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A Critical and Comprehensive Study on Paddy Market Trends, Predictive Models, and Stability for Agricultural Revenue Enhancement

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The way agricultural commodities' prices behave indicates how prices occasionally fluctuate between markets [1]. Comprehensive analysis provides valuable insights into the dynamics of paddy prices in Gujarat, emphasizing the importance of considering both short-term fluctuations and long-term trends. The findings contribute to a better understanding of market behaviour, aiding stakeholders in informed decision-making within the agricultural sector. In order to provide farmers with the knowledge of how much prices fluctuate over time in commodity markets and so increase their revenue, a ten-year study on the price behaviour of paddy was conducted inside the borders of the state of Gujarat (2009-2019). In order to gather statistics, three paddy markets in the state of Gujarat were specifically chosen based on the paddy arrivals that were highest. The trend diagram of the wholesale prices' yearly index number showed constant price fluctuations across the study

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period. Cuddy Dell Valle Index (CDI) was calculated to measure the instability in yearly and monthly prices. Based on the investigation, it was determined that paddy displayed a poor stability index within their respective marketplaces. The trend in paddy prices was measured using the linear and quadratic models. For paddy markets, the coefficient of multiple determination (R2) was greater than 70%. Thus, it can be said that a significant portion of the changes in paddy prices over the chosen study period can be attributed to the linear model. In keeping with the quadratic trend, the markets for paddy, or Ahmedabad and Gandhinagar, also showed a positive coefficient of the quadratic term, or T2. Comparing the quadratic and linear model for the markets of paddy the quadratic model performed better in Gandhinagar than the linear model did in Ahmedabad and Surat. Compound rate of increase in annual prices were analysed by exponential model. The rates of growth in the prices of Paddy in Ahmedabad, Surat, and Gandhinagar were 5.80 percent, 5.84 percent, and 4.68 percent, respectively. To separate seasonal variation from the original composite data, a multiplicative model was applied. To arrive at the twelve-month total of 1200 points, these ratios were averaged for each of the twelve months for the whole period. The Ahmedabad market's paddy produced the highest coefficient of seasonal variation (25.84 percent).

Keywords: Variation; instability; price trends; inter and intra year variation etc.

1. INTRODUCTION

Rice, botanically classified as Oryza sativa L. within the Gramineae family, encompasses two primary cultivated species of paddy: i) *Oryza sativa* and ii) *Oryza glaberriumn*. Oryza sativa is prevalent in various regions of Asia and the Americas, while Oryza glaberriumn is exclusive to Africa. The global diversity of rice includes three subspecies: *Indica* (long grain), Japonica (round grain), and Javanica (medium grain). As a monocot seed, rice is a self-pollinated crop with fibrous roots, belonging to the category of annual grasses.

Rice stands as the cornerstone of Indian staple food, contributing significantly to daily energy requirements with approximately 60% and constituting 41% of the total food grain production derived from 35% of the national food grain area. Its pivotal role in ensuring national food security cannot be overstated. However, as we look towards the future, the imperative to further augment rice production becomes apparent, driven by the escalating food demands in the face of fierce competition for limited agro-resources, especially productive land and water [2].

To address this challenge, two primary options emerge: the first involves horizontal expansion by increasing the cultivation area for rice, yet this option presents limited feasibility. The second, and more viable, approach entails vertical expansion—enhancing rice yield through the adoption of technologies geared towards increasing productivity [3]. This necessitates a significant boost in production amidst the context of diminishing and deteriorating resource bases such as land, water, labor, and other inputs, all while ensuring the preservation of environmental quality [4].

Moreover, various studies have underscored substantial yield gaps in rice production, emphasizing the need for thorough research to identify underlying causes. This exploration is crucial for bridging these gaps and ultimately achieving an increase in rice production [5,6]. In navigating the future of rice cultivation, sustainable and innovative approaches are imperative to meet the growing demands while preserving the delicate balance of our agricultural and environmental ecosystems. Rice serves as a vital high-energy calorie food source, with a predominant composition of carbohydrates in the form of starch. Its protein content features glutelin, also known as oryzenin. The by-product of rice, rice bran, contains approximately 18-20% oil suitable for cooking purposes. Additionally, rice straw finds utility as cattle feed.

1.1 Objectives

1. Investigating the Price Variability of paddy.
2. Quantifying Trends and Rates of Price Escalation in paddy.
3. Analysing Seasonal Fluctuations in paddy Prices

2. MATERIALS AND METHODS

2.1 Area of Study

The study on price behaviour of paddy is performed within the boundary of Gujarat state.

2.2 Sources and Methods of Data Collection

In order to study inter-year variability and trends in paddy price, secondary data on yearly index numbers of wholesale prices in Gujarat state for Paddy was compiled for the period from year 2009 - 2019. The index numbers for yearly wholesale prices were prepared by taking the simple average of the decided years. For the study of intra-year variability secondary data on monthly index numbers of wholesale prices in Gujarat state for the period from January 2009 to December 2019 were collected. The monthly data on prices of paddy from 2009 to 2019 were collected from different market Committees or agricultural websites. The three largest markets were selected on the basis of highest arrivals seepana [7].

2.3 Analytical Framework

2.3.1 Variability in prices

First of all, coefficient of variation was calculated to measure the instability in yearly and monthly prices Rani et al. [8], Asmatoddin et al. [9].

$$CV\ \% = \frac{SD}{Mean} * 100$$

Where,

CV% = Coefficient of variation

SD=Standard Deviation = (Variance)$^{1/2}$

$$Variance = \frac{\sum_{i=1}^{n}(x_i - \bar{x}_i)\hat{}2}{n-1}$$

2.3.2 Instability index

The use of coefficient of variation as a measure shows the instability in any time series data with some limitation. Cuddy Dell Valle Index (CDI) is used to overcome this limitation of C.V. Because if the time series data exhibit trend behaviour than variation measured by CV can be overestimated [10]. The simple coefficient of variation overestimates the level of instability in time series data if it is characterized by long term trends behaviour whereas the Cuddy Della Valle index corrects the coefficient of variation. As against that Cuddy Della Valle index attempts detrends the C.V. by using coefficient of determination (R^2). Hence C.V. adjusts with R^2 to detrend the production series. Thus, it is a better measure to calculate instability in agricultural production. A low value of this index shows the low instability in farm production and vice versa. Rakesh Sihmar, [11,12].

Cuddy-Della valle index = C.V.(1 –R^2)$^{0.5}$*

Where C.V. = Coefficient of Variation i.e.

$$CV\ \% = \frac{SD}{Mean} * 100$$

SD=Standard Deviation = (Variance)$^{1/2}$

$$Variance = \frac{\sum_{i=1}^{n}(x_i - \bar{x}_i)\hat{}2}{n-1}$$

R^2 = ESS/TSS i.e., ratio of explained variation to total variation.

ESS = Variation explained by explanatory variable.

TSS = Total Variation.

2.3.2.1 Different range of instability are as follows

- Low instability = between 0 to 15
- Median instability = greater than 15 and lower than 30
- High instability = greater than 30 [13]

2.3.3 Trend in yearly prices

Initially, a trend diagram of yearly index numbers of wholesale prices of paddy was drawn for the period from January 2009 to December 2019. The trend in annual prices were analysed with the help of following models Shelke et al. [14]. Karthikeyan and Nedunchezhian [15].

2.3.3.1 Linear and quadratic model

$P_t = \beta_0 + \beta_1 T + U$ ……. (model 1)

$P_t = \beta_0 + \beta_1 T + \beta_2 T^2 + U$ …… (model 2)

P_t = yearly index number of wholesale prices

T = Time (1,2,3…10)

U = Disturbance term with usual assumption

$\beta_0, \beta_1, \beta_2$ = parameters to be estimated

Adjusted coefficient of multiple determination ($\bar{R}^2$) was worked out using the following formula for above models for paddy.

$$\bar{R}^2 = 1 - \frac{(1-R^2)(T-1)}{T-K-1}$$

Where,

$\bar{R}^2$ = Adjusted coefficient of multiple determination.

T = Number of observations.

K = Number of independent variables.

2.3.3.2 Exponential model

Compound rate of increase in annual prices were analysed by exponential model for the period of year 2009-2019 for each paddy.

$P_t = \beta_0 \beta_1^T U$…… (model 3)

The logarithmic transformation is as below

Log P = log β_0 + T log β_1 + log U

Compound rate of increase in per cent was calculated by

r = (Antilog of log β_0-1) *100

where,

r = compound rate of increase per annum all other symbols have same meanings as defined earlier.

2.3.4 Seasonal variation in prices

2.3.4.1 Computation of seasonal variation

The seasonal variation (Sharma and Burak [16] was calculated by multiplicative model of following form.

P = T*C*S*I

Where,

P = Monthly prices.

T = Trend values.

C = Cyclic variation.

S = seasonal variation.

I = Irregular variation.

The seasonal indices of whole period for paddy was calculated. To remove the effect of trend and cyclic variation, moving average of 12 months was calculated and centered. Further to obtain the combined effect of S*I ratio of original price to centered moving average was obtained. And to remove the effect of I, these ratios were averaged and adjusted seasonal indices were obtained. Mech, [17]. Mahalle et al. [18].

2.3.4.1 Coefficient of average seasonal variations

Highest and lowest values were compared by plotting the seasonal indices graph and coefficient of the average seasonal price index variation was obtained by using the following formula. (Sudhakarrao and Katkade, [19].

$$coeff.of\ av.seasonal\ price\ index = \frac{highest\ index - lowest\ index}{\frac{highest\ index + lowest\ index}{2}} * 100$$

3. RESULTS AND DISCUSSION

3.1 Coefficients of Variation in Yearly Prices of Paddy

The aforementioned data showed that the variability across the whole study period ranged from 17.77 percent (paddy in Gandhinagar) to 24.01 percent (Paddy in Ahmedabad). It came to the refesion that the yearly prices of the paddy under investigation in Gujarat fluctuated somewhat. It can be the result of production variations that had an impact on supply.

For the period of 2009 to 2019, a distinct trend diagram of the yearly index number of wholesale prices was created for paddy. The trend diagrams are displayed in Fig. 1 and illustrate a continual variation in prices over the studied period. Areef et al. [20].

3.2 Instability Index

Time series data exhibit trend behaviour, although in these circumstances, the variance as measured by C.V. may be exaggerated Mech, [17,21] Table 2 presents the results of measuring the annual price index from 2009 to 2019 in order to overcome the situation of C.V. under trend behaviour. Although it was said that the index is categorised into low, medium, and high levels, none of the markets displayed the medium or high levels of instability, hence they are not displayed here. The investigation came to the conclusion that paddy displayed a poor stability index in the relevant markets.

3.3 Intra-Year Variability

The pace at which stocks enter the market provides insight into the variations in agricultural commodity prices that occur within a given year. Singh and Supriya, [22], Ragade et al. [23] Table 3 for the Ahmedabad market's paddy prices revealed a significant degree of fluctuation, ranging from 5.27 to 27.73 percent. The year 2011 had the lowest variability while the year 2019 had the largest variability. The market's variability in Surat varied from 2.46 to 10.07 percent. The year 2015 had the least variability, while the year 2012 had the most variability. The range of fluctuation in the Gandhinagar market is 3.65 to 9.88 percent. The year 2017 had the lowest variability while the year 2009 had the largest variability. From 2009 to 2019, the markets in Ahmedabad had significant fluctuations, whereas the other markets displayed just modest unpredictability.

3.4 Trends in Paddy

3.4.1 Estimation of linear trend

Table 4's results showed that each market's regression coefficient was more significant. The rate of rise for paddy was 7.40 percent highest in Surat. For paddy markets, the coefficient of multiple determination (R2) was greater than 70%. Thus, it can be said that a significant portion of the changes in paddy prices over the chosen study period can be attributed to the linear model. Sharma [24,25].

Table 1. Coefficients of variation in yearly prices of paddy in Gujarat during 2009-2019

crop	Markets	Coefficients of variation (%)
Paddy	Ahmedabad	24.01
	Surat	19.03
	Gandhinagar	17.77

Table 2. Price instability index in major cereals in Gujarat during 2009-2019

Markets	Crops	Instability index
Ahmedabad	Paddy	7.87
Surat	Paddy	5.27
Gandhinagar	Paddy	6.11

Table 3. Coefficient variation of monthly prices of paddy of Gujarat during 2009-2019. (percent)

	Paddy		
Year	**Ahmedabad**	**Surat**	**Gandhinagar**
2009	10.37	3.51	9.88
2010	7.62	8.61	8.66
2011	5.27	6.38	6.38
2012	6.7	10.07	7.71
2013	5.93	5.85	4.56
2014	5.31	3.52	7.05
2015	14.5	2.46	5.51
2016	17.87	5.77	6.77
2017	14.87	3.8	3.65
2018	11.94	4.8	4.29
2019	27.73	3.65	3.66

Table 4. Estimates of linear trend in yearly prices of paddy in Gujarat during 2009-2019 (Model 1)

(n=11)

Crops	Markets	Intercept B_0	Coefficient For time β_1	R^2	Adjusted R^2
Paddy	Ahmedabad	83.49	6.95	0.89	0.88
	Surat	89.30	7.40	0.92	0.91
	Gandhinagar	85.14	5.42	0.88	0.86

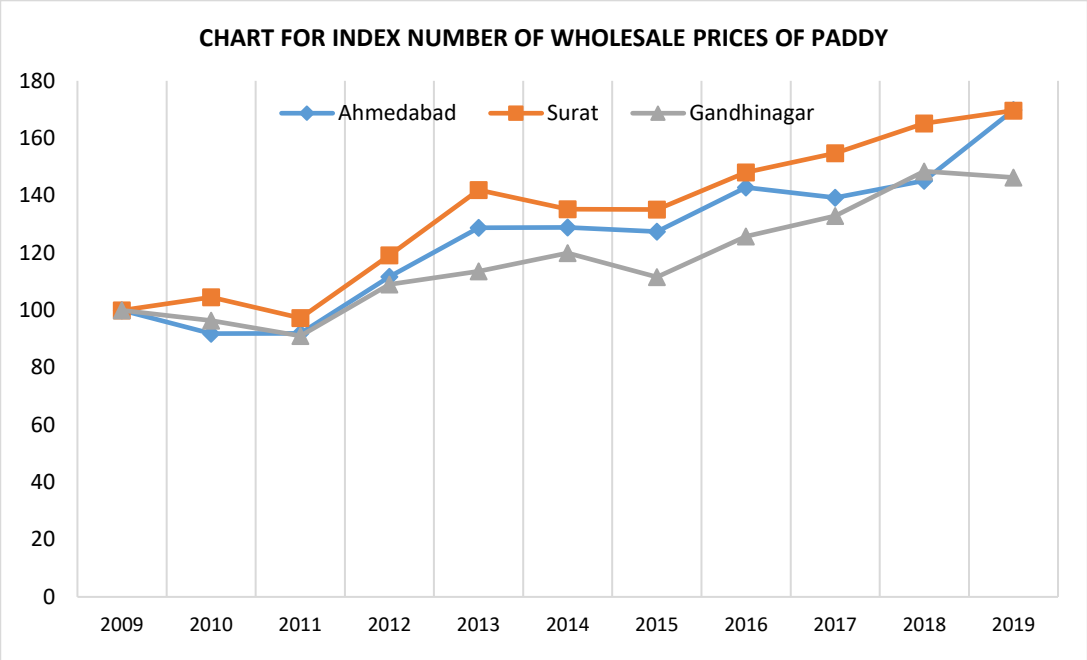

Fig. 1. Index numbers of wholesale prices of Pearl millet in Ahmedabad, Surat and Gandhinagar

3.4.2 Estimation of quadratic trend

A quadratic model [26] was utilised to analyse the crucial premise that the rate of rise was constant across the chosen time period, which was 2009 to 2019.

Table 5 displays the final outcome for the paddy and corresponding markets. The findings demonstrated that all of the co-efficients of regression for the time variable (β1) in the paddy markets had positive values. At 5%, these coefficients were statistically significant. Likewise, it was discovered that the coefficient of the quadratic term, or T2, was positive in the case of the paddy markets, or the marketplaces in Ahmedabad and Gandhinagar. The quadratic trend [27] explained the larger variation, or more than 70%, in the prices for all paddy marketplaces reported in the co-efficient for multiple determination (R2). In the case of paddy, the quadratic model performed better in Gandhinagar than the linear model did in Ahmedabad and Surat. Sharma [24].

3.5 Estimation of Compound Rate of Increase in Annual Prices

The estimates of the paddy prices' compound annual growth rates were calculated. For paddy estimation, the same exponential function was applied. The results are displayed in Table 6. Rani et al. [8].

Table 5. Estimation of quadratic trend in yearly price of paddy in Gujarat during 2009-2019. (Model 2)

(n=11)

Crops	Markets	Intercept β_0	Coefficient For time (T)β_1	Coefficient for T^2 β_2	R^2	Adjusted r^2
Paddy	Ahmedabad	86.98	5.34 (3.72)	0.13 (0.30)	0.89	0.86
	Surat	88.16	7.92 (3.32)	-0.04 (0.26)	0.92	0.90
	Gandhinagar	94.41	1.14 (2.68)	0.35 (0.21)	0.91	0.88

figures in the parentheses are standard errors

Table 6. Estimation of compound rate of increase in major cereals in Gujarat during 2009-2019 (Model 3)

(n=11)

Crops	Markets	b*	Estimates of β	Compound rate of increase (%)	R^2
Paddy	Ahmedabad	0.02	1.05	5.80	0.88
	Surat	0.02	1.05	5.84	0.90
	Gandhinagar	0.01	1.04	4.68	0.88

b is the estimates of log β*

The rates of growth in the prices of Paddy in Ahmedabad, Surat, and Gandhinagar were 5.80 percent, 5.84 percent, and 4.68 percent, respectively

3.6 Indices of Seasonal Variation

To separate seasonal variation from the original composite data, a multiplicative model was applied. For every month throughout the course of eleven years, the centering of twelve-month averages and the ratio of the initial price indices to these centering averages were calculated. To arrive at the twelve-month total of 1200 points, these ratios were averaged for each of the twelve months for the whole period. Verma et al. [28].

Table 7 displays the modified monthly seasonal indicators for Paddy. The seasonal index in the Ahmadabad market reaches its highest point in December (120.04) and its lowest point in March (92.56). It showed that the price variance for paddy crop in the Ahmadabad market occurred once within a year. The seasonal index for the Surat and Gandhinagar markets peaked in July at 105.16 and 103.71, respectively. October and September, respectively, represent its lowest points over the study period, which runs from 2009 to 2019. In the markets of Surat and Gandhinagar, paddy thus displayed two intra-year cycles.

3.6.1 Co-efficient of average seasonal price index

For paddy markets from 2009 to 2019, the analysis of the coefficient of average seasonal price index was done in order to determine the difference in the magnitude of the seasonal fluctuation for the peak and through period of research. Sharma and Burak, [24]. Table 8 presents the completed findings.

Table 8 indicates that the market for paddy in Ahmedabad had the highest value for the coefficient of seasonal variation (25.84 percent). However, the Gandhinagar market's paddy likewise had the lowest value for the same (7.21 percent).

Table 7. Variation in seasonal index of wholesale prices of paddy in Ahmedabad, Surat and Gandhinagar markets at Gujarat during period 2009 to 2019

Month	Ahmedabad	Surat	Gandhinagar
January	97.16	99.59	100.93
February	95.10	98.64	100.16
March	92.56	98.16	98.71
April	93.32	97.90	98.72
May	94.16	101.66	99.82
June	95.10	103.27	98.88
July	100.83	105.16	103.71
August	99.55	101.93	102.10
September	98.33	99.85	101.74
October	94.42	96.68	96.49
November	119.36	98.25	98.59
December	120.04	98.85	100.10
	1200	1200	1200

Table 8. Co-efficient of average seasonal price index variation of paddy from period 2009 to 2019

Crops	Markets	Coefficient of average seasonal price index (%)
Paddy	Ahmedabad	25.84
	Surat	8.40
	Gandhinagar	7.21

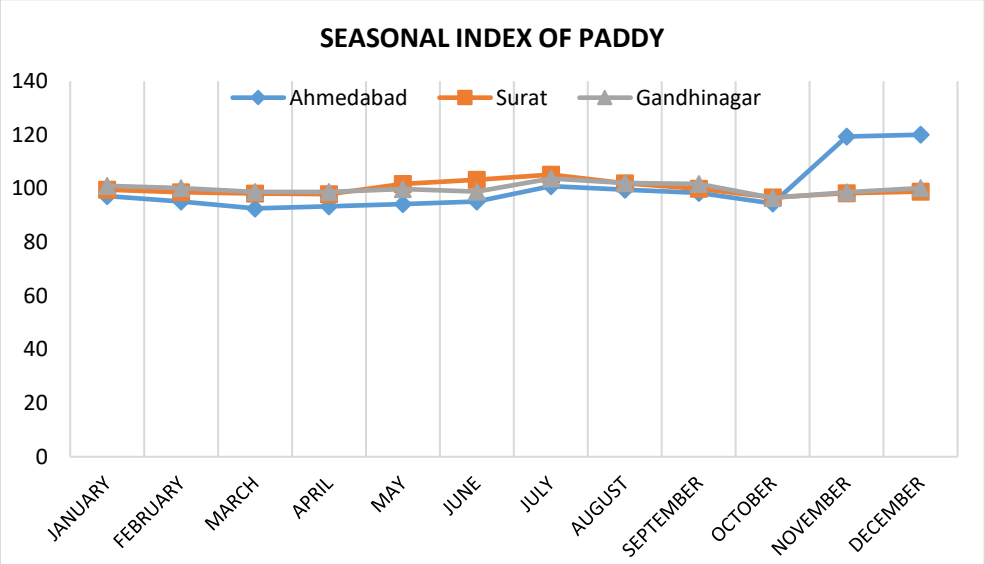

Fig. 2. Average seasonal variation in wholesale prices of Paddy in Ahmedabad, Surat and Gandhinagar

4. CONCLUSION

In conclusion, the analysis of yearly prices of paddy in Gujarat from 2009 to 2019 reveals several key findings regarding the market dynamics, stability, trends, and seasonal variations [29]. The coefficients of variation across different markets, such as Ahmedabad, Surat, and Gandhinagar, indicate varying degrees of price fluctuation, with Ahmedabad experiencing the highest variability at 24.01% and Gandhinagar the lowest at 17.77%.The instability index further emphasizes the poor stability of paddy prices in the studied markets, with values ranging from 5.27 to 7.87. This suggests that the markets experienced significant fluctuations in annual prices, possibly influenced by factors such as production variations affecting supply. Singh et al. [30]. Verma et al. [31].

The intra-year variability analysis [32] highlights fluctuations within each year, with Ahmedabad showing significant variation from 5.27% to 27.73%, Surat ranging from 2.46% to 10.07%, and Gandhinagar fluctuating between 3.65% and 9.88%. These variations indicate the importance of considering the pace at which stocks enter the market in understanding price dynamics.Linear and quadratic trend analyses [33], Andhalkar et al. [34] further reveal insights into the long-term price trends of paddy. The linear model suggests a steady increase in prices over time, with coefficients of determination (R2) exceeding 70%. The quadratic trend model, on the other hand, explains larger variations, especially in Gandhinagar, indicating a more complex trend in that market. Anitha [35] Timilsina and Bhandari [36]. Kumar et al. [37].

The compound annual growth rates (CAGR) provide a quantitative measure of the annual increase in prices, with Ahmedabad, Surat, and Gandhinagar experiencing growth rates of 5.80%, 5.84%, and 4.68%, respectively. These growth rates underscore the upward trend in paddy prices over the study period.The analysis of seasonal variation using a multiplicative model reveals distinct intra-year cycles in the markets. Ahmedabad exhibits a single cycle, while Surat and Gandhinagar display two cycles, with peaks in July and lows in October or September [38].

The coefficient of average seasonal price index variation further emphasizes the differences in seasonal fluctuation magnitude, with Ahmedabad having the highest coefficient at 25.84%, Surat at 8.40%, and Gandhinagar at 7.21% [39,40].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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