of 223.0 kg/ha, which was slightly less accurate compared to Kangra, at the F1 stage. The error structures for the districts Bilaspur, Chamba, Hamirpur, Kullu, Mandi, Sirmaur, Solan, and Una were as follows: RMSE± 339.9, 315.6, 235.4, 225.0, 249.6, 326.9, 208.6, and 283.9 kg/ha with PE i.e. -3.1, -8.1, 9.8, 5.3, 5.8, 7.6, -6.8, and -5.3% (Table 2).

The wheat yield projection for Solan district at the F2 stage exhibited the highest correlation (cc=0.93) and a lower RMSE value (208.6 kg/ha), while the Kangra district had a correlation of 0.86 and an RMSE of 177.6 kg/ha. The validation of forecast models revealed that the Root Mean Square Error (RMSE) values for Bilaspur, Chamba, Hamirpur, Kullu, Mandi, Shimla, Sirmaur, Solan, and Una at the F2 stage were 339.9, 315.6, 235.4, 225.0, 249.6, 223.0, 326.9, and 283.9 kg/ha. The Percentage Error (PE) values for the same locations were -4.0, -9.1, -5.8, 6.2, 6.4, -6.3, 6.5 and -8.0% respectively. The information is presented in Table 3.

The projected wheat yields fell within the permissible margin of error (±10%) for all districts. The study determined that temperature and relative humidity were the primary factors influencing wheat output at all phases of yield forecasting in the majority of districts. The validation findings showed that the forecast for all ten districts of Himachal Pradesh was outstanding.

4. DISCUSSION

The wheat yield forecasting models were created for ten districts of Himachal Pradesh, India using weekly meteorological data from the 48th week to the 03rd week (F1) and from the 48th week to the 07th week (F2). The coefficient of determination (R2) ranged from 0.52 to 0.88 during the vegetative stage (F1) and from 0.43 to 0.93 at the pre-harvest stage (F2), indicating yield variations of 52% to 88% and 43% to 93%, respectively. The results were consistent with the findings of Khavse et al. (2014), who said that 67.0% of crop variation is primarily influenced by prevailing meteorological conditions, while the remaining 33.0% is attributed to other crop management elements. Singh et al. (2022) found similar outcomes when employing statistical models to predict wheat production in the western regions of Uttar Pradesh, India, during the pre-harvest stage. The R^2 values varied from 0.44 to 0.96 percent.

The Kangra district had the most accurate predictions among the studied districts, followed by Shimla and Bilaspur districts, at both growth periods. Verma et al. (2017) observed similar results in Himachal Pradesh when predicting wheat production at the district level. They used simulated and statistical models and found that the yield was more accurate when predicted before the harvest stage, specifically for Kangra district. The wheat yield forecasting models accurately anticipated the wheat yield with an error margin of ±10% for all districts. Similar findings were observed in the validation of wheat yield forecast models for eleven districts of Uttar Pradesh in India, as reported by Singh et al. (2014), Gupta et al. (2018) and Atamanyuk et al. (2023). The characteristics that had the greatest impact on wheat yield in most districts throughout the prediction period were temperature and relative humidity. This aligns with the findings of Kakati et al. (2022). All crop production forecasting models built for various districts provided accurate forecasts and generated error percentages within an acceptable range. Thus, productivity forecast of wheat crop could help the Government in estimating the production and making decisions regarding export and import policies, distribution and price structure and for exercising measures for storage and marketing.

The maximum and minimum temperatures, together with relative humidity (RH), were crucial climatic factors in determining wheat yield in the region. According to Singh et al. (2010) and Singh et al. (2011), the wheat yield per hectare in India has decreased in recent years. This decline can be attributed to the consistent increase in temperature throughout the critical months of January, February, and March, which are vital for the wheat crop. The predicted yield closely approximated the measured yield, therefore making it suitable for yield forecasting and planning purposes. However, regression models can predict the crop yields at district level and do not consistently provide adequate accuracy for larger area as they are empirical in nature (Verma et al., 2017).

The variables used in the regression models to increase the accuracy (R2) cannot be of global application as such variables differ from region to region. The statistical models utilized crop growth parameters for yield forecasting. This approach does not easily lead to an explanation of the cause and effect relationship but is a practical approach for assessment of wheat yield for the state. These models will provide a quantitative estimate of the expected wheat yield over a given area, in advance of the harvest, provided no extreme weather conditions occur. As the data used for developing these models is of high degree of accuracy, its reliability is also high. However, variations with different trends suggest further refinement in the model equations.

5. CONCLUSIONS

The present study employed 32 years (1990-2022) of yield data and weekly meteorological data to construct pre-harvest yield projection models for wheat in ten districts of Himachal Pradesh. The interplay of meteorological factors significantly influences the assessment of wheat yield. The generated models had R^2 values ranging from 43% to 93%, suggesting a considerable degree of accuracy. The percentage deviation between the observed and simulated yield remained within the acceptable range of ±10% for all districts. The agro meteorological indicators, which are determined by the combination of maximum and minimum temperatures along with relative humidity, have a significant impact on forecasting the wheat crop yield in the area. From the model's performance, it can be inferred that the model is direct and appropriate for predicting at the district, agro climatic zone, and state levels.

Supplementary information ↑

Funding sources

The author received no specific funding for this work.

Supplementary material

Not applicable.

Data availability

The data used to support the findings of this study are available with author and can be made available only on reasonable request.

Acknowledgements

The paper is based on the findings of research project on ''Forecasting Agricultural Output using Space, Agrometeorology and Land based observations (FASAL)'' funded by India Meteorological Department (IMD), Pune, India. The author is grateful to Meteorological Centre, Shimla and State Agricultural Department for providing meteorological and crop yield data, respectively, used in this study.

Authorship contribution statement

Sangita Sharma: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Supervision, Validation, Visualization, Manuscript writing-original draft, Writing-review and editing.

Competing interests

The authors has declared that no competing interests exist.

Statement on the use of Artificial Intelligence

The author(s) employed Google translator in order to translate the title, abstract and keywords from English to Spanish while preparing this work. Following their use, the author(s) assumed full responsibility for the publication's content and reviewed and edited it as necessary.

REFERENCES

Agrawal R, Jain RC, Jha MP, 1986. Models for studying rice crop-weather relationship. Mausam 37: 67-70. https://doi.org/10.54302/mausam.v37i1.2153

Agrawal R, Mehta SC, 2007. Weather based forecasting of crop yields, pests and diseases-IASRI Model. J Ind Soc Stat 61: 255-263.

Agrawal R, Aditya K, 2012. Use of discriminates function analysis for forecasting crop yield. Mausam 63: 455-458. https://doi.org/10.54302/mausam.v63i3

Atamanyuk I, Valerii H, Vitalii N, Diachenko O, Tepliuk M, Chebakova T, Trofimova H, 2023. Forecasting of Winter Wheat Yield: A Mathematical Model and Field Experiments. *Agriculture* 13(1): 41. https://doi.org/10.3390/agriculture13010041

Baweja PK, 2002. Predicting grain yield in maize: canopy temperature based regression indices. J Agromet 4: 177-179. https://doi.org/10.54386/jam.v4i2.465

Bazgeer S, Kamali GA,Eslamian SS,Sedaghakerdar A, Moradi I, 2008. Pre-harvest wheat yield prediction using agrometeorological indices for different regions of Kordestan Province. Iran Res J Env Sci 2: 275-280. https://scialert.net/abstract/?doi=rjes.2008.275.280

Ghosh K, Balasubramanian R, Bandopadhyay S, Chattopadhyay N, Singh KK, Rathore L, 2014. Development of crop yield forecast models under FASAL- a case study of kharif rice in West Bengal. J Agromet 16: 1-8. https://doi.org/10.54386/jam.v16i1.1479

Giri AK, Bhan M, Agrawal KK, 2017. Districtwise wheat and rice yield predictions using meteorological variables in eastern Madhya Pradesh.A. 19: 366-368. https://doi.org/10.54386/jam.v19i4.610

Gupta S, Singh A, Kumar A, Shahi UP, Sinha NK, Roy S, 2018. Yield forecasting of wheat and mustard for western Uttar Pradesh using statistical model. J Agromet 20: 66-68. https://doi.org/10.54386/jam.v20i1.508

Kakati N, Deka RL, Das P, Goswami J, Khanikar PG, Saikia H, 2022. Forecasting yield of rapeseed and mustard using multiple linear regression and ANN techniques in the Brahmaputra valley of Assam, North East India. Theor Appl Climatol 150: 2001-2015. https://doi.org/10.1007/s00704-022-04220-3

Khavse R, Singh R, Manikandan N, Chaudhary JL, 2014. Influence of temperature on rapeseed mustard yield at selected locations in Chhattisgarh state. Curr World Env 9: 1034-1036. http://dx.doi.org/10.12944/CWE.9.3.59

Kumar N, Pisal RR, Shukla SP, Pandey KK, 2016. Crop yield forecasting of paddy and sugarcane through modified Kendrick and Scholl technique for South Gujarat. Mausam 67: 405-410. https://doi:10.54302/mausam.v67i2.1339

Kumar S, Sidana, BK, Thakur S, 2023. Climate change and its impact on productivity of major kharif and rabi crops in Punjab. Mausam 74: 151-160. https://api.semanticscholar.org/CorpusID:255296021

Lal M, Singh KK, Rathore LS, Srinivasan G, Saseendran SA, 1998. Vulnerability of rice and wheat yields in NW India to future changes in climate. Agr Fores Meteoro l89: 101-114. https://doi:10.1016/S0168-1923(97)00064-6

Munu D, Hussain R, Sharma A, Sarmah K, Deka RL, 2013. Yield prediction of winter rice employing meteorological variables in central and upper Brahmaputra valley zone of Assam. J Agromet 15: 162-166.

Nayak RK, Sharma S, Singh J, 2023. Major Insects Pests of cereals crops in India and their management. In: Pest Management Strategies in Pulses and Cereal Crops; Kumar A, Hasan W, Verma B, Singh CP (eds.). pp: 205-216. Kripa Drishti Publications, Pune, Maharashtra, India: https://www.kdpublications.in

Ravi K, Bains GS, 2007. Thermal time requirement and heat use efficiency in summer green gram. J Agromet 9: 96-99. https://doi.org/10.54386/jam.v9i1.1099

Sati VP, 2023. The future of food and agriculture in India: Trends and Challenges. Sayam 1: 29-39. https://doi.10.63419/sayam.v1i1.48

Sharma S, Singh M, Bhan SC, 2017. A study on pre-harvest forecast of maize yield using statistical model for Himachal Pradesh. Mausam 68: 369-374.https://doi.org/10.54302/mausam.v68i2.645

Singh H, Hasan KNB, Khan AA, 2010. Agroclimatic models for prediction of growth and yield of rice (*Oryza sativa*) under temperate Kashmir conditions. Ind J Agr Sci 80: 254-257. https://epubs.icar.org.in/index.php/IJAgS/article/view/253

Singh K, Sharma SN, Sharma, 2011. Effect of high temperature on yield attributing traits in Bread Wheat. Bangladesh J Agr Res 36: 415-426. https://doi.org/10.3329/bjar.v36i3.9270

Singh RS, Patel C, Yadav NK, Singh KK, 2014. Yield forecasting of rice and wheat crops for eastern Uttar Pradesh. J Agromet 16: 199-202. https://doi.org/10.54386/jam.v16i2.1521

Singh M, Sharma S, 2017. Forecasting of maize yield at pre-harvest stage using climatic variables. J Agromet 19: 167-169. https://doi.org/10.54386/jam.v19i2.715

Singh A, Nagar V, Tanwar N, Sahil UP, Bhan SC, 2022. Use of statistical models in yield forecasting of wheat, mustard and potato crop in western districts of Uttar Pradesh, India. Int J Env Climate Change 12: 66-72. https://doi.org/10.9734/ijecc/2021/v11i1230648

Tripathi MK, Mehra B, Chattopadhyay N, Singh KK, 2012. Yield prediction of sugarcane and paddy for districts of Uttar Pradesh. J Agromet 14: 173-175. https://doi.org/10.54386/jam.v14i2.1420

Varshneya MC, Chinchorkar SS, Vaidya VB, Pandey V, 2010. Forecasting model for seasonal rainfall for different regions of Gujarat. J Agromet 12: 202-207. https://doi.org/10.54386/jam.v12i2.1306

Verma K, Rana RS, Thakur S, Salaria S, 2017. Comparison of simulated and statistical model prediction of wheat at district scale yield under sub-temperate climate of North Western Himalayas. Int J Pure Appl Bios 5: 1035-1050. http://dx.doi.org/10.18782/2320-7051.5236