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Fitting Statistical Model to Some Agricultural Dynamic Variables Maize (Zea Mays) Production and Productivity in Betul District

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Abstract

For the Betul District, stochastic models for maize production and productivity were fitted in this work. Linear model, Quadratic model, Compound model, Cubic model, and Power stochastic models were used. We utilised different comparison metrics to assess model fitting performance like R^2, adjusted R^2 and residual mean squared error. According to the findings, the compound and power models are the best at forecasting all of the important elements in Betul District.

Key Words: stochastic models; maize crop; r square; adjusted r square

Introduction:

Using the correlation & path analysis approach, this study identifies the noteworthy factors impacting maize output in Betul District and Madhya Pradesh as a whole. The region has the greatest direct influence on total maize output, whereas the price of maize has the greatest indirect influence. It shows that as the size of the region grows, so does productivity.

The comparison criteria like R^2, adjusted R^2 and residual mean squared error (RMSEE), compound and power are the best suited model for predicting for the crucial two elements production and productivity in the current study. Singh (2013) utilised a similar model fitting method and concluded that compound and power are the best statistical models based on different goodness of fit criteria. Betul, a maize crop, is one of the most significant Cereals crops in Madhya Pradesh, providing 6.0 percent. From 1988 to 2017, the area, production, and productivity all increased at a positive pace for 30 years in a row During the time, expanding the area, production, and productivity of maize shall be done by increasing the area, production, and productivity by 6.30 percent, production by 8.90 percent, and productivity by 2.60 percent.

Madhya Pradesh is the largest producer, accounting for 5.7 percent of national maize production, and similar areas, production, and productivity have all grown at a positive rate, with area increasing by 1.0 percent, production increasing by 2.70 percent, and productivity increasing by 1.70 percent during the period. Statistical methods and procedures should be utilised to correctly assess the scope of growth in order to attain this aim. I expect that the findings of the proposed research would be useful to farmers and researchers in determining or increasing the trend of area, production, productivity, price of maize crop and fertiliser distribution pattern in Betul District and Madhya Pradesh State.

Materials and Methods:

For the objective of the project, data on five essential parameters linked to maize will be collected for the Betul District. For 30 years, data from the Directorate of Economics and Statistics and M.P.Krishi.org will be collected (1988 to 2017).

Statistical Model Fitting:

The above-mentioned models' functional form is $Y_t = f\left(t_i, \beta_j\right); i = 1,2...,30 \;\; j = 1,2,3$

where, Y_t is the Maize output / productivity in the i**th** year, β_j is unknown parameter

to be estimated, P is Parameter and ε_t is random error i.e. $\varepsilon_{t'}$ s~ i.i.d. N (0, σ^2).
The five models were fitted on the data of year wise, one year at a time, up to the 30 year, which was the final step. These models' functional for RMSE are as follows:

1. Linear : $Y_t = \alpha + \beta_1 t + \varepsilon_t$ (1)
2. Quadratic : $Y_t = \alpha + \beta_1 t + \beta_2 t^2 + \varepsilon_t$ (2)
3. Compound: $Y_t = \alpha (\beta_1)^t \times \varepsilon_t$ (3)
4. Cubic : $Y_t = \alpha + \beta_1 t + \beta_2 t^2 + \beta_3 t^3 + \varepsilon_t$ (4)
5. Power : $Y_t = \alpha (t)^{\beta} \times \varepsilon_t$ (5)

where, Y_t = response of the i-th factor in the t-th year
α, β = unknown parameter, to be estimated, of the model, α (constant).
ε_t = multiplicative error

The linear models' parameters were calculated using the ordinary least squares (OLS) approach. The parameters of nonlinear models with multiplicative error terms were linearized using appropriate transformations, and the model parameters were estimated using the OLS approach.
These models are also stable when it comes to forecasting future values for each component. On the basis of the parameters R^2, RMSE, and Adjusted R^2 values, the results obtained after fitting various models were compared. On the basis of available data, the model with the lowest mean squared error and greatest R^2 was deemed the best for that particular factor.

For model validation, the following parameter was used:

- Coefficient of determination(R^2)
- Adjusted(R^2)
- Residual mean squared error (RMSE)

In order to establish the model's validity as a dynamic system, its stability and capability to stimulate historical data were studied. The model's performance was evaluated using the coefficient of determination (R^2), residual mean squared error, and adjusted R^2.

1. Coefficient of determination:

The coefficient of determination is used to assess the goodness of fit.

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(Yi - \hat{Y}i)^2}{\sum_{i=1}^{n}(Yi - \bar{Y}i)^2}$$

2. Residual variance:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(Yi - \hat{Y}i)^2}{n}}$$

The lower the RMSE number, the better the model.

3. Adjusted R^2:

The change in R^2 that changes the number of words in a model is known as adjusted R^2. The proportion of the variance in the dependent variable accounted for by the explanatory factors is calculated using the adjusted R^2.
The Adjusted R^2 defined as:

$$\bar{R}^2 = 1 - \frac{\sum_{i=1}^{n}(Yi - \hat{Y}i)^2/(n-k)}{\sum_{i=1}^{n}(Yi - \bar{Y}i)^2/(n-1)}$$

$$R^2_{adj} = 1-(1-R^2)\frac{n-1}{n-k}$$

where k is the number of model parameters including the intercept term.

Separately, the aforesaid criteria were applied to data sets on production statistics relevant to the issues under investigation. The OLS method was used to estimate the parameters of these models. Fitted improved models were largely checked and evaluated for their suitability in terms of error characteristics by critically comparing and assessing parameter estimates, summary statistics, such as coefficient of determination R^2; residual mean squares (RMSE) or error variance, and Adjusted R^2 values. A best fitted parsimonious model has the least RMSE with the fewest parameters among a collection of competing best fitted appropriate models.

Year	Maize Production X_2 (000 tons) Betul District	Maize Productivity X_3 (ton/ha.) Betul District
1988	10.4	0.965
1989	12.4	1.020
1990	13.3	1.137
1991	13.2	1.025
1992	13.4	0.980
1993	16.5	0.995
1994	15.1	1.025
1995	13.4	1.075
1996	19.7	1.112
1997	23.1	1.185
1998	22.7	1.242
1999	30.5	1.433
2000	39.4	1.789
2001	72.9	2.882
2002	60.5	2.273
2003	71.3	2.221
2004	85.1	2.017
2005	72.0	1.618
2006	72.0	1.597
2007	50.6	1.054
2008	63.5	1.373
2009	59.8	1.406
2010	59.0	1.267
2011	75.8	1.563
2012	72.0	1.456
2013	176	3.500
2014	59.2	1.115
2015	43	2.389
2016	133	2.229
2017	179	2.400

Table1: Total Maize Production and Maize Productivity (Yield) of Betul District in the past.

Source: The data gathered from the Directorate of Economics and Statistics, M.P.Krishi.org (1988-2017).

Models	t = 26	t = 27	t = 28	t =29	t = 30
	R^2(%) RMSE Adjusted R^2	R^2(%) RMSE Adjusted R^2	R^2(%) RMSE Adjusted R^2	R^2(%) RMSE Adjusted R^2	R^2(%) RMSE Adjusted R^2
Linear	67.10 467.69 0.657	62.80 508.56 0.614	55.10 591.82 0.533	59.60 618.13 0.581	62.00 776.93 0.606
Quadratic	68.90 460.95 0.662	63.00 527.89 0.599	55.70 606.47 0.522	59.60 641.89 0.564	63.40 774.96 0.607
Cubic	69.20 476.94 0.650	63.50 543.70 0.587	59.30 580.70 0.542	59.90 661.15 0.551	64.00 791.26 0.599
Compound	85.70 0.097 0.851	82.60 0.115 0.819	76.30 0.151 0.753	78.30 0.145 0.775	80.40 0.143 0.797
Power	75.80 0.163 0.748	75.80 0.160 0.748	73.80 0.166 0.728	74.60 0.170 0.737	74.80 0.184 0.739

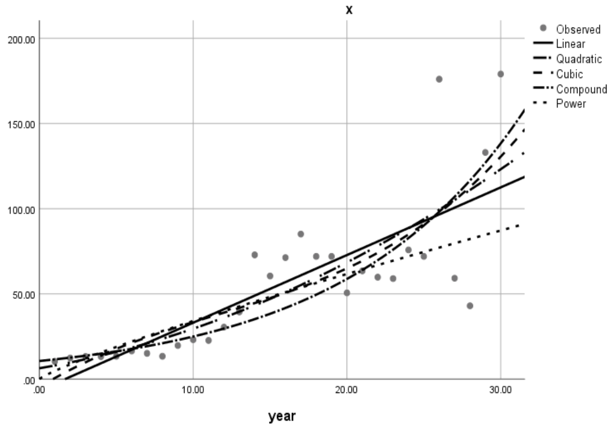
Table:2 The impact of several criteria (model-by-model) on overall maize output in the Betul District.

Models	t = 26	t = 27	t = 28	t =29	t = 30
	R^2(%) RMSE Adjusted R^2	R^2(%) RMSE Adjusted R^2	R^2(%) RMSE Adjusted R^2	R^2(%) RMSE Adjusted R^2	R^2(%) RMSE Adjusted R^2
Linear	13.00 0.082 0.094	16.90 0.080 0.136	21.80 0.079 0.188	29.30 0.091 0.267	35.90 0.100 0.336
Quadratic	19.90 0.078 0.129	20.20 0.080 0.135	22.70 0.081 0.165	29.60 0.094 0.242	38.40 0.099 0.339
Cubic	20.20 0.082 0.093	22.50 0.081 0.124	27.90 0.079 0.188	41.00 0.082 0.339	52.50 0.080 0.470
Compound	14.40 0.041 0.109	18.20 0.040 0.149	22.70 0.040 0.197	29.40 0.042 0.268	35.50 0.043 0.332
Power	19.90 0.039 0.166	22.50 0.038 0.194	25.40 0.038 0.225	53.40 0.042 0.259	31.50 0.046 0.290

Table 3: The impact of several criteria (model-by-model) on maize productivity in Betul District.

For maize production in Betul District, the best fitting models with parameter R^2, RMSE, and Adjusted R^2 are compound, power, and quadratic. In 2013, the value of the compound model with parameters R^2, RMSE, and Adjusted R^2 was 85.7 percent, 0.97, 0.851, and in 2014, the value of R^2, RMSE, Adjusted R^2 was 82.6 percent, 0.115, 0.819, and the value of R^2, RMSE, Adjusted R^2 was 82.6 percent, 0.115, 0.819. In 2015, adjusted R^2 was 76.3 percent, 0.151, 0.753, and the value of R^2, RMSE, In 2016, adjusted R^2 was 78.3 percent, 0.145, 0.775, and the value of R^2, RMSE, In 2017, the adjusted R^2 was 80.4 percent, 0.143, and 0.797.

The value of power model with parameter R^2, RMSE, and Adjusted R^2 is 75.8%, 0.163, 0.748 in year 2013 and the value of R^2, RMSE, Adjusted R^2 in 2014 is 75.8%, 0.160, 0.748 and value of R^2, RMSE, Adjusted R^2 in 2015 is 73.8%, 0.166, 0.728 and value of R^2, RMSE, Adjusted R^2 in 2016 is 74.6%, 0.170, 0.737 and value of R^2, RMSE, Adjusted R^2 in 2017 is 74.8%, 0.184, 0.739.



Graph 1: Diagram showing the fitting of maize production in Betul District.

In 2013, the value of a quadratic model with parameter R^2, RMSE, and Adjusted R^2 was 68.9%, 460.95, 0.662, and in 2014, the value of R^2, RMSE, Adjusted R^2 was 63.0%, 527.89, 0.599, and in 2015, the value of R^2, RMSE, Adjusted R^2 was 55.7 percent, 606.47, 0.522, and in 2016, the value of R^2 (Table 4.9). Compound, power, and quadratic models are determined to be the best fitting models for maize production in Betul District when parameter R^2, RMSE, and Adjusted R^2 are taken into account. In 2013, the value of the compound model with parameter R^2, RMSE, and Adjusted R^2 was 14.4%,.041, 0.109, and in 2014, the value of R^2, RMSE, Adjusted R^2 was 18.2%, 0.040, 0.149, and in 2015, the value of R^2, RMSE, Adjusted R^2 was 22.7 percent,0.040,0.197. In 2016, the value of R^2, RMSE, Adjusted R^2 was 29.4 percent, 0.042, 0.268, In 2017, R^2, RMSE, Adjusted R^2 was 35.5 percent, 0.043, 0.268, respectively. The value of power model with parameter R^2, RMSE, and Adjusted R^2 is 19.9%, 0.039, 0.166 in year 2013 and the value of R^2, RMSE, Adjusted R^2 in year 2014 is 22.5%, 0.038, 0.194 and value of R^2, RMSE, Adjusted R^2 in 2015 is 25.4%, 0.038, 0.225 and value of R^2, RMSE, Adjusted R^2 in 2016 is 53.4%,0.042, 0.259, in 2017, the value of R^2, RMSE, and Adjusted R^2 was 31.5 percent, 0.046, 0.290. In the year 2013, the value of the quadratic model with parameter R^2, RMSE, and Adjusted R^2 was 19.9%, 0.078, 0.129, and the value of R^2, RMSE, Adjusted R^2 in 2014 was 20.2 percent, 0.080,0.135, and the value of R^2, RMSE, Adjusted R^2 in 2015 was 22.7 percent, 0.081, 0.165, and the value of R^2, RMSE, Adjusted R^2 in 2016 was (Table 4.10).

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