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Yield prediction of rice using weather based statistical model in Bilaspur District of Chhattisgarh (2019)

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Abstract
Weather and climatic condition plays on important role for growing the crops. Weather affect the crop growth at different phenological phase and thus responsible for variation in yields from year to year and place to place. These differences in weather and climatic conditions at different areas, regions and states helps us to select or grow the suitable crops according to that area so, that the formers can achieve maximum yield and profit. A research has been made in this paper to study the effect of vital weather parameters on rice yield and to develop a multivariate statistical model for yield forecast of Bilaspur district of Chhattisgarh. On the basis of 18 years (2000-2017) weather and rice production data 7 models have been developed using SPSS software. Result revealed that model 7 has the highest R^2 value 0.99, which describes the 99% variability in rice yield due to weather parameters i.e. Bright Sunshine Hours of 12th Week after Sowing, Minimum Relative Humidity of 4th Week after Sowing, Bright Sunshine Hours of 10th Week after Sowing, Minimum Temperature of 9th Week after Sowing, Maximum Relative Humidity of 1th Week after Sowing, Maximum Temperature of 10th Week after Sowing and Rainfall of 11th Week after Sowing. This may be due to more weather factors involved in the Model 7, instead of any other models.

Keywords: Rice, Multivariate model, SPSS

Introduction
Rice is the most important cereal crop in India Rice occupies an area of around 43.6 (kharif 39.6 and rabi 4.0) million hectare and recorded nearly 2.1 tonnes /ha productivity of rice in year 2015-16 (kharif 2.0 tonnes/ha and rabi 3.1 tonnes/ha), (Economic Survey, 2015-16). Rice is cultivated in an area of 43 million ha with a total production of 86.30 million tonnes (Singh *et al*., 2001).

India is the second largest producer and consumer of rice in the world after China and has an area of over 439.49 lakh ha. With the production of 106.54 million tonnes and productivity 2424 kg/ha in 2013-14. (Indian budget 2015) It occupies about 23.3% of the food grain production and 55% of cereal production. Accounts for 21 percent of the world's total rice production. Chhattisgarh state, famous as "Rice bowl of India", occupies an area around 3756.80 thousand hectare with the production of 5.22 million tonnes and productivity of 2050 kg/ha (Krishi dairy 2016). Rice is mainly grown under rainfed conditions, which is about 50.52% of geographic area of Chhattisgarh plain and 28.62% of Bastar plateau and 20.86% of Northern hill agro climatic zones (Pandey *et al*., 2005; Verulkar *et al*., 2010). The prime causes of low productivity in chhattisgarh are limited irrigation 28%, lack of improved varieties under different ecosystem and inappropriate nutrient, several insect pest concentration and crop management practices. Bilaspur has a tropical climate. The summers here have a good deal of rainfall, while the winters have very little. The production and productivity of rice is low in Chhattisgarh and India as compared to world production. Amongst various constraints for low productivity of rice the insect's pests and diseases are very important. However, the productivity of rice in the state is much lower than national average productivity level.

Weather and climate greatly affect agricultural productivity in any region. Agricultural production of any region is being regulated by the prevailing climate of that area through temperature, rainfall, light intensity, radiation, sunshine duration etc. (Sastri 2010). The importance of temperature and humidity in enhancing plant nutrient availability and role in disease and pest infestation is well documented. Relationship between two or more weather parameters with grain yield of crops can be used for yield prediction well before the actual harvesting of the crops (Sastri *et al*., 1996). Although the climate is the least manageable part of environmental resources, yet a better understanding of the climatic resources and their interactions with agricultural parameter can help to increase the crop productivity (Goswami *et al*., 2006). The major weather parameters affecting growth and yield include solar radiation, temperature and rainfall. Temperature, solar radiation and rainfall are important weather factors that influence rice yield directly by affecting the physiological processes involved in grain production and indirectly, through their effect on diseases and insects pest. Empirical statistical model are developed on the basis of long term relationship between crop yield and several variables (representing weather, soil characteristic, technology trend, etc.) The independent variables are either measured meteorological parameters such as temperature, rainfall, solar radiation or estimates such as potential evapo-transpiration, simulated soil moisture regime etc. The weighting coefficients in these equations are by necessity obtained in an empirical manner using standard statistical procedure such as multiple regression analysis. This approach does not easily lead to an explanation of cause and effect relationships. Advantages of these methods are ease in formulation and analysis, simplicity and good performance in spite of their obvious limitations. (Joshi, 2008).

Therefore, while considering the effect of weather on yield we must consider in addition to rainfall, the distribution of rainfall, maximum and minimum temperature, humidity and such other things over different months/weeks days of the year. These weather variables affect the crop differently during different stages of its growth. Thus weather needs to be recognised as a multidimensional phenomenon. Once the detailed knowledge has been acquired of how, and at what growth stages, climatic factors influence the yield, it is possible to derive complex variates that give appropriate weight to the different factors for correlation with yield in naturally varying climates, and use them to predict yield from meteorological records (Watson 1963).

Crop yield is mostly affected by technological changes and weather variability. It can be assumed that the technological factors will increase yield smoothly through time and therefore, year or other parameters of time can be used to study the overall effect of technology on crop yield. The variability both within and between seasons is the second and uncontrollable sources of variability in yields Weather variables affect the crop differently during different stages of development.

Materials and methods

Study area

Bilaspur is located in Chhattisgarh (22° 33' to 21° 14' N Latitude and 82° 6' to 81° 38' E Longitude.) The average temperature in Bilaspur is 26.8 °C. Average precipitation is around 1259 mm (Rice zone) of the state. The weekly maximum and minimum temperature were recorded as 38.1 and 20.5 °C respectively.

Crops yield data

Yearly production (q) and area (ha) under crop in Bilaspur district for the period 2001-2017 were collected from the (Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare). For each year, the total production of the district was divided by the total acreage to calculate the Rice Productivity.

Weather data

The weekly Average data of weather parameters *viz.* (Maximum temperature (ºC) Minimum temperature (ºC) relative humidity minimum (%) relative humidity maximum (%) Bright sunshine hours/day Annual Rainfall (mm) of the respective years Bilaspur district from year 2001-2017 was collected from the agro meteorological observatory located in I.G.K.V. Raipur Chhattisgarh.

Software- SPSS

SPSS (Statistical Package for the social science) its first version was released in 1968 after being developed by Nie and Hull. SPSS is the most widely used among the programs used for statistical analysis in social science. SPSS places constraints on internal file structure, data type, data processing and matching files, which together consider as the simplified programming. Parameters used in SPSS are yield of rice and weather variable.

Development of Statistical Model

Spatio temporal variability in rice crop productivity and climatic variables has been studied in this study using different statistical procedure. The statistical models were developed for yield production of rice for Bilaspur district using SPSS software. Multiple linear regressions equations have been developed between the dependent variable (yield) and independent variables (weather parameters). The goal of multiple linear regressions (MLR) is to model the relationship between the explanatory and response variables. The model for MLR, given n observations, is:

$$Yi = B0 + B1Xi1 + B2Xi2 + \_\_\_\_\_ + BpXip + E$$

Where i = 1, 2... n

Yi = Dependent Variable, X= Independent Variables, B1, B2……are regression coefficient, Bp = slope coefficients for each independent variable, E = the models error term.

In order to find out the relationship between weather variables and rice yield correlation analysis was carried. Correlation studies between yields of crop with the various weather parameters were carried out with the help of methodology described by Gomez and Gomez (1984).

Results

Relationship between weather variable and rice yield

The correlation between weather variables and rice yield was done to assess the impact of different variables prevailed during the crop season for the different stages which were significant in making use of the weather resources for the production of rice yield are considered. Correlation study between yield of the rice crop with the various weather parameters were carried out Bilaspur district with the help of methodology described by Gomez and Gomez (1984). For this study, the correlation between weekly weather parameters and yield of rice crop has been established. The length of each growth stage is greatly influenced by temperature, rainfall, relative humidity and bright sunshine.

Correlation between rice yield and weather variables

The comprised of Bilaspur district correlation matrix for the rice yield and weather variables for season i.e. from 27th SMW (growing week) to 40th SMW (harvest week) was developed. The relationship of weather variables with the rice yield during the crop season for period 2000-2017 has been depicted in the Fig. 1.

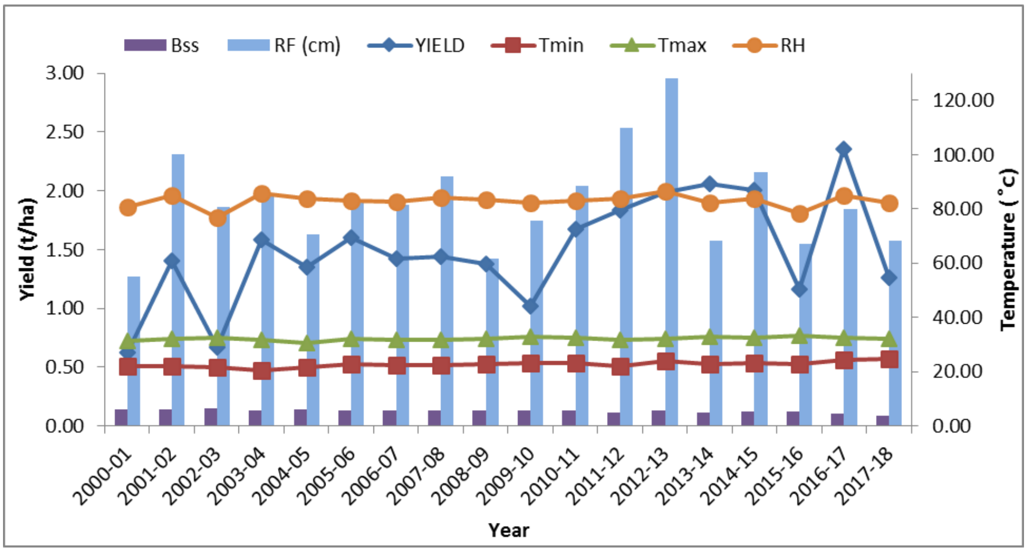


Fig 1: Seasonal variation between weather parameters and rice yield.

The result revolted that there was a significant positive and negative relationship between the weather variables and the yield of rice. Table 3 shows important weather variables sowing strong and positive/negative relationship between weekly weather variables of crop season and rice yield. The value of correlation coefficients is significant=1% there is positive and strong correlation between maximum relative humidity and yield during vegetative phase (27th SMW to 32th SMW) of rice, positive and strong correlation between maximum temperature and yield during reproductive phase (33th SMW to 35thSMW), positive and strong correlation between maximum relative humidity and yield during repining phase (37th SMW to 40th SMW) of rice, while a negative and strong correlation between bright Sunshine hours and yield during reproductive phase and repining phase (34th SMW to 38th SMW) of crop season. In case of rainfall overall there is positive correlation present between it and rice yield, but in the reproductive phase (33th SMW to 35th SMW) of crop season there is negative correlation present between it and yield. Rainfall overall there is positive correlation present between it and rice yield, but in the reproductive phase (33th SMW to 35th SMW) of crop season there is negative correlation present between it and yield. These implies that during germination and seed filling stage of rice crop requires water the results are in accordance with the study conducted by Jayabhai *et al.* (2014) on impact of weather variability on growth and yield of growth and yield of soybean under different plant geometries. They concluded that during emergence to seedling stage (P2) all weather variables showed highly significant positive association. While, seedling to branching (P3) stage rainfall (0.526**), Rainy days (0.440*) and RH-2 (0.564**) showed highly significantly positive correlation.

Development of multivariate statistical rice yield model

In this study the yield prediction model has been developed for rice crop. The multivariate statistical model for rice has been developed 7 models. Model 1 has shown the R^2 value (0.58) with the variable i.e. Bright sunshine hours of 12th week after sowing, model 2 has shown the R^2 value (0.73) with the variables i.e. Bright sunshine hours of 12th week and minimum relative humidity of 4th week after sowing, model 3 has shown the R^2 value (0.84) with the variables i.e. Bright sunshine hours of 12th week after sowing, minimum relative humidity of 4th week and bright sunshine hours of 10th week after sowing model 4 has shown the R^2 value (0.92) with the variable i.e. Bright sunshine hours of 12th week after sowing, minimum relative humidity of 4th week after sowing, bright sunshine hours of 10th week and minimum temperature of 9th week after sowing model 5 has shown the R^2 value (0.99) with the variable i.e. Bright sunshine hours of 12th week after sowing, minimum relative humidity of 4th week after sowing, bright sunshine hours of 10th week after sowing, minimum temperature of 9th week and maximum relative humidity of 1th week after sowing model 6 has shown the R^2 value (0.99) with the variable i.e. Bright sunshine hours of 12th week after sowing, minimum relative humidity of 4th week after sowing, bright sunshine hours of 10th week after sowing, minimum temperature of 9th week after sowing, maximum relative humidity of 1th week and maximum temperature of 10th week after sowing model 7 has the highest R^2 value (0.99), which describes the 99% variability in rice yield due to weather parameters i.e. Bright sunshine hours of 12th week after sowing, minimum relative humidity of 4th week after sowing, bright sunshine hours of 10th week after sowing, minimum temperature of 9th week after sowing, maximum relative humidity of 1th week after sowing, maximum temperature of 10th week after sowing and rainfall of 11th week after sowing. This may be due to more weather factors involved in the Model 7, instead of any other models. (Table no. 3)

Fig.1 Depicted that the RMSE values for observed rice yield during the estimation period (2000-2014) of model 1, 2, 3, 4, 5, 6 and 7 were 18.47%, 19.33%, 20.28%, 7.94%, 4.56%, 4.25% and 2.09%, respectively and for predicted rice yield during the period (2015-2017) of model 1, 2, 3, 4, 5, 6 and 7 were 36.58%, 32.37%, 29.85%, 19.77%, 23.80%, 28.05% and 27.41%, respectively.

Table 1: Generalized growth stages of Rice

Pheno phases	Growth stages	DAS	SMW
P1	Vegetative stage	1-42	27-32
P2	Reproductive stage	43-70	33-36
P3	Ripening stage	71-98	37-40

For Rice Crop in Bilaspur District of Chhattisgarh eight different models were developed with help of SPSS. Seven models were selected and tested on yield prediction of rice. The coefficient of determination of these multivariate models has been presented in Table 2 the highest R^2 value was of Model 7 (0.99), while lowest of Model 1 (0.58) with one parameter *i.e.* bright sunshine hours. Model

Table 2: Multiple variable equations and R^2 Value developed between Rice yield and weather parameters

S.NO.	MODEL	R^2
1.	$Y=2.47-0.175*BSS_{12}$	0.58
2.	$Y=1.055-0.16*BSS_{12}+0.02*RH_{min4}$	0.73
3.	$Y=1.91-0.14*BSS_{12}+0.02*RH_{min4}-0.15*BSS_{10}$	0.84
4.	$Y=6.66-0.20*BSS_{12}+0.015*RH_{min4}-0.2*BSS_{10}-0.19*T_{min9}$	0.92
5.	$Y=3.32-0.17*BSS_{12}+0.01*RH_{min4}-0.24*BSS_{10}-0.206*T_{min9}+0.046*RH_{max1}$	0.99
6.	$Y=2.69-0.18*BSS_{12}+0.01*RH_{min4}-0.24*BSS_{10}-0.22*T_{min9}+0.04*RH_{max1}+0.04*T_{max10}$	0.99
7.	$Y=3.29-0.18*BSS_{12}+0.008*RH_{min4}-0.25*BSS_{10}-0.22*T_{min9}+0.04*RH_{max1}+0.03*T_{max10}+0.001*R_{f11}$	0.99

Where, Y = Rice Yield (t/ha.), BSS_{12} = Average Bright Sunshine Hours of 12th Week after Sowing, RH_{min4} = Average Min Relative Humidity of 4th Week after Sowing, BSS_{10} = Average Bright Sunshine Hours of 10th Week after Sowing, T_{min9} = Average Min Temperature of 9th Week after Sowing, RH_{max1} = Average Max Relative Humidity of 1th Week after Sowing, T_{max10} = Average Max Temperature of 10th Week after Sowing, R_{f11} = Average rainfall of 11th Week after Sowing

Table 3: Correlation coefficient between weather parameter and grain yield of Rice at

Growth stage	SMW	T. Max	T. Min	RF	RH. Max	RH. Min	BSS
P1	27	-0.049	0.259*	0.278*	0.654**	0.492**	-0.221*
	28	-0.055	0.001	0.097	0.290**	0.202	0.200
	29	0.005	-0.053	0.281*	0.359**	0.162	-0.119
	30	-0.327**	0.441**	0.308**	0.476**	0.507**	-0.245*
	31	0.189	-0.024	0.496**	0.668**	0.539**	-0.253*
	32	-0.126	0.016	0.019	0.416**	0.558**	-0.026
P2	33	0.298**	-0.003	-0.304**	-0.274*	-0.273*	0.224*
	34	0.219*	0.108	-0.023	0.272*	0.039	-0.492**
	35	0.342**	0.082	-0.284**	-0.182	0.013	0.012
	36	0.275*	0.282*	-0.041	0.146	0.179	-0.522**
P3	37	-0.219*	0.136	0.249*	0.499**	0.431**	-0.565**
	38	-0.142	0.213	0.102	0.393**	0.483**	-0.649**
	39	-0.163	-0.070	0.461**	0.083	0.079	0.030
	40	0.259*	0.142	0.008	0.428**	0.269*	-0.101

*Significance of $r \geq 0.217$ at 5%, **Significance of $r \geq 0.283$ at 1%.

Table 4: Comparison between observed and predicted Rice yield for Bilaspur using Multivariate - meteorological yield model. (1, 2, 3, 4, 5, 6 and 7)

YEAR	YIELD	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7
2000-01	0.62	1.28	1.21	1.19	0.90	0.71	0.55	0.63
2001-02	1.40	1.12	1.42	1.47	1.32	1.47	1.35	1.39
2002-03	0.67	0.77	0.92	0.98	0.80	0.69	0.62	0.70
2003-04	1.58	1.60	1.82	1.80	1.56	1.62	1.53	1.61
2004-05	1.35	1.44	1.67	1.46	1.33	1.47	1.31	1.37
2005-06	1.60	1.44	1.87	1.91	1.51	1.60	1.49	1.62
2006-07	1.43	1.16	1.44	1.65	1.47	1.47	1.39	1.45
2007-08	1.44	1.44	1.53	1.57	1.39	1.53	1.39	1.47
2008-09	1.38	1.82	2.02	1.99	1.52	1.47	1.34	1.42
2009-10	1.02	1.16	0.94	1.15	0.79	1.07	0.95	1.03
2010-11	1.68	1.82	1.96	1.86	1.64	1.70	1.61	1.74
2011-12	1.84	1.70	1.71	1.86	1.90	1.91	1.75	1.86
2012-13	1.99	1.82	2.20	2.23	1.94	2.02	1.90	2.02
2013-14	2.06	2.02	2.00	2.19	2.06	2.06	2.01	2.07
2014-15	2.01	1.56	2.02	2.44	2.11	2.12	2.00	2.06
2015-16	1.16	1.30	1.44	1.73	1.56	1.54	1.49	1.53
2016-17	2.35	1.70	1.95	2.29	2.27	2.54	2.45	2.51
2017-18	1.26	2.02	2.00	1.86	0.90	0.76	0.56	0.62

Table 5: Comparison between observed and predicted RMSE%

Multivariate Models	Estimated		Predicted		
	RMSE	RMSE%	RMSE	RMSE%	Std. Error of the Estimate
MODEL 1	0.27	18.47	0.58	36.58	0.293326
MODEL 2	0.28	19.33	0.52	32.37	0.246954
MODEL 3	0.30	20.28	0.48	29.85	0.195433
MODEL 4	0.12	7.94	0.31	19.77	0.142461
MODEL 5	0.07	4.56	0.38	23.80	0.049338
MODEL 6	0.06	4.25	0.45	28.05	0.030851
MODEL 7	0.03	2.09	0.44	27.41	0.017847

Conclusion

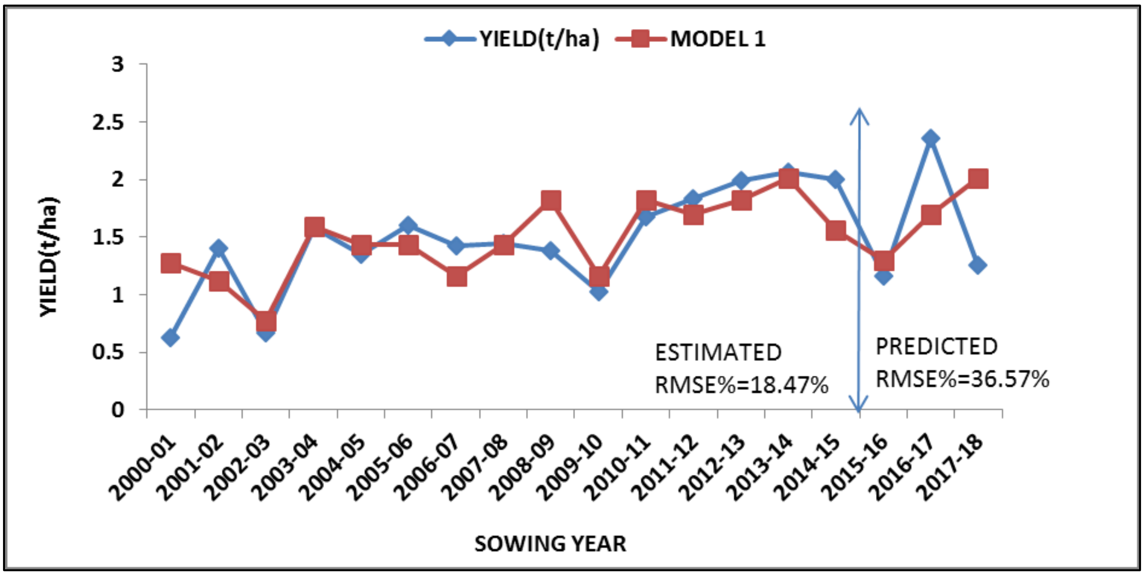
From the study it was concluded that weather plays an important role in rice production in Chhattisgarh in different phonological stages.

1. Weather variable have both positive & negative correlation with rice yield, it was found that maximum relative humidity plays important role in 27th to 32th SMW which lies in vegetative stage of rice. While rainfall & bright sunshine hours has negative correlation with the rice during reproductive phase.
2. From the study it was also inferred that out of 7 yield prediction model, the 7th model having weather parameter *i.e.* bright sunshine hours of 12th week after sowing, minimum relative humidity of 4th week after sowing, bright sunshine hours of 10th week after sowing, minimum temperature of 9th week after sowing, maximum relative humidity of 1th week after sowing, maximum temperature of 10th week after sowing, rainfall of 11th week after sowing, play an important role in yield prediction of rice for Bilaspur district.
3. Model 7 shows the best performance among the all models.

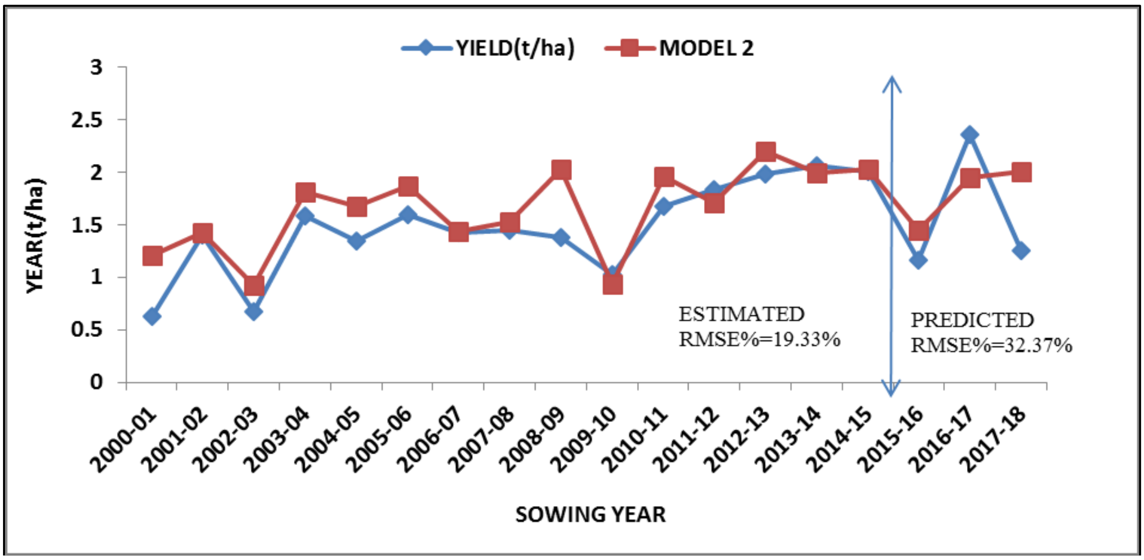
Equation used in model 7 is

$$Y = 3.29 - 0.18 \times BSS_{12} + 0.008 \times RH_{min4} - 0.25 \times BSS_{h10} - 0.22 \times T_{min9} + 0.04 \times RH_{max1} + 0.03 \times T_{max10} + 0.001 \times R_{f11}$$

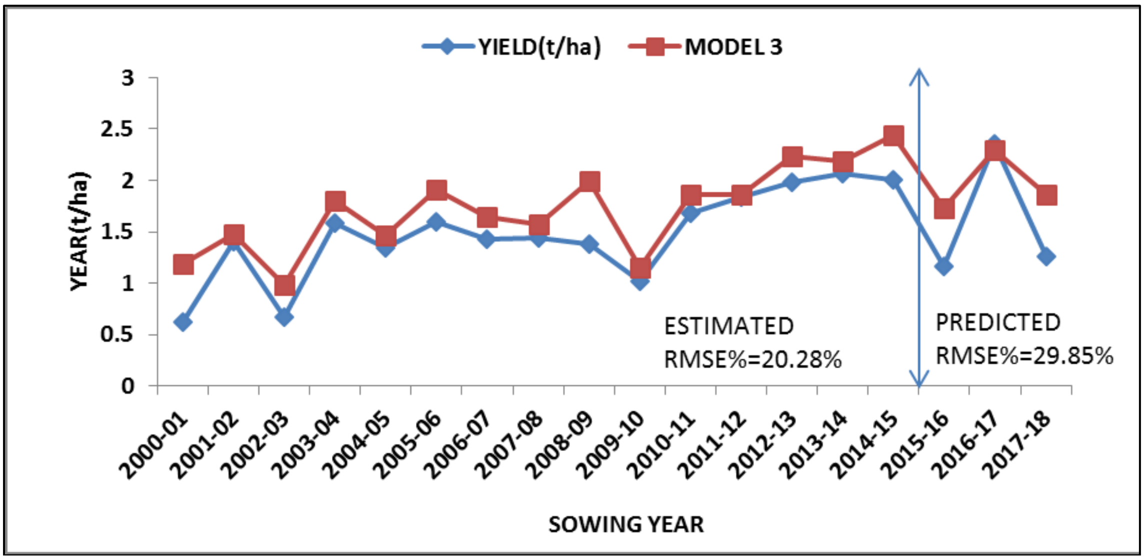
Using this equation we can predict the rice yield for upcoming years. Thus this study is helpful for yield prediction of rice in case of Bilaspur district.



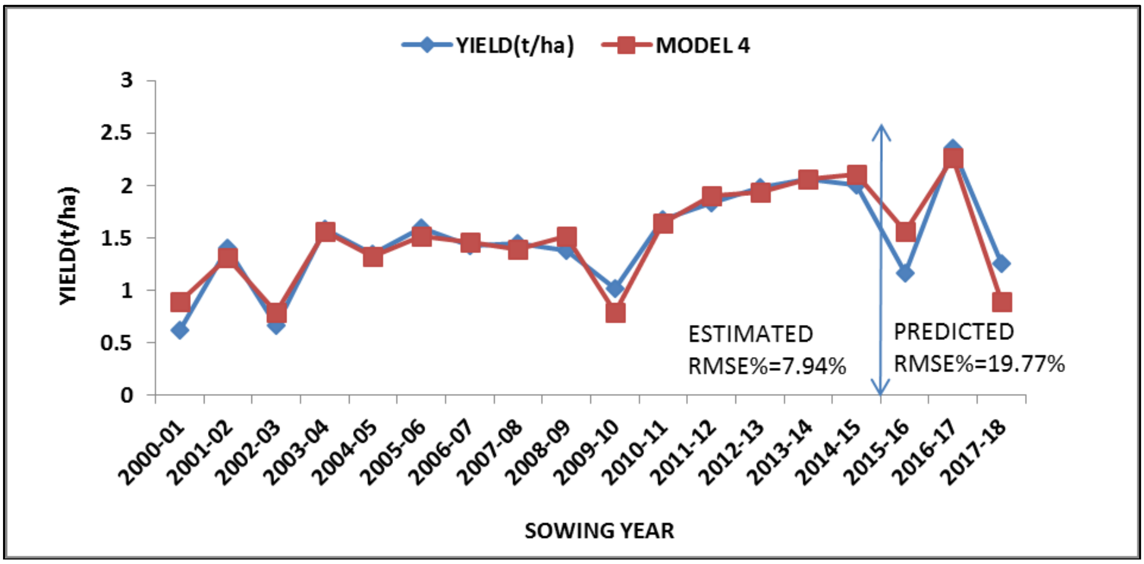
Model 1: Shown the R2 value (0.58)



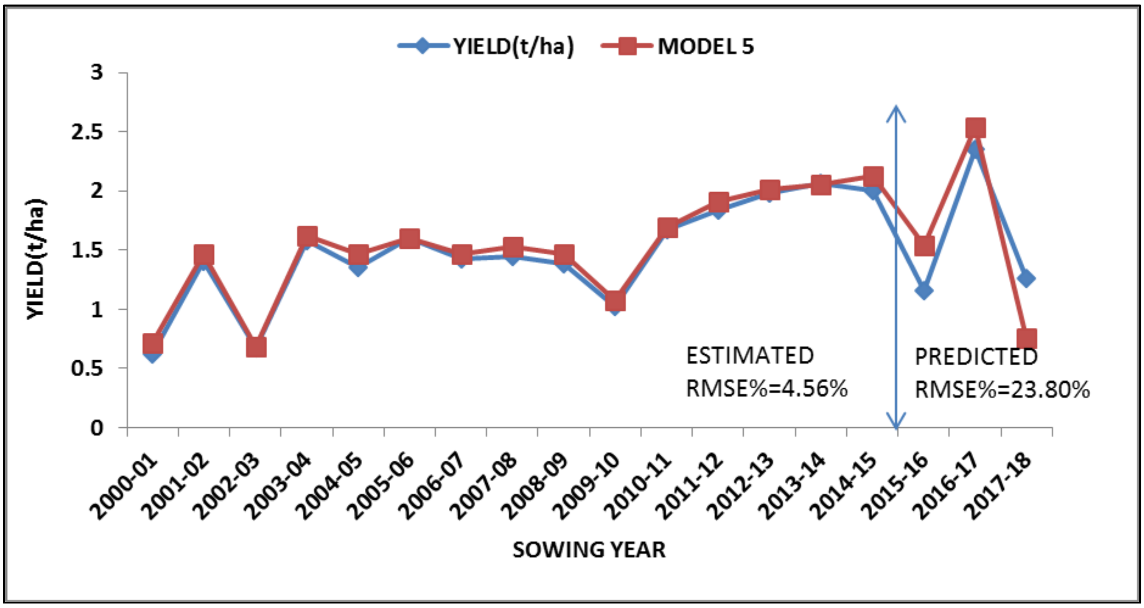
Model 2: Shown the R2 value (0.73)



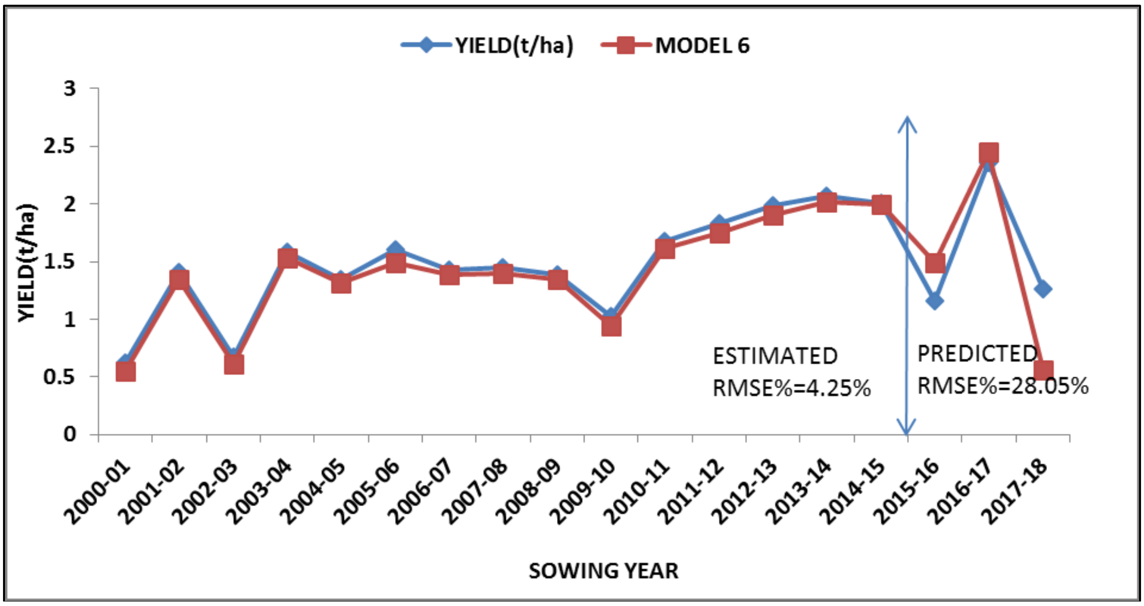
Model 3: Shown the R2 value (0.84) with the variables i.e



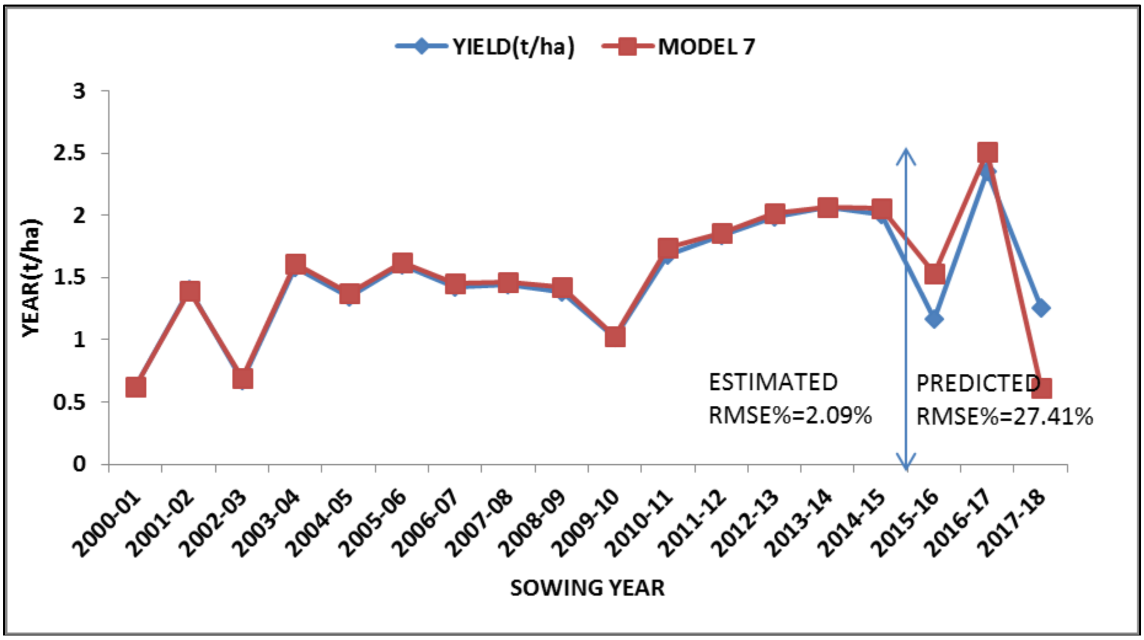
Model 4: Shown the R2 value (0.92)



Model 5: Shown the R2 value (0.99)



Model 6: Show the R2 value (0.99)



Model 7: Show the highest R2 value (0.99)

References

1. Abdi, H. Coefficient of variation. Encyclopedia of research design. 2010; 1:169-171.
2. Adejuwon, Odekunle. Variability and the Severity of the “little Dry Season” in southwestern Nigeria. The Bulletin of the American Meteorological Society, 2006, 483-493.
3. Adejuwon. Crop yield Response to Climate Variability in the Sudano- Sahelian Ecological Zones of Nigeria in southwestern Nigeria. In AIACC Report of Workshop for Africa and Indian Ocean Island. Dakar Senegal, 2004, 15-16.
4. Agrawal R, Jain RC, Jha MP. Models for studying rice crop-weather relationship. Mausam, 1986; 37(1):67-70.
5. Akpenpuun TD, Busari RA. Impact of climate on tuber crops yield in Kwara State, Nigeria. American International Journal of Contemporary Research. 2013; 3(10):52-57.
6. Anonymous. State level Agriculture statistics, Directorate of Agriculture, Raipur, Chhattisgarh, India, 2010.
7. Auffhammer M, Ramanathan V, Vincent JR. Climate change, the monsoon, and rice yield in India. Climatic Change. 2012; 111(2):411-424.
8. Bhuarya SK. Agroclimatic analysis of chhattisgarh state with respect to sustainable crop production (doctoral dissertation, Indira Gandhi Krishi Vishwavidyalaya, Raipur), 2015.
9. Chaudhary JL. Rainfall-rice yields relationship-a case study for Chhattisgarh region of Madhya Pradesh in central India. Indian Journal of Agricultural Research. 1999; 33(1):31-34.
10. Choudhury S. The Assessment of production potential of Rice under stress (Moisture and Thermal) as well without stress condition in Raipur district using CERES – Rice model, Deptt. of Agrometeorology, College of Agriculture, I.G.K.V.V. Raipur (CG), 2003.
11. Chowdhury A, Sarwade G. Evaluating the effect of technology and weather fluctuations on rice yields in Punjab. Mausam. 1985; 36(2):209-214.

12. Cohen P, West SG, Aiken LS. Applied multiple regression/correlation analysis for the behavioral sciences. Psychology Press, 2014.
13. Das HP, Kamble MV, Shaikh SM. Impact of Climate Change on Agricultural Productivity in India, India Meteorological Department. Agricultural Meteorology Division, Pune, 1989, 411:5.
14. Datta D. Principles and practices of rice production. International Rice Research Institute, 1981.
15. Diwan UK, Puranik HV, Das GK, Chaudhary JL. Yield Prediction of Wheat at Pre-Harvest Stage Using Regression Based Statistical Model for 8 District of Chhattisgarh, India. International journal of current microbiology and applied sciences. 2018; 7(1):2180-2183.