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RESEARCH ARTICLE

Price analysis and forecasting patterns of maize grown in the states of Tamil Nadu and Karnataka

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Abstract

Maize (*Zea mays* L.) is the most important cereal crop in India. It serves as a vital component in the food, feed and industrial sectors and contributing significantly to the agricultural economy. This study analyses the price dynamics and forecasting patterns of maize in India, with a specific focus on the regional markets of Salem in Tamil Nadu and Haveri in Karnataka, over a 10-year period from 2015 to 2024. A comprehensive time series analytical framework was employed, incorporating tools such as the Compound Annual Growth Rate (CAGR), seasonal indices, standard deviation and coefficient of variation, along with the Autoregressive Integrated Moving Average (ARIMA) model, to investigate trends, seasonal behaviour, price volatility and price forecasting. This study highlights long-term trends in the area, production and yield of maize at both national and state levels. The studies revealed that Tamil Nadu demonstrated comparatively stronger growth performance than Karnataka, with higher averages across all parameters. This advantage could be attributed primarily to improved irrigation infrastructure, adoption of hybrid varieties and targeted policy support. Seasonal index analysis uncovered distinct price movement patterns, with Salem showing seasonal peaks in August and Haveri in September, coinciding with lean supply months. Price volatility analysis showed moderate fluctuations, with Salem exhibiting slightly greater variability. The ARIMA model predicted a gradual rise in maize prices from July to December 2025 in both markets. This research provides meaningful insights for farmers, traders, policymakers and agri-business firms to develop better crop planning, price risk management and marketing strategies.

Keywords: ARIMA model; compound annual growth rate; maize; price forecasting; time series analysis

Introduction

Maize (*Zea mays* L.), also known as the “Queen of Cereals”. It is considered as one of the most vital cereal crops across the globe (1). It is a highly versatile crop capable of growing under diverse agro-climatic conditions. Unlike many other crops, maize can thrive in environments ranging from 58° N to 40° S latitude, at altitudes from below sea level to over 3000 m and in areas receiving annual rainfall ranging from 250 mm to more than 5000 mm (2). Owing to its broad adaptability, maize serves as a vital raw material for multiple industries, including livestock feed, starch production, food processing and bio-ethanol manufacturing. Additionally, corn starch derivatives are widely utilized in various sectors such as pharmaceuticals, cosmetics, textiles, paper production and food industry (1).

Globally, maize ranks as the third most important cereal crop after wheat and rice. It accounts for approximately 8 % of the global cultivated area and contributes around 25 % to the total cereal output. The major maize producing countries include the United States, China, Brazil, Mexico and India (3). In India, maize stands as the third most vital cereal crop after rice and wheat, thus playing a key role in the countrys’ agricultural output and economy. As of 2023–2024, India ranks fourth globally in terms of area under maize cultivation and seventh in production, with 9.20 M ha under cultivation and a total output of 27.80 million metric tonnes (4). The major maize producing states in India include Karnataka, Madhya Pradesh, Maharashtra, Tamil Nadu, West Bengal, Rajasthan, Bihar, Andhra Pradesh, Uttar Pradesh and Telangana (5).

In recent years, maize has gained prominence in Tamil Nadu, primarily driven by its growing demand for poultry feed and industrial uses. This is attributed mainly to the strong presence of poultry industry in the region. The area under maize cultivation in the state has nearly tripled over the last decade. Districts such as Salem, Perambalur, Dindigul and Erode have emerged as key production zones, collectively accounting for around 50 % of the maize area and output in the state. In contrast, Karnataka continues to hold the distinction of being the leading maize producing state in India. Six key districts namely Haveri, Davangere, Belgaum, Bellary, Bagalkot and Chitradurga together account for nearly 60 % of the total maize area in the state (6).

To support maize production and reduce the gap between demand and supply, the Government of India has implemented several production-oriented initiatives. A Notable intervention is the National Food Security Mission (NFSM), launched in 2008-2009 to increase the production, area and productivity of key food grains, including maize. In 2019-2020, the mission was expanded with revised targets, aiming to produce an additional 2 million tonnes of nutrient-rich coarse cereals. The updated objectives also placed greater emphasis on enhancing post-harvest value addition at the farm level, enabling farmers to obtain better prices through stronger market linkages and efficient value chains (7).

Despite these policy interventions, maize cultivation in India continues to face several challenges. Unpredictable climate variations often result in reduced yields across different agro-climatic zones. In states such as Chhattisgarh and Uttar Pradesh, the adoption of high-yielding hybrid maize seeds remains limited, thereby restricting productivity. Insufficient farm mechanization techniques further affect the timeliness and efficiency of crucial operations like sowing and harvesting. Furthermore, poor market infrastructure, high input costs and limited access to quality seeds and fertilizers persists as major constraints on both productivity and profitability (6).

The present study seeks to analyse long-term trends in the area, production and yield of maize in India, with a focus on Tamil Nadu and Karnataka. It also investigates seasonality and price instability in two key regional markets - Salem (Tamil Nadu) and Haveri (Karnataka). The study employs ARIMA modelling to forecast short-term maize prices in these markets so that market planning and policy formulation can be implemented. The present study was conducted with the following objectives.

- To investigate the trend and seasonal patterns in price of maize across selected markets.
- To assess the extent of price volatility in maize among the selected markets.
- To forecast price of maize in the selected markets.

Methodology and Data collection

This study adopts a quantitative research design to examine the price behaviour of maize in Tamil Nadu and Karnataka. Utilizing time series analysis, it investigates price trends, seasonal fluctuations and provides forecasts for future market movements, based on a 10-year monthly dataset spanning from January 2015 to June 2025. Average monthly prices of maize were sourced from reputable databases such as AGMARKNET (8) and INDIASTAT (9).

To evaluate seasonal variations and long-term trends, various analytical tools were employed, including the CAGR, Seasonal Index, Standard Deviation (SD) and Coefficient of Variation (CV), along with the ARIMA model was applied to generate price forecasts.

Trend analysis - Compound Annual Growth Rate

The exponential CAGR for maize area, production and yield were calculated using linear functions applied to time series data. To examine the trend in growth rates more effectively, a semi-logarithmic function was employed, as it is considered a suitable functional form for such analysis. Specifically, the growth rate was determined using the following model (10):

$$\text{Log}\, Yt = a + bt \qquad \text{(Eqn. 1)}$$

The (Eqn. 1) can be further explained as follows:

$$Yt = Y_0 (1+r)\, t$$

Taking the log on both sides:

$$\text{Log}\, Yt = \text{Log}\, Y_0 + t\, \text{Log}\, (1+r),$$

Which can be written as,

$$Y = a + bt$$

Where,

Yt = area/production/yield

a = constant

b = regression coefficient that shows the growth rates

The annual compound growth rate is calculated using the following formula:

$$\text{Antilog}\,(b) = \text{Antilog}\,(\log (1+r))$$

$$\text{Antilog}\,(b) = 1+r$$

$$r = \text{Antilog}\, b - 1$$

Multiplying the result by 100, the percentage growth rate in the area, production and yield is obtained. This represents the CAGR:

$$(\%) = r = (\text{Antilog}\, b - 1) * 100 \qquad \text{(Eqn. 2)}$$

Seasonal Index

This tool helps to reveal seasonal patterns in the movement of prices throughout the year. It shows when prices typically drop below or rise above the yearly average during certain months, giving a clearer picture of how the market tends to behave. The seasonal index is calculated by dividing the average price of each month by overall annual average price and then multiplying the result by 100.

$$\text{Seasonal Index} = (\text{Monthly average price} / \text{Annual average price}) * 100 \qquad \text{(Eqn. 3)}$$

The seasonal index represents the relationship between each months' price and the overall annual average, using 100 as the base value. This method helps to spot months with the highest prices as well as periods when prices decline, offering a clear view of seasonal highs and lows throughout the year.

Price stability analysis – Standard Deviation and Coefficient of Variation

The SD and CV are employed to evaluate the extent of price variability in maize across various markets. These measures facilitate price comparisons between markets and help to assess the degree to which prices deviate from the average.

Standard Deviation (SD)

It reflects the overall spread or deviation of monthly prices from the yearly average, providing a measure of how widely price values differ from the mean. A higher SD indicates greater price fluctuations, while lower value suggests more consistent and stable pricing throughout the year.

$$SD = \sqrt{[\sum (Xi - \bar{X})^2 / n]} \qquad \text{(Eqn. 4)}$$

Where,

Xi – Individual monthly price

$\bar{X}$ - Annual average price

n – Number of observations (in months)

Coefficient of Variation

It represents the extent to which prices vary from the average, serving as an indicator of the stability or instability of a particular parameter. The value was calculated using the following formula (11):

C.V. = (SD/AA) *100 (Eqn. 5)

Where,

SD = standard deviation

AA = annual average price

Auto Regressive Integrated Moving Average (ARIMA)

The Box-Jenkins methodology (1976) is particularly effective for short-term forecasting because ARIMA models tend to give more weight to recent observations compared to older data, making them well-suited for capturing current trends and patterns (12).

ARIMA belongs to the statistical methods. In general, the literature suggests that prediction can be approached from two main perspectives: statistical methods and artificial intelligence (AI) techniques. ARIMA models are often regarded as robust and highly effective for financial time series forecasting, particularly for short-term predictions, where they can even outperform popular artificial neural network (ANN) approaches. Their application has been widespread, especially in the domains of economics and finance (13).

Structure of ARIMA model

It integrates three main components, denoted as ARIMA (p, d, q), with each element representing a distinct aspect of the model:

p – number of autoregressive terms

d – number of differencing operations needed to make the data stationary

q – number of moving average items

Component models

Autoregressive (AR) component

It relies on past observations of the variable to estimate its current values, it is represented as,

$Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \alpha_3 Y_{t-3} + \ldots\ldots\ldots\ldots + \alpha_p Y_{t-p} + \varepsilon_t$ (Eqn. 6)

Here, the present price is influenced by the prices from earlier periods, with each past value assigned a particular coefficient in the forecasting equation.

Moving average (MA) component

It adjusts past forecasting errors to enhance the accuracy of current predictions. Represented as,

$Y_t = \mu + \varepsilon_t - \varphi_1 \varepsilon_{t-1} - \varphi_2 \varepsilon_{t-2} - \ldots\ldots - \varphi_q \varepsilon_{t-q}$ (Eqn. 7)

Here, the current values are refined by accounting for the errors made in previous forecasts.

Combined ARIMA model

This model combines both the autoregressive and moving average elements, represented jointly by (p, q),

$Y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \alpha_3 y_{t-3} + \ldots. + \alpha_p y_{t-p} + \varepsilon_t - \varphi_1 \varepsilon_{t-1} - \varphi_2 \varepsilon_{t-2} - \ldots\ldots - \varphi_q \varepsilon_{t-q}$ (Eqn. 8)

It integrates the impact of previous observations and past forecast errors to enhance the accuracy of predictions.

Integration (I) component

The integration part deals with differencing the data to eliminate trends, helping to transform the series into a stationary one where its statistical characteristics remain consistent over time.

The process begins with testing for stationarity, where the price data is examined using autocorrelation function (ACF) plots to determine whether it is stationary. If the data is non-stationary, differencing is applied repeatedly until the statistical properties stabilize over time, this level of differencing is recorded as the parameter ‘d’.

This is followed by the model identification stage, which involves analysing the ACF and partial autocorrelation function (PACF) plots to appropriately determine the values of ‘p’ (autoregressive terms) and ‘q’ (moving average terms) for the ARIMA (p, d, q) model.

The third step is parameter estimation, where the models’ coefficients are calculated using the maximum likelihood estimation to find the values that best align with the historical price data.

Following this model validation, where the residuals (errors) from the model are checked to ensure they are randomly and normally distributed. The identification process is repeated with different parameters if the pattern exists.

Finally, in the model selection stage, the most suitable model is chosen on statistical criteria such as the Akaike Information Criterion (AIC), Schwarz-Bayesian Criterion (SBC), Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE). MAPE serves as a relative metric to compare the forecasting accuracy of different models for the same data series.

$$\text{MAPE} = \frac{\sum_{t=1}^{n} \left| \frac{y_t - \hat{y}\_t}{yi} \right|}{n} \times 100 \qquad \text{(Eqn. 9)}$$

y- actual value at time ‘t’

ŷ_t- predicted value at time ‘t’

n - number of observations

The final stage involves generating forecasts using basic statistical measures and confidence intervals to assess the reliability of the predictions and monitor the models’ performance in identifying any deviations or control issues. In this study, SPSS is utilized to estimate and forecast the ARIMA model. This approach follows the methodology outlined in a prior study (14). A model is considered to have a better fit when it produces lower values of error metrics such as MAPE.

Results and Discussion

Trend analysis of maize area, production and yield (2015-2024)

Understanding the long-term trends in maize cultivation helps reveal whether the crop is gaining or losing ground in terms of cultivated area, output and productivity. The CAGR serves as a valuable metric for this purpose, as it smooths out year-to-year fluctuations and highlights the overall growth trajectory (15).

National trends in maize cultivation

At the national level, the maize cultivation area expanded at a CAGR of 2.20 %, while production and yield grew by 5.79 % and 3.51 % respectively (Table 1). This positive performance likely reflects the wider adoption of hybrid varieties, increased mechanization and the implementation of improved crop management practices across major maize-growing states. Furthermore, national policies such as the National Food Security Mission (NFSM-Maize) have contributed to enhancing productivity and optimising resource utilization (16).

Performance of Tamil Nadu

Tamil Nadu recorded the highest growth rates among the study regions, with a 3.18 % increase in cultivated area, a 9.50 % rise in production and a 4.98 % improvement in yield (Fig. 1 and 2). The performance can be attributed to enhanced irrigation infrastructure, rapid adoption of single-cross hybrids and targeted agricultural extension programs. The growing demand from the poultry feed industry and supportive government procurement policies have further incentivized farmers to expand maize cultivation. The data clearly show that Tamil Nadu outpaced Karnataka across all parameters during 2015-2024. This underscores the effectiveness of localized interventions such as better water management and advanced seed technology in boosting performance (17).

Table 1. Trend in area, production and yield of maize in India and in states Tamil Nadu & Karnataka (2015-2024)

	CAGR (in percentage)		
	Area	Production	Yield
India	2.20	5.79	3.51
Tamil Nadu	3.18	9.50	4.98
Karnataka	1.94	2.92	2.03

Performance of Karnataka

Karnataka displayed moderate but stable growth, with a CAGR of 1.94 % for area, 2.92 % for production and 2.03 % for yield (Table 1). The relatively slower progress can be linked to climatic constraints such as periodic droughts and erratic monsoon patterns, which adversely affect both productivity and farmer confidence in maize expansion. Nevertheless, Karnataka continues to be a leading maize producer in India due to its large cultivation base and established market networks (18).

Seasonal variation in maize prices

The seasonal index was calculated to analyse recurring monthly patterns in maize prices. The seasonal index values for the Salem market (Tamil Nadu) and the Haveri market (Karnataka) are given in Table 2. In Salem, the index values are highest in August (105.00 %) and July (104.75 %), indicating high prices during the lean season when arrivals decrease and demand remains strong, especially from feed mills. Prices dip during January (95.85 %), reflecting surplus post-harvest supply.

In Haveri, seasonal price movements are slightly more volatile, with higher peaks observed in September (107.17 %) and August (107.12 %). These trends reflect lower market arrivals during monsoon and increased procurement by poultry industries, which use maize as a staple in feed formulation. A combined visual representation of the seasonal price movements of maize in the Salem and Haveri markets are given in Fig. 3. Salem experiences price peaks during mid-year, with a clear dip in the early months whereas Haveri exhibits sharper seasonal price around August-September, likely coinciding with lean supply periods.

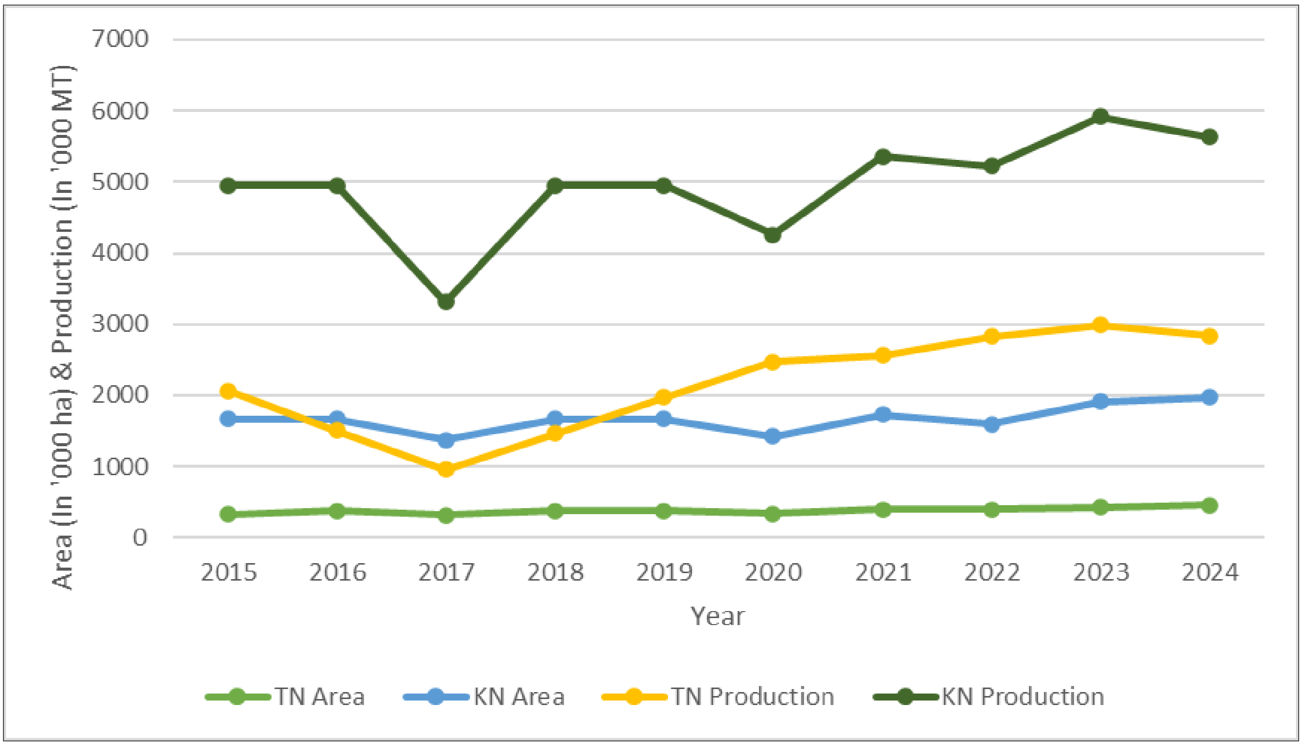

Fig. 1. Trends in area and production of maize in Tamil Nadu and Karnataka for the time period of 2015-2024.

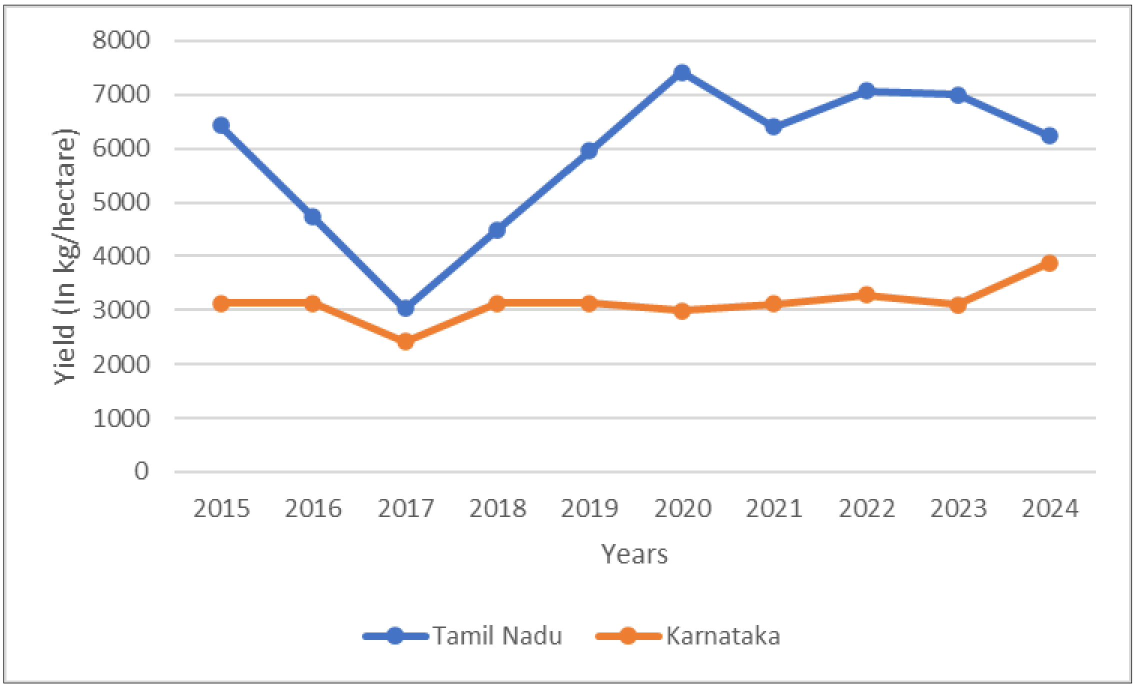

Fig. 2. Yield of maize in Tamil Nadu and Karnataka for the time period 2015-2024.

Table 2. Seasonal price index for maize in Salem and Haveri markets (2015-2024)

	Seasonal index for maize (in percentage)	
Month	**Salem**	**Haveri**
January	95.85	96.51
February	97.40	96.93
March	98.82	97.98
April	102.03	96.38
May	98.18	96.54
June	101.03	99.98
July	104.75	106.29
August	105.00	107.12
September	100.80	107.17
October	98.29	100.44
November	96.16	96.15
December	101.64	98.45

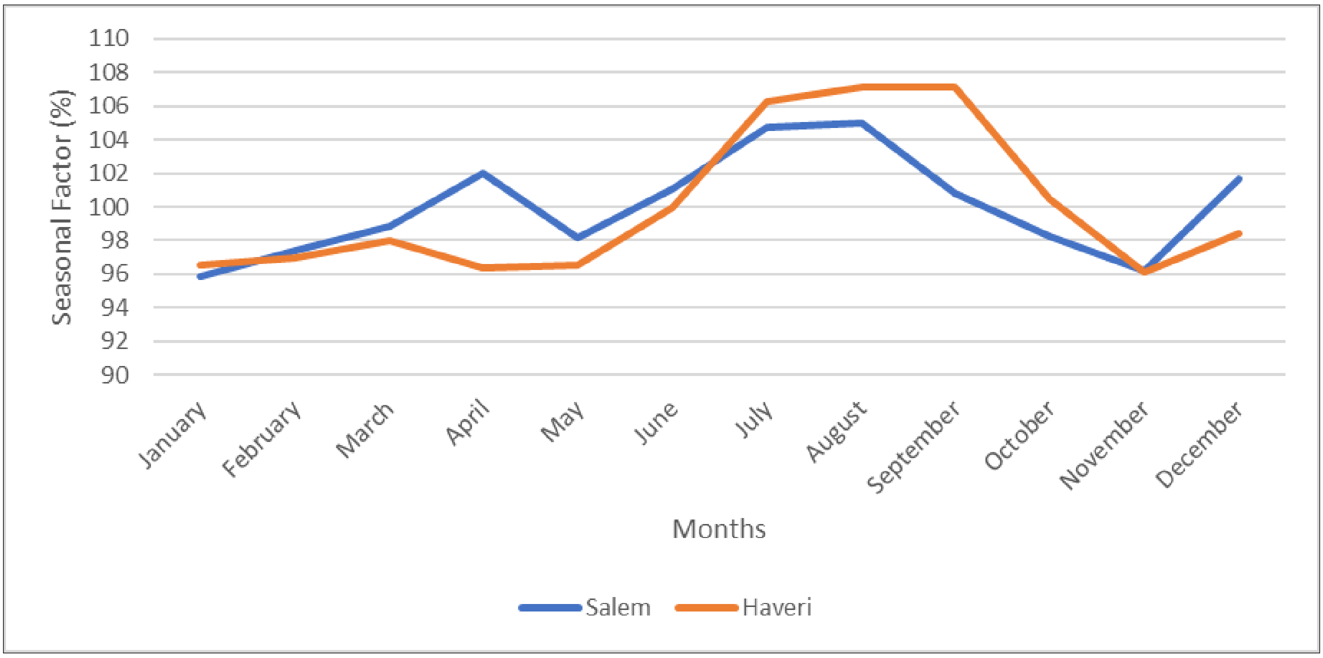

Fig. 3. Monthly average seasonal index for maize in Salem and Haveri market 2015-2024.

These seasonal patterns indicate that the optimal time for farmers to sell maize is during the lean season, when prices are relatively higher. Conversely, during periods of bulk arrivals at harvest, farmers may need to adopt storage strategies or rely on institutional procurement mechanisms to avoid distress sales and stabilize income (11).

Price volatility in maize markets

Price volatility was assessed using descriptive statistics, including SD and CV (Table 3). The Salem market recorded a high mean price of ₹1794.46/quintal, with a standard deviation of ₹466.55 and a CV of 0.248. The Haveri market had a slightly lower mean price of ₹1727.83/quintal, with a standard deviation of ₹402 and a CV of 0.232. These findings indicate that Salem market experienced greater price swings, the Haveri market demonstrated relatively more stable price behaviour (11).

The CV values confirm that relative price variability is moderate in both markets. Factors contributing to this fluctuation include post-harvest handling practices, presence or absence of storage facilities and procurement interventions by government agencies such as the Food Corporation of India (FCI), the Tamil Nadu Civil Supplies Corporation (TNCSC) and the Karnataka Food and Civil Supplies Corporation Limited (KFCSC).

ARIMA model - Forecasting maize prices

The ARIMA model was employed to predict future price behaviour (19). Model selection was guided by autocorrelation and partial autocorrelation diagnostics, along with MAPE to assess forecast accuracy.

Among the five models in the Salem market, the ARIMA (1, 1, 1) model was identified as the best-fitting model, with the lowest MAPE value of 8.933 (Table 4). The ACF and PACF plots revealed significant correlation supporting the choice of this model (Fig. 4 and 5). The residual ACF and PACF plot confirmed that the residuals were free from systematic patterns, exhibiting a white-noise distribution and thus validating the adequacy of the model (Fig. 6).

ACF stands for autocorrelation function. It is a statistical tool used to measure the correlation between observations of a time series separated by different time intervals (lags). In time series analysis, a lag refers to the time difference between two observations. For example, a lag of 1 compares the current value with the value from the immediately preceding time period, a lag of 2 compares with two periods before and so on. Partial ACF stands for partial autocorrelation function. Unlike the regular ACF, which measures the total correlation between a time series and its lagged values, the partial autocorrelation measures the correlation between the series and a lag after removing the effects of the intermediate lags in between (20).

The forecasted prices for Salem under the ARIMA (1, 1, 1) model are presented in Table 4. The data show a steady increase in prices of maize from ₹2534.10/q in July 2025 to ₹2570.50/q in December 2025. This upward trend suggests a possible tightening of maize supply or continued strong demand from the poultry, feed and ethanol industries during the second half of the year (21).

Table 3. Descriptive statistics of maize prices by markets (2015-2024)

Market	Mean price (Rs.)	Standard Deviation (Rs.)	Coefficient of variation
Salem	1794.46	446.55	0.248
Haveri	1727.83	402.00	0.232

Table 4. The forecasted monthly prices of maize in Salem and Haveri markets

Market	ARIMA model	MAPE	Forecasted price (in Rs/q)					
			July2025	August 2025	September 2025	October 2025	November 2025	December 2025
Salem	(1,1,1)	8.933	2534.1	2532.3	2539.4	2549.4	2559.8	2570.5
Haveri	(1,1,1)	4.315	1730.0	1733.3	1737.0	1740.7	1744.5	1748.3

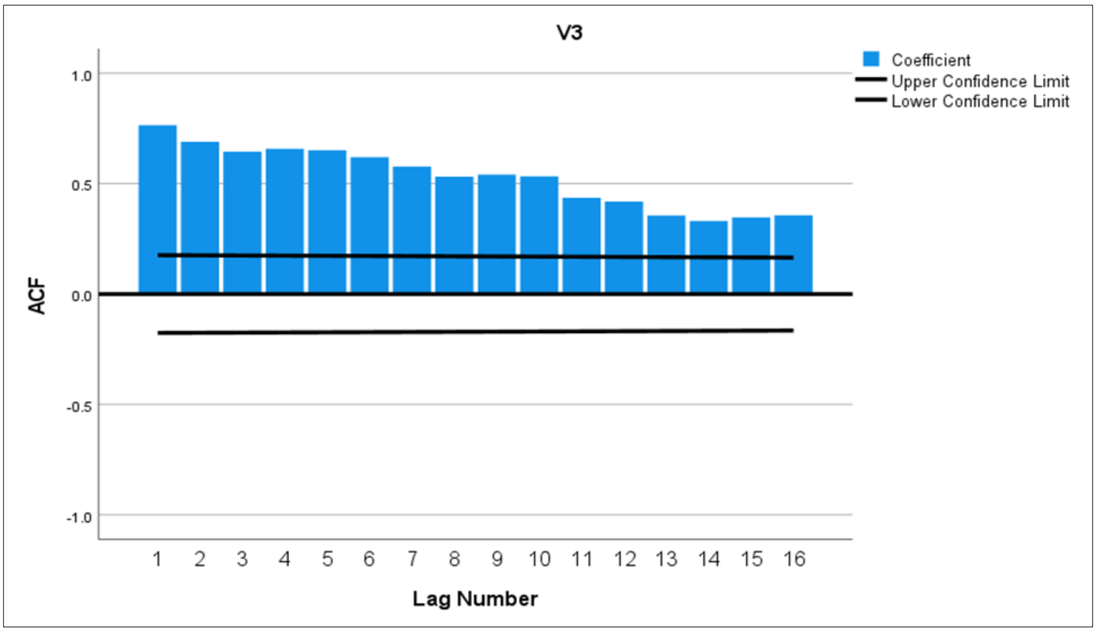

Fig. 4. Autocorrelation plot of maize price series in Salem market.

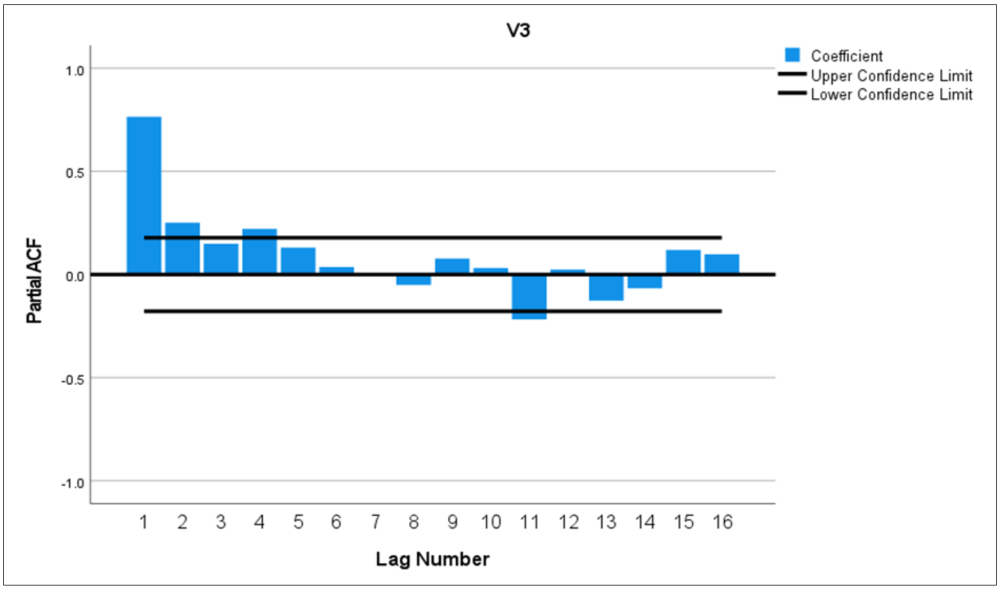

Fig. 5. Partial autocorrelation plot of maize price series in Salem market.

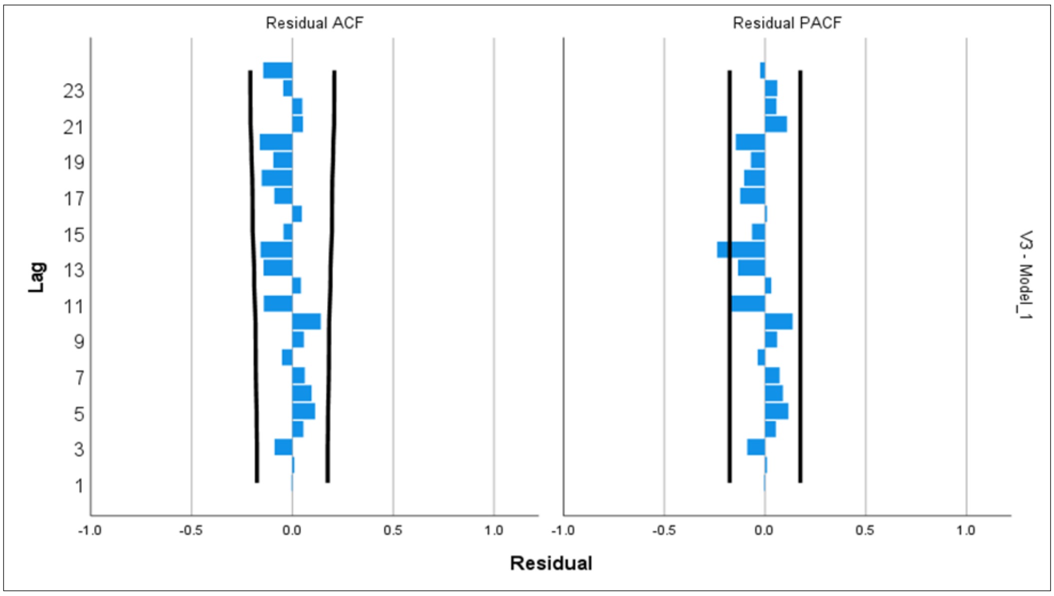

Fig. 6. The ACF and PACF for the selected ARIMA (1, 1, 1) model.

Among the five models in the Haveri market, the ARIMA (1, 1, 1) model again provided the best forecast with a MAPE of 4.315 (Table 4). The ACF and PACF plots (Fig. 7 and 8) supported the structure of the model and the residual ACF and PACF plot in Fig. 9 indicated no significant autocorrelations, confirming the robustness of the model. The forecasted prices for Haveri range from ₹1730.00/q in July to ₹1748.30/q in December 2025, reflecting moderate and consistent price growth in the market. The slower price increase in Haveri compared to Salem could be due to localized procurement activities, reduced input costs, or better access to warehousing facilities, which buffer sudden market fluctuations and ensure price stability (22).

Conclusion

This study provides an understanding of maize price and production patterns across the two states, emphasizing the influence of local conditions and market dynamics. Tamil Nadu exhibited more area under maize cultivation and production and yield, reflecting the positive impact of supportive policies and improved farming practices. The seasonal price differences between Salem and Haveri highlighted the need for localized strategies to effectively manage market fluctuations. The ARIMA (1, 1, 1) forecasts indicated a steady price rise from July to December 2025, enabling farmers and traders to plan more effectively. Overall, the study recommends adopting location-specific approaches, improving storage infrastructure and utilizing accurate forecasting tools to enhance maize market efficiency and support better outcomes for farmers.

Table 4. The forecasted monthly prices of maize in Salem and Haveri markets

Market	ARIMA model	MAPE	Forecasted price (in Rs/q)					
			July2025	August 2025	September 2025	October 2025	November 2025	December 2025
Salem	(1, 1, 1)	8.933	2534.1	2532.3	2539.4	2549.4	2559.8	2570.5
Haveri	(1, 1, 1)	4.315	1730.0	1733.3	1737.0	1740.7	1744.5	1748.3

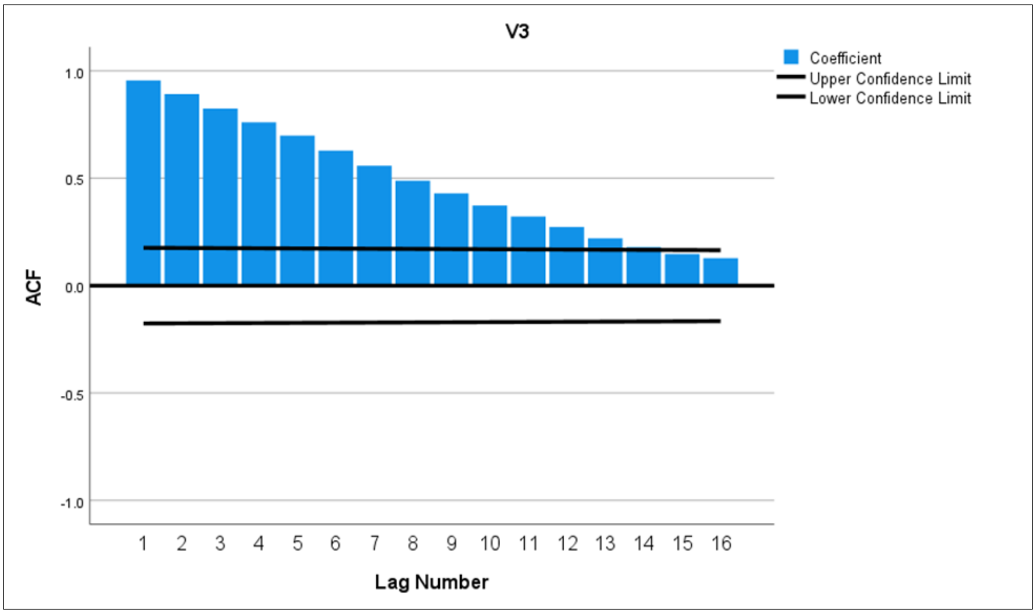

Fig. 7. Autocorrelation plot of maize price series in Haveri market.

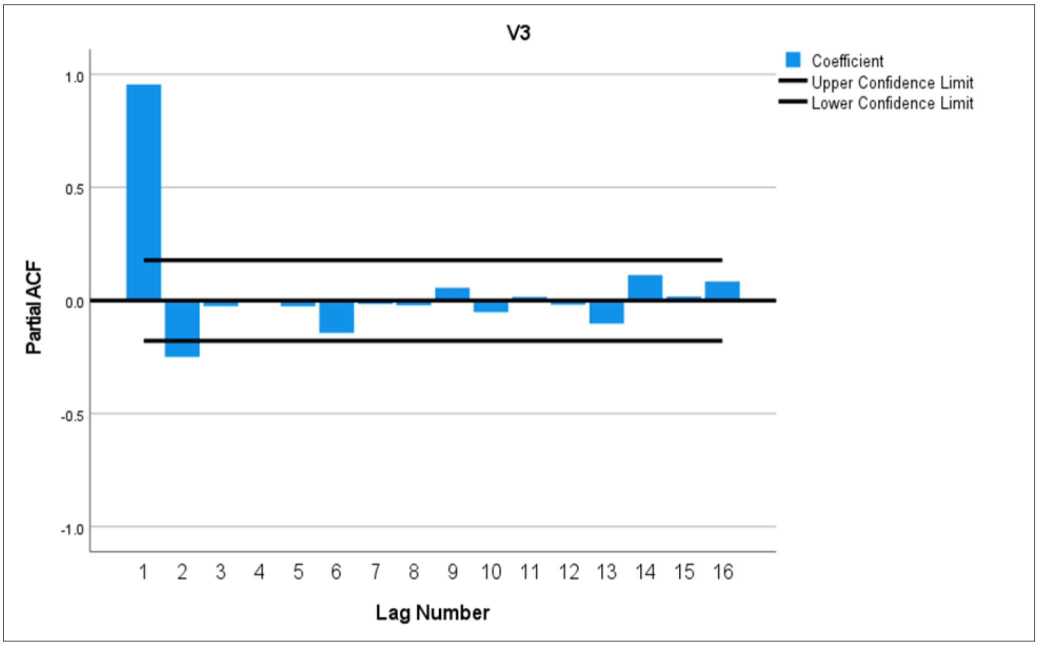

Fig. 8. Partial autocorrelation plot of maize price series in Haveri market.

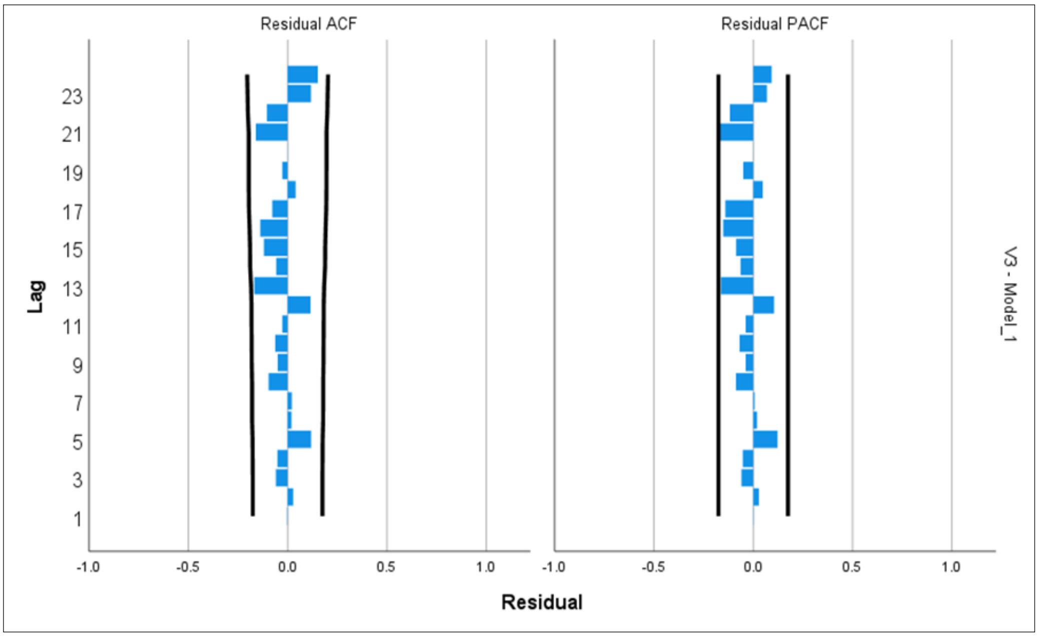

Fig. 9. The ACF and PACF for the selected ARIMA (1, 1, 1) model.

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Authors' contributions

KRJ participated in article collection, analysis, interpretation, writing and editing the manuscript. MK conceived the study, reviewed the manuscript. SS, PR and AV participated in finalising the manuscript. All authors have read and approved the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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