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Forecasting of grape production in Maharashtra state using ARIMA model

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ABSTRACT

The present study aims to identify an appropriate statistical model for analyzing and forecasting grape production in Maharashtra state. This study analyzed the production trends of grapes in Maharashtra using secondary data spanning 32 years (1991-92 to 2022-23). To identify the most reliable forecasting tool, various statistical models, including Linear, Polynomial (2nd and 3rd degree), Compound, Exponential, Logarithmic, Power, and the Autoregressive Integrated Moving Average (ARIMA) model, were fitted and compared.

The descriptive analysis revealed a mean production of 1580.30 thousand metric tons during the study period. The estimated compound annual growth rate (CAGR) indicated a significant increasing trend of 7.41% per annum. Among the models evaluated, the ARIMA (6,1,0) model outperformed others with the lowest RMSE (318.22) and AIC (156.05), proving to be the most efficient for capturing temporal production patterns. Based on this model, the forecasted grape production for Maharashtra for the year 2023-24 is estimated to be 2703.38 thousand metric tons, with a prediction interval ranging from 1921.17 to 3485.59 thousand metric tons. The study concluded that ARIMA models are more effective for time series forecasting of grape production in Maharashtra.

Keywords: Forecasting, Grape, Production, Time series analysis

1. Introduction

Grape is an important table fruit in the World. It is a sub-tropical crop and is cultivated under tropical conditions. The total grape production of India was 3489.40 thousand tons during the year 2021-22 (source: website of APEDA). Grape is one of the important fruits covering an area of 161.91 thousand hectares, occupying 2.30% of the total area of fruit production in 2021-22. The country is also a major exporter of fresh grapes to the world. India exported 267,950.39 MT of grapes to the world, worth Rs. 2,543.42 crores / 313.70 USD Millions during the year 2022-23. The major export destinations are Netherlands, Bangladesh, United Arab Emirates, U.K., and Russia.

Major grape-growing states are Maharashtra, *Karnataka*, Tamil Nadu, and Andhra Pradesh. Maharashtra ranks first in terms of production, accounting for more than 70% of total production and the highest productivity in the country during 2021-22. *Karnataka* is the second largest producer of Grapes with a share of 25% in 2021-22. Nasik and Sangli districts are the major grape-growing districts of Maharashtra. Apart from these two leading districts, grape is also grown in Ahmednagar, Pune, *Satara*, Solapur, and Osmanabad districts.

The main objective of the study is to identify the best statistical model for the production of grapes, to compare the efficiency of different statistical models, and to forecast the grape production of Maharashtra state by using the best-fitted model.

2. Material and Methods

The secondary data on the area, production, and productivity of grapes of Maharashtra state (1991-92 to 2022-23) were used for model construction. Agricultural production may vary from year to year due to the nature of cultivation, environmental changes, and government policies. Sometimes production of a crop can increase or decrease at a certain rate. To investigate such trends, we consider the following statistical models in the present research study:

1. **Linear** $y_i = a + bt + \epsilon_i$ (1)

2. **Polynomial 2nd degree** $y_i = a + bt + ct^2 + \epsilon_i$ (2)

3. **Polynomial 3rd degree** $y_i = a + bt + ct^2 + dt^3 + \epsilon_i$ (3)

4. **Compound** $y_i = ab^t + \epsilon_i$ (4)

where, y_i is the production of grape, t is the time and ϵ_i is the random error. Taking logarithm on both sides of eq. (3), we get

$$\log y_i = \log a + t \log b + \varepsilon_i$$

$$5. \text{ Exponential } y_i = ae^{bt} + \varepsilon_i \dots \dots \dots (5)$$

$$6. \text{ Logarithmic } y_i = a + b \ln(t) + \varepsilon_i \dots \dots \dots (6)$$

$$7. \text{ Power } y_i = at^b + \varepsilon_i \dots \dots \dots (7)$$

Durbin Watson Test

The Durbin Watson test statistic is formulated as:

$$DW(d) = \frac{\sum_{t=2}^T (e_t - e_{t-1})^2}{\sum_{t=1}^T e_t^2}$$

where $e_t = (y_t - \hat{y}_t)$, y_t and $\hat{y}_t$ are observed and estimated values of response variable for individual t . $DW(d)$ becomes smaller as the serial correlations increase.

$$y_t = \mu + \varphi_1 y_{t-1} + \dots + \varphi_p y_{t-p} - \theta_1 e_{t-1} - \dots - \theta_q e_{t-q}$$

Where, μ is the constant, φ_p is the autoregressive (AR) coefficient at lag p , θ_q is the moving average (MA) coefficient at lag q and $e_{t-q} = y_{t-p} - \hat{y}_{t-p}$ is the forecast error that was made at period $t-p$.

The main steps of ARIMA modeling are model identification, parameter estimation, diagnostic checking and forecasting.

3. Results and Discussion

The descriptive statistics of area, production, and productivity of grapes in Maharashtra are presented in Table 1. The results revealed that the mean area, production, and productivity of grapes were 62.32

To test the autocorrelation at significance level α , the test statistic d is compared to lower and upper critical values ($d_{L,\alpha}$ and $d_{U,\alpha}$):

- If $d < d_{L,\alpha}$, there is statistical evidence that the error terms are positively autocorrelated.
- If $d > d_{U,\alpha}$, there is no statistical evidence that the error terms are positively autocorrelated.
- If $d_{L,\alpha} < d < d_{U,\alpha}$, the test is inconclusive.

ARIMA (Autoregressive Integrated Moving Average) model

Autoregressive Integrated Moving Average (ARIMA) also known as Box-Jenkins methodology was used for the time series modeling. It includes AR and MA terms with their respective order p and q respectively. Differencing eliminates trends and seasonality and stabilizes mean of the time series. The first order differencing was used in order to make the series stationary. The non seasonal ARIMA (p, d, q) model for the grape production (y) in period t based on data up to period $t-1$ was used as follows

thousand hectares, 1580.30 thousand metric tons, and 22.06 MT/ha, respectively. The median for area, production, and productivity was 45.50 thousand ha., 1279.60 thousand MT, and 22.38 MT/ha, respectively. The maximum area under cultivation was 118.94 thousand hectares, maximum production was 9116.60 thousand MT, and maximum productivity was 28.30 MT/ha. Conversely, the minimum area under cultivation was 17.10 thousand ha., with a minimum production of 275.10 thousand MT and minimum productivity of 5.40 MT/ha. The values of skewness and kurtosis indicated that the grape data components were not normally distributed.

Table 1. Descriptive Statistics of Area, Production, and Productivity of Grapes

Particular	Area (' 000 ha)	Production (' 000 mt)	Productivity (mt/ha)
Mean	62.32	1580.30	22.06
Standard Error	6.32	280.86	1.03
Median	45.50	1279.60	22.38
Mode	29.80	NA	28.30
Standard Deviation	35.76	1588.80	5.81
Kurtosis	-1.61	16.65	1.30
Skewness	0.28	3.56	-1.23
Range	101.84	8841.50	22.90
Minimum	17.10	275.10	5.40
Maximum	118.94	9116.60	28.30

The results of the compound growth rate of grape production in Maharashtra state are presented in Table 2. The production has in-

creased significantly at a compound growth rate of 7.41 per cent per annum with a standard error of 0.15.

Table 2. Compound Growth Rate of Grape Production (1991-92 to 2022-23)

Particular	Compound growth rate	S.E.
Grape production of Maharashtra ('000MT)	7.41**	0.15

For analyzing the pattern of grape production, various linear and non-linear models were fitted. Measures of goodness of fit typically summarize the discrepancy between observed and predictive values under the model. In this research, the performance parameters of different statistical models were checked using R^2 and error metrics including

Mean Squared Error (MSE), Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and Akaike Information Criterion (AIC). The estimated parameters along with their Durbin Watson Statistic (DW), R^2 , and AIC values are presented in Table 3.

Table 3. Parametric Estimates and Goodness-of-Fit Criteria for Conventional Models

Model	DW Statistic	Co-efficient	Estimate	R ²	RMSE	MSE	MAE	AIC
Linear	1.22	a	21.12	0.84	318.37	100092.5	181.84	159.01
		b	79.11**					
Polynomial 2 nd degree	1.33	a	240.52	0.86	322.68	91614.49	193.30	157.82
		b	39.22					
		c	1.25					
Polynomial 3 rd degree	1.34	a	345.23	0.86	330.80	90478.34	188.65	157.65
		b	2.81					
		c	4.05					
		d	-0.06					
Compound	1.68	a	326.68	0.79	336.69	113358.79	265.25	160.69
		b	1.07					
Exponential	1.68	a	326.68	0.79	5136.57	26384307.29	4188.14	234.06
		b	0.07					
Logarithmic	0.60	a	-567.71	0.64	711.51	506250.18	539.65	180.84
		b	736.2					
Power	1.33	a	165.03	0.71	399.21	159371.76	283.95	165.27
		b	0.72					

After applying the Durbin Watson test to the residuals of the different models, it was observed that the conventional models (linear, polynomial, compound, exponential, logarithmic, and power) exhibited positively autocorrelated residuals. Therefore, time series modeling via ARIMA was executed to address this dependency.

The results of the Augmented Dickey-Fuller (ADF) test are presented in Table 4. It indicated that grape production is non-stationary at level ($d = 0$, p -value = 0.25) and becomes stationary after the first difference ($d = 1$, p -value = 0.04). The optimal lag order and structural parameters p and q were identified from the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) plots.

Table 4. Result of Augmented Dickey Fuller test of grape production.

Data	Difference	Lag order	Dickey -Fuller	P value
Grape production('000MT)	$d = 0$	3	-2.83	0.25
Grape production (Diff)	$d = 1$	3	-3.66	0.04

The time series dataset of grape production with 32 data points was partitioned: 26 data points were used as the training set, while 6 years of data points were reserved as the testing/validation set. The compar-

ative performance evaluation proved that the ARIMA (6,1,0) model performed exceptionally well, achieving the lowest RMSE (318.22) and AIC (156.05) relative to all other conventional structures.

Table 5. Parameter Estimates for the Best-Fit ARIMA(6,1,0) Model

Particulars	Estimate	S.E.	t	Sign.
AR				
Constant	76.370	19.534	3.910	0.001
Lag1	-0.339	0.179	-1.893	0.070
Lag2	-0.455	0.190	-1.390	0.065
Lag3	-0.308	0.195	-1.574	0.128
Lag4	-0.389	0.195	-1.405	0.574
Lag5	-0.169	0.189	-0.896	0.379
Lag6	-0.420	0.181	-1.319	0.290
Difference	1			

The model validation details and specific out-of-sample forecasts are provided in Table 7. Based on these findings, grape production in

Maharashtra is expected to continue its upward trajectory into the 2023-24 season.

Table 6. Results of ARIMA modeling

ARIMA model	R ²	RMSE	MAPE	MSE	MAE	AIC	BIC	Ljung Box Q(18)
ARIMA(6,1,0)	0.87	318.22	26.39	80314.44	202.69	156.05	12.31	N.S.

(continued on next page)

Table 7. Results of Validation and predicted value of grape production for Maharashtra State

Year	Observed	LCL	Predicted	UCL
2017-18	2286.44	1405.24	2058.00	2710.75
2018-19	2283.96	1656.38	2309.14	2961.9
2019-20	2350.37	1835.31	2488.07	3140.82
2020-21	2399.72	1799.11	2451.86	3104.62
2021-22	2466.54	2018.34	2671.10	3323.86
2022-23	2477.31	1863.98	2516.74	3169.5
Forecasted (2023-24)				
2023-24		1921.17	2703.38	3485.59

4. Conclusion

The estimated compound annual growth rates revealed that the production of grapes has shown a significantly increasing trend of 7.41% per annum over the study period. The ARIMA model proved to be a substantial improvement over conventional models, making it more appropriate to visualize the temporal trend of grape production in Maharashtra state. It is concluded from the study that on comparing different linear and non-linear statistical models, the ARIMA (6,1,0) model performed better for describing and forecasting grape production in Maharashtra state. The predicted value of grape production for the year (2023-24) using the best-fit model ARIMA (6,1,0) is estimated to be 2703.38 thousand metric tons, lying within a confidence interval (Lower Control Limit) of 1921.17 and (Upper Control Limit) of 3485.59 thousand metric tons.

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