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A statistical modeling approach of area, production and productivity of maize crop in Dindigul district

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Abstract

The present study has been undertaken to identify the best Linear and Non-Linear growth models, time series models like ARIMA to predict the future forecasts (up to 2021 A.D) in area, production and productivity of Maize during the study period from 1990-91 to 2016-17. The best fitted model was chosen based on model selection criteria like highest coefficient of determination (R^2), Adjusted R^2 and with least MAPE, RMSE and MAE values for the purpose of future forecasts up to 2021 A.D. The time series data pertaining to area, production and productivity of Maize in Dindigul district of Tamil Nadu were collected from Seasonal crop report of Tamil Nadu and Ministry of Agriculture, Govt. of India, www.indiastat.com for the period of 27 years i.e., from 1990 to 2016. The analysis of area, production and productivity of Maize in Dindigul district of Tamil Nadu revealed the following features over a period of time. It is observed that the average area, production and productivity under maize in Dindigul district of Tamil Nadu during the study period were 27128 thousand hectares, 97686 thousand tonnes and 3417 kg/ha respectively. The future forecasts by cubic model were indicated that there would be substantial decreasing in area and production and increasing trend in productivity in the future. It was observed that the forecasted area by 2021 AD would be 6706.26 hectares. The forecasted production and productivity would be 125781.96 tonnes and 9838.36 kg/ha respectively by 2021 AD.

Keywords: Linear model, non-linear model, ARIMA, MAE and RMSE

Introduction

Maize is the most important cereal crop cultivated widely throughout the world. It is used as a feed, fodder and it is also used for industrial purposes. In global, USA is the largest producer of maize followed by China and Brazil. In India, maize is cultivated in an area of about 9.26 Mha with the production of 23.67 Mt (Agricultural Statistics, 2014). Andhra Pradesh and Karnataka dominated the production of maize which contributes to around 38 per cent of the total production in India. In Tamil Nadu, maize is cultivated in an area of about 355064 ha with the production of about 2532330 Tonnes (Crop Production Statistics, 2015-16). Tamil Nadu is one of the nine states that accounts for 85% of India's maize production and 80% of area under cultivation. In 2016-17 the area, production and productivity of maize in Tamil Nadu are 0.3 m ha, 0.9 m t and 3 t/ha respectively. In Tamil Nadu, Perambalur has the highest area of maize about 0.05 m ha which accounts for 15% of total cultivated area of Tamil Nadu (2015-16). Salem has the highest production of maize about 0.3 m t. which accounts for 14.9% of total production of TN. Dindigul has the highest productivity of maize 9.5 t/ha. To help macro level planning, in this research, it is proposed to fit the most appropriate model for area, production and Productivity of Maize for Dindigul district of Tamil Nadu. This modeling effort will help on one hand, to understand the past performance and on the other, to forecast future possibility.

Materials and Methods

The present study was based on secondary data. The time series pertaining to area, production and productivity of maize for Dindigul district have been collected for the period of 27 years from 1990 to 2016 from the official website Indiastat.com, Seasonal Crop Report. Data was analyzed by using MINITAB and SPSS version 16.0 software. In this study, the linear trend Model was also used by Finger (2007) ^[2], Broken *et al.*, (2000) ^[1] and Rimi *et al.*, (2011) ^[5],

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Exponential, Quadratic and S-Curve Models of trend analysis were applied for this study. Also Logistic, Monomolecular and fuzzy time series models were fitted for the production data. The best fitted Model was selected on the basis of three accuracy measures. These accuracy measures were Mean Absolute Percentage Error (MAPE), Mean Absolute Deviation (MAD) and Root Mean Square Error (RMSE). Mean Absolute Percentage Error (MAPE) measures the accuracy of fitted time series values. It expresses accuracy as a percentage. Mean Absolute Deviation (MAD) measures the accuracy of fitted time series values. It expresses accuracy in the same units as the data, which helps conceptualize the amount of error. The Root Mean Square Error (RMSE) is a measure of accuracy, to compare forecasting errors of different models for a particular dataset and not between datasets, as it is scale-dependent. Smaller values of all these measures indicate a good fitted Model with minimum forecasting errors (Karim *et al.*, 2010) [4]. The relative measures give equal weight to all errors in contrast to the MSE, which squares the errors and there by emphasizes large errors. It would be helpful to have a measure that considers

both the disproportionate cost of large errors and provides a relative basis for comparison with naive methods. This statistics allows a relative comparison of normal forecasting methods with naive approaches and also squares the errors involved so that large errors are given much more weight than small errors. The best fitted Model was applied for forecasting area, production and Productivity of Maize in Dindigul district respectively from the year 2017 to 2021.

Results and Discussion

In the present study, linear, non-linear models *viz.*, linear, logarithmic, inverse, quadratic, cubic, compound, S-curve, growth, power and exponential models have been fitted where as time series models include Auto Regressive (AR), Moving Average (MA) and Auto Regressive Integrated Moving Average (ARIMA) have been fitted to the data on area, production and productivity of the Maize in Dindigul district by considering 27 years data from 1990-91 to 2015-16. The results obtained for area of maize in Dindigul District by fitting all the linear, non-linear and time series models were presented in Table 1.1.

Table 1: Linear, Non-linear and Time series models of Maize area in Dindigul District of Tamil Nadu

Parameter					Criteria				
Model	a	b	c	d	R ²	Adj R ²	RMSE	MAE	MAPE
Linear	14557.57**	897.87**			45.2	43.0	7702.34	6415.39	29.49
Logarithmic	3637.49	9824.37**			60.8	59.2	4515.93	5254.58	20.24
Inverse	32303.27**	-35509.04**			46.2	44.1	7628.75	6786.65	32.24
Quadratic	-469.05	4006.83**	-111.03**		78.6	76.8	4814.14	3749.54	16.15
Cubic	9890.48*	-67.24	246.19*	-8.505**	87.7	86.0	3654.33	2818.09	13.38
Power	7427.58**	0.502**			76.0	75.0	7069.36	5442.89	20.03
S	10.412**	-2.07**			73.7	72.6	6988.25	5889.35	22.23
Exponential	13543.74**	0.043**			49.3	47.2	8956.53	7044.29	29.41
Logistic	0.000073**	0.958**			49.3	47.2	8956.53	7044.29	29.41
Time Series Models									
ARIMA (0,1,0)					45.2	43.4	6787.2	4788.4	17.257
ARIMA (0,1,1)					79.6	75.4	6533.4	4575.4	16.387
ARIMA(0,1,2)					81.9	79.6	6487.6	4431.3	15.919
ARIMA(1,1,0)					77.0	74.3	6629.3	4703.5	16.931
ARIMA(1,1,1)					80.6	78.5	6524.4	4555.4	16.328
ARIMA(1,1,2)					81.6	79.9	6064.4	4193.4	14.585

**,* indicate significant at 1% and 5% level of probability respectively.

Forecasted Cubic model is $\hat{Y}_{area} = 9890.48 - 67.40 x + 246.19 x^2 - 8.505 x^3$

From the above Table 1, it was found that all the models fitted well showing significant adjusted R² values. In comparison with all other models, Cubic model was with high R² (87.7%) with significant adjusted R² (86%) and the low MAPE (13.38) values. Hence, the Cubic model was chosen for future forecasts of maize area in Dindigul district. Among the linear, non-linear growth models cubic model identified as the best fitted model based on model selection criteria.

The results obtained for production of maize in Dindigul district during the study period by fitting all the models were presented in Table 2.

Forecasted Cubic model is $\hat{Y}_{production} = 73912.07 - 25747.97 x + 2952.89 x^2 - 70.61 x^3$

In case of maize production in Dindigul district from the above Table 2, the value of all fitted models showing significant adjusted R². But cubic model was with high R² (67.3%), highest significant adjusted R² (63%) and the least MAPE (66.40) values. Hence, the cubic function was chosen for future forecasts of Maize production in Dindigul district. Among the time series models ARIMA (0, 1, 2) identified as the best fitted model based on model selection criteria but cubic model was best as compared to ARIMA (0, 1, 2) model.

Table 2: Linear, Non-linear and Time series models of Maize Production in Dindigul District of Tamil Nadu

Parameter					Criteria				
Model	a	b	c	d	R ²	Adj R ²	RMSE	MAE	MAPE
Linear	-10372.96	7718.53**			56.6	54.9	52593.05	36421.66	59.76
Logarithmic	-56950.95	64674.24**			44.7	42.5	59411.86	49474.13	95.69
Inverse	123954.39**	-182254.27*			20.2	17.0	71353.71	62931.56	114.91
Quadratic	-12089.55	8073.69	-12.68		56.7	53.0	52588.97	36627.21	60.78
Cubic	73912.07	-25747.97	2952.89*	-70.61*	67.3	63.0	45704.60	34926.26	66.40
Power	8977.28**	0.851**			66.8	65.5	58034.52	39798.85	45.70

S	11.556**	-2.906**			44.4	42.1	72536.39	54278.83	61.04
Exponential	19650.35**	0.089**			65.6	64.3	58414.05	34271.41	45.52
Logistic	0.000051**	0.914**			65.6	64.3	58414.05	34721.41	45.52
Time Series Models									
ARIMA (0,1,0)					53.2	50.1	69810.00	42458.00	56.46
ARIMA(0,1,2)					63.6	61.2	64488.00	37974.00	53.89
ARIMA(1,1,2)					60.3	58.2	63533.00	39938.00	54.63

**,* indicate significant at 1% and 5% level of probability respectively.

The results obtained for productivity of maize in the Dindigul district during the study period by fitting all the models were presented in Table 3.

Table 4.3: Linear, Non-linear and Time series models of Maize Productivity in Dindigul District of Tamil Nadu

Parameter					Criteria				
Model	a	b	c	d	R ²	Adj R ²	RMSE	MAE	MAPE
Linear	656.96	197.12**			47.8	45.7	1570.68	1348.93	96.66
Logarithmic	-124.76	14181.14**			30.3	27.5	1919.53	1711.09	93.20
Inverse	3933.43**	-3585.50			10.1	6.5	2270.74	2021.24	107.34
Quadratic	1792.014	-37.72	8.39		51.9	47.9	1489.47	1098.18	47.55
Cubic	3584.51*	-742.65	70.20	-1.47	57.9	52.4	1345.03	1092.88	53.46
Power	1178.62**	0.371**			28.7	25.9	1963.07	1476.38	56.23
S	8.09**	-0.897			9.6	6.0	2389.55	1790.06	67.96
Exponential	1445.17**	0.05**			44.2	42.0	1616.44	1183.44	43.15
Logistic	0.001**	0.95**			44.2	42.0	1616.44	1183.44	43.15
Time Series Models									
ARIMA (0,1,0)					24.8	21.5	1969.10	995.46	36.65
ARIMA (0,1,1)					45.0	43.2	1616.60	1210.40	51.57
ARIMA(0,1,2)					44.9	41.2	1814.80	1180.80	49.54
ARIMA(1,1,0)					32.2	30.6	1837.20	1079.90	41.09
ARIMA(1,1,1)					44.9	41.1	1615.00	1176.40	49.45
ARIMA(1,1,2)					34.0	33.2	1622.40	1218.40	48.69

**,* indicate significant at 1% and 5% level of probability respectively.

Forecasted Cubic model is $\hat{Y}_{productivity} = 3584.51 - 742.65x + 70.20x^2 - 1.47x^3$

Under maize productivity of Dindigul district, all the linear and non-linear models showing highly significant adjusted R². But comparison with model selection criteria among the entire models cubic model was with highest R² value (57.9), with significant adjusted R² value (52.4) and with MAPE value of (53.46). Hence, the cubic function was chosen for further forecast of Maize productivity. Similar results were reported

by Sandika *et al.* (2009) [6] selected the same growth model for projecting Rice productivity.

Forecasting of Maize Area, Production and Productivity using best fitted Model

The future forecasts of area, production and productivity of Maize in Dindigul district by 2021 AD were calculated and the results were presented in table 4 as follows.

Table 4.7: Forecasted values of Maize Area, Production and Productivity of Dindigul district by Cubic Model

Year	Forecasted Area (hectares)	Forecasted Production (tonnes)	Forecasted Productivity (Kgs/ ha)
2017	18937.36	183440.36	7667.62
2018	16782.13	133858.16	8178.20
2019	13665.81	131618.64	8710.18
2020	10307.19	128926.57	9263.57
2021	6706.26	125781.96	9838.36

Based on the best identified model (Cubic) the area of maize area in Dindigul district was forecasted and tabulated in the Table 4. The forecasted area of maize area in Dindigul district by 2021 AD would be 6706.26 hectares. The forecasted values of area showed a decreasing trend by 2021 AD from the average of study period.

Regarding the production of Maize in Dindigul district Cubic model was selected as the best fitted model for future forecasts by 2021 AD as it had exhibited highest R² and Adjusted R² having least MAPE values. From the table 4, by using Cubic model the forecasted production would be 125781.96 tonnes. The forecasted values of Maize production in Dindigul district showed a decreasing trend by 2021 AD from the average of study period.

Productivity of Maize in Dindigul district was forecasted by using Cubic model which had exhibited highest R² and Adjusted R² having least MAPE values. By using Cubic model the forecasted productivity would be 9838.36 kg /ha. The forecasts showed an increasing trend by 2021 AD from the average of study period and results were presented in the Table 4.

Conclusion

Based on the least RMSE, MSE and MAPE value, among all the linear, nonlinear and time series models for Maize area, production and Productivity cubic model was best fitted model for Dindigul district. It is observed that the average area, production and productivity under maize in Dindigul district of Tamil Nadu during the study period were 27128

thousand hectares, 97686 thousand tonnes, and 3417 kg/ ha respectively. The future forecasts by cubic model were indicated that there would be substantial decreasing in area and production and increasing trend in productivity in the future. It was observed that the forecasted area by 2021 AD would be 6706.26 hectares. The forecasted production and productivity would be 125781.96 tonnes and 9838.36 kg /ha respectively by 2021 AD.

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