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Forecasting Productivity of Sugarcane in Coimbatore using ARIMA with Exogenous Variables

S R Krishna Priya[1], N Kausalya[2]
Assistant Professor[1], Research Scholar[2]
Department of Statistics, PSG College of Arts & Science, Coimbatore

Abstract: This paper proposes an appropriate ARIMAX model that is used to forecast the Sugarcane Productivity in Coimbatore. The Auto Regressive Integrated Moving Average with exogenous inputs (ARIMAX) model can take the impact of covariates on the forecasting process into account to improve the comprehensiveness and accuracy of the forecasting. The data used for the study is sourced from the indiastat website for a period of 56 years from 1960 to 2015. The Akaike Information Criterion AIC is adopted to assess the adequacy of the models. The ARIMAX (2,1,4), ARIMAX (1,1,2), ARIMAX (1,1,2), ARIMAX (1,1,3) with AIC values of -2.016, -1.920, -1.964, -2.013 are considered as the appropriate model to be combined with the Exogenous Variables such as Temperature, Rainfall, Sunshine Hours, and Evaporation. Commercial greenhouse operations can reap numerous advantages from employing Productivity forecasting. It allows growers to allocate resources as efficiently as possible, to start. It also helps with decision-making and crop planning. Producers are able to forecast market demand and adjust planting dates accordingly.

Keywords: AIC, RMSE, Weather Parameters, ARIMAX Model

INTRODUCTION

Coimbatore, in the Tamil Nadu state of India, is well-known for its robust agricultural industry, which includes sugarcane cultivation. In this location, sugarcane is a major crop, and its growth is aided by the good climate and fertile soil. Coimbatore's sugarcane farming boosts the local economy by generating jobs and supplying raw materials for the region's sugar industry. Along with other crops including rice, cotton, and lentils, sugarcane farming is essential to Coimbatore's entire agricultural environment.

In the past decades many researchers worked on ARIMAX models for forecasting in various field such as Agriculture, Economy, Meteorology, Cargo and Tourism (Hamjah. 2014, Cherdchoongam. & Rungreunganun. 2016, Vishwajit et al., 2016, Wongsathan. & Chankham. 2016, Adli. 2020, Dharmaraja et al., 2020, Li et al., 2020, Andreas et al., 2021, Primageza et al., 2021, Rahmayanti et al., 2021, Kawakita et al., 2022, Xiang-qian et al., 2022).

MATERALS & METHODS

Source of Data

The detailed information required for the study was collected from secondary sources of data in order to accomplish the objectives of the study. In this study, Coimbatore data on Sugarcane Productivity and Weather Variables such as Temperature, Rainfall, Sunshine Hours and Evaporation for 56 years span of data from 1960 to 2015 has been used as the historical observations for the prediction. The information was gathered from the **indiastat** website.

RESULTS & DISCUSSION

In the present study, ARIMA Model and ARIMAX Model have fitted to the data on Productivity of Sugarcane crop in Coimbatore district. The first 51 observations i.e. the data from 1960 to 2010 used for model building and the remaining 5 data points, i.e. the data from 2011 to 2015 used for validating the model. For Sugarcane Productivity, ARIMAX Model performs better for forecasting.

The first step in building an ARIMAX model consists of identifying a suitable ARIMA model for the endogenous variable. The application of ARIMAX model requires the stationarity before modelling. In an effort to improve the predictive performance, ARIMAX models were tried, keeping in view the non-stationary behaviour of the series under consideration and utilizing the best weather contributors, rainfall and temperature. After confirming stationarity, proceed to ARIMA with Exogenous Variables method with the weather parameters such as Temperature, Rainfall, Sunshine Hours and Evaporation.

Productivity with Temperature

The ARIMAX method of the 2 and 4 lags of AR and MA terms with first order differencing. According to the results, it gives an AIC value of -2.016. This value is the best result out of the generated combinations. Here, AR value is 0.00 is less than significant value 0.05, hence it is significant. So ARIMAX (2,1,4) has chosen as an appropriate fit.

Table 1. Parameter Estimates of ARIMAX Model with Temperature

Variable	Coefficient	Std. Error	t-statistic	Prob.
ARIMAX (2,1,4)	0.640	0.069	9.228	0.000
Temp-Max	-0.031	0.004	-7.298	0.000
Temp-Min	0.016	0.003	4.837	0.000
AR (1)	1.540	0.192	8.012	0.000
AR (2)	-0.765	0.135	-5.636	0.000
MA (1)	-2.475	7.112	-0.347	0.729

MA (2)	1.484	14.098	0.105	0.916
MA (3)	0.491	5.357	0.091	0.927
MA (4)	-0.501	0.973	-0.514	0.609
σ^2 *value*	0.003	0.062	0.060	0.951

Table 2. Error Measures of ARIMAX Model with Maximum Temperature

MAE	MSE	AIC	RMSE
6.887	65.416	-2.016	8.088

Table 3. Error Measures of ARIMAX Model with Minimum Temperature

MAE	MSE	AIC	RMSE
6.729	61.061	-2.016	7.814

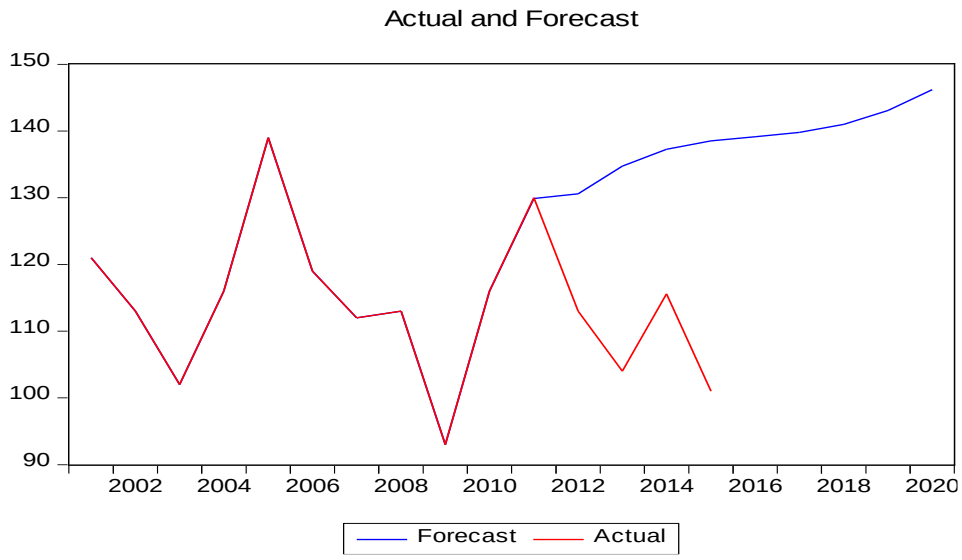

Figure 1. Actual and Forecast of Sugarcane Productivity with Temperature

Productivity with Rainfall

The ARIMAX method of the 1 and 2 lags. This means there is 1 lag of AR and 2 lags of MA with first order differencing. According to the results, it gives an AIC value of -1.920. This value is the best result out of the generated combinations.

Table 4. Parameter Estimates of ARIMAX with Rainfall

Variable	Coefficient	Std. Error	t-statistic	Prob.
ARIMAX (1,1,2)	-0.0493	0.023	-2.092	0.042
Rainfall	0.0260	0.011	2.187	0.034
AR (1)	-0.392	0.167	-2.340	0.024
MA (1)	5.50E-06	0.065	8.45E-05	0.999
MA (2)	-0.999	20431.99	-4.89E-05	1.000
σ^2 *value*	0.005	18.886	0.0003	0.999

Table 5. Error Measures of ARIMAX Model with Rainfall

MAE	MSE	AIC	RMSE
6.705	82.095	-1.920	9.060

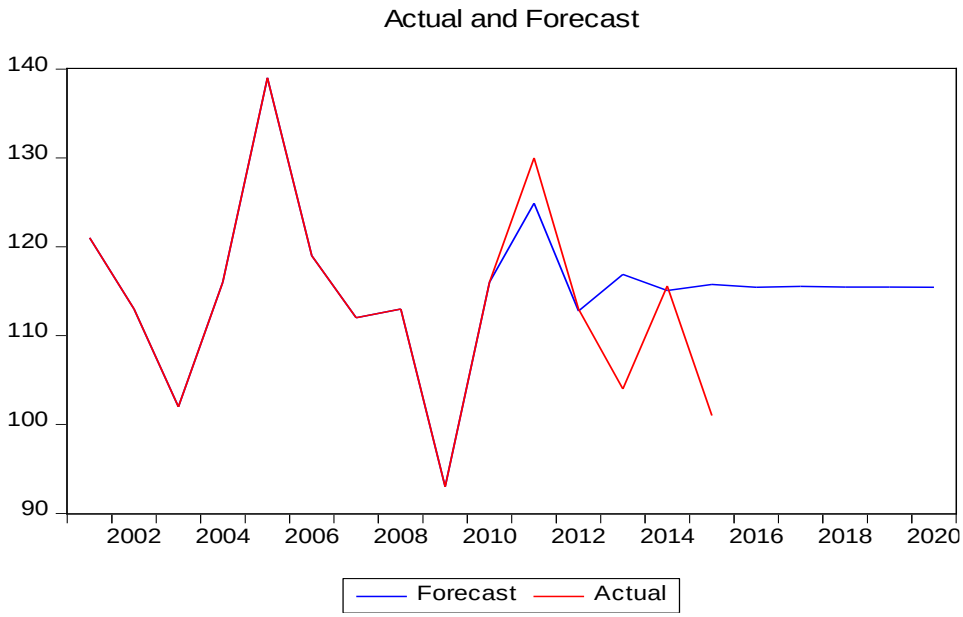

Figure 2. Actual and Forecast graph of Sugarcane Productivity with Rainfall

Productivity with Sunshine Hours

The ARIMAX method 1 lag of AR and 2 lag of MA with first order differencing. According to the results, it gives an AIC value of -1.964.

Table 6. Parameter Estimates of ARIMAX with Sunshine Hours

Variable	Coefficient	Std. Error	t-statistic	Prob.
ARIMAX (1,1,2)	-0.007	0.0364	-0.210	0.834
Sunshine Hours	0.001	0.005	0.261	0.794
AR (1)	-0.357	0.182	-1.960	0.056
MA (1)	1.04E-06	0.121	8.56E-06	1.000
MA (2)	-0.999	202664.4	-4.93E-06	1.000
σ^2 *value*	0.005	173.551	3.01E-05	1.000

Table 7. Error Measures of ARIMAX Model with Sunshine Hours

MAE	MSE	AIC	RMSE
7.372	64.209	-1.964	8.013

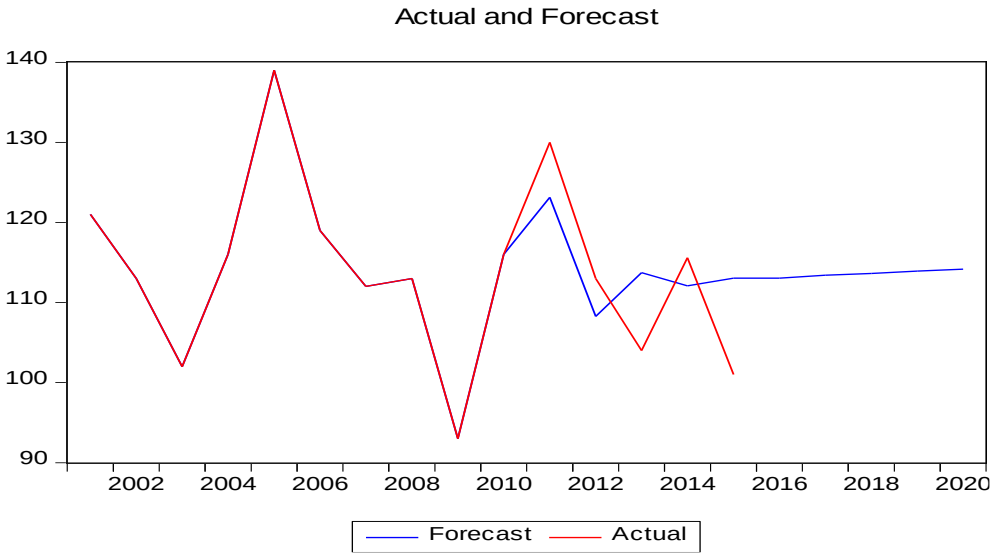

Figure 3. Actual and Forecast graph of Sugarcane Productivity with Sunshine Hours

Productivity with Evaporation

The ARIMAX method 1 lag of AR and 3 lag of MA with first order differencing. According to the results, it gives an AIC value of -2.013.

Table 8. Parameter Estimates of ARIMAX with Evaporation

Variable	Coefficient	Std. Error	t-statistic	Prob.
ARIMAX (1,1,3)	0.076	0.0311	2.473	0.017
Evaporation	-0.013	0.005	-2.429	0.019
AR (1)	0.414	0.247	1.677	0.101
MA (1)	-1.211	68.667	-0.017	0.986
MA (2)	-0.576	81.755	-0.007	0.994
MA (3)	0.788	150.553	0.005	0.995
σ^2 *value*	0.004	0.062	0.069	0.944

Table 9. Error Measures of ARIMAX Model with Evaporation

MAE	MSE	AIC	RMSE
6.131	51.693	-2.013	7.189

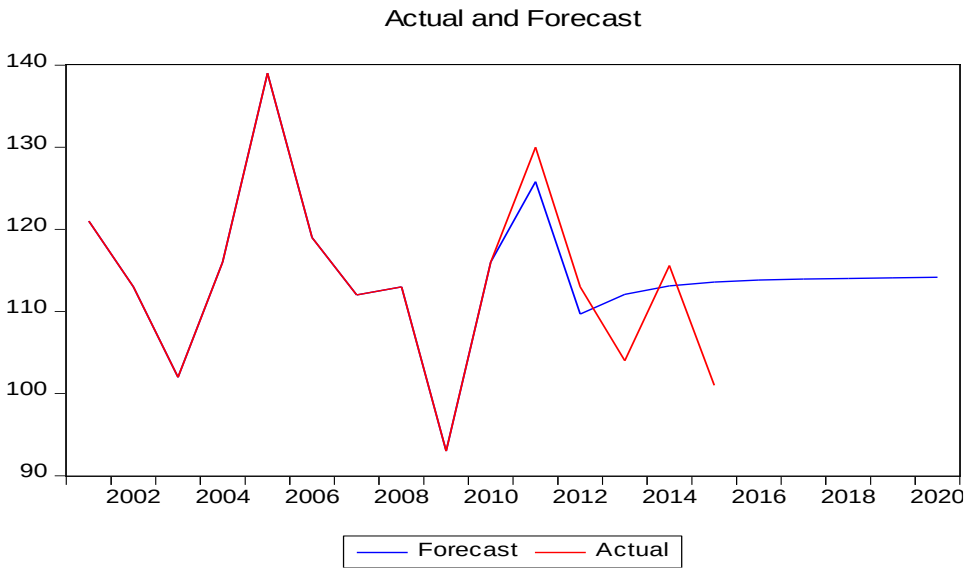

Figure 4. Actual and Forecast graph of Sugarcane Productivity with Evaporation

Data Forecasting

Different models were fitted to the productivity of the sugarcane for the entire study period from 1960-2015. The results obtained by error measures are given in the table 10.

Table 10. Error Measures of ARIMAX Model with Exogenous Variables

Variables	ARIMAX Model	
	Criteria	Error Values
Maximum Temperature	MAE	6.887
	MSE	65.416
	RMSE	8.088
Minimum Temperature	MAE	6.729
	MSE	61.061
	RMSE	7.814
Rainfall	MAE	6.705
	MSE	82.095
	RMSE	9.060
Sunshine Hours	MAE	7.372
	MSE	64.209
	RMSE	8.013
Evaporation	MAE	6.131
	MSE	51.693
	RMSE	7.189

The table 10, shows the error measure values of the respective variables. The weather variables are taken as an independent variables and Productivity as a dependent variable. All the weather variables such as Maximum Temperature, Minimum Temperature, Rainfall, Sunshine Hours, & Evaporation has its own and equal importance in the Productivity of Sugarcane. Using ARIMAX model in this dataset, among all the weather variables, Evaporation plays an important role in the Sugarcane Productivity has its own importance and has its equal importance in the Productivity of Sugarcane is consider as a best fit.

The future projections of Productivity of Sugarcane using the weather variables such as Maximum Temperature, Minimum Temperature, Rainfall, Sunshine Hours, & Evaporation were calculated for Coimbatore have been forecasted and tabulated in the Table 11.

Table 11. Forecasted values of Sugarcane Productivity in Coimbatore

Year	Forecasted Values of Sugarcane Productivity from 2016-2020				
	Maximum Temperature	Minimum Temperature	Rainfall	Sunshine Hours	Evaporation
2016	114.695	111.853	115.452	113.049	113.813
2017	115.251	111.665	115.540	113.401	113.940
2018	115.737	111.440	115.476	113.635	114.026
2019	116.169	111.177	115.472	113.913	114.094
2020	116.561	110.875	115.444	114.175	114.156

Conclusion

The aim of this paper is to identify an adequate ARIMAX model that will be used to forecast Sugarcane Productivity in Coimbatore. Based on the Akaike Information Criteria value of -2.016, ARIMAX (1,1,3) is thought to be the better model to combine with exogenous variables. The Productivity of Sugarcane is influenced more by the Evaporation variable. Productivity forecasting has several benefits for growers to begin allocating resources as effectively as feasible. Farmers are able to predict consumer demand and modify the planting schedule accordingly.

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