Journal of Scientific Research and Reports

Volume 30, Issue 11, Page 552-561, 2024; Article no.JSRR.126328
ISSN: 2320-0227

Time Series Analysis of Dry Chilli Price Trends in Byadagi Market, Haveri District, Karnataka, India

Mangala C. Devihosoor [a++*], Ashalatha K. V. [a#], Vasantha Kumari J. [a†], Huchesh Budihal [a‡] and Basavaraj A. Arabhanvi [a++]

[a] Department of Agricultural Statistics, College of Agriculture, Dharwad UAS, Dharwad-580 005. India.

Authors' contributions

This work was carried out in collaboration among all authors. Authors MCD wrote the whole manuscript, Authors AKV & HB corrected the mistakes in the manuscript, author HB helped put graphs in and submit the manuscript to the journals, and author BAA helped for statistical analysis. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jsrr/2024/v30i112583

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/126328

Original Research Article

Received: 03/09/2024
Accepted: 05/11/2024
Published: 09/11/2024

ABSTRACT

Spices are conventional aromatic vegetables mainly utilized for flavoring of food. Among these, chilli (*capsicum annuum*), is one of most important spice used around the world**.** The present study examined dry chillies price behaviour in the Byadagi market of Haveri District, Karnataka. The study

[++] *M. Sc. (Agri.) Student;*
[#] *Professor and Head;*
[†] *Assistant Professor;*
[‡] *Assistant Professor (Temporary);*
**Corresponding author: E-mail: mangalad39@gmail.com;*

Cite as: *Devihosoor, Mangala C., Ashalatha K. V., Vasantha Kumari J., Huchesh Budihal, and Basavaraj A. Arabhanvi. 2024. "Time Series Analysis of Dry Chilli Price Trends in Byadagi Market, Haveri District, Karnataka, India". Journal of Scientific Research and Reports 30 (11):552-61. https://doi.org/10.9734/jsrr/2024/v30i112583.*

was based on secondary data from 2000-2022 collected in Agmarketnet.in. Time series analysis involves a complex mix of four main components: trend (Tt), seasonal (St), cyclical (Ct), and irregular (It) variations. The result revealed that there was a significant increasing trend in prices of dry chillies from 2000-2022. The Multiplicative model of TCSI was used in this study, the polynomial regression was also used for the trend analysis and found the Third-degree model best fit. The highest seasonal index was found in January (112.44) while the lowest seasonal index in the month of July (93.28) the analysis of seasonal indices in the price of dry chilli would help to understand the status of dry chilli marketing in the Byadagi market. The dry chilli prices exhibit no oscillatory movement and no definite periodicity during the study period.

Keywords: Cyclical variations; moving average method; irregular price fluctuations; price behavior; seasonal indices, trend analysis.

1. INTRODUCTION

India, often known as the "Spice Bowl of the World" or the "Land of Spices," is prominent in the global spice industry due to its extensive production, rich diversity, and historical importance in the spice trade. These titles reflect India's leading role as a cultivator and exporter of many spices. The country's unique geography, encompassing tropical, subtropical, and temperate climates, allows it to grow around 63 different varieties of spices (Agarwal, et al., 2018). As the world's largest producer, consumer, and exporter of spices, India is widely recognized as the global spice capital. It's fertile soil and diverse climate conditions provide the perfect environment for cultivating various spices. For centuries, India's strategic location and thriving spice trade attracted foreign traders and explorers, leading to the discovery of new sea routes and drawing European colonizers to its shores said by *A.L. Basham* in "The Wonder That Was India,". This rich history has cemented India's global significance in the spice trade and shaped its historical development. Price trend analysis helps determine the compound growth rate, trend, cyclic, and seasonal price time series data patterns.

Phadte et el., (2023) conducted "a study on Trend analysis of arrivals and prices of coconut in Goa agricultural produce and livestock marketing board, Arlem-Goa. For the present study, the time series secondary data on monthly arrivals and prices of coconut from the year 2010 to 2021 were utilized. The data was collected from the Goa Agricultural Produce Livestock Marketing Board. The highest arrivals were found in the year 2017 i.e., 81.84 per cent higher over the base year, while the lowest arrivals were in the year 2011 which was - 17.25 per cent. In the case of prices of coconut, high prices were observed during the year 2021 which was 249.69 per cent higher than the base year and lowest in the year 2012. Prices showed an increasing trend over the base year. The arrivals and prices of coconut have increased significantly by 3.73 per cent and 11.50 annually over the years from 2010 to 2021. Here there is no particular cycle was observed for coconut crops during the study period".

Rathod, et al., (2021) studied "on trends in area, production, and productivity from Maharashtra, India, and the World. The secondary data were taken from the various issues of a horticultural database of the National Horticulture Board, Department of Agriculture and Co-operation. The results of the study revealed that during the overall period (1960-2017) the compound annual growth rates of bananas for area and production showed significant growth of 1.97 and 2.73, 2.88 and 5.19, 2.3 and 4.67 per cent per annum, for the World, India, and Maharashtra, respectively".

Gholap, et al. (2021) conducted "a study to examine the arrivals and price behaviour of tomatoes in the Gultekdi market in Pune which was based on the secondary data from 2009-10 to 2018-19 and computed trends in area, production, productivity, prices and arrivals along with seasonal and cyclical variations. The results revealed that there was an increasing trend in the area, production and productivity of tomatoes in India during the study period. There was a declining trend in the area and production of tomatoes in Maharashtra however; productivity increased significantly with a growth rate of 2.91 per cent. The monthly seasonal indices for arrivals were higher immediately after harvesting. The price indices were lower during peak arrivals months and vice versa (Deokate et al., 2020). CV of real prices was found to be more than arrivals. To minimize the price risk and to protect price security of the farming community the long-term procurement policy should be adopted to

maintain price stability by declaring the minimum support price (MSP)".

Vani and Rajeswari, (2020) studied "the price behaviour of cocoons in the Dharmavaram market of Andhra Pradesh. There was a significant increasing trend in the prices of cocoons in selected markets and found to be significant statistically from 2006-2015. The highest seasonal index was found in August (110.69) while the lowest seasonal index in May (92.25). The cocoon prices exhibit no oscillatory movement and no definite periodicity in their occurrence during the study period".

Benke et al., (2016) experimented to "examine the price behaviour of green gram in Akola district. The data on arrivals and prices of green gram crops under study for the period of 20 years i.e., from 1987-2006 were used. The data were collected from the records of Akola APMC. The results indicated that compound growth rate of production and arrival were found to be positively associated in period I (1987-96) and negatively associated in period II (1997-2006) respectively for Akola APMC. Despite pronounced seasonality in arrivals, there were negligible variations in seasonal prices of green gram. Cyclical fluctuations were found to be more pronounced than seasonal fluctuations in prices. This showed that when maximum production was there, prices decreased and increased during the pre-harvest month. The Co-efficient of Variation (CV) was seen lowest for the green gram crop".

Singh et al., (2016) studied "the trend analysis of arrivals and price of major commodities in Meghalaya state. The study was based on the secondary data collected from the State Agricultural Marketing Board which was set up in 1983. Secondary data were collected from the marketing board of Meghalaya for the commodities that are notified by the state government. Compound annual growth and seasonal index were applied for the study. the study reveals that the compound annual growth for quantity arrival of broom stick and tezpatta were positive but for potato, it was found to be negative during the year 1996-97 to 2015-16. During December the price of broom sticks was found to be highest as the quantity arrival was found to be lowest in this month. But for potato, price was found to be highest in November when the quantity arrival was also highest. During August the price of tezpatta was found to be highest where quantity arrival was low. The peak season for broomstick, potato, and tezpatta was found during March, November, and January, respectively".

Sharma, (2016) "Trend and seasonal analysis of wheat in selected market of Sriganganagar district. Given this, the present study was undertaken by collecting monthly wholesale prices of wheat in Sriganganagar district of Rajasthan. This study was based on the secondary data on arrival and prices of wheat in APMC, Sriganganagar, Sadulsahar, Gharsana, Anupgarh, Vijaynagar, Suratgarh, Gajsinghpur, Karanpur and Raisinghnagar for the period of 10 years i.e. from 2005 up to 2014. In the analysis, all the selected markets showed a positive trend in prices. The seasonal price index provides a measure of the month-to-month variation in wheat prices. Price of wheat was found to be highest during of season and lowest during harvest season (Fatima, et al., 2015). Since wheat is a rabi crop, the arrivals were high during March to May. The higher seasonal indices of prices were observed during December to February during which the arrivals were found to be low".

2. MATERIALS AND METHODS

The study was based on secondary data, month-wise price data was collected from 2000 to 2022. Time series analysis was done to study the variations in monthly prices of dry chilli for 22 years. A time series is a complex mixture of four components namely, Trend (Tt), Seasonal (St), Cyclical (Ct), and irregular (It) variations. These four types of movements are frequently found separately or in combination in a time series. The relationship among these components is assumed to be additive or multiplicative, but the multiplicative model is the most commonly used method in economic analysis. The material and method for this objective were adapted from books, *viz*., Applied Regression Analysis (1998) by Norman R Draper and Smith H and Fundamentals of Applied Statistics (1978) by Gupta S C and Kapoor V K.

A multiplicative model is appropriate if the magnitude of the seasonal fluctuation varies with the level of the series

$$Y_t = T_t \times C_t \times S_t \times I_t$$

Where,
Y_t = monthly data of dry chilli prices at a time 't'.
T_t = Trend component,
S_t = Seasonal variations,

C_t = Cyclical element,
I_t = Irregular fluctuations.

2.1 Estimation of Linear Trend (T_t)

For estimating the long-run trend of prices, the method of least squares estimate was employed. This method of ascertaining the trend in a series of annual prices involves estimating the co-efficient of intercept (β_0) and slope (β_i) in the functional form. The equation adopted for this purpose was specified as follows.

1. Linear model: The simple linear regression model for n observations can be written as

$$Y = \beta 0 + \beta 1\ X1 + \mathcal{E}.$$

Where,
Y = Dependent variable (monthly price),
X = Independent variable (Time),
β0 = Intercept,
β1 = coefficient to be estimated,
Ɛ = error.

2. Quadratic model: Here the model is

$$Y = \beta\ 0 + \beta 1X + \beta 2X2 + \mathcal{E}.$$

Where,
Y = Dependent variable (monthly price),
X = Independent variable (Time),
β0 = Intercept,
β1, β2 = coefficients to be estimated,
Ɛ = error.

3. Cubic model: Here model is

$$Y = \beta 0 + \beta 1X + \beta 2X2 + \beta 3X3 + \varepsilon.$$

Where,
Y = Dependent variable (monthly price),
X = Independent variable (Time),
β0 = Intercept,
β1, β2, β3 = coefficients to be estimated,
Ɛ = error.

4. Polynomial model: Here model is

$$Y = \beta 0 + \beta 1X + \beta 2X2 + \beta 3X3 + \beta 4X4 + \varepsilon$$

Where,
Y = Dependent variable (monthly price),
X = Independent variable (Time),
β0 = Intercept,
β1, β2, β3, β4 = coefficients to be estimated,
Ɛ = error.

The purpose of estimating a trend line is to extract a trend from the data, the changes that are caused by broad secular forces.

Multiple Linear Regression (MLR) is a powerful tool in trend analysis, especially when using Root Mean Squared Error (RMSE) to evaluate model performance. MLR allows analysts to understand relationships between a dependent variable and several independent variables, making it ideal for examining trends across time series data. In trend analysis, MLR can model how variables such as time and other influencing factors contribute to trends in a target variable, like sales, prices, or stock values.

Trend Analysis with MLR: MLR helps identify and quantify how different predictors contribute to the overall trend, enabling precise forecasting. When analyzing prices over time, for example, MLR can be used to model the dependent variable (price) as influenced by time and other factors (season, economic indicators, etc.). This approach allows analysts to separate the impact of each variable, offering clearer insights into the factors that drive observed trends.

Using RMSE in MLR: RMSE is an essential metric in trend analysis using MLR because it measures the model's accuracy by calculating the average magnitude of error between observed and predicted values. A lower RMSE indicates a better model fit, showing that the MLR model can effectively capture the trend without significant deviation. RMSE is particularly useful for comparing different models (e.g., linear, quadratic, cubic) to determine the best fit for complex data trends.

In sum, MLR combined with RMSE provides a framework for accurate trend analysis. By quantifying error in predictions, RMSE helps assess how well the MLR model captures the underlying trend, ensuring that forecasts are reliable and precise. This approach is valuable across fields such as finance, economics, and environmental science, where accurate trend forecasting is essential for decision-making.

2.2 Estimation of Seasonal Indices (Si)

To measure the seasonal variations in prices seasonal indices are calculated employing the monthly averaging method and expressed in percentage.

The seasonal indices were calculated by adopting the following steps:

In the first step, monthly prices for the study period were computed. In the second step, the overall average was computed for the whole length of the study period. Then the monthly average values were converted into seasonal indices by computing the ratio of monthly average values by the overall average value and expressed in percentage.

The first step to estimate the seasonal index, a 12-month centered moving average was calculated as follows.

$$SI_i = \frac{Average_i}{Overall\ average}$$

Where,
SI_i = Seasonal Index for i[th] month,
$Average_i$ = Average value for i[th] month.

2.3 Estimation of Cyclical Indices (Ci)

Cyclical movements are fluctuations that differ from periodic movements. Cyclical movements have a longer duration than a year and are periodicity of several years as in business cycles. The most commonly used method for estimating the cyclical movement of a time series is the residual method by eliminating the seasonal variation and trend. This is accomplished by dividing (Yt) by corresponding (S) for time 't'. Symbolically,

$$T.C.I = \frac{T.C.S.I}{S}$$

Further, cyclical movements along with irregular fluctuations are calculated by detrending. Symbolically,

$$C.I = \frac{T.C.I}{T}$$

These de-seasonalized data contain trend, cyclical and irregular components. This trend cycle components are plotted against time for examining cyclical behaviour. If there is any existence of cycle, the periodicity of cycle is noted. Again, moving average of length equal to periodicity of cycle is computed to eliminate cyclical behaviour.

These moving averages are arranged cycle-wise. These are adjusted for cyclical indices, as in the case of seasonal indices. The trend cycle values (TC) are divided by adjusted components CI.

The examination of both the graphs of trend cycle component as well as the trend component will give a clear idea of the presence of the cycle.

If there is a similarity in these two graphs, it is an indication of non-existence of the cycle. However, the non-similarity in the two graphs is an indication of the presence of the cycle. If ultimately a cycle is reflected, then the cyclical effect is removed from T-C components. If no cycle is detected, then the trend cycle values are treated as pure trend values.

3. RESULTS AND DISCUSSION

The study of trends enables us to indicate the general direction of prices in the market. The data on the nature of trend movement in the prices of chilli in the Byadagi market showed that the third-degree polynomial equation was the best fit with the lowest RMSE (1805.13) values. The trends are the changes over the years and are associated with changes in technology of production, input supply, infrastructure, etc. From Table 1, it could be seen that the degree of the polynomial increases, the model's flexibility is enhanced, resulting in a lower RMSE for the 3rd-degree model. The 3rd-degree model best fits with the lowest RMSE of 1805.13, suggesting it effectively captures the true relationship between time and price. However, the slightly higher RMSE (1807.89) in the 4th-degree model indicates that further increasing the polynomial degree could lead to overfitting, trend was visually represented in Fig. 2(a) for the overall period and Fig. 2(b), and (c) for the period I and II where the model becomes overly complex and starts capturing noise in the data rather than the actual trend. Shashikumar, (2014) also observed an upward trend in the prices of dry chilli.

Table 1. Different degrees of polynomial for dry chilli prices of the Byadagi market

Degrees	Equations	RMSE
1^{st}	$y = 48.897\,x + 1340.5$	2452.15
2^{nd}	$y = 0.2808\,x^2 - 28.88\,x + 4944.2$	1861.65
3^{rd}	$y = 0.0012\,x^3 - 0.2062\,x^2 + 25.174\,x + 3685.2$	1805.13
4^{th}	$y = 0.000002\,x^4 + 0.0003\,x^3 - 0.0469\,x^2 + 15.328\,x + 3823.8$	1807.89

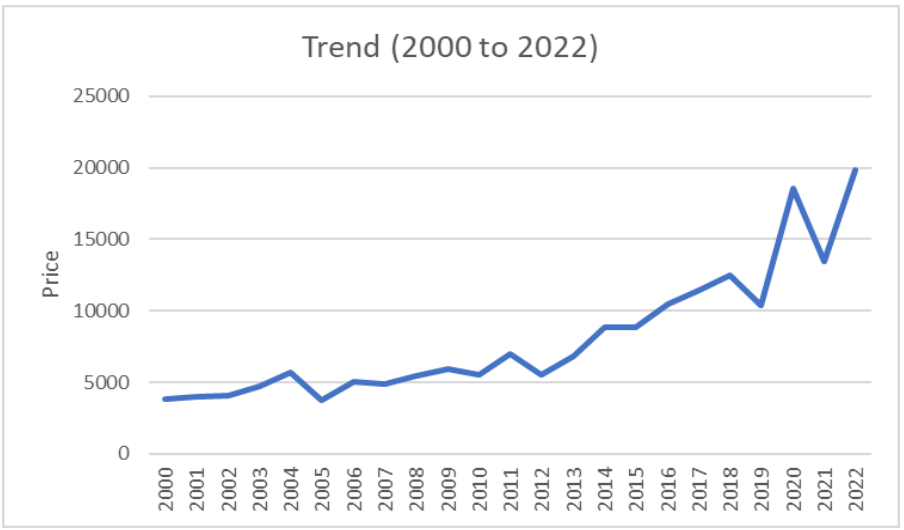

Fig. 1(a). Trends in prices of dry chilli in the Byadagi market (2000-2022)

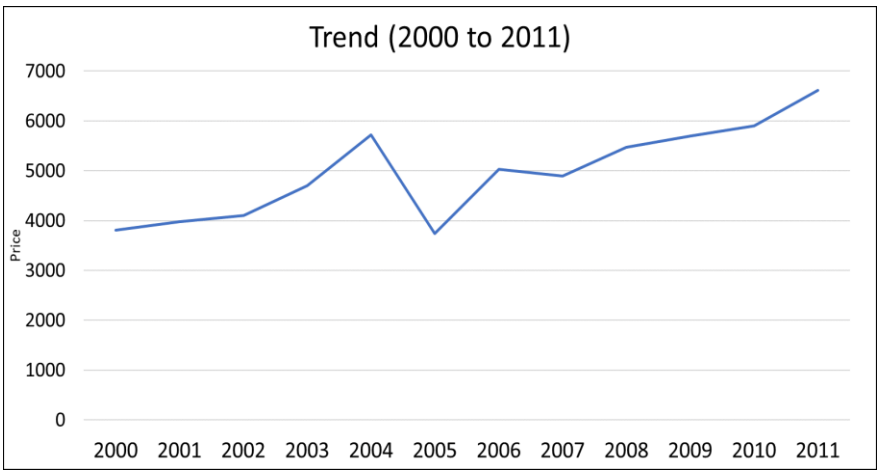

Fig. 1(b). Trends in prices of dry chilli in the Byadagi market (2000-2011)

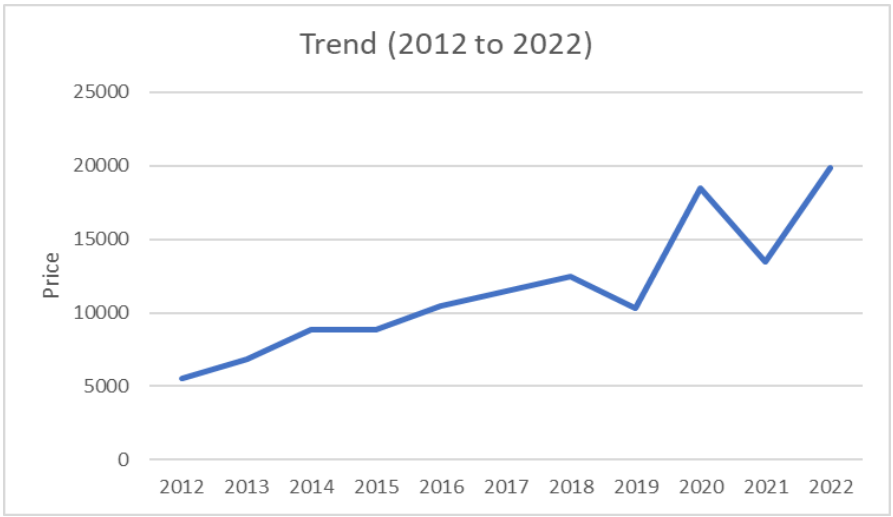

Fig. 1(c). Trends in prices of dry chilli in the Byadagi market (2012-2022)

3.1 Cyclic Indices for Dry Chilli Prices of the Byadagi Market

Cyclical variations are long-term oscillatory movements lasting over a year. The residual method, which removes seasonal variation and trends, is commonly used to estimate these cycles. Cycles are classified into Kitchin (less than 3.3 years), Juglar (less than 10 years), and Kondratiev (less than 60 years), as defined by Schumpeter, (1939). A 23-year analysis of deseasonalized and detrended data was conducted to estimate the amplitude and hidden periodicity in dry chilli price cycles at APMC, Byadagi. The computed coefficients are visually represented in Fig. 2(a) for the overall period and in Figs. 2(b) and (c) for periods I and II, with a summary in Table 2. The analysis shows no discernible trend in chilli prices at APMC, Byadagi from 2000 to 2022. However, the data from 2001 to 2011 indicates a consistent decline in cyclic indices, followed by stabilization from 2011 to 2013. From 2014 to 2021, there is a clear upward trend, but no clear cycles were detected for the entire 2000-2022 period. From the table and figures, it was clear that there was no particular cycle was observed for coconut crop during the study period. The same result was found by Phadte et al., (2023).

Table 2. Cyclic indices of dry chilli prices in the Byadagi market, Haveri district

Year	Cyclic Indices
2000	
2001	179.97
2002	149.85
2003	138.63
2004	117.88
2005	104.68
2006	85.77
2007	87.28
2008	83.63
2009	79.99
2010	80.06
2011	72.66
2012	72.71
2013	73.74
2014	80.74
2015	87.40
2016	90.19
2017	95.90
2018	91.47
2019	104.46
2020	102.47
2021	120.54
2022	

Table 3. Seasonal indices of dry chilli prices in the Byadagi market, Haveri district

Sl. No	Month	Seasonal
1	January	112.44
2	February	109.52
3	March	102.22
4	April	98.60
5	May	97.51
6	June	94.08
7	July	93.28
8	August	94.22
9	September	95.52
10	October	95.46
11	November	100.13
12	December	107.03

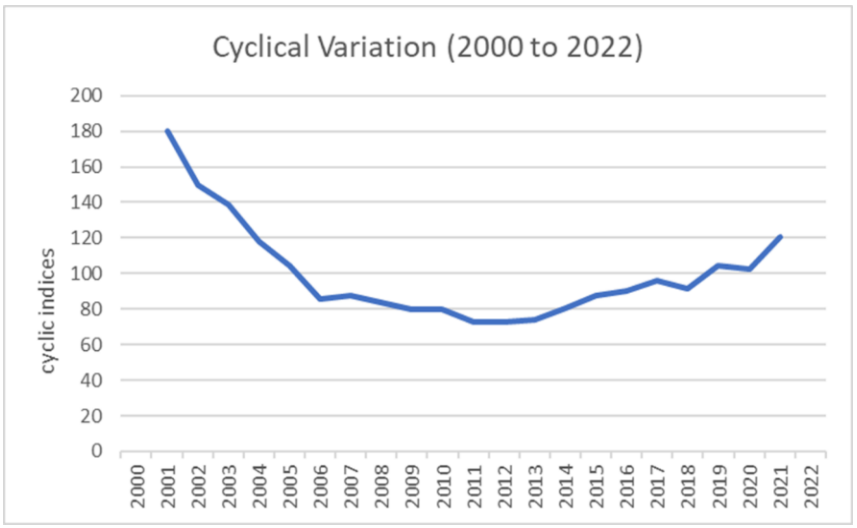

Fig. 2(a). Cyclic variation in prices of dry chilli in the Byadagi market (2000-2022)

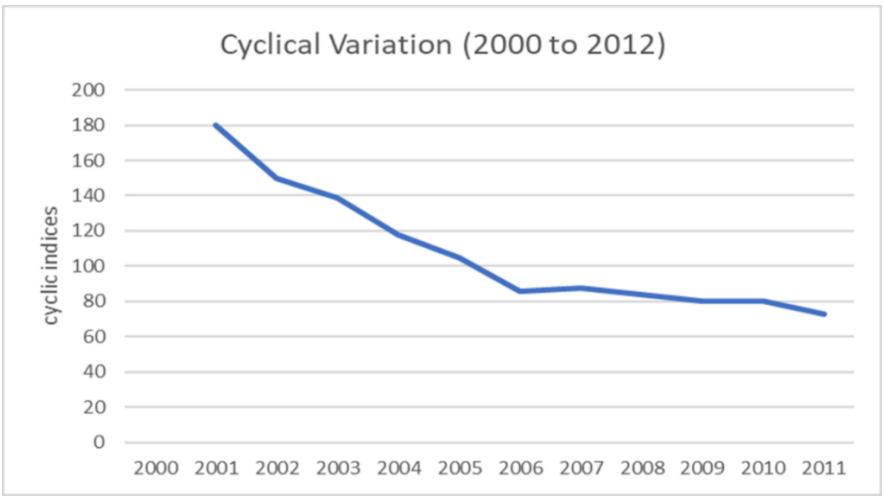

Fig. 2(b). Cyclic variation in prices of dry chilli in the Byadagi market (2000-2011)

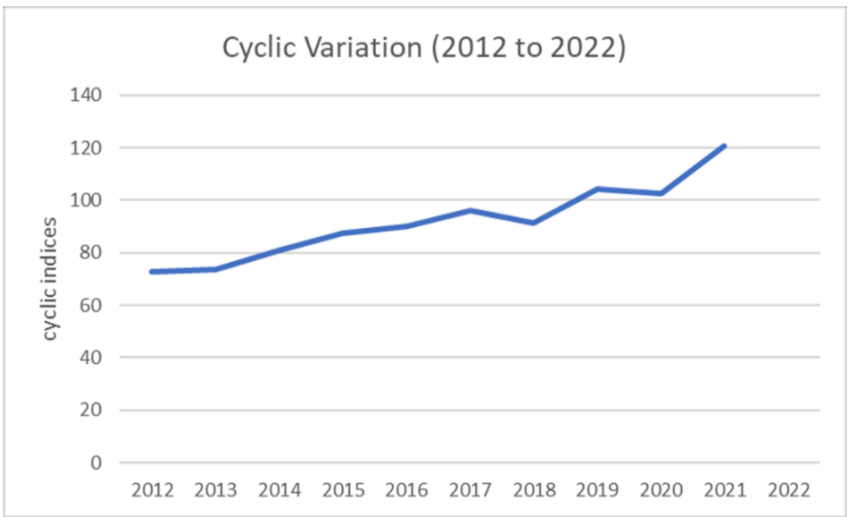

Fig. 2(c). Cyclic variation in prices of dry chilli in the Byadagi market (2012-2022)

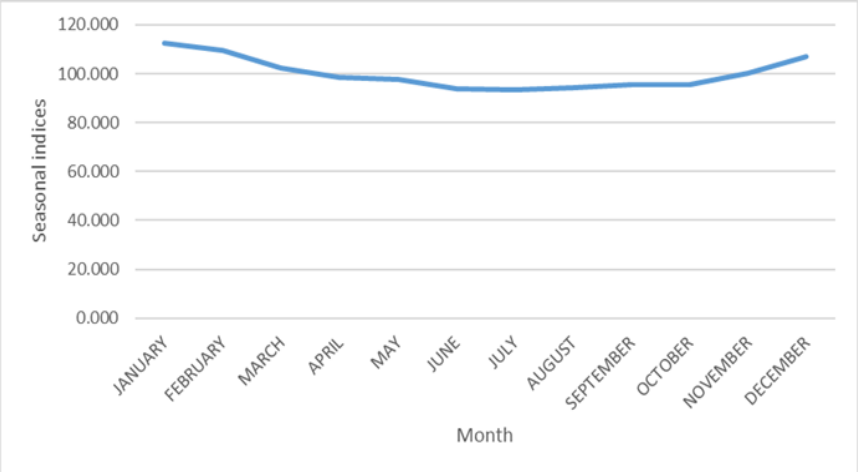

Fig. 3. Seasonal Variations in prices of dry chilli in the Byadagi market

3.2 Seasonal Indices for Dry Chilli Prices of the Byadagi Market

The seasonal price index for dry chilli, presented in Table 3, shows that January is the peak month with the highest index of 112.44, followed by February (109.52), December (107.03), March (102.22), and November (100.13). The lowest prices are observed in July, with an index of 93.28. Fig. 3 illustrates the monthly price variations, highlighting that farmers receive better prices from November to March. Similar findings were reported by Ashoka et al. (2022).

3.3 Irregular Variations in Chilli Prices

Irregular price movements represent that part of the behaviour of prices, which is not systematic. No generalizations can be made about such price fluctuations because of irregularity in their occurrence. The random effect is the residual effect left after the trend, seasonal and cyclical effects have been removed from the original observations. The indices of irregular variations have been worked out to capture the random effect. The results revealed that chilli prices are subjected to high irregular variations during the period of study. Satheesh et al. (2012) also reported high irregular variations of cardamom prices during the period from 1995 to 2012.

4. CONCLUSION

As the polynomial degree increases, model flexibility improves, reducing RMSE. The 3rd-degree model achieved the best fit with the lowest RMSE of 1805.13, accurately capturing the relationship between time and price. The 4th-degree model, with a slightly higher RMSE of 1807.89, suggested that further increasing the polynomial degree may lead to overfitting, capturing noise rather than the true trend.

The analysis of 23 years of deseasonalized and detrended data at APMC, Byadagi, focused on identifying cycles in dry chilli prices, such as Kitchin, Juglar, and Kondratiet cycles. The results reveal no discernible trend in dry chilli prices from 2000 to 2022, indicating that the prices fluctuated without a clear pattern or direction during this period.

The dry chilli crop, mainly grown in Karnataka under rain-fed conditions, is sensitive to moisture stress. Chilli seedlings are transplanted in May and June, with harvesting from November to January, requiring warm, dry weather for ideal growth and post-harvest techniques. Thus, the highest prices for farmers occur from November to March, with the lowest in June to July, reflecting climatic influences.

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Details of the AI usage are given below:

1. Author(s) hereby declare that generative AI technologies such as ChatGPT, version-ChatGPT-4, Model-GPT-4, and Source-OpenAI have been used during editing of this manuscript.

ACKNOWLEDGEMENTS

The first author wrote the whole manuscript, the second and third authors corrected the mistakes in the manuscript, the fourth author helped put graphs in and submit the manuscript to the journals, and the fifth author helped with analysis.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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