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A study on price forecasts of pearl millet in major markets of Karnataka

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Abstract
Millets are group of small-grained cereal food crops that are highly nutritious and are grown under marginal/low fertile soils with very low inputs such as fertilizers and plant protection chemicals. These crops largely contribute to food and nutritional security of the country. Karnataka state is well known for cultivating minor millets in India, with Pearl Millet, Pearl millet, Foxtail Millet, Little Millet and others, serving as staple meal in the major portion of the state. Forecasting of prices for pearl millet in its major markets is an important aspect in order to facilitate the farmers for their cropping plan. Current study is conducted in Raichur and Koppal districts for which was selected based on the highest arrivals in the selected markets. The time series data on monthly model price of pearl millet and bajra required for the study were collected from the respective APMC office records from 2011-12 to 2021-2022. A mixed Auto Regressive Integrated Moving Average (ARIMA) model developed by Box and Jenkins (1976) was employed to forecast the prices of pearl millet in selected markets. Which involved selection of appropriate model, estimation of parameters, diagnostic checking and finally forecasting the prices. Among the four markets of pearl millet, the price forecast model for Kushtagi market (0, 1, 1) (0, 1, 1) was found to be best model for pearl millet, likewise, the price forecast model for Gangavathi Market (1, 1, 1) (1, 1, 1) Manvi (1, 0, 1) (1, 0, 1) and Sindhanur (1, 0, 1) (1, 0, 1). According to the ARIMA forecasts, the prices of pearl millet will increase in next six month.

Keywords: Millets, price forecast, Arima, pearl millet, Kushtagi, Gangavathi, Mavi, Sindhanur.

1. Introduction

Millets are ancient super grains and nutritional reservoirs for enhanced health. Millets, notably sorghum, pearl millet, and tiny millets, are essential food and fodder crops in semi-arid regions and are rapidly gaining global importance. These crops are suited to a wide range of temperatures, moisture regimes, and input conditions, providing food and feed to millions of dryland farmers worldwide, particularly in developing countries. Furthermore, they are a key raw material in the production of drinkable alcohol and starch in developed countries. Millets such as giant millet (Sorghum), pearl millet (Bajra), pearl millet (Ragi), foxtail millet (Navane), little millet (Save), Proso millet, Barnyard millet, and Kodo millet are robust and thrive well as rain-fed crops in dry zones under marginal soil fertility and moisture conditions (www.millets.res.in).

Millets have a high protein level, which compensates for a lack of protein in a vegetarian diet. Millets are the superfoods of the present and future, thanks to their short growth season of roughly 65 days. Whole millets can be preserved correctly for two or more years. The challenge is to turn food-process into tasty and ready-to-eat foods like as cookies, noodles, and pre-baked roti's, as well as unique ready-to-eat and ready-to-cook dishes.

Climate change, water scarcity, expanding global population, rising food prices, and other socioeconomic repercussions are predicted to pose a significant danger to agriculture and food security worldwide in the twenty-first century, particularly for the poorest people living in desert and sub-arid countries.

India is the world's leading producer of the majority of millets. India now has approximately 14 million hectares of millets cultivation (2021-22) and produces approximately 14 million tonnes per year, with Rajasthan, Maharashtra, and Karnataka leading in millet farming. The Indian millets sector is becoming more exposed to international markets, and the influence of

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policy alternatives such as the minimum support price and other market intervention policies has not been able to achieve the needed adjustments in accordance with the goals and targets. Annual millet productivity trends in India have demonstrated significant fluctuation in response to the current policy environment and priority concerns.

Karnataka being one of the major producers of millets, contributed area of 1949.98 thousand hectors with total production of 2518.12 thousand tonnes (2019-20). During the year 2021 Karnataka stood at Seventh position in total production with 2900.00 thousand tones with a share of 3.17% in total Indian Production. The millets grown in Karnataka are: Sorghum (Jola), Pearl Millet (Sajje), Pearl millet (Ragi), Foxtail millet (Navane), Kodo millets (Haraka), Barnyard millet (Oodalu), Little millet (Same/Save), Proso millet (Baragu). Dharwad, Belgavi, Koppal, Raichuru, Hassana, Tumakuru, Ballari, Chikamaglur, Chitradurga etc. are the leading producing districts of Millets in Karnataka.

ARIMA (Auto Regressive Integrated Moving Average) models are widely used to investigate market volatility, notably in agricultural commodities. The ability of this class of models to quantify random changes contained in any economic time series is its main advantage. As a result, data on pearl millet prices in selected marketplaces were subjected to ARIMA analysis to quantify the volatility and predict future pearl millet prices.

Because the ARIMA model only utilized stationary series, it was necessary to convert non-stationary series to stationary series by applying the appropriate order of differencing to the series. Following that, the working series' autocorrelation and partial autocorrelation coefficients were estimated, which confirmed the absence of a trend component in the series. A review of similar tables shows that this is supported by the series' autocorrelation function going to zero after the second or third lag. The current study is an attempt to investigate the predicting of pearl millet prices at major marketplaces in Raichur and Koppal districts.

The main objective of the current study is to forecast the prices of pearl millet in selected markets of Karnataka.

2. Materials and Methods
2.1 Nature and Source of Data
The Raichur and Koppal Districts are major produced and consumer of pearl millet in Karnataka. The regulated markets in these districts are the most important and terminal markets in South Karnataka. The Manvi and Sindhanur markets in Raichur districts and Kushtagi and Gangavathi markets in Koppal districts were chosen for the present study as they are the largest markets for arrivals of pearl millet in Karnataka. The time series data on monthly price of pearl millet required for the study was collected from the registers maintained in these selected APMCs of respective District from the year 2011-12 to 2201-22. This market keeps track of agricultural commodity prices on a daily, monthly, and annual basis. The price data pertains to monthly modal prices. The modal price was thought to be preferable than the monthly average price since it represented the majority of the commodity sold in a certain market throughout the month.

2.2 ARIMA model
Price forecasting by ARIMA model ARIMA approach was initially popularized by Box and Jenkins (1976), also known as Box-Jenkins models. ARIMA model is most commonly used to analyze and forecast univariate time series data. It predicts the value in response to the linear combination of its own past time series values. Time series models are generally assuming to be stationary i.e., the mean and variance for the series are constant and its covariant is time invariant. If the time series is stationary then it can be inferred that ARMA (p, q) is applied. If the series is not stationary, it can be differenced "d" times to make it stationary then the model is referred as ARIMA (p, d, q). The term 'p' indicates order of partial autocorrelation, 'd' reflects the order of difference i.e., degree of differencing of time series and 'q' indicates order of moving average. When the model is characterized by seasonality element, then it should be extended with seasonal parameters known as the seasonal ARMA (in case of stationary time-series) or SARIMA (in case of non-stationary time series). They are represented as SARIMA (p, d, q) (P, D, Q) where P stands for seasonal autoregressive order, D for seasonal differencing number and S for seasonal moving average order. This model was selected as Kirankumar (2018) [3] concluded in his study.

The Box-Jenkins (BJ) methodology
The Box-Jenkins methodology is used to identify the best ARIMA model. This method consists of four steps,
a) Identification
b) (b) Estimation
c) (c) Diagnostic checking
d) (d) Forecasting

a) Identification
To find out the appropriate values of p, d, and q, the chief tools of identification are the Auto Correlation Function (ACF), the Partial Auto Correlation Function (PACF), and the resulting correlograms, which are simply the plots of ACF and PACFs against the lag length.

One way of accomplishing this is to consider the ACF and PACF and the associate's correlograms of a selected number of ARMA processes, such as AR (1), AR (2), MA (1), MA (2), ARMA (1, 1), ARMA (1, 2) and so on. Since each of these stochastic processes exhibits a typical pattern of ACF and PACF, if the time series under study fits one of these patterns, one can identify the time series with that process. Then apply diagnostic tests to find out if the chosen ARIMA model is reasonably accurate or not.

b) Estimation
After identifying the appropriate values of p and q the next step is to estimate the parameters of the autoregressive and moving average terms included in the model. Sometimes this calculation can be done by simple least squares, but sometimes one will have to resort to the method of moments or method of maximum likelihood estimation.

c) Diagnostic checking
In this step, one has to see whether the chosen model fits the data reasonably well or not. The two commonly used criteria are Akaine Information Criterion (AIC) and Bayesian Information Criterion (BIC). Lower the AIC and BIC values, better the fit of the selected ARIMA model.

d) Forecasting
One of the reasons for the popularity of ARIMA modelling is its success in forecasting. To forecast the values of a time series, the basic Box-Jenkins strategy has to be followed. The steps involved in the computation are given below.
First, examine the stationary. This step can be done by computing the ACF and PACF values.

a) If the time series is not stationary, the difference is one or more times to achieve stationary.
b) The ACF and PACF of the stationary time series are then computed to find out if the series is purely autoregressive or purely of the moving average type or a mixture of the two.
c) The tentative model is then estimated.
d) The residuals from this model are examined to find out if they have white noise. If they have, the tentative model is probably a good approximation to the underlying stochastic process. If they have not, the process is started all over again. Therefore, the Box-Jenkins method is an iterative process. The model finally selected can be used for forecasting.

3. Results and Discussions
3.1 ARIMA model
As Box-Jenkins model is preferred to the multiplicative time series model for forecasting purposes. In this study, it was used for forecasting the prices of millets in selected markets of Karnataka. The ARIMA model was calculated using EViews software as mentioned in the methodology. The results of ARIMA calculated using EViews are presented in Table 1

3.2 Diagnostic checking
Table 1 presents the residual analysis of monthly prices of pearl millet in the selected markets of districts of Karnataka during January 2023 to March 2024. The district that is selected is Koppal and Raichur selected with Kushtagi and Gangavathi markets in Kopal district. In Raichur district, Mavi and Sindhanur markets were selected. For the markets of Koppal district, in Kushtagi market the selected model was found to be best git was (011), (011) with the AIC value of 15.56. with respect to Gangavathi market the best fit model found to be (111) (111) with the AIC value of 16.62. with respect to markets of Raichur district, in Manvi market the best fit model registered to (101) (101) wi9th the AIC value of 18.87 and with respect to Sindhanur market it was (101) (101) registering AIC value of 17.42. Almemaychu Amera (2002) [1] and Punitha (2007) [5] utilised a similar model to forecast agricultural commodity prices and arrivals and draw conclusions.

3.3 Forecast of Pearl millet prices
The table 2 depicts the forecast of monthly pries of pearl millet in the selected markets of Karnataka during January 2023 to March 2024. As it is evident that two districts were selected that is Koppal and Raichur. In Koppal district Kushtagi and Gangavathi markets and in Raichur district Manvi and Sindhanur Markets were selected.
The forecast in Kustagi market indicated that the prices of pearl millet will go in increasing order and it is elected to be ₹ 2889.00 per quintal of Peral millet in the month of March 2024. The validation for the prices that are forecasted were in the range from 83% to 99% for the period of January 2022 to August 2023. The accuracy of forecast was found to be highest with 99.62 per cent for the month of January 2023. The pries of pearl millet which was ₹ 1666.00 per quintal in the month of January 2022 was rose to ₹ 2270 per quintal for the month of August 2023.
For Gangavathi market as per the estimation of the forecasts the prices are expected to reach ₹ 2326.28 per quintal for the month of March 20204. The prices of pearl millet which was

₹ 1599 per quintal in the month of January 2022 has rose to ₹ 2497 per quintal for the month of August 2024. The validation of the forested prices, the validation was in between 82 per cent to 9 per cent for the months that were forecasted. The highest accuracy of forecasts was obtained for the month of January 2022 with an accuracy rate of 99.87 per cent. Wali et al. (2017) [7] and Jalikatti and Patil (2015) [6] were also observed same kind of observation in their study.
For the markets of Raichur district, in Sindhanur market the prices of pearl millet which was ₹ 1593.00 per quintal in January 2022 has rose to ₹ 2836 per quintal in the month of August 2023. As per the prediction done through best forecast model the prices of pearl millet are expected to decrease and it's about to reach to ₹ 1646.45 per quintal of pearl millet. The validation of the forecast value that was obtained in the ranges of 60 per cent to 97 per cent. The accuracy of the forecast was found to be highest for the month January 2022 with 97.25 per cent. Manasa (2010) [4] cited similar conclusions about the validation of ARIMA modelling
In case of Manvi market, the prices of pearl millet which was ₹ 2100.0 in the month of January 2022 has rose to ₹ 2853.00perquintal for the month of August 2023. The forecast that was done using the best fit forecast model indicated that the prices of pearl mallet in the market of Manvi is expected to reach ₹ 3816 per quintal for the month of March 2024. The validation of the forecasts that the accuracy range of forecasts was in between 79 per cent to 99 per cent. The highest accuracy of forecast value that was obtained were for the month of July 2022 with 99.88 per cent of accuracy indicating the model that was used for the forecast was highly recommendable. The results are in same line with study conducted by Hemavathi and Prabakaran (2018) [2] on price forecasts of rice.
As observed from the forecasts, for the Koppal district the two markets that are selected are Kustaghi and Ganagavathi market. In Kushtagi market the forecasted prices is exhibiting an increasing trend which is expected to be high in the month of March 2024. The validation of the forecasts indicated that the forecasts were accurate to the tune of more than eighty percent in almost all the months that was considered for the study. While for Ganagavthi market the validation indicated that the prices that were forecasted using the best ARIMA fit model was found to be accurate to the tune more than eighty per cent in almost all the months. The prices of pearl millet are ought to be maximum in the months of March 2024 signifying the increasing trend. In the markets of Raichur district, in Sindhanur market the prices of the pearl millet are expected to decrease and anticipated to be less than the prevailing price. The validation of the forecasts indicated that the prices were found to be accurate to the tune of more than sixty per cent in almost all the months that was considered for the study. In case of Manvi market, the prices of pearl millet as per the forecasts are anticipated to be maximum in the month of March 2024 and validation of the price indicated the prices were accurate to the tune of more than seventy five percent.

Table 1: Residual analysis of monthly prices of millets in selected markets of Karnataka district during 2022 January to 2024 March

	Districts	Markets	MODEL	AIC
Pearl millet	Koppal	Kushtagi	(0, 1, 1) (0, 1, 1)	15.86
		Gangavathi	(1, 1, 1) (1, 1, 1)	16.62
	Raichur	Manvi	(1, 0, 1) (1, 0, 1)	18.87
		Sindhanur	(1, 0, 1) (1, 0, 1)	17.42

Table 2: Forecast of monthly prices of pearl millet in selected markets of Karnataka during 2022 January to 2024 March

Districts	Koppal						Raichur					
Markets	Kushtagi			Gangavathi			Sindhanur			Manvi		
Month and Years	Actual Price	Forecasted Price	Validation	Actual Price	Forecasted Price	Validation	Actual Price	Forecasted Price	Validation	Actual Price	Forecasted Price	Validation
Jan-22	1666.00	1629.00	97.72	1599.00	1596.86	99.87	1593.00	1637.56	97.25	2100.00	1985.00	94.21
Feb-22	1802.00	1709.00	94.56	1760.00	1628.08	91.87	1369.00	1597.14	85.72	2224.00	2085.03	93.34
Mar-22	2049.00	1899.00	92.12	1982.00	1695.70	83.13	1535.00	1493.41	97.22	2147.00	1999.71	92.63
Apr-22	2168.00	2141.00	98.76	2201.00	1871.82	82.41	2150.00	1545.78	60.91	2510.00	2245.45	88.22
May-22	1923.00	2144.00	89.70	2184.00	2134.67	97.69	1560.00	1813.12	86.04	2414.00	2314.05	95.68
Jun-22	2134.00	2051.00	95.94	2155.00	2080.00	96.39	1184.00	1648.82	71.81	2911.00	2443.67	80.88
Jul-22	2220.00	2139.00	96.22	2376.00	2279.01	95.74	1817.00	1469.69	76.37	2894.00	2836.71	97.98
Aug-22	2276.00	2236.00	98.20	2260.00	2167.44	95.73	1959.00	1669.43	82.65	2640.00	2636.93	99.88
Sep-22	2069.00	2299.00	89.98	1949.00	2347.76	82.99	2100.00	1751.91	80.13	2397.00	2737.95	87.55
Oct-22	1897.00	2029.00	93.49	1758.00	2059.91	85.36	2500.00	1837.21	63.92	3304.00	2904.00	86.23
Nov-22	1941.00	1993.00	97.39	2019.00	1907.34	94.15	2345.00	2074.34	86.95	2874.00	2929.25	98.11
Dec-22	2084.00	2012.00	96.45	2045.00	1943.25	94.76	2162.00	2071.07	95.61	3268.00	2929.74	88.45
Jan-23	2085.00	2077.00	99.62	2136.00	2032.29	95.14	2165.00	2030.65	93.79	3098.00	3231.74	95.86
Feb-23	2285.00	2214.00	96.89	2120.00	2077.29	97.99	2632.00	1934.83	73.51	2781.00	3378.30	82.32
Mar-23	2490.00	2462.00	98.88	2230.00	2128.26	95.44	2515.00	1908.03	75.87	2932.00	3257.98	89.99
Apr-23	2160.00	2582.00	83.66	2238.00	2189.35	97.83	2442.00	1939.64	79.43	2984.00	3464.73	86.13
May-23	2262.00	2338.00	96.75	2432.00	2249.55	92.50	2771.00	1787.47	64.51	2736.00	3400.83	80.45
Jun-23	2202.00	2551.00	86.32	2123.00	2147.04	98.88	2792.00	1710.12	61.25	2894.00	3553.08	81.45
Jul-23	2710.00	2638.00	97.34	2538.00	2325.73	91.64	2634.00	1774.47	67.37	2937.00	3680.91	79.79
Aug-23	2270.00	2695.00	84.23	2497.00	2173.90	87.06	2836.00	1743.94	61.49	2853.00	3487.66	81.80
Sep-23		2489.00			2226.91			1748.10			3560.19	
Oct-23		2318.00			2085.34			1797.38			3560.74	
Nov-23		2363.00			2185.29			1743.40			3501.37	
Dec-23		2507.00			2211.03			1715.58			3641.67	
Jan-24		2501.00			2217.17			1684.54			3749.97	
Feb-24		2639.00			2262.61			1671.55			3927.26	
Mar-24		2889.00			2326.28			1646.45			3816.79	

Conclusion

The ARIMA modeling approach has proven to be a valuable tool for forecasting pearl millet prices in selected markets of Karnataka. The process of model identification, parameter estimation, and diagnostic checking was carried out meticulously, leading to the selection of suitable ARIMA models for each market. These models provided forecasts for the period from January 2022 to March 2024. The forecasts and validation of the prices was done using ARIMA model, the best fit model was utilized for the study which are for pearl millet price forecasts the best ARIMA fit model was 011 for Kustagi market, 111 for Koppal market, 101 for Manvi and Sindhanur market. The accuracy of the forecasts was validated, and the results showed a high degree of accuracy, ranging from 77.22 per cent to 99.88 per cent. This suggests that the ARIMA models were effective in capturing the underlying patterns in pearl millet prices, providing valuable insights for market participants and policymakers.

The study's findings align with previous research and highlight the potential for using ARIMA models to forecast agricultural commodity prices. Almemaychu Amera (2002) [1] and Punitha (2007) [5] utilised a similar model to forecast agricultural commodity prices and arrivals and draw conclusions. It is evident that there is a rising trend in pearl millet prices, indicating increased demand for the crop. This information can inform production and marketing strategies, encouraging farmers to expand pearl millet cultivation and consider suitable marketing opportunities. In summary, the ARIMA modeling approach has demonstrated its utility in forecasting pearl millet prices, providing valuable insights into market dynamics. These forecasts can serve as a valuable resource for stakeholders in the agricultural sector, aiding in decision-making and planning for the future.

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