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Mutation point and trend analysis of mango exports from India

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Abstract
Mango is one of the most important fruit crops in India and plays a significant role in the country's horticultural exports. The present study was undertaken to identify mutation points and examine trends in India's mango exports during the period 2005-2024 using time-series data on export quantity and value collected from Trade Map. Pettitt's test, Buishand Range test and Standard Normal Homogeneity (SNH) test were employed to detect structural changes, while the Mann-Kendall test and Sen's slope estimator were used to assess the direction and magnitude of trends. The findings consistently identified 2014 as a significant mutation year for export quantity, whereas export value showed only marginal indications of a structural change around 2016. Export quantity showed a significant annual decline of 8.44 thousand tonnes, while export value showed non-significant and unstable fluctuations. Among the fitted trend models, the quadratic model provided the best fit for export quantity, while export value exhibited low predictability. The findings highlight a declining trend in export quantity and export value was highly variable, underscoring the importance of effective trade strategies and quality improvement measures to enhance the competitiveness of India's mango exports globally.

Keywords: Mutation point, Mango export, Trend analysis, India, Statistical model

Introduction
Agriculture is the primary occupation in India, and within this sector, horticulture has emerged as one of the fastest-growing segments. It plays a vital role in the Indian economy, contributing around 33 per cent to the Gross Value Added (World Bank, 2025) [21]. Among the horticultural crops, mango is one of the most ancient and widely cultivated fruits. Mango (*Mangifera indica* L.) is one of the world's most important tropical and subtropical fruits belonging to the family Anacardiaceae. Mango cultivation is believed to have originated in Asia, particularly in India and Burma, around 4000 years ago (Yadav and Singh, 2017) [22]. Mango is widely known as the "King of Fruits" and is also called the "Peach of the Tropics". It is also known as the national fruit of India and the national tree of Bangladesh (Chovatiya and Lakhlani, 2025) [6]. It is the second-most-traded tropical fruit in the world. Mango is rich in vitamins A and C, carbohydrates, dietary fiber and essential minerals such as potassium and magnesium (Savaria *et al*., 2020) [18]. Global Mango production is dominated by Asia, which accounts for nearly three-fourths of total output. At present, Mango is grown in more than 100 countries (Mitra, 2014) [12]. India is the world's largest producer of Mangoes, contributing nearly 45 per cent of global production (FAO, 2025) [7]. The trend of mango production in India has been consistently upward and has shown steady growth over the years due to improved cultivation practices, expansion of orchard area, and better irrigation facilities (Oganja *et al*., 2024 [13]; Bani *et al*. 2025 [3]). Mango accounts for 22 per cent of India's total fruit production. India produces over 20 million tonnes of Mangoes annually (Thakor, 2019) [20]. The incremental growth of mango production is due to adoption of modern technologies such as drip irrigation, high-density planting, mulching, improved grafted varieties, and fertigation (Parmar *et al*., 2024 [14]; Pithiya *et al*., 2024 [16]). The major Mango-growing states are Uttar Pradesh, Andhra Pradesh, Bihar, Karnataka, Gujarat, Madhya Pradesh and Tamil Nadu. Although India is the largest producer of Mango, it contributes only 2-3 per cent to exports. During 2024-25, India exported 29938.40 metric tonnes of Mango valued at USD 56.50 million. Major export destinations for Indian Mango

include UAE, USA, UK, Kuwait and Qatar. The Mango export sector in India is largely driven by Maharashtra, Gujarat and Uttar Pradesh (APEDA, 2024) [2].

In recent years, India's mango export performance has shown noticeable fluctuations due to variations in domestic production, changing global demand, stringent quality standards, trade regulations and climatic conditions (Bharodia *et al*., 2025) [4]. Identifying long-term trends and structural changes, commonly known as mutation points. Analysis of export trends helps exporters and policymakers to understand market changes, improve trade strategies and enhance export competitiveness. Therefore, the present study aims to analyse trends and mutation points in India's mango exports.

Objective

To identify the mutation point and trend in the export of Mango.

Methodology

The present study deals with the identification of mutation points and trends in India's mango exports. To achieve this objective, secondary data on export quantity and export value of mango for the period 2005 to 2024 were collected from Trade Map and analysed using the XLSTAT trial version.

Analytical Tools

Tests for mutation point detection

Mutation point detection tests were used to identify the period in which a significant structural change occurs in the time series data on Mango exports from 2005-06 to 2024-25. Pettitt's test, Buishand range test and Standard Normal Homogeneity Test were applied to detect the change points in the time series data of Mango exports.

Pettitt test

Pettitt test is a nonparametric rank-based method for detecting abrupt changes in the mean of the variables. This method was commonly applied to detect a single change point in time series data.

$$U_t = \sum_{i=1}^{t} \sum_{j=t+1}^{n} sign\,(x_t - x_j)$$

$$sign\,(x_t - x_j) = \begin{bmatrix} 1, \text{if } (x_i - x_j) > 0 \\ 0, \text{if } (x_i - x_j) = 0 \\ -1, \text{if } (x_i - x_j) < 0 \end{bmatrix}$$

Test statistic K and the associated confidence level (ρ) for the sample length (n) may be described as:

$$K = \text{Max } |U_t|$$

$$\rho = \exp\left(-\frac{K}{n^2 - n^3}\right)$$

When ρ was smaller than the specific confidence level, the null hypothesis was rejected. The approximate significance probability (p) for a change-point was defined as given below:

$$p = 1 - \rho$$

Whenever a significant change point existed, the series was divided at that point into two sub-series. The test statistic K was compared with standard values at different confidence levels to detect a change point in the series (Pettitt, 1979) [15].

Buishand range test

The Buishand Range Test is a parametric change-point detection test used to identify a single shift (break) in the mean of a time series. The adjusted partial sum (S_k), that was the cumulative deviation from the mean for the kth observation of a series $x_1, x_2, x_3 \ldots. xk \ldots. x_n$, with mean $(\overline{x})$ can be computed using the following equation (Buishand, 1982) [5]:

$$S_k = \sum_{i=1}^{k} (x_i - \overline{x})$$

The significant break point can be computed by the method of rescaled adjusted range (R) if the $S_k \cong 0$, in this case, R is defined by

$$R = \frac{\text{Max } (S_k) - \text{Min } (S_k)}{\sqrt{n}}$$

Standard Normal Homogeneity (SNH) test

Test statistic (T_k) was used to compare the mean of the first n observations with the mean of the remaining (n-k) observations, with n data points.

$$T_k = kZ_1^2 + (n-k)Z_2^2$$

Z_1 and Z_2 can be computed as:

$$Z_1 = \frac{1}{k} \sum_{i=1}^{k} \frac{(x_i - \overline{x})}{\sigma x}$$

$$Z_2 = \frac{1}{n-k} \sum_{i=k+1}^{n} \frac{(x_i - \overline{x})}{\sigma x}$$

$\bar{x}$	=	Mean
σx	=	Standard deviation
k	=	Potential change point, representing a structural break in the series where the value of T_k attains its maximum value.

Where,

The null hypothesis was rejected when the calculated test statistic exceeds the critical value, which was determined by the sample size (n).

For confirmation of the mutation point, at least the results of two tests out of the three tests should be the same. That point was considered the true mutation point. The significance was tested for 1 per cent and 5 per cent probability levels (Alexandersson, 1986) [1].

Trend Analysis

Trend analysis was used to measure the direction and magnitude of changes in a variable over a period of time. Generally, the magnitude of a trend is measured in terms of ratios, which indicate whether the trend is increasing, decreasing or remaining stable (Polisetty and Paidipati,

2019) [17]. The presence of a significant trend in the time series was tested by using Mann-Kendall test and the magnitude of trend was estimated using Sen's slope estimator. Together, these methods helped in determining both the existence and the extent of the trend in the time series data.

Mann-Kendall test

The main objective of trend analysis is to assess the monotonic fluctuations in long-term data series. This was effectively carried out using a non-parametric linear trend test known as the Mann-Kendall test. The test statistic of the Mann-Kendall test (S) was expressed as (Mann 1945 [11]; Kendall 1975 [8]):

$$\mathbf{S} = \sum_{i=1}^{n} \sum_{j=1}^{i=1} \mathbf{sign}\,(x_i - x_j)$$

where, n is the total length of data, xi and xj are two generic sequential data values and the function sign(xi-xj) assumed the following values:

$$\mathbf{sign}(x_i - x_j) = \begin{bmatrix} 1, \text{if } (x_i - x_j) > 0 \\ 0, \text{if } (x_i - x_j) = 0 \\ -1, \text{if } (x_i - x_j) < 0 \end{bmatrix}$$

Under this test, the statistic S is approximately normally distributed with the mean E(S) and the variance Var(S) can be computed as follows:

$$\mathbf{E(S) = 0}$$

$$\mathbf{Var(S)} = \frac{1}{18}[n(n-1)(2n+5) - \sum_t (t-1)(2t+5)]$$

Where,

n	=	Length of the time series
t	=	Extent of any given tie
Σt	=	Summation over all tie numbers of values

The standardized test statistics Z for this test was computed by the following equation:

$$\mathbf{Z} = \begin{bmatrix} \dfrac{S+1}{\sqrt{Var(S)}}, \text{if } S > 0 \\ 0, \text{if } S = 0 \\ -1, \text{if } S < 0 \end{bmatrix}$$

Table 1: Detection of a trend based on the value of Z

Z Value	Results
Zero	The data does not follow any trend.
Positive	The trend is in an upward direction.
Negative	The trend is in a downward direction.

Sen's slope estimator

Assuming that the time series data exhibited a significant trend, either positive or negative, the slope of the trend was estimated using Sen's slope estimator. It represents the average rate of change over time. Sen's method calculates the slope as the change in the variable with respect to the change in time (Maheta *et al*., 2025) [10]. The slope of the trend was estimated using the following test statistic:

$$\mathbf{T_i} = \frac{y_J - y_K}{J-K} \text{ for i= 1,2,3… N}$$

Here, y_j and y_k represented the data values at time j and k (j > k), respectively. The median of these N values of Ti was considered as the Sen's slope estimator, which was defined as follows:

$$\beta = \begin{Bmatrix} T_{\frac{N+1}{2}} \text{ N is odd,} \\ \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right) \text{ N is even} \end{Bmatrix}$$

Here, if the value of β was positive, it indicated a rising trend, whereas a negative value of β indicated a declining trend (Sen, 1968) [19].

Statistical models for trend analysis

To analyze the trend pattern in Mango exports, trend values were computed by fitting linear, exponential and quadratic models.

Linear model

$$\mathbf{y_t = a + bt}$$

Where y_t denotes the time series value at time t. The values of the constants a and b were obtained using the principle of least squares by solving the following normal equations:

$$\mathbf{\sum y_t = na + b\sum t}$$

$$\mathbf{\sum ty_t = a\sum t + b\sum t^2}$$

Where n represents the number of observed values.

Exponential model

$$\mathbf{y_t = ae^{bt}}$$

Taking natural log on both sides of above equation, we have

$$\mathbf{\log_e y_t = \log_e a + bt \log_e e}$$

where,

$Y_t = \log_e y_t$, $A = \log_e a$ and $\log_e e = 1$

The normal equations for estimating the values of A and B are as follows:

$$\mathbf{\sum y_t = nA + b\sum t}$$

$$\mathbf{\sum ty_t = A\sum t + b\sum t^2}$$

Finally, the value of a is obtained on using

a = antilog (A)

Quadratic model

$$\mathbf{y_t = a + bt + ct^2}$$

The values of constants 'a', 'b' and 'c' were obtained by using the principle of least squares as follows (Kumar *et al*., 2025) [9]:

$$\mathbf{\sum y_t = na + b\sum t + c\sum t}$$

$$\mathbf{\sum ty_t = a\sum t + b\sum t^2 + c\sum t^2}$$

$$\sum t^2 y_t = a\sum t^2 + b\sum t^3 + c\sum t^4$$

Results and Discussion

Table 2 summarized the descriptive statistics of export volume and value of Mango exports. The export quantity varied between a minimum of 107295 tonnes and a maximum of 286775 tonnes, with a mean value of 199504.10 tonnes and a standard deviation of 54854.03 tonnes. This relatively high standard deviation indicated considerable fluctuations in export quantity over the study period, which was due to changes in international demand, seasonal production variability and policy interventions. Similarly, the export value ranged between 122710 thousand USD and 228654 thousand USD. The mean export value was 180094 thousand USD, while the standard deviation was 30269.60 thousand USD, indicating moderate fluctuations in export earnings over time.

In the current study, The Pettitt's test, SNH and Buishand's range tests have been applied to identify the mutation point for year wise export quantity and export value of Mango from 2005 to 2024. The results of the mutation point analysis for Mango exports from India were presented in Table 3, Figure 1 and Figure 2. For export quantity, all three tests consistently identified 2014 as the significant break point, with p-values less than 0.0001, indicating a highly significant structural break at the 1 per cent level. This clearly reflected a distinct shift in export quantity during this period. The post-2014 fluctuations in Mango export quantity were mainly due to stricter import standards, occasional shipment rejections, production variability caused by weather and pest issues, rising domestic demand and increasing competition from other exporting countries. Although some recovery was observed in certain years due to improved production conditions, enhanced export handling practices and the support from schemes like MIDH and APEDA infrastructure development initiatives.

For export value, the results of mutation point analysis showed inconsistent change points across the three tests. Pettitt's test indicated 2016 as the change point, but it was not statistically significant ($p = 0.536$). In contrast, the SNH test detected 2016 as a significant mutation point at the 5 per cent level ($p = 0.033$), suggesting a possible structural shift in export value during that year. Meanwhile, the Buishand range test identified 2007 as a non-significant (p-value = 0.289) structural break point, indicating no strong evidence of a structural break. Overall, the findings indicated that Mango export value exhibited gradual and uneven fluctuations over the study period. These variations were mainly driven by fluctuations in international prices, variations in import demand, and changes in trade competitiveness.

Table 2: Summary statistics of Mango exports from India during 2005 to 2024

Variable	Minimum	Maximum	Mean	Std. deviation
Quantity (tonnes)	107295.000	286775.000	199504.100	54854.038
Value (thousand USD)	122710.000	228654.000	180094.000	30269.601

Table 3: Mutation point analysis of Mango exports from India (2005 to 2024)

Variable	Pettitt's test		Buishand range test		SNH test	
	Change point	p-value	Change point	p-value	Change point	p-value
Export quantity	2014***	<0.0001	2014***	<0.0001	2014***	<0.0001
Export value	2016	0.536	2007	0.289	2016**	0.033

Note: *, ** and *** indicate significance at 10 per cent, 5 per cent and 1 per cent level of significance respectively.

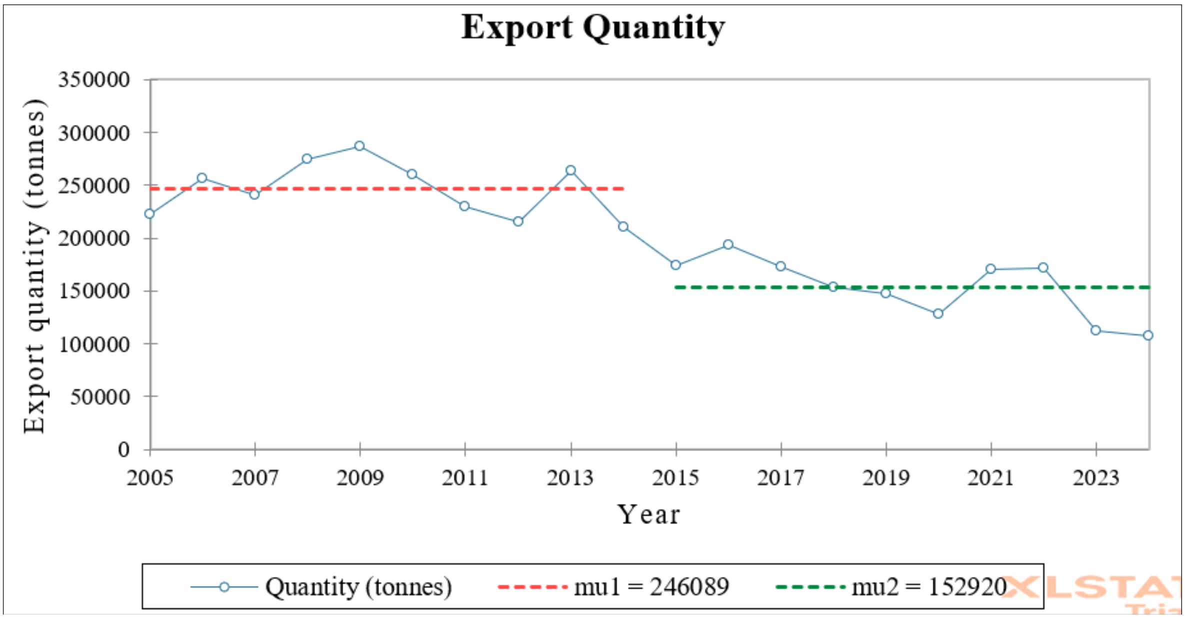

Fig 1: Identified mutation point in the export quantity of Mango from India

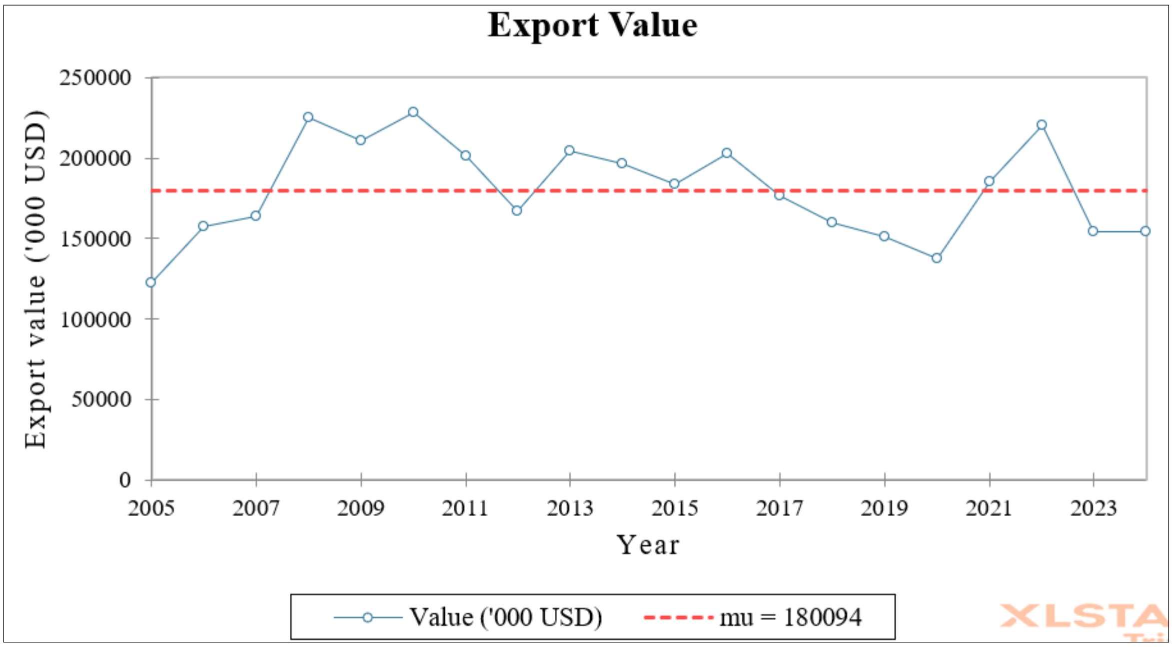

Fig 2: Identified mutation point in the export value of Mango from India

The Mann-Kendall (MK) test was used to determine the presence and significance of monotonic trends in the time series data, while Sen's slope estimator was applied to measure the magnitude and direction of the trend. As per Table 4, once the mutation point was identified, the entire time series was divided into three segments: pre-mutation period, post-mutation period and overall study period for trend analysis. Based on the analysis, 2014 was identified as the mutation point for export quantity; therefore, the series was segmented into 2005-2013 as pre-mutation period, 2014-25 as post-mutation period and 2005-2004 as the entire study period and for export value 2016 was considered as the major change point; hence, the time series was divided into 2005-2015 as the pre-mutation period, 2016-2024 as the post-mutation period, and 2005-2024 as the overall study period.

From the MK-test and Sen's slope estimator analysis, it was observed that Mango export quantity showed a statistically significant declining trend over the overall period at the 1 per cent level of significance, with the maximum rate of decline (8436.515 tonnes/year), indicating a continuous reduction in export quantity from India. In the segmented analysis, the pre-mutation period showed a weak and non-significant positive trend (954.393 tonnes/year), whereas the post-mutation period exhibited a strong and significant negative trend at the 1 per cent level with quantity decreased at the rate of 8305.000 tonnes/year, reflecting a sharp decline in exports after 2014. In export quantity, only the pre-mutation period (2005-2013) showed an increasing trend.

In the case of export value, trends across all periods were statistically non-significant ($p > 0.05$). Export value decreased at the rate of 1301.798 thousand USD/year during the overall period. The pre-mutation period showed a positive but non-significant trend and was the only period that exhibited an increasing trend (2935.33 thousand USD/year) among the three segments, whereas the post-mutation period reflected a non-significant and the highest declining trend (-3322.78 thousand USD/year). This confirmed that the export value was highly fluctuating and did not have a stable directional pattern during the study period.

Overall, the results indicated a significant and consistent decline in Mango export quantity, while export value remained unstable during the study period. The trends reflected challenges in export performance, fluctuations in global demand and changing trade conditions affecting India's Mango exports.

Table 4: Mann-Kendall test and Sen's slope estimators of Mango exports during 2005-2024 from India

Variable	Segmentation year	MK-test	Kendall's tau	p-value	Sen's slope
Export quantity (tonnes)	2005-2013	2	0.056	0.917	954.393
	2014-2024	-39	-0.709***	0.003	-8305.000
	2005-2024	-136	-0.716***	<0.0001	-8436.515
Export value (thousand USD)	2005-2015	11	0.200	0.436	2935.334
	2016-2024	-6	-0.167	0.602	-3322.786
	2005-2024	-32	-0.168	0.315	-1301.798

Note: *, ** and *** indicate significance at 10 per cent, 5 per cent and 1 per cent level of significance respectively.

Trend analysis was carried out by fitting linear, exponential and quadratic models to the data and the corresponding model equations were presented in Table 5 and the corresponding trends were presented in Figure 3 and Figure 4. The accuracy of these models was evaluated using the coefficient of determination (R^2), which indicates how well each model explains the variation in the respective export parameters over time

Table 5: Model equations with R^2 values for Mango export from India

Variable	Model name	y	R^2
Export quantity	Linear model	$y = 2E{+}07 - 8128.9t$	0.769
	Exponential model	$y = 5E{+}43 \cdot e^{0.044t}$	0.724
	Quadratic model	$y = -1E{+}09 + 1E{+}06t - 297.03t^2$	0.796
Export value	Linear model	$y = 2E{+}06 - 658.69t$	0.017
	Exponential model	$y = 6E{+}07 \cdot e^{0.003t}$	0.016
	Quadratic model	$y = -2E{+}09 + 2E{+}06t - 428.82t^2$	0.202

For export quantity, the quadratic model recorded the highest R^2, indicating about 76.9 per cent of the variation was explained by this model. This indicated that the quadratic model gave the best fit and showed a changing trend over time, with periods of increase and decrease. The linear (0.77) and exponential (0.72) models also showed a fairly good fit but were relatively less effective in explaining the variability.

For export value, all three models showed very low R^2 values, indicating a poor fit and weak ability to explain the variation over time. The linear (0.01) and exponential (0.01) models showed similarly poor performance. The quadratic model showed a relatively higher R^2 value (0.20), but still explained only 20.2 per cent of the variation. This indicated that export value exhibited high fluctuations and was influenced by factors other than time, making it less predictable than export quantity.

Overall, the export quantity showed a non-linear (curved) pattern, whereas the export value showed a weak model fit and remained highly unstable.

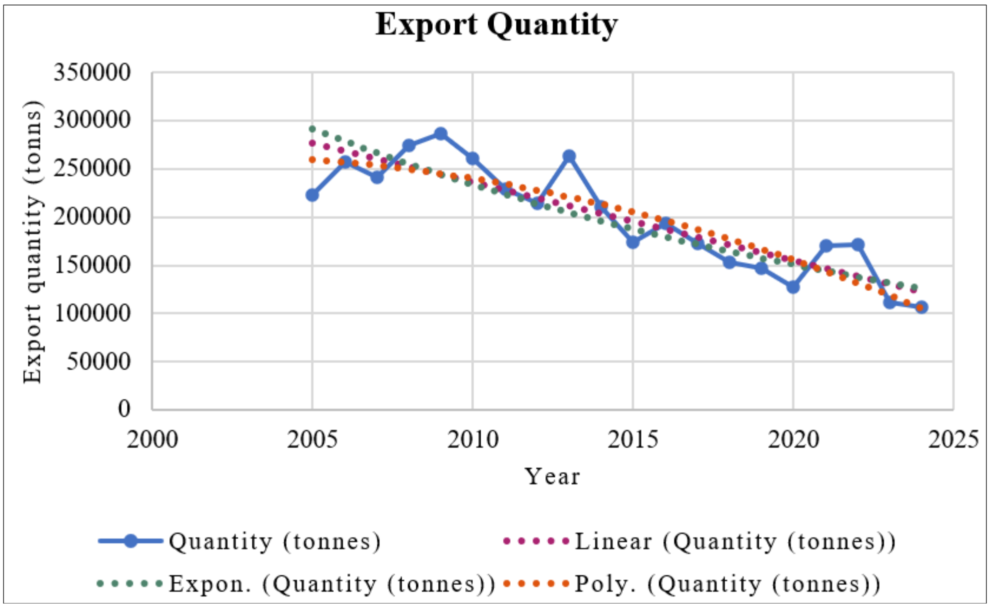

Fig 3: Trend pattern in the export quantity of Mango exports from India

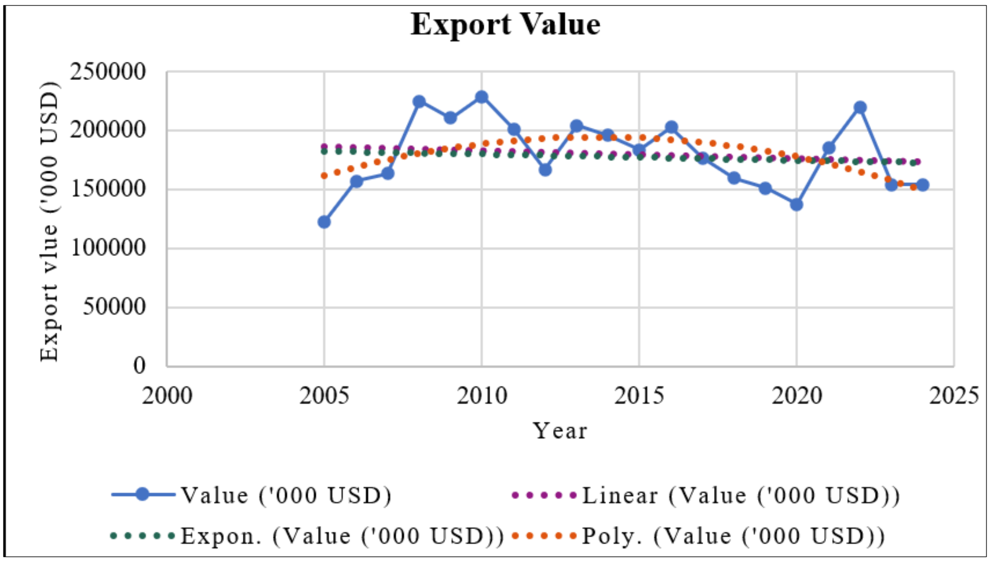

Fig 4: Trend pattern in the export value of Mango exports from India

Conclusion

The study examined structural changes and trends in India's mango exports from 2005 to 2024. Structural break tests identified 2014 as a significant mutation point in export quantity, while export value showed only weak evidence of change around 2016. Trend analysis revealed a significant decline in export quantity, especially after 2014, whereas export value remained unstable with no significant trend. The quadratic model best explained the trend in export quantity, while export value showed high variability and poor predictability. The findings indicated that global demand, price fluctuations, quality standards and competition strongly influence mango exports. These findings underscore the importance of improving export infrastructure, maintaining quality standards and expanding market diversification to ensure sustainable growth of India's mango exports.

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