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# Understanding the Growth and Trend Patterns of Palm Oil Imports in India: An Innovative Trend Analysis

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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

**Aim:** India, with its large population, is one of the world's largest consumers of edible oils, and palm oil is a major component of this consumption. The objective of the study was to understand the growth and trend patterns of palm oil imports in India.

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**Data Description:** Monthly palm oil imports to India in terms of quantity from April 2007 to March 2023 was collected from various sources, including ICT Trade Map and UNCOMTRADE, based on the six-digit Harmonized System (HS) code.
**Methodology:** Various parametric (Linear regression) and non-parametric (Modified Mann-Kendall's Test, Sen's slope and Innovative Trend analysis) approaches used for analyzing the trend in the India's palm oil imports quantity.
**Results:** The analysis revealed a mixed trend in palm oil imports, with a weak but definite pattern indicated by the linear regression analysis ($R^2 = 0.1079$). The Modified Mann-Kendall test identified significant growth in August and September, while the Innovative Trend Analysis highlighted strong increasing trends in February, March, April, and August, with September showing the most significant import growth.
**Conclusion:** These findings underscore the importance of monitoring and understanding palm oil import trends for policymakers, traders, and stakeholders in the edible oil industry.

*Keywords: Vegetable oils; palm oil; imports; innovative trend analysis; Sen's slope; modified Mann-Kendall's test.*

## 1. INTRODUCTION

"Vegetable oils are oils or fats extracted from a plant. Their texture can be described as liquid, oily and fatty. Most vegetable oils are able to fulfill two functions: they can either be used as cooking oil or for fuel and diesel production. In terms of consumption as a food product, vegetable oils are seen as the healthier alternative as they contain more unsaturated fatty acids than animal fats. The most common vegetable oils used for consumption in India include palm oil, soybean oil, rapeseed oil and sunflower seed oil" [1].

"Palm oil is primarily found in the tropical climate of Africa, South America and South East Asia.Oil which is extracted from Oil palm plant is more unsaturated, but the oil to bunch ratio is extremely low, making it uneconomical to plant on a commercial scale" [2]. "The oil palm is the most efficient oil-producing plant, with about 4.5 tonnes of oil per hectare per year" [3]. "Crude palm oil (CPO) is produced from fresh fruit bunches (FFB) of Oil Palm (*Elaeis guineensis Jacq*.) and the palm kernel oil (PKO) is produced from fruit's nut" [4]. "It is estimated that about 90 percent of palm oil is used for food consumption, whereas industrial consumption such as cosmetic products or fuel and diesel claim the remaining 10 percent" (https://www.statista.com/statistics/263937/vegetable-oils-global-consumption).

The Fig. 1 presents data on palm oil consumption, production, and supply in India from 2001 to 2023. Consumption of palm oil in India has witnessed a gradual increase, with some fluctuations, from 2760 thousand metric tons (MT) in 2001 to 9750 thousand MT in 2023.This growth reflects the rising demand for palm oil, driven by factors such as population growth, urbanization, and changes in dietary habits. Palm oil production in India remained relatively stable at around 35-50 thousand MT until 2010, indicating that domestic production has not kept pace with the increasing demand. However, there was a notable increase in production from 2011 onwards, reaching 305 thousand MT in 2023. This suggests efforts to boost domestic production to reduce reliance on imports.

The supply of palm oil, which includes both domestic production and imports, has also been increasing to meet the rising demand. Supply, representing the total availability of palm oil in the market, also varied but generally increased over the years, ranging from 2882 thousand MT in 2001 to 12024 thousand MT in 2023. While domestic production has seen some growth, it has not kept pace with the increasing consumption, leading to a significant reliance on imports to bridge the gap. The gap between domestic consumption and production has widened over the years, necessitating higher imports to meet the demand.

ASEAN countries such as Indonesia and Malaysia are the two largest producers of palm oil at the global level [5,6]. "Malaysia is the world's second largest supplier of palm oil after Indonesia" [7]. "In India more than half of the consumption is met through imported oils and three-fourths of these edible oil's imports are palm oil from Indonesia and Malaysia" [8,9]. "The edible oils/ oilseeds sector currently faces several challenges. Oilseed cultivation is

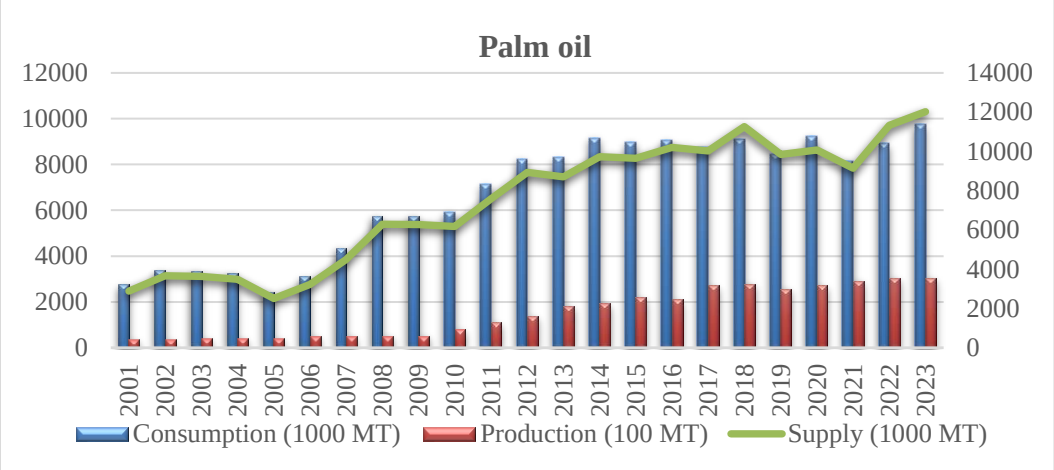


**Fig. 1. Palm oil scenario in India**

becoming increasingly unattractive due to low and unstable yields" (Srinivasan, 2005).

"To address these challenges and enhance the performance of the oilseed sector, the Indian government has implemented various policies and initiatives. Recently, the government has launched schemes such as National Mission on Edible Oils – Oil Palm (NMEO-OP) to promote palm cultivation and reduce the country's dependence on edible oils imports, especially crude palm oil (CPO) involving expansion of area under Oil Palm cultivation by 6.50 lakh hectares by 2025-26" [10].

In this regard, the study made an attempt to analyze the trend patterns or dynamics in the palm oil imports in India. This study helps to identify the gap between consumer demand and production of palm oil, highlighting the need for strategic interventions to bridge this gap. Understanding the import trends also offers valuable information for policymakers, industry stakeholders, and investors, enabling them to make informed decisions regarding production, import strategies, and sustainability practices in the palm oil sector.

## 2. MATERIALS AND METHODS

### 2.1 Data and Source of Study

Monthly time series data on the imports of palm oil to India from the world was collected from various sources, including ICT Trade Map, World Bank Portal, and UNCOMTRADE trade data. The data was collected based on the six-digit Harmonized System (HS) code from the UNCOMTRADE web portal. The monthly data of import quantity of palm oil was collected for the period spanning from April 2007 to March 2023.

### 2.2 Statistical Tools Employed in The Analysis

Keeping the objectives set for the study in view, the following tools and methods have been employed.

#### 2.2.1 Trend analysis

Trend refers to a pattern found in the time series dataset. The trend may be positive or negative and upward or downward. It can be estimated by using statistical parametric or non-parametric tests. In this research work for assessing rainfall parametric and non-parametric test were used. By using the standard mathematical procedures [11] descriptive statistics was computed. Linear regression analysis, Mann-Kendall's test, Sen's slope estimator, Modified Mann-Kendall test and to test the randomness Wallis and Moore phase-frequency test was used and those details were given as follows;

i. Linear regression analysis
ii. The Mann-Kendall's trend test
iii. Sens slope estimator
iv. Modified Mann-Kendall's test
v. Innovative trend analysis (ITA)

*2.2.1.1 Linear regression analysis*

To detect a trend in a data series one of the most used parametric models is Linear regression analysis. By applying a linear equation to the collected data, this model creates a relationship between two variables (the dependent and

independent variables). The linear regression model is generally described by the following equation:

$$Y = mX + C \quad (1)$$

Where Y is the dependent variable, X is the independent variable, m is the slope of the line, C is the intercept constant. The t-test is used to determine whether the linear trends are significantly different from zero at the 5% significance level.

*2.2.1.2 The mann–kendall's trend test*

The significance of the trends was tested by a nonparametric test known as the Mann–Kendall (MK) test [12,13,14]. It identifies trends in the data of time series but trend may or may not be linear. Let $x_1, x_2, x_3, x_n$ represents n data points, where $x_j$ represents the data points at time *j*. The Mann-Kendal statistic (S) is given by

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(x_j - x_i) \quad (2)$$

Where $x_i$ and $x_j$ are the annual values in years' *j* and *i, j>i* respectively and N is the number of data points. The values of $sign(x_j - x_i) = 0$. This statistic represents the number of positive differences minus number of negative differences for all the differences considered. For large samples (N>10), the test is conducted using z statistics with mean and the variance as follows

$$E[S] = 0 \quad (3)$$

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p-1}^{q} t_p(t_p-1)(2t_p+5)\right] \quad (4)$$

Where q is the number of tied groups and $t_p$ is the number of observations in the p[th] group. Compute MK test statistic, $Z_{MK}$, as follows:

$$Z_{MK} = \frac{S-1}{\sqrt{VAR(S)}} \text{ if } S>0 \quad (5)$$

$$= 0 \quad \text{if } S=0 \quad (6)$$

$$= \frac{S-1}{\sqrt{VAR(S)}} \text{ if } S<0 \quad (7)$$

A positive (negative) value of $Z_{MK}$ indicates that the data tend to increase (decrease) with time. To test either an upward or downward monotone trend (a two tailed test at $\alpha$ level of significance $H_0$ is rejected if $|Z_{MK}| \geq Z_{1-\alpha/2}$.

*2.2.1.3 Sens's slope estimator*

Sen's slope is to identify the magnitude of trend in a data series which not serially auto-correlated. The Sen's method [15] can be used in cases where the trend can be assumed to be linear.

$$f(t) = Qt + B \quad (8)$$

Where *Q* is the slope, *B* is a constant and *t* is time. To get the slope estimate Q, the slopes of all the data value pairs is calculated using the equation:

$$Q_i = \frac{x_j - x_k}{j-k} \quad (9)$$

Where $x_j$ and $x_k$ are the data values at time j and k (*j>k*) respectively. If there are n values $x_j$ in the time series, there will be as many as $N = \frac{n(n-1)}{2}$ slope estimates $Q_t$. The N values of $Q_t$ are ranked from the smallest to the largest and the Sen's estimator is

$$Q = Q_{\left[\frac{n(n+1)}{2}\right]} \text{ , if N is odd or } Q = 1/2\left(Q_{\left[\frac{N}{2}\right]} + Q_{\left[\frac{(N+2)}{2}\right]}\right), \text{ if N is even.} \quad (10)$$

To obtain the estimate of B in equation *f(t)* the n values of differences $x_i - Q_{ti}$ values are calculated. The median of the values gives an estimate of B.

*3.2.1.4 Modified mann-kendall test*

The non-parametric statistical method known as the modified Mann-Kendall test is used to examine monotonic upward or downward trend of the series when there is a positive autocorrelation [16]. It deals with the issue of serial correlation using the variance correction approach. The variance of s statistic is as follows;

$$V^*(S) = V(S)\frac{n}{n^*} \quad (11)$$

Where $\frac{n}{n^*}$ is a correction factor. V(S) is calculated as in the original MK test. The null hypothesis $H_0$ indicate there is no trend in the given series, the null hypothesis is rejected when the Z-transformed statistic value is greater than the Z critical value at 5% level of significance ($|Z_{MMK}| \geq Z_{1-\alpha/2}$).

*3.2.1.5 Innovative trend analysis (ITA)*

The innovative trend analysis (ITA) proposed by Şen [17] was also applied to detect the trends in

time series. Unlike the most commonly used classical trend analysis methods like the M-K/mM-K and SS tests, the ITA method is free from the assumptions of serial autocorrelation, normality, and length of the records. The time series is divided into two equal parts in ITA from the first date to the end date. Both sub-series are arranged in ascending order. The first half of the series is placed on X-axis, and the second half is placed at the Y-axis of the Cartesian coordinate system. If the data points are collected on 1:1 line, it indicates there is no trend in the data. If the data points fall above the 1:1 line, it is indicative of a positive trend, while if the data points accumulate below the 1:1 line, it indicates a negative trend. The slope of the ITA (SITA) test was proposed by Şen [18]. A positive SITA value indicates an increasing trend, while a negative SITA shows a decreasing trend in time series. The ITA was performed using "trendchange" package [19] in R software version 4.0.2 (R Core Team 2020). In this paper, the null hypothesis of no trend against the alternate hypothesis of there is a trend in the India's imports of vegetable oils time series data was tested at two different significance levels (α), i.e., α = 5% and α = 1%.

## 3. RESULTS AND DISCUSSION

### 3.1 Palm oil

Fig. 2 represents the monthly imports of palm oil in India. The linear regression analysis was done for monthly palm oil imports. The graph depicts the mixed nature of trend in palm oil imports of India for the time period April 2007 to March 2023.However, it does not specify the particular months in which these variations occur significantly. The value of Coefficient of determination (R2) for linear equation is at lower magnitude (0.1079) which indicate that data under consideration has definite pattern.

Before proceeding with the Modified Mann-Kendall's test need to test the data for normality and auto-correlation.

The results from two statistical tests performed on the data presented in Table 1**,** indicate significant findings. The Box-Pierce test for autocorrelation suggests that the imports are not independent over time, with a test statistic of 108.42 and a p-value < 2.2e-16, strongly rejecting the null hypothesis of independence. Additionally, the Shapiro-Wilk test for normality reveals that the data is not normally distributed, as evidenced by a test statistic of 0.95983 and a p-value of 2.791e-05, leading to the rejection of the null hypothesis of normality. These results suggest that the palm oil imports exhibit autocorrelation and are not normally distributed, highlighting potential patterns and deviations from normality in the import data.

The results of Modified Mann-Kendall trend analysis for palm oil imports by India were depicted in Table 2. It revealed the significant growing trend of palm oil imports in the months of August and September as the Z transformed test statistic is significant at 5 per cent level of significance. There was no noteworthy trend in the remaining months as the test results were

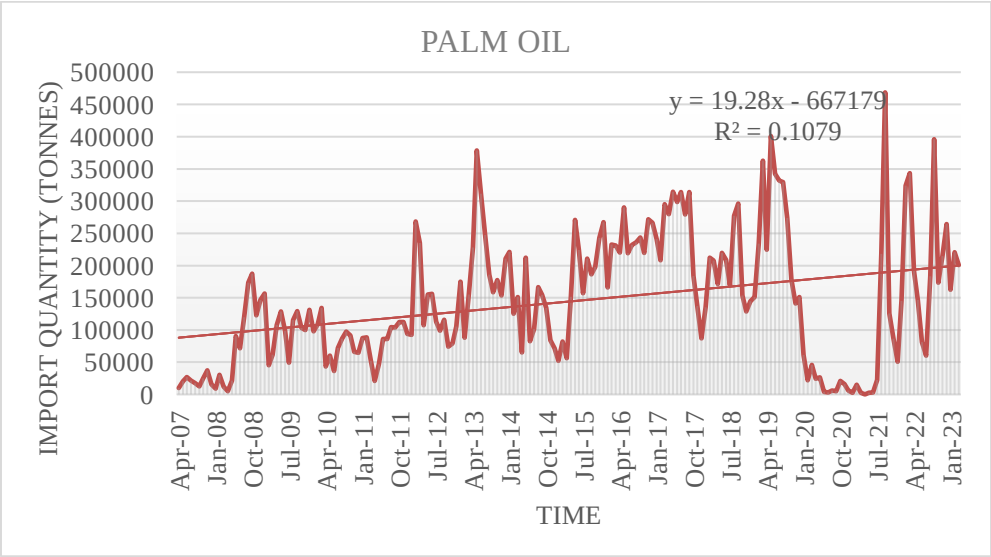


**Fig. 2. Trend of Palm oil imports of India from world using linear regression analysis**

**Table 1. Normality and Autocorrelation test for palm oil imports**

| Test | Test statistic | P value | Result |
|---|---|---|---|
| Shapiro-wilk test | 0.96 (w) | 0.00 | Data is not normally distributed. |
| Ljung box test | 108.42 (X- squared) | 0.00 | Autocorrelation presents in the data |

**Table 2. Modified Mann-Kendall test of trend analysis of monthly and annual palm oil import data**

| Parameter | Z- Transformed test Statistic | Trend | Sens slope |
|---|---|---|---|
| January | 0.94 | NS | 4902.95 |
| February | 1.85 | NS | 13839.95 |
| March | 1.85 | NS | 3800.06 |
| April | 1.44 | NS | 7220.22 |
| May | 1.11 | NS | 8663.06 |
| June | 0.78 | NS | 8478.06 |
| July | 1.77 | NS | 13402.06 |
| August | 2.68 | * | 16332.22 |
| September | 2.68 | * | 20409.41 |
| October | 0.37 | NS | 1773.85 |
| November | 1.28 | NS | 4134.94 |
| December | 0.45 | NS | 2747.54 |
| Annual | 2.35 | * | 120734.75 |

*NS - non-significant trend; * - significant trend*

non-significant. It revealed the significant growing trend of annual palm oil imports in India as the Z transformed test statistic $Z_{cal}$ was greater than $Z_{tab}$ at 5 per cent level of significance so the null hypothesis was rejected.

In Table 3 presented the results of the ITA with Significance Test at 99%, 95%, and 90% confidence levels. Figs. 3, 4 and 5 showing the trend slopes as well as the top and lower bounds of the trend for each month at 0.10, 0.05 and 0.01 level of significance. The results of the innovative trend analysis provide an in-depth understanding of the temporal patterns in the data, highlighting the direction, strength, and significant nature of trends for every month. The rate of change is indicated by the trend slope, where positive values denote a rising trend and negative values denote a falling trend. In addition, the trend indicator provides information on the strength of the trend; larger values correspond to more pronounced trends. The lower and upper confidence limits (LCL and UCL) provide a range within which the true trend slope is likely to fall, aiding in assessing the reliability of the trend estimates.

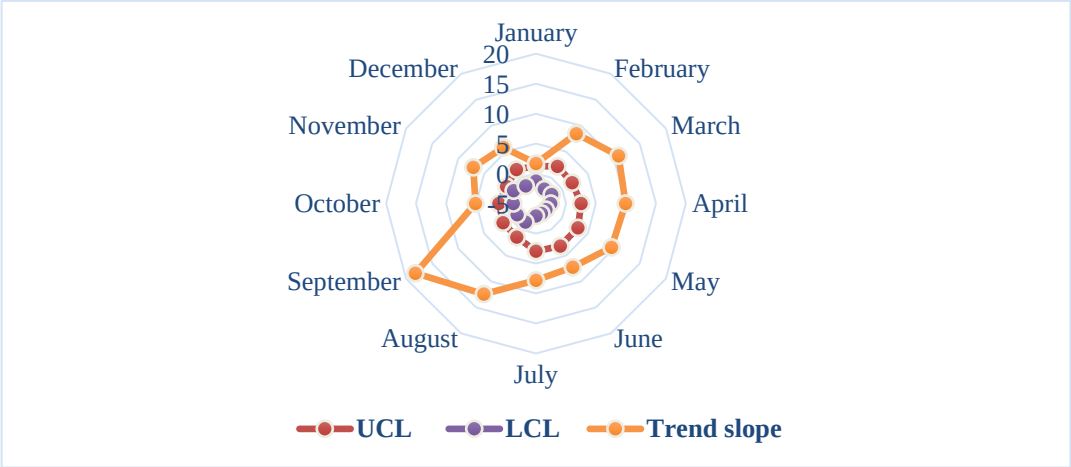


**Fig. 3. Radar chart for Innovative trend analysis of Palm oil imports in India at 0.10 level of significance**

**Table 3. Innovative trend analysis (ITA) of monthly and annual palm oil import of India**

| Parameter | Trend slope | Trend Indicator | $\propto = 0.10$ | | $\propto = 0.05$ | | $\propto = 0.01$ | |
|---|---|---|---|---|---|---|---|---|
| | | | LCL | UCL | LCL | UCL | LCL | UCL |
| January | 1684.90 | 1.36 | -1252.17 | 1252.17 | -1491.94 | 1491.94 | -1960.84 | 1960.84 |
| February | 8447.76 | 7.61 | -2188.08 | 2188.08 | -2607.08 | 2607.08 | -3426.45 | 3426.45 |
| March | 10929.15 | 9.27 | -1973.15 | 1973.15 | -2350.98 | 2350.98 | -3089.86 | 3089.86 |
| April | 9940.67 | 11.51 | -2534.23 | 2534.23 | -3019.51 | 3019.51 | -3968.49 | 3968.49 |
| May | 9525.41 | 6.33 | -3069.64 | 3069.64 | -3657.45 | 3657.45 | -4806.93 | 4806.93 |
| June | 7259.13 | 5.56 | -3150.43 | 3150.43 | -3753.70 | 3753.70 | -4933.44 | 4933.44 |
| July | 7770.69 | 6.93 | -2953.16 | 2953.16 | -3518.66 | 3518.66 | -4624.53 | 4624.53 |
| August | 12437.17 | 9.45 | -1428.88 | 1428.88 | -1702.50 | 1702.50 | -2237.57 | 2237.57 |
| September | 18210.59 | 13.09 | -1351.58 | 1351.58 | -1610.39 | 1610.39 | -2116.52 | 2116.52 |
| October | 5111.96 | 3.84 | -1185.81 | 1185.81 | -1412.87 | 1412.87 | -1856.92 | 1856.92 |
| November | 7098.64 | 6.38 | -661.58 | 661.58 | -788.26 | 788.26 | -1036.00 | 1036.00 |
| December | 5844.35 | 4.73 | -1567.68 | 1567.68 | -1867.87 | 1867.87 | -2454.92 | 2454.92 |
| Annual | 104260.46 | 7.09 | -23333.34 | 23333.34 | -27801.43 | 27801.43 | -36539.02 | 36539.02 |

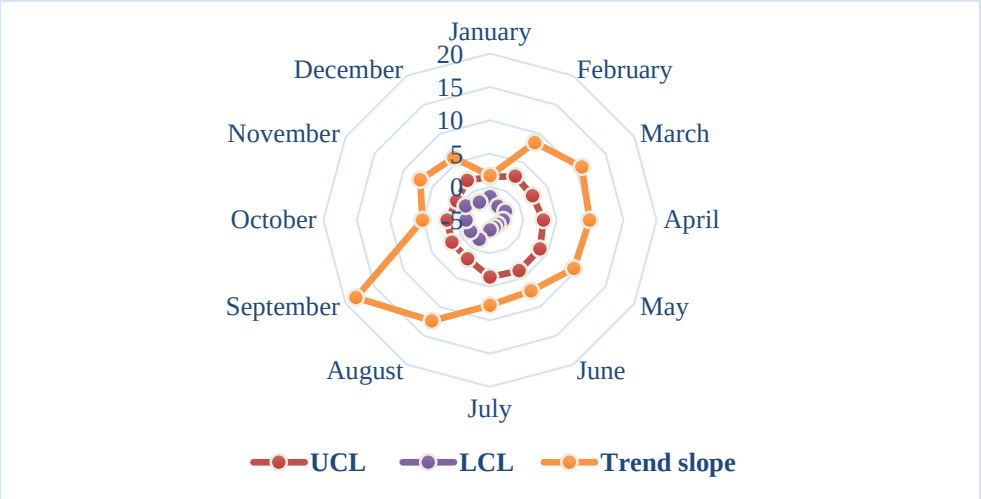


**Fig. 4. Radar chart for Innovative trend analysis of Palm oil imports in India at 0.05 level of significance**

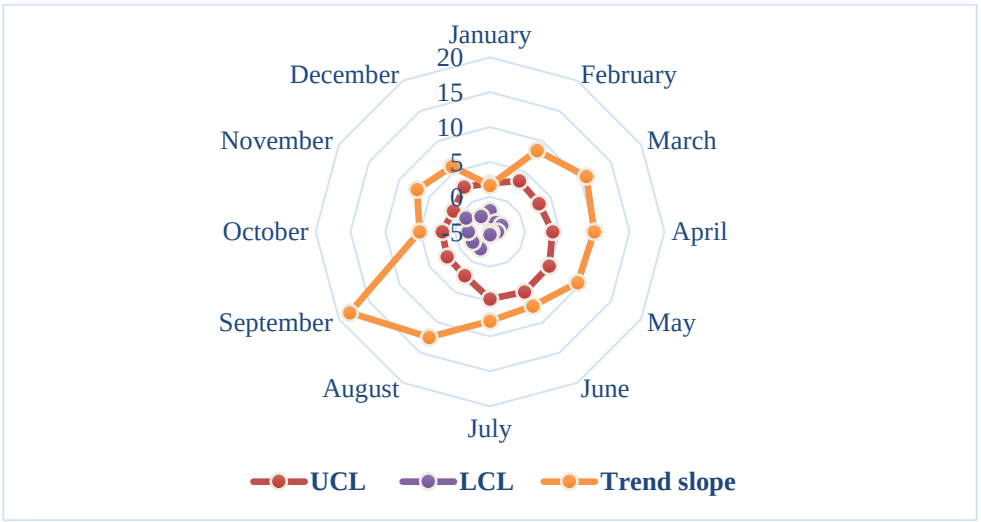


**Fig. 5. Radar chart for Innovative trend analysis of Palm oil imports in India at 0.01 level of significance**

The analysis of monthly palm oil imports by India using innovative trend analysis revealed several significant trends. February, March, April, and August stand out as months with particularly strong increasing trends. In February, the trend indicator of 7.61 signifies a significant and consistent rise in imports, which is also supported by statistical significance across confidence levels. March and April follow suit with even stronger trend indicators of 9.27 and 11.51, respectively, indicating substantial and statistically significant growth in imports during these months. August month showed a similar pattern with a trend indicator of 9.45, suggesting a significant increase in palm oil imports during this period.

September, however, emerged as the most significant month in terms of import growth, with a remarkable trend indicator of 13.09. This value indicated a very strong and statistically significant upward trend in palm oil imports during September, pointing to a particularly pronounced surge in import volumes.

Other months, such as May, June, July, and November, also exhibited moderate increasing trends, indicating ongoing growth in palm oil imports during these periods. In contrast, January and October showed comparatively weaker increasing trends, suggested less pronounced growth in import volumes during these months. Overall, this analysis highlighted

distinct periods of growth in palm oil imports by India, with September standing out as a month of exceptional and rapid increase in import volumes.

## 4. CONCLUSION

Palm oil, a major vegetable oil imported by India, was selected for the study due to its importance in the country's culinary practices and large population. The data on palm oil imports from April 2007 to March 2023 was collected from various sources, including ICT Trade Map, World Bank Portal, and UNCOMTRADE trade data. The analysis of monthly palm oil imports by India revealed several significant trends.

The linear regression analysis showed a mixed trend in palm oil imports over the studied period, with a coefficient of determination ($R^2$) of 0.1079, indicating a definite but relatively weak pattern. The Modified Mann-Kendall test identified a significant growing trend in palm oil imports in August and September, with no noteworthy trend in other months. The annual trend analysis also indicated a significant increase in palm oil imports in India.

The Innovative Trend Analysis (ITA) provided further insights, showing strong increasing trends in February, March, April, and August, with September being the most significant month for import growth. These findings highlight distinct periods of growth in palm oil imports and underscore the importance of monitoring and understanding these trends for policymakers, traders, and stakeholders in the edible oil industry.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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