WEATHER-BASED RICE CROP YIELD FORECASTING USING DIFFERENT REGRESSION TECHNIQUES& NEURAL NETWORK APPROACH FOR PRAYAGRAJ REGION

ABSTRACT

Rice crop yield data and weather data ~~of~~for the past twenty-nine years (1991-2019) were collected for Prayagraj District of Uttar Pradesh from DACNET & College of Forestry, SHUATS Prayagraj respectively. Analysis was carried out by fixing 26 years of dataset for calibration (90%) and theremaining dataset for ~~the~~ validation (10%). In this study, 75.9 % of data were used for training the ANN model and theremaining 24.1% ofdata were used for testing and Validation (100%) for model efficiency. Stepwise linear regression technique and neural network used for predicting the yield of rice crop. Performance analysis is done withthe least Normalized Root Mean Squared Error (nRMSE) values for the study. Regression- based model outperforms the ANN model as the performance of nRMSE is best suited. The present study concluded that the performance of Bright Sunshine Hour withrespect to nRMSE and coefficient of determination is recordedat0.00025 and 0.94 respectively.

Keywords:Regression, yield, model, parameter,artificial neural networks, coefficient of determination

Introduction

Agriculture has always been one of the vital occupations that serve mankind, both in terms of livelihood and employment. Due to the substantial increase in the population, the nutritional status of the poor is growing bad, which must be improved. The major effect of population increase has been prominently shown on the environment, the damage of which is increasing rapidly, which ultimately hinders agricultural production. Predicting the yield of the crop is a vital agricultural problem. Every single farmer constantly tries to estimate how much yield can be expected from their fields. In the past, the prediction of yield was calculated by analyzing the farmer's previous results on a particular crop. Crop yield is primarily dependent on weather conditions, pests, and the planning of harvest **operation.**Accurate information about the history of crop yield is a vital criterion for making decisions related to agricultural risk management. The proposed method uses Regression and Neural Network techniques to predict the yield of rice.Predicting crop yield is crucial to addressing emerging challenges in food security, particularly in an era of global climate change. Accurate yield predictions not only help farmers make informed economic and management decisions but also support famine prevention efforts.

Several yield prediction models have been developed using **numberof** weather variables and crop data to establish regression and artificial neural network models. These have been widely used to evaluate the association between weather parameters and crop yield of different regions **(Banakara*, et al.*, 2018; Latwal*, et al.*, 2017; Diwan*et al.*, 2018 and Kumar *et al.*, 2014). Bankara*et al.*,2018)** compared the technique of Multiple Linear Regression (MLR). (**Diwan*et al.*, 2018)** also developed **crop** yield forecast model by employing **stepwise** linear regression technique and found that temperature (maximum & minimum) and relative humidity were significant predictors in crop yield forecast. Similar studies were conducted by **(Kalubarme and Ahuja, 1996; Chauhan*et al.*, 2009)** to develop **agrometeorologicaldata based**rice yield prediction **model** for Karnal, central Punjab and Bulsar**district** of Gujarat respectively.**(Ghosh*et al.*, 2014)** also developed **rice**forecast model for various **district** of West Bengal.

In this research paper, regression models and ANN**technique** are used for predicting the yield of rice **crop**depending on weather and crop parameters are proposed. The best yield prediction technique has been developed based on the nRMSE.

Study area

The study was conducted **for Prayagraj**district of Uttar Pradesh. Prayagraj is situated in Southern Eastern part of the state of Uttar Pradesh. It lies between the parallels of 24º 47’ north latitude and 81º 19’ east longitudes. Prayagraj is bounded on the eastern side by district Sant Ravi Das Nagar (Varanasi).

MATERIALS AND METHODS

Yearly Production (Kg) and area (ha) under Rice **crop** in Prayagraj District for the period 1991 – 2019 were collected from the (Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare). Weekly and Monthly data of maximum & minimum Temperature (ºC), Relative Humidity (%),and Rainfall (mm) number of rainy days for the period 1991 – 2019 were collected from the agro meteorological observatory located in Sam Higginbottom University of Agriculture, Technology and Sciences, Department of Agrometeorology,

College of Forestry, Prayagraj. In the present study rice yield forecasting was done using **artificial** neural network &**multi linear**regression technique. SPSS software was used for the statistical analysis and to develop a multiple regression model for rice.

Development of Statistical Regression Model Using Weekly Weather Parameter

Overall analysis was carried out by fixing 26 years of **dataset** for calibration (90%) and **remaining** dataset for the **validation** (10%). In this **method** the rice yield prediction model was developed using weekly weather **parameter** of crop growing season .i.e. SMW 22nd to 37th. In this study weekly weather parameters are considered as independent variables and rice yield was considered as **dependent** variable in SPSS. The stepwise regression technique in SPSS was used to develop the multivariate statistical models.

Development of Statistical Regression Model using Weighted and Un-weighted Parameter

Here, the rice crop yield data set consists of a total **29** years. Out of which **26 year**records are considered as training& testing. Weighted and un-weighted parameter is considered as independent variable and rice yield was considered as dependent variable in SPSS. The stepwise regression technique in SPSS was used to develop the multivariate statistical models.

Simple and weighted weather indices are developed for Prayagraj District. Summation of individual weather **variable** or interaction of two weather **variable** at a time were used for generating simple weather indices, **sum** product of individual weather variable or interaction of weather variables and its correlation with adjusted crop yield **were resulted with** weighted weather indices. **Computation** of simple and weighted weather indices **were**based on **following** formula.

Table1. Simple and weighted weather indices:

Simple weather indices

$$Zij = \sum_{w=1}^{m} Xiw$$

$$Zij = \sum_{w=1}^{m} Xiw$$

$$Zii'j = \sum_{w=1}^{m} Xiw\, Xi'w$$

Weighted weather indices

$$Zij = \sum_{w=1}^{m} r^j iwXiw$$

$$Zii'j = \sum_{w=1}^{m} r^j ii'wXiwXi'w$$

Where,

$Xiw/Xii'w$= value of i'^{th}/i'^{th}weather variable under study in weather week,

$r^j iw/r^j ii'w$ = correlation coefficient of yield with ith weather variable or product of i'^{th}/i'^{th}weather variable in the week.

Weather Parameter	***Simple weather indices***					***Weighted Weather indices***				
	Tmax	***Tmin***	***R/F***	***RH(I)***	***RH(II)***	***Tmax***	***Tmin***	***R/F***	***RH(I)***	***RH(II)***
Tmax	*Z10*					*Z11*				

Tmin	*Z120*	*Z20*							*Z121*	*Z21*				
R/F	*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*	

Table 2: Simple and weighted weather indices used for developing model:

Now, Simple and weighted weather indices used for developing **model** are given in Table 4.

Development of Statistical Regression Model Using Bright Sunshine Hour with Weighted & Un-weighted Parameter

In this study, rice yield prediction model was developed using Bright Sunshine Hour of crop growing season .i.e. SMW 22nd to 37th with weighted & un-weighted **parameter**. These parameters are considered as independent variable and rice yield was considered as dependent variable in SPSS. The stepwise regression method used in SPSS for statistical modeling.

Development of Statistical Regression Model Using Actual Evapotranspiration with Weighted & Un-weighted Parameter

In this technique the regression equation for **rice**yield model was developed using Actual Evapotranspiration and weighted and un-weighted parameterswere considered **of** SMW 22nd to 37th week. A multivariate model was then formed for the rice yield prediction using statistical regression **technique** in SPSS.

Rice yield forecasting using machine learning approach (ANN)

Multilayerperceptron (MLP) technique is one of the popular neural network types. This network **interpreted** as a form input-output model, with weights and threshold (biases) as free parameters of the model. The number of hidden layers and the number of neurons in each hidden layer are often varied to optimize the performance of the final model **(Tufail*et al.*,2008).** The number of nodes in each layer is evaluated by trial and error. The MLP is trained with a training set of input and known output data. MLP transforms *m* **inputs**to *n* **outputs** through some nonlinear functions. With **activation** of the units in the output layer, **theoutput** of the MLP network will be determined as follows:

$$X_o = f(\sum X_h w_{ho} + b_j)$$

where,(f) is the activation function, X_h is the activation of hidden layer node; w_{ho} is the interconnection between **hidden** and output layers nodes and the b_j is the bias. **Back propagation** proposed by (**Rumelhart*et al.*,1986)** is the most popular algorithm for training **of** the MLP network **(Wasserman, 1989; Fausett, 1994; Haykin,1994).**

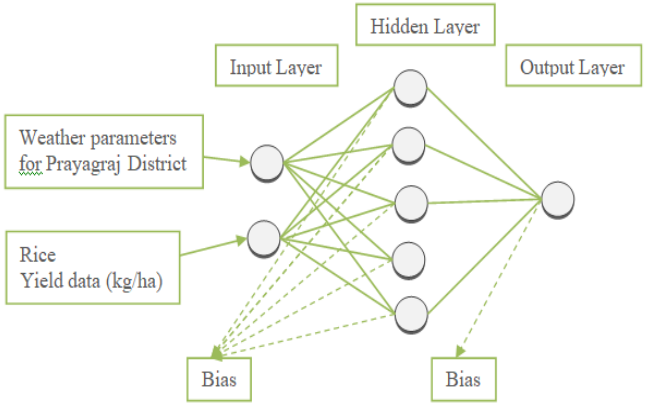

Fig.1. Different layers and different network structural representation of the ANN used in the study.

Training ANN model

In this study, 76 % data were used for training ANN model and remaining24% data were used for testing and for validation (100%) of data is been used. In this (Table 3), the ANN model with transfer functions of Hyperbolic Tangent gives the best results in training and testing stages (i.e., the least RMSE and nRMSE values).

Table 3: The Network Information

Input Layer	Number of Units[a]	30
	Rescaling Method for Covariates	Standardized
Hidden Layer(s)	Number of Hidden Layer	1
	Number of Units in Hidden Layer 1[a]	5
	Activation Function	Hyperbolic Tangent
Output Layer	Dependent Variables	Yield
	Number of Units	1
	Rescaling Method for Scale Dependents	Standardized
	Activation Function	Identity
	Error Function	Sum of Squares

a. Excluding the bias unit

Model Performance

For testing the performance of developed statistical forecasting models, R^2, Root Mean Square Error (RMSE) and Normalized Root Mean Square Error (nRMSE) were calculated using the following formula:

$$R^2 = \left(\frac{\frac{1}{n}\sum_{i=1}^{n}(M_i - \bar{M})\,(O_i - \bar{O})}{\sigma M \sigma O} \right)$$

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(O_i - M_i)^{\,2}}$$

$$\text{nRMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(O_i - M_i)} \times \frac{100}{\bar{O}}$$

Where,
RMSE is Root Mean Square Error**,** *nRMSE* is Normalized Root Mean Square Error, P_i is the predicted value,O_i is the observed value, *n* is the number of observations and *M*is the mean of **observed** value.

Model performs excellent having nRMSE value > 10%, good having nRMSE value between 10-20%, **fair** having nRMSE value between 20-30%.

RESULTS

Rice yield prediction using statistical modelingbased on different weather parameters.

In this **method** the rice yield prediction model was developed using various weather **parameter** of crop growing season .i.e. SMW 22nd to 37th. In this **study** various weather parameters are considered as independent variables and rice yield was considered as **dependent** variable in SPSS. The stepwise regression technique in SPSS was used to develop the multivariate statistical models**are** as follows:

Development of Statistical Regression Model Using Weekly Weather Parameter

In this only one model was developed, Model 1 has taken time as an independent factor to estimate the rice yield for Prayagraj region having R^2 value of about 0.55 which has explained the 55% variation **on** yield. **Thus** Model 1 was used to obtain **forecast** yield of rice for Prayagraj&**can** be observed **from** (Table 4).It may be observed for 2018 and 2019 model **had** underestimated the yield of rice **crop**(Table 5)**where** for the year 2017 Model **has** predicted the rice yield nearby actual yield, so it may be inferred that **Model has**performed well for 2017**.It**can be observed from the results of **the** (Table 5) that the percent deviation ranges from 7.05 to 15.99 is also indicating that the model is best fitted.

The above result can be justified by the research on yield forecasting of Rice and Wheat for Central Uttar Pradesh using **Statistical** Model by **Khan *et al.*,2020** in which **twenty three**years (1992-2015) **weather** data of rainfall (mm), Maximum and Minimum temperature (^{o}C), maximum and minimum relative humidity (%) and yield data of rice and wheat crop for 12 districts were used for yield prediction using **statistical** method under FASAL Project, Department of Agronomy, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur Uttar Pradesh. The regression equation was generated for statistical method using **SPSS** package. The models were validated using 2 year (2016 and 2017) data. The result indicated that **model**explained 45 to 73 percent variation in rice crop yield and 49 to 74 percent variation in **wheat** crop in different districts.

Table 4.Rice yield forecast equation using stepwise regression method based on different parameters.

Parameter	Model	Yield forecast equation	R^2	Std. Error
Bright Sunshine Hour	1	Y=3050.840+1.680(Z251)	0.406	260.872
	2	Y=2952.795+2.193(Z251)+51.442(TIME)	0.651	212.258
	3	Y=5520.653+2.084(Z251)+90.284(TIME)+2.942(Z131)	0.866	140.41
	4	Y=4218.547+2.711(Z251)+49.740(TIME)+3.797(Z131)+0.079(Z250)	0.946	96.51
Actual Evapotranspiration	1	Y= 1510.268+43.649*(TIME)	0.673	263.577
	2	Y=1944.048+51.035*(TIME)+1.40*(Z251)	0.782	219.598
	3	Y=3446.649+60.969*(TIME)+1.327*(Z251)+1.811*(Z131)	0.844	189.546
	4	Y=2260.633+55.417*(TIME)+1.796*(Z251)+1.783*(Z131)+0.043*(Z250)	0.875	173.237
Weighted and Unweighted	1	Y= 1588.077+35.641*(TIME)	0.556	248.822
	2	Y=2049.774+43.823(TIME)+1.499(Z241)	0.756	188.501

Weekly Weather	**1**	Y= 1588.077+35.641*(Time)	0.556	248.82

Development of Statistical Regression Model using Weighted and Un-weighted Parameter

In this **case** only two models had been developed. Model 1 has taken time as an independent factor to estimate the rice yield for Prayagraj region having R^2 value of about 0.55 and Model 2 has taken time and Z241 as the independent variable which has explained the 75% variation by them. **Thus** Model 2 was used to obtain **forecasted** yield of rice for Prayagraj (Table 4). It was observed for 2018 and 2019 model **had** underestimated the yield of rice **crop**(Table 5)**where** for the year 2017 Model **has** predicted the rice yield nearby **actual** yield, so it may be inferred that **Model has**performed well for 2017.

As a justification of work,a study is conducted by **Kakati*et al.*, 2022,** yield forecasting models which are based on simple weather variables and composite weather variables (weighted and un-weighted) **for period**of 1992-2018, various multiple linear regression equation **is** obtained for the forecasting of **yield** of rapeseed and mustard.

Development of Statistical Regression Model Using Bright Sunshine Hour with Weighted & Un-weighted Parameter

Total**four** multivariate statistical models for rice yield had been developed using **stepwise** regression technique in SPSS. The best model from the total four models was used to obtain **forecasted** yield of rice for Prayagraj. In this **case** model four has taken Z251, Z131, Z250 and time as an independent **factor**to estimate the rice yield for Prayagraj region having R^2 value of about (0.94) It may be observed from **the** (Table 4) that model number four has been the best model with 94% variability explained by the parameters used in **equation.**It was observed that for the year 2019 (Table 5), Model 4 **has** overestimated the rice yield whereas for year 2017 it has underestimated the yield of **rice crop**. For the 2018 **Model 4 has**predicted the rice yield nearby **actual** yield, so it may be inferred that Model has performed well for 2018.

A samesort of research is conducted by **Rajavel*et al.*,2018**, the models are developed to forecast **district level**yield of rice in Chhattisgarh in mid-season, **multi variate**models has been developed based on BSS for **period** of 2014 and 2015. **Forecast** yield obtained is validated with **actual** yield of **corresponding** year to find the accuracy of **developed** model.

Methods		**2017**		**2018**		**2019**	
		Predicted Yield	**Error %**	**Predicted Yield**	**Error %**	**Predicted Yield**	**Error %**
Bright Sunshine Hour	**Model 1**	2315	15.6	2113	13.75	2438	13.74
	Model 2	2608.60	4.93	2397.43	23.15	2873.21	7.939
	Model 3	2521.54	8.10	2951.41	5.403	3307.75	-5.98
	Model 4	2396.01	12.6	3050.16	2.238	3347.20	-7.24
Actual Evapotranspiration	**Model 1**	2823.79	-2.9	2872.44	7.934	2921.08	6.405
	Model 2	2708.40	1.29	2591.85	16.92	2913.67	6.642
	Model 3	2560.40	6.69	2825.12	9.451	3058.41	2.005
	Model 4	2605.20	5.05	2894.44	7.229	3159.65	-1.23
Weighted and Unweighted	**Model 1**	2550.38	7.05	2586.02	17.11	2621.66	15.99
	Model 2	2576.01	6.12	2440.40	21.78	2774.16	11.11

Weekly Weather	**Model 1**	2550.40	7.05	2586.04	17.11	2621.68	15.99
Artificial Neural Network	**Model 1**	2533.87	7.65	2861.5	8.285	2954.19	5.344

Table5. Validation of Rice yield forecast models &error analysis.

Development of Statistical Regression Model Using Actual Evapotranspiration with Weighted & Un-weighted Parameter

In this **study** the **four yield**prediction model has been developed for rice **crop**. Model 4 has shown the R^2 value (0.87) with the variable i.e. minimum temperature& maximum relative humidity, maximum temperature& minimum temperature, minimum temperature & maximum relative humidity& time. Four models are used to obtain **forecasted** yield of rice for Prayagraj. It may be observed from **the** (Table 4) that model number four has been the most suitable model with 87% variability.It was observed that for the year 2019, Model 4 **has** overestimated the rice yield whereas for year 2017 it has underestimated the yield of **rice crop.** For the 2018 Model 4 **has** predicted the rice yield nearby **actual** yield, so it may be inferred that Model has performed well for 2018, it can be observed from (Table 5). This model was used to obtain **forecast** yield of rice for Prayagraj.

Based on the results conducted by **Patil and Puttanna, 2009**, a model has been generated to predict **yield** of finger millet with time for Banglore area. A **multi linear**statistical equation has been developed based on GDD, actual Evapotranspiration and BSS for **period of**1988-2005. This same model was used to forecast the yield of finger **millet for**Kharif 2005.

Rice yield forecasting using machine learning approach (ANN)

The model summary deals with Training and Testing within the sum of square **error** of 3.462 & 1.641 respectivelyhas been mentioned in Table no 6.It may be **observed** from the Fig.2 that thecoefficient of determination was 0.66 between the yield predicted by the ANN and observed yield. **Rice** yield model developed using ANN approach has explained 66% variability in rice due to weather parameters. It was observed that for the year 2019, **model has**underestimated the rice yield whereas for **year** 2017 **has** predicted the rice yield nearby **actual** yield, so it may be inferred that the ANNmodel developed by using MLP **has**performed well for **year** 2017.

The percent deviation for **testing**period was observed to vary from **range**5.34 to 8.28 % (Table no.5), which had come under the accepted range of PD. It implies that **model** has perfectly predicted the yield of rice **crop** with **maximum** deviation of about 8%.

Table 6. Model summary of neural network model for training and testing for single network

Training	Sum of Squares Error	3.462
	Relative Error	0.346
	Stopping Rule Used	1 consecutive step with no decrease in error
	Training Time	0:00:00.02
Testing	Sum of Square Error	1.641

	Relative Error	1.279

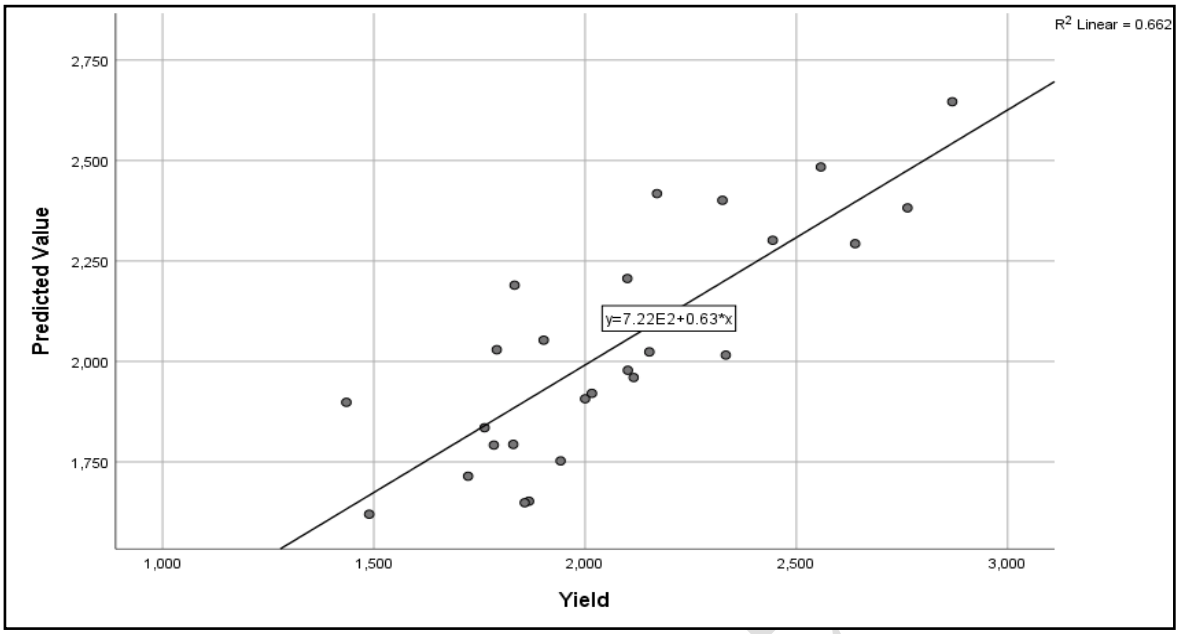

Fig.2. Comparison between actual and predicted yield

A study is conducted by **Emamgholizadeh *et al.*., 2015**on 'Seed yield prediction of sesame using artificial neural network'. In this study, two methods namely artificial neural network (ANN) and multiple regression model (MLR) were employed to estimate the seed yield of sesame (SYS) from readily measurable plant characters. The ANN and MLR were tested using field data. Results showed that the ANN predicts accurately with a root-mean-square-error (RMSE) of 0.339 t/ha and a determination of coefficient (R^2) of 0.901.

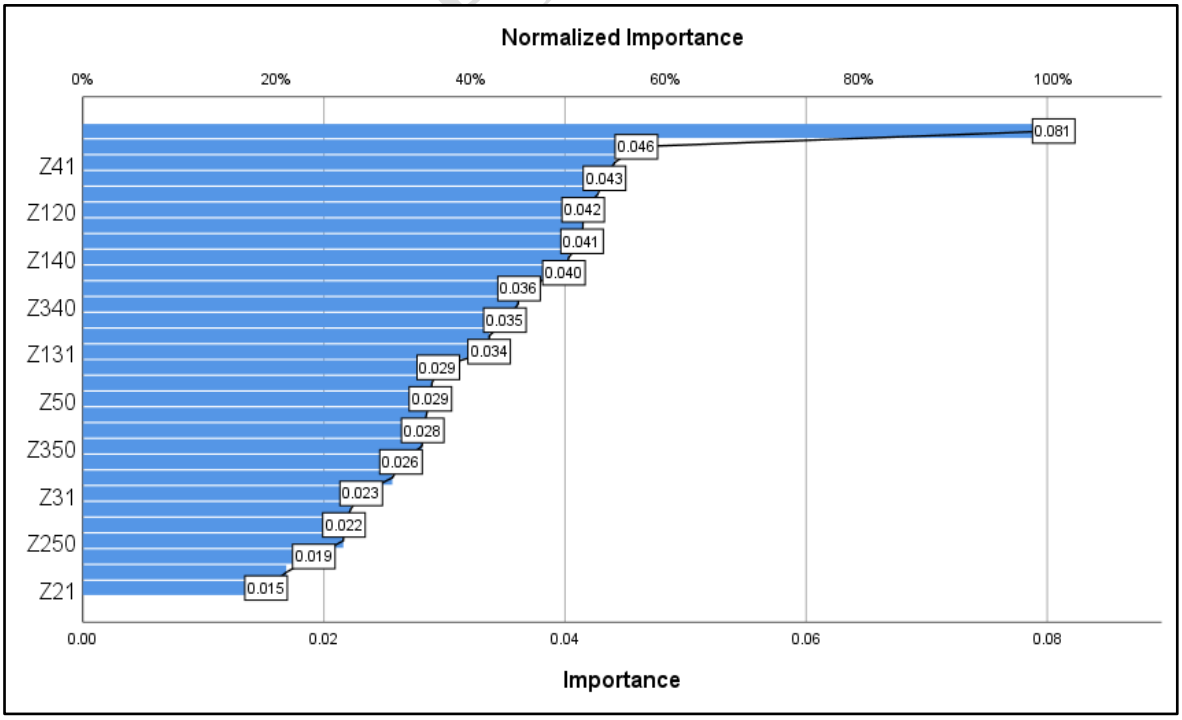

Fig.3. Relative contribution of predictors (weighted and un-weighted weather variables)

Fig.3. presents the relative contribution of predictors (weighted and un-weighted weather variables) to the prediction of rice yield, obtained by ANN. The vertical axis represents **top**ten input variables (weighted and **un-weighted**weather variables) plotting the highest contributing variable (largest sum of square derivative SSD value) at the top andother variables below in their decreasing order of contribution to **prediction** of a given variable. The scale of the horizontal axis varies with the differentmean importance. The variable having the highest SSD value (i.e, the highest contribution) is assigned a value of 100%. Other variables are assigned this value (in %) based on their SSD values in comparison to the SSD value of the highest contributing variable.

The predictors have significant contributions **for** the yield prediction of rice (Fig. 3).Results indicate that **predictor**, followed by the morning relative humidity (Z41) is the most important **determinants** of yield prediction.

Performance analysis of fitted models for different methods

The accuracy of the predicted model has been presented with the help of RMSE and nRMSE. Among the regression models developed using **stepwise** regression technique, the best models are taken to compare **it**with the ANN model.

It may be observed from **the** (Table 7) that the model developed with regression technique having BSS and AET as additional input with the weighted and un-weighted weather parameters has shown **best** results with **least**nRMSE, followed by ANN network approach, weighted& un-weighted **model** and lastly by model developed by weekly weather parameters. If we go through **by**RMSE, then the modeldeveloped using AET has shown best result among all.

Table7. Inter comparative study of Regression and ANN based fitted best models with accuracy measure of RMSE &nRMSE

Weekly Weather		**Bright Sunshine Hour**		**Weighted and Un-weighted**		**Actual Evapo-transpiration**		**Artificial Neural Network**	
RMSE	**nRMSE**	**RMSE**	**nRMSE**	**RMSE**	**nRMSE**	**RMSE**	**nRMSE**	**RMSE**	**nRMSE**
0.436	0.0061	0.242	0.00025	0.451	0.00135	0.154	0.00027	0.215	0.00051

Conclusion

The effort demonstrated that regression techniques can be utilized for yield prediction for the area with satisfactory results. **In order to**predict the yield, **Regression** model and ANN is utilized as a **prediction** tool as yield should be **dependent** variable and weather parameters should be **independent** variable. Every model is run a few times to deal with conceivable estimations of normalized root mean square and R^2 statistics values. By utilizing the best method for the investigation, the forecast of **generation** of rice **crop** is done for chosen years. The outcomes demonstrate that the proposed regression model is a suitable method for foreseeing yield production. The results of different models are compared based **upon** the normalized root mean square, R^2 statistics and percentage prediction error. The model which gives the lower Normalized root mean square, percentage prediction error and Higher R^2 statistics values is considered to be the best model for crop yield prediction.

From the recent study, **development of yield**prediction model of rice **crop** using various statistical methods and machine learning **approach** shows the **best performing**method. It may be observed that the **best fitted**model based on performance analysis, the Model-4 of Bright Sunshine Hour with weighted and un-weighted weather **parameter** had the least nRMSE value of **0.00025** and higher variability of 94% among all other models.

As Bright Sunshine **Hour based**model had **least**nRMSE value from all the models selected from **different technique**used in the study, Thus Bright Sunshine Hour with weighted and un-weighted weather **parameter** is considered as the most accurate and reliable weather variable for the prediction of rice crop yield.

Reference

Banakara, K. B. and Popat R. C., Amaresh and Pandya H. R. (2018). Pre-harvest forecast of Kharif Rice using weather parameters in Bharuch district of Gujarat state. Int. J. Chem. Stud., 6(6), 1111- 1116.

Chauhan, V.S., Shekh, A.M., Dixit, S.K., Mishra, A.P. and Kumar,S. (2009). Yield prediction model of rice in Bulsar district of Gujarat. J. Agrometeorol., 11 (2): 162-168.

Diwan, U. K., Puranik, H. V., Das, G. K. and Chaudhary, J. L. (2018). Yield prediction of wheat at preharvest stage using regression based statistical model for 8 district of Chhattisgarh, India. Int. J. Curr.Microbiol. Appl. Sci.,7(1):2180-2183,

Fausett, L.V., 1994. Fundamentals of Neural Networks: Architectures, Algorithms, and Applications. Prentice-Hall, Upper Saddle River, NJ, USA.

Ghosh K, Balasubramanian R, Bandopadhyay S, Chattopadhyay N, Rathore SK, LS, (2014) Development of crop yield forecast models under FASAL- a case study of kharif rice in West Bengal. J Agrometeorol 16(1):1–8
Haykin, S., 1994. Neural Networks: A Comprehensive Foundation, second ed. Prentice Hall, Upper Saddle River, NJ, USA.

Kakati, N.; Deka, R.L.; Das, P.; Goswami, J.; Khanikar, P.G.; Saikia, H. 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. 2022, 150, 1201–1215.

Kalubarme, M.H., and Ahuja, S.C. (1996).Agrometeorological rice yield modelling in Karnal. J. Indian Soc. Remote Sens., 24:125– 132.

Kumar N., Pisal R., Shukla, S. P. and Pandey, K. K. (2014).Crop yield forecasting of paddy, sugarcane and wheat through linear regression technique for south Gujarat.Mausam. 65: 361-364.

Latwal, A., Nain, A. S., Jha, A. and Ranjan, R. (2017). Wheat yield prediction using satellite data and meteorological parameters for Udham Singh Nagar district of Uttarakhand. Int. J. Basic Appl. Agril. Res., 15(3): 130-132.

Naushad Khan, Ajay Kumar, Vijay Dubey, C.B. Singh, Sanjeev Kumar and Shubham Singh. 2020. Estimated Yield Forecasting of Rice and Wheat for Central Uttar Pradesh using Statistical Modal.*Int.J.Curr.Microbiol.App.Sci.* 9(8): 2490-2495.

Patil C. S. and Puttanna B., 2009, 56Influence of actual evapotranspiration, growing degree days and bright sunshine hours on yield of finger millet", Mausam, 60, 3, 343-348

Rajavel M, Khare P, Prasad JR, Singh KK, Puranik HV, Das GK. Development of Rice Yield Forecast in Midseason Using Weather Indices based Agrometeorological Model in Chhattisgarh VayuMandal. 2018;

44(1):38-45.

Rumelhart, D., Hinton, G. & Williams, R. Learning representations by back-propagating errors. *Nature* 323, 533–536 (1986).

SamadEmamgholizadeh, M. Parsaeian, Mehdi Baradaran,. Seed yield prediction of sesame using artificial neural network, European Journal of Agronomy, Volume 68, 2015, Pages 89-96, ISSN 1161-0301,

Tufail, M., Ormsbee, L., Teegavarapu, R., 2008.Artificial intelligence-based inductive models for prediction and classification of fecal coliform in surface waters. J. Environ. Eng. 134 (9), 789e799.

Wasserman, P.D., 1989. Neural Computing: Theory and Practice. Van Nostrand Reinhold Co., New York.

1. https://mail.ijsdr.org/viewpaperforall.php?paper=IJSDR2210154

   Stepwise linear regression technique and neural network used for predicting the yield of rice crop. Performance analysis. Keywords: Yield forecasting……

2. https://www.studocu.com/in/document/university-of-delhi/introductory-econometrics/article-38-predicting-crop-yield-using-mulch-regression-model/24458799

   Article 38- Predicting Crop Yield Using Mulch Regression ...Article 38 - dont use it its useless - Abstract Yield prediction ...

3. https://www.coursehero.com/file/205241107/FINAL-REPORTdocx

   Due to the substantial increase in the population, the nutritionalstatus of the poor is growing bad, which must be improved.

4. https://www.coursehero.com/file/205241107/FINAL-REPORTdocx

   The major effect of populationincrease has been prominently shown on the environment, the damage of which is increasingrapidly, which ultimately hinders ...

5. https://www.nature.com/articles/s41598-021-97221-7

   Agriculture has always been…..

6. www.nature.com › articles › s41598/021/97221-7An interaction regression model for crop yield prediction

7. https://www.scribd.com/document/462089875

8. www.ncbi.nlm.nih.gov › pmc › articlesAn interaction regression model for crop yield prediction – PMC

9. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8423743

10. www.researchgate.net › publication › 338230926_WheatWheat yield prediction using satellite data and meteorological...
11. https://www.ijcmas.com/9-8-2020/Naushad%20Khan,%20et%20al.pdf
12. https://www.ijcmas.com/abstractview.php?ID=18845
13. https://www.ijcmas.com/9-8-2020/Naushad%20Khan,%20et%20al.pdf
14. https://www.scribd.com/document/462089875/Prediction-of-Crop-Yield-using-Regression
15. ijcmas.com

References

1. **1986**
2. **1989**
3. **1994**
4. **1994**
5. **1996**
6. **2008**
7. **2009**
8. **2009**
9. **2014**
10. **2014**
11. **2015**

---------- 11 Old ones----------

12. **2018**
13. **2018**
14. **2020**

---------- 03 -Old ones, but within 2015-2020----------

15. **2022**

---------- Recent one----------