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Research Article

Growth dynamics and forecasting of minor millets in India: A time series analysis

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Abstract
The forecasting behaviour of millet plays a critical role in production planning at the Indian farm level. This study made an effort to forecast the area and production of small millets in India with time series analysis. The performance of the forecasting models was appraised and collated by the Mean Absolute Percentage Error (MAPE), Partial Autocorrelation Function (PACF) and Auto Correlation Function (ACF) criteria. For this analysis, the yearly data of the area and production of small millet from 1950 to 2021 were calculated. Among all Autoregressive Integrated Moving Average (ARIMA) models, ARIMA (0,1,0) was found to be the best fitted for forecasting the area and production of minor millets in India since, principally, this model relies on historical ideals of the sequences in addition to earlier error relations for forecasting minor millets and it does not adopt information of any fundamental model or associations as in some other approaches. The predicted values of minor millet area showed decreased trend from 422.4 thousand hectares in the year 2022 to 409.2 thousand hectares in the year 2026. Likewise, the production under small millets declined from 393.5 thousand tons to 159.5 thousand tons for the corresponding period. Hence, production of these crops can be enhanced by suitable use of inputs and timely application of inputs, high yielding varieties, government interventions like policy support, subsidising through the Public Distribution System and awareness by the way of propaganda and demonstration.

Keywords: Area, Forecasting, Minor millets, Production, Time series analysis

INTRODUCTION

Millet is an important grain crop in India, especially in areas where deficient water is widespread. Despite its economic consequence, this millet crop has received diminutive consideration (Gowri and Sivakumar, 2020a) compared with other cereal grains, such as rice and wheat (Rimi *et al.,* 2011). These crops are very resistant to water stress and drought conditions and tailored to various ecological circumstances (Gowri and Prabhu, 2017). Minor millets are loaded sources of vitamins, minerals and nutrients. All these attributes of small millet cultivation systems lead to climate amends that portend less water and rain, lower malnutrition and high heat (Gowri and Sivakumar, 2020b).

Over the years, the area and production of small millets have been shrinking, and it is alarming for policymakers to progress their consideration of the direction of minor millet cultivation models and ratify policies that generate an enabling environment for Indian millet farmers. Under the distorted situation today, forecasting of different aspects of agriculture is vital (Paul *et al.,* 2014). For planning and making policies related to food distribution and food security, predicting future area, production and yield in advance are very important in millet farming (Chughtai e*t al.,* 2004). Additionally, it is crucial in import and export policies, storage, marketing, and post-harvest operations (Paul *et al.,* 2013). Forecasting is the course of action of building statements in relation to actions (Paul and Sinha, 2016) whose real outcomes have not thus far been noticed.

The magnitude of appropriate and consistent forecasts of the area, production and yield of the most important crop need not be exaggerated for India (Padulosi *et al.,* 2015), where the economy is primarily based on farming production. The principal gain of forecasting agricultural crops (Broken, 2000) is that it imparts diverse stakeholders with precious details that can be worn to formulate termination regarding the future. Conversely, the statistical models used should be proficient in providing crop predictions with realistic accuracy before harvests for intriguing, timely options (Narloch*et al.,* 2011). Different procedures have been implemented for predicting such a system of agriculture, and many studies on forecasting agricultural areas, production and prices can be created regarding the uses of time series techniques and models. The most commonly applied model in this consideration has been the ARIMA. Therefore, the present study was conducted to predict the area and production of minor millet to provide valuable information to millet farmers, market intermediaries such as traders, processors, wholesalers and retailers, agencies of government and others, which is useful for policymakers concerning stock and logistics in minor millet farming.

MATERIALS AND METHODS

The present analysis was regulated by applying data on time series of minor millet cultivated area and production for the 1950 to 2021 period. The data pertained from the different issues of Season and Crop Report of Tamil Nadu, Directorate of Economics and Statistics, published by the Government of India, 2020. Data were explored by using SPSS software. For the present study, linear, quadratic and exponential tend models were implemented. Based on the measures of accuracy, the best model was selected. The accuracies were MAPE (mean absolute percentage error), PACF (partial autocorrelation function) and ACF (autocorrelation function). Minimum standards of all these actions are a sign of a fine built-in model with the least forecasting errors (Beniston, 2004); it was also used by Karim *et al.,* 2010. For this paper, the best model for predicting the future area and production of small millets was a quadratic model for the years 2022 to 2026.

To measure the associations, observations contained in the series were analysed by the Auto-Regressive Integrated Moving Average model (Box–Jenkins). This model communicated as ARIMA (p, d, q), and it was pretentious (Box and Jenkins, 1976). Past values of the differenced sequence occurring in the equation of forecasting are termed as Auto Regressive and history values of the error term in forecasting are called as Moving Average. For stationary data, time series data that need to be differenced are called integrated time series. This model combines three kinds of processes, namely, P (autoregressive), D (differencing for making data stationary) and Q (moving average). It is related to fixed data/stationary and for the non-stationary data differencing of data is a must.

$$Dt = Yt - Yt\text{-}1. \qquad \text{Eq.1}$$

The Dt series is said to be the first difference of Yt and Vt=Dt - Dt-1 is called the second difference.

The ARIMA incorporates the following steps.

Recognition of the model is alarmed with pronounced proper values of three orders *viz.,*

P, D, Q

P is the autoregressive (non seasonality)

Dis the differencing (non seasonality)

Q is the moving average (non seasonality)

Before recognizing the model, choose the distinctiveness of time series data for stationary and seasonality in case of vegetables and fruits as supposed above, and a similar must be detached. After differencing the data for stationarity, the subsequent step in furnishing the ARIMA model is to predict and correct the autocorrelation that leftovers the time series data if any. Certainly, software in the vein of stat graphics could attempt to the diverse amalgamation of terms and find what the best is. However, the organized method involves observing the diagram of the ACF and PACF of the differenced data. The autocorrelation function plot is purely a bar chart of the correlation coefficients among the time series and their lags. The partial autocorrelation function plot is the bar chart of the partial correlation coefficients among the time series and their lagged values.

After selecting the best model, the next walk is to have the squares of minimum. Evaluating the coefficients of this model is a relatively convoluted nonlinear assessment issue. To overcome these problems, commercial statistical software was used, *viz.,* SPSS, ANN, SAS, Minitab, etc. for the parameter estimation. After parameter estimation, it is essential to check that the selected model is satisfactory. After fulfilling the adequacy, it can be applied to forecast time series data.

RESULTS AND DISCUSSION

Scenario of minor millets in India

Over the last eleven years, the area under minor millet has decreased considerably from 2010-11 to 2021-22 (Fig. 1). The area of minor millet shrinked at a rate of 5.62 percent annually from 798 thousand hectares (2010-2011) to 452 thousand hectares (2021-2022). Likewise, production under minor millets was also reduced at a rate of 1.61 percent annually, from 442 thousand tons to 425 thousand tons for the same period. However, the marginal gain in the productivity of small millets was observed, but it was very small compared to other crops like cereals, pulses, groundnut and cotton in India (Gowri and Shivakumar, 2020a). Importantly, the shrinking area and production of small millets were the tradeoff among cereal crops such as wheat and rice with small millet, and policy shore-ups for the cultivation of coarse cereals will recover small millet production (Burark and Sharma, 2012).

Forecasting model for the area and production of minor millets in India

The present study used a time series model for the trend analysis of minor millet in India on evidence of small values of accuracy actions (Karim *et al.,* 2010). From Table 1, it was observed that accuracy measure values for the minor millet scenario in India were minor. Hence, the ARIMA model is the best fit to predict the values for future areas and production of minor millets in India for the next five years.

Identification of model

The ARIMA method is predictable only after modifying the variables under prediction into a series of *stationary, i.e.*, constant variance and constant mean. It was examined through plots. The recently assembled variable Yt was constant mean (stationary), the further is to recognize the autoregressive and moving average values. For this PACF and ACF were assessed (Fig. 2). The time series model recognized above was anticipated through the SPSS package. Different forms of ARIMA models were calculated *viz.,* ARIMA (1, 0, 1); ARIMA (0, 1, 0);ARIMA (0, 1, 1); ARIMA (1, 1,1); ARIMA (2, 1, 0) and ARIMA (2, 1, 2) and found that the best fitted model ARIMA (0, 1, 0) was selected on the basis Maximum Absolute Percentage Error (MAPE) values (Table 1), it was examined that MAPE for area (11.558) and production (4.306) were the smallest value for ARIMA (0, 1, 0) model. Hence, ARIMA (0, 1, 0) was the most indicative model for the area and production of small millets in India.

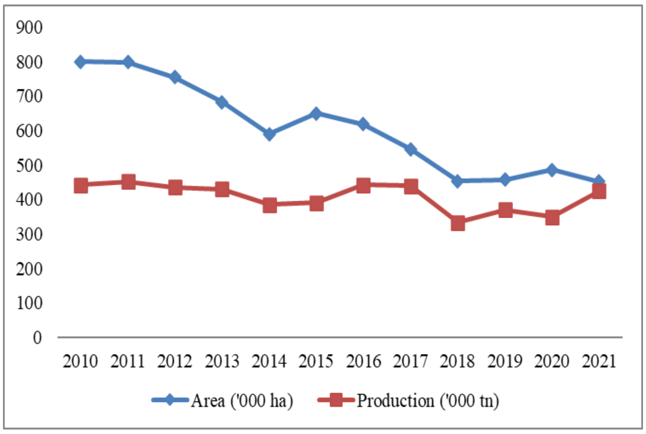

Fig. 1. *Trend of area and production of minor millets in India*

Checking of diagnostic error

The model confirmation is alarmed with the residuals checking; if residuals enclosed regular pattern, it might be eliminated. This could be completed by observing the residuals of autocorrelations. For this reason, different autocorrelations up to 23 lags were calculated, and similar results were examined (Fig. 2). The results revealed that none of the abovementioned autocorrelations was significantly dissimilar from zero at any rational level. This demonstrated that the chosen ARIMA model was suitable for forecasting the area and production of small millets in India.

Forecasted scenario of minor millets in India

The rate of area under minor millet growth has a negative trend in India. The plot of the trend analysis for the minor millet area in India is shown in Fig. 3. The red colour indicates the actual values, and the blue colour indicates the small millet area's forecasted values. The outcome from Table 2 shows that if the existing growth rate remains similar, the area of Indian minor millet would be 422.4, 419.1, 415.8, 412.5 and 409.2 thousand ha for 2022, 2023, 2024, 2025 and 2026, respectively. The predicted values of area under minor millets showed a decreasing trend in the upcoming five years due to the disregard of the Indian government and policymakers as a negligible crop.

Table 1. ARIMA Model summary

Fit Statistic	Area	Production
Stationary R-squared	0.707	0.000
R-squared	0.918	0.991
RMSE	188.309	167.679
MAPE	11.558	4.306
MaxAPE	45.271	18.230
MAE	134.316	109.783
MaxAE	583.065	691.493
Normalized BIC	10.536	10.304

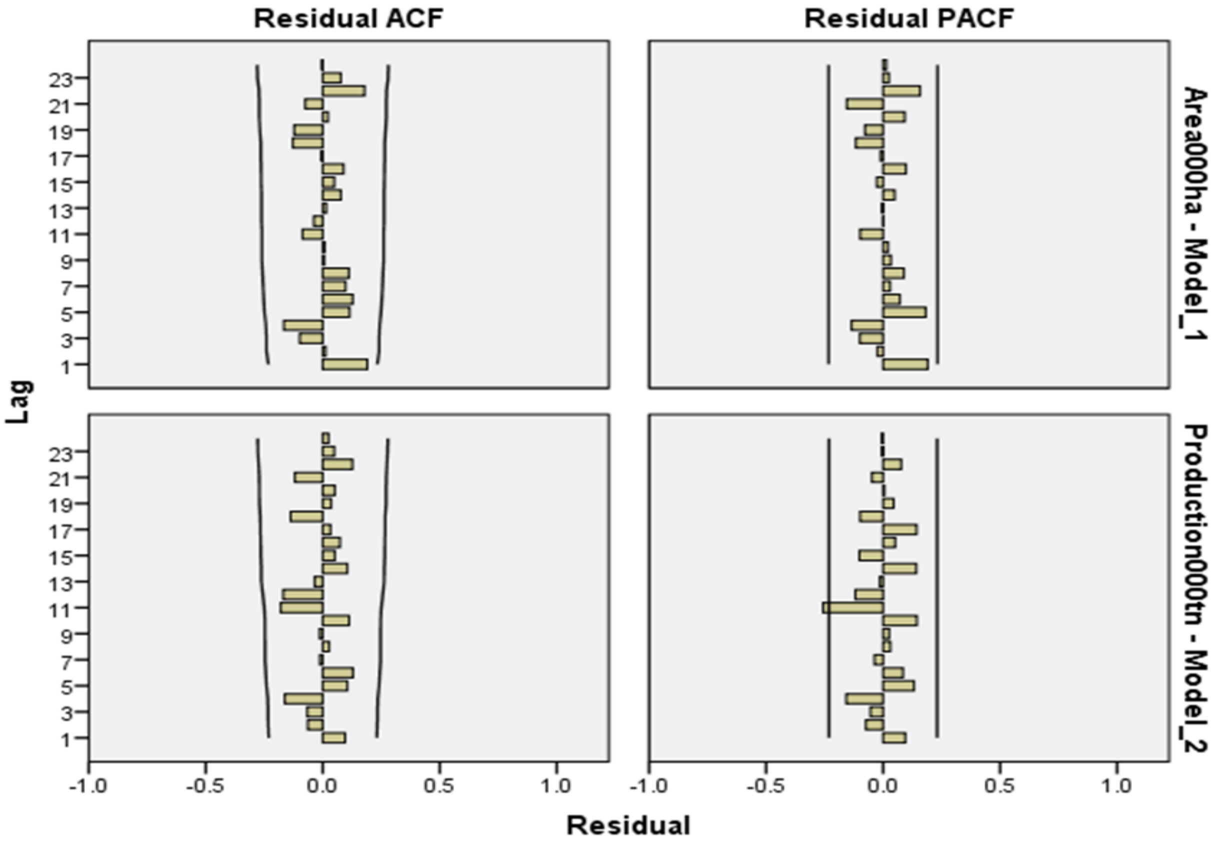

Fig. 2. *ACF and PACF functions of area and production of minor millets*

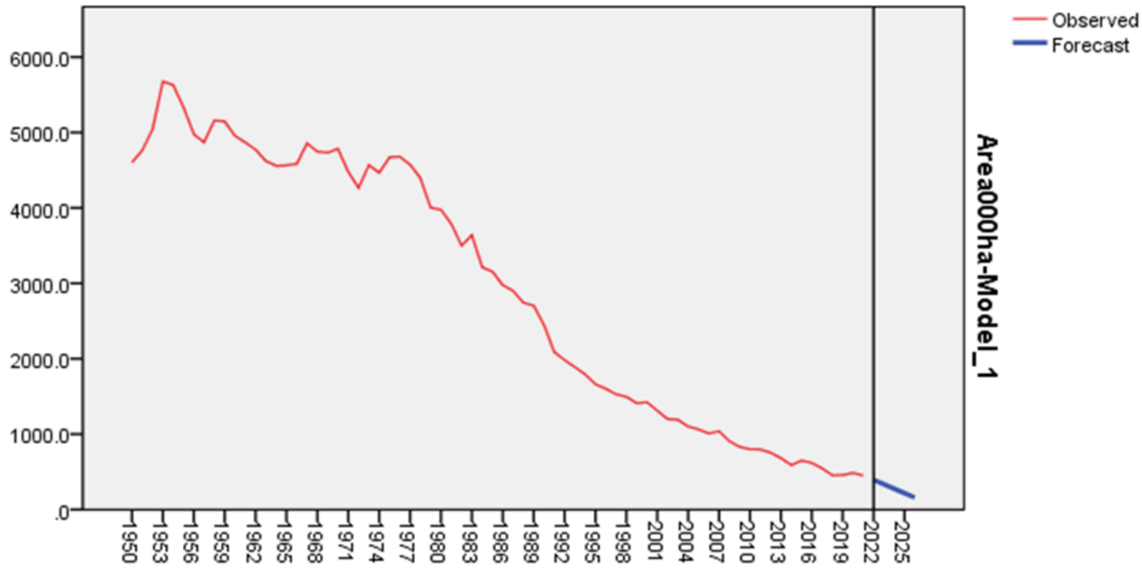

Fig. 3. *Forecasted values of minor millets area (thousand hectare)*

The growth rate of small millet production also decreased in India, and Fig. 4 displays the trend plot for small millet production in India. Forecasted production under small millets in India for the next five years would be 393.5, 335, 276.5, 218, and 159.5 thousand tons, respectively. Forecasted production values under minor millets in India also have a negative trend in the coming five years. The production of these crops can be improved by the suitable use of inputs, high-yield varieties and awareness through propaganda and demonstration (Gowri and Prabhu, 2017).

For the present study, the ARIMA model (Box-Jenkins) was used in the analysis for forecasting minor millets. It is world widely considered the most efficient forecasting technique and is used extensively for time series forecasting in India. The use of ARIMA for forecasting mi-

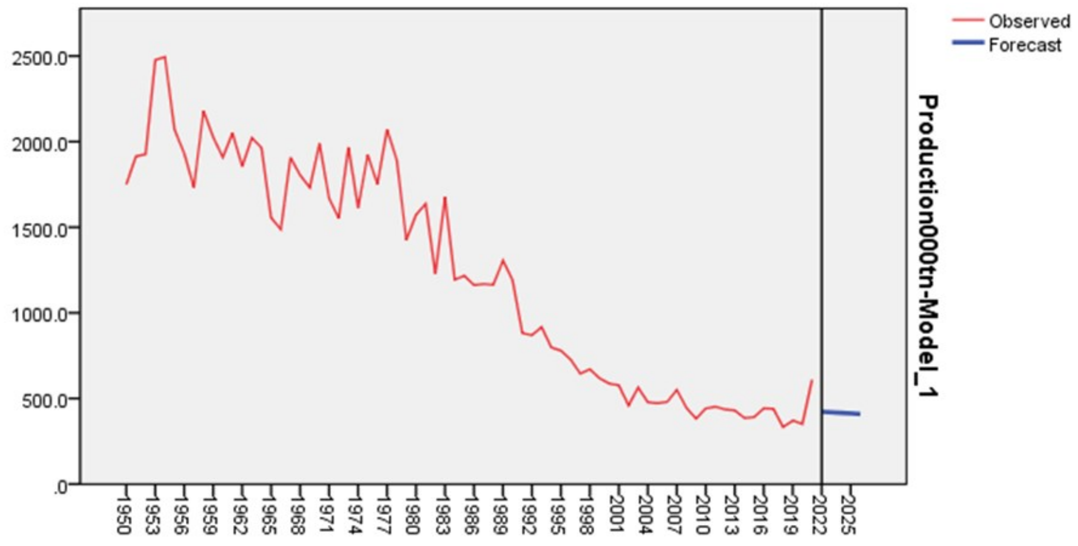

Fig. 4. *Forecasted values of minor millets production (thousand tons)*

nor millets is important with uncertainty as it does not assume knowledge of any underlying model or relationships as in some other methods. In this study, ARIMA relied on previous values and previous error terms of minor millets and produced the best results for forecasting.

Conclusion

From this study of trend analysis of minor millet area and production in India, it was obvious that the swing from 1950 to 2021 for both area and production was constructed to be significantly negative. However, the issue was decisive, as the refined area under minor millet decreased more rapidly, whereas production decreased relatively at a slower rate. Moreover, important small millet production forecasting was significant in semiarid areas in India, where precipitation was incorrigible for a shorter period. In this study, ARIMA model was applied to forecast the area and production of minor millets in India, and the area and production trend over the years were examined. It was created that ARIMA (0,1,0) model was best fitted and it exhibited a decreasing trend in upcoming years. The error term from the best fitted ARIMA method was explored to observe autocorrelation among the values and indicated that the errors have constant variance and zero, which designates the appropriate condition of the model for forecasting the area and production of minor millets. The predicted values of area and production under minor millets showed a decreasing trend in the upcoming five years because of non awareness about their nutritional values and unsupported policy measures making them negligible crops. Hence, the production of these crops can be improved by the suitable use of inputs and timely application of inputs, high

Table 2. Forecasted area, production of minor millets in India

Year	Area ('000 ha)	Production ('000 tn)
2022	422.4	393.5
2023	419.1	335.0
2024	415.8	276.5
2025	412.5	218.0
2026	409.2	159.5

yield varieties and awareness through propaganda and demonstration. Additionally, minor millet crops can be subsidized through a public distribution system and provide incentives to small millet farmers who produce higher yields from minor millet cultivation, which can enhance the economic status of China as well as the food and nutritional security of India.

Conflict of interest

The authors declare that they have no conflict of interest.

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