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AN EMPIRICAL STUDY ON ASSESSMENT OF TREND ANALYSIS: FOOD GRAIN PRODUCTION IN INDIA

Kalpana Polisetty[1], Christophe Chesneau[2*], Gowthami Paltati[1] and Kiran Kumar Paidipati[3]

[1]School of Applied Sciences & Humanities, Vignan's Foundation for Science, Technology and Research, India
[2]Department of Mathematics, LMNO, Université de Caen-Normandie, Campus II, Science 3, 14032 Caen, France
[3]Area of Decision Sciences, Indian Institute of Management Sirmaur, Paonta Sahib, HP-173025, India

Abstract: Considering the importance of the food grains to be specified—rice, wheat, coarse cereals, and pulses-is vital in developing the Indian economy. This paper carries out change point detection and trend analysis for the annual historical series of food grains in India. The change points were identified by the methods of the Pettitt's test (PT), the Buishand's range test (BRT), and the standard normal homogeneity test (SNHT). On the other hand, the Mann-Kendall (MK) test was used to determine the presence and absence of trends in food grain production, and their slopes were assessed by the Sen's slope estimator. The change point analysis result shows significant change points for food grains at a 95% level. The discrete change points were observed from 1982 to 2009, but the ideal change point, i.e., 1987, was captured in all food grains. In India's history, agricultural production in the year 1987 was vulnerable due to drought, and thus it is strong evidence of the need to consider methods based on proven facts. The MK test results reveal that the trend in food grain production was statistically significant and had an upward direction in all three segmentation periods after 1987.

Key words: food grains, change point, trend analysis, statistical analysis, statistical significance.

Introduction

Food is the most important item in terms of basic human needs. Since its independence, India has taken progressive steps towards food security. There is an inclination toward multigrain cereals in India, which has seen a significant ascent. These multigrain cereals are rich in a wellspring of proteins, minerals, iron, etc., with high levels of nourishing substances.

*Corresponding author: e-mail: christophe.chesneau@gmail.com

Eating such varieties of food grains with a high source of proteins and minerals keeps one 'full and fulfilled' and supports the immune system, movement of functions, etc., in the human body. The assortment of whole grains such as whole wheat, rice, pulses, and coarse cereals offers a complete package of health benefits by providing nutrients, fiber, protein, vitamins, minerals, and other solid plant compounds that support a sound digestive system and lower the risk of heart disease. For instance, wheat provides energy, helps to control weight, and fights against some diseases such as cancer and cardiovascular disease, among others. Let us present the benefits of rice, coarse cereals, and pulses in turn. Rice provides energy that restores glycogen levels and is easy to digest. Coarse cereals aid in the prevention of cancer, type II diabetes, and other diseases. Pulses aid in the maintenance of a healthy heart as well as the reduction of body weight. A growing number of customers are placing an emphasis on healthy living, changing their metabolism in order to prevent chronic diseases, and using dietary supplements made by nature.

India is a global agricultural powerhouse, and agriculture forms the foundation and prime sector of the Indian economy. With the growth of the agricultural sector, the industrial sector also developed its economy by procuring raw materials from agriculture. However, in farming, the targets require quick expansion in food grain creation, as well as significantly faster development through broadening.

There are various time series models such as linear (ARIMA) and non-linear (ANN) methods used by some renowned professionals to build the mathematical models for food grain production and productivity (Mishra et al., 2015; Vijay and Mishra, 2018; Puneet, 2019). The trend pattern of food grains in India is analyzed by examining the growth rate and instability of food grain areas, production, and yield (Sanjay and Deepak, 2012; Sharma, 2013; Mukesh and Shallu, 2014; Ruche, 2017). Parul (2016) analyzed the trend in the compound growth rate for food grains in the pre-economic reform period. Kalpana and Kiran (2019) applied non-parametric techniques to assess the change point and trend of wheat in India.

However, from the above literature, we have observed that there is not much research done on food grains. A few other researchers considered that only parametric methods could build the best forecast models to predict future production and assess trends in food grains.

Most researchers have successfully used non-parametric methods to detect trends and find abrupt changes in longer-term data sets (Reshu et al., 2014; Tabari et al., 2014; Ijaz et al., 2015; Jamaludin and Zulkifli, 2018; Kalpana and Kiran, 2019; Kalpana et al., 2020; Zinabu and Michael, 2020; Annie and Madan, 2021; and many others). Therefore, in this paper, we considered non-parametric methods with the objective of studying the performance of food grains in India. Here, the main focus was on trend analysis by considering abrupt changes in the most important food grains in India.

Material and Methods

Considering the importance of food grains, the annual production of rice, wheat, coarse cereals, and pulses from 1950 to 2019 was used in this study. These food grains have the only major production share compared to other grains in India.

Tests to capture the change point

Within trend analysis, the prior task is verifying the nature of the time series data. This means whether the data are homogeneous or not. In this context, the three main homogeneity tests, such as the PT, BRT, and SNH tests, were conducted on the annual production of various food grains. The decision to consider the significant breakpoints followed the rules: 1. Assuming that the data represent homogeneity, it indicates no abrupt change has been recorded, and 2. In the case of inhomogeneity, it is possible to consider the breakpoint in time series data (Reiter et al., 2012; Ijaz et al., 2015; Arikan and Kahya, 2019). The non-parametric homogeneity methods are briefly discussed below.

Pettitt's test (PT)

The PT, established in the 1980s, introduced non-parametric methodologies to estimate the breakpoint in time series data. Later, most researchers adapted this method for trend analysis to compute shifts in various fields. The PT statistic is then defined by

$$K = \max_{1 \le k \le n} |U_k|, \text{ where } \mathrm{U}_k = 2\sum_{i=0}^{n} R_i - k(n+1). \tag{1}$$

Here, R_i represents the rank of the i^{th} observation when the data is arranged in ascending order, and n is the number of observations in the data set, i.e., x_i (i=1, 2, …, n).

Buishand's range test (BRT)

The BRT is one of the most widely used homogeneity tests in its construction. The adjusted partial sum is computed as

$$S_k = \sum_{m=1}^{k} (x_m - \bar{x}) \tag{2}$$

where x_m $(m = 1, 2, ..., n)$ and $\bar{x}$ = mean of n observations.

The significant breakpoint can be computed by the method of rescaled adjusted range (*R*) if the $S_k = 0$, in this case, R is defined by

$$R = \frac{\underset{0 \le k \le n}{Max}\left(S_k\right) - \underset{0 \le k \le n}{Min}\left(S_k\right)}{\bar{x}} \tag{3}$$

Standard normal homogeneity test (SNHT)

Alexandersson (1986) developed the SNHT to study the abrupt change in the rainfall data. The SNHT is a likelihood ratio test that was first performed to study the homogeneity of rainfall. The test statistic is indicated as

$$Z_t = t\bar{z}_1 + (n-t)\bar{z}_2, \quad (1<t<n),$$

$$\text{where, } \bar{z}_1 = \frac{1}{t}\sum_{i=1}^{k}\left(\frac{y_i - \bar{y}}{\sigma}\right) \text{ and } \bar{z}_2 = \frac{1}{n-t}\sum_{i=t+1}^{n}\left(\frac{y_i - \bar{y}}{\sigma}\right) \tag{4}$$

Trend analysis

The main task in trend analysis is to assess the monotonic fluctuations in long-period data sets, which can be well performed through a non-parametric linear trend test, i.e., the Mann-Kendall test (Tabari et al., 2014; Jaiswal et al., 2015; Jamaludin and Zulkifli, 2018; Kalpana and Kiran, 2019; Kalpana et al., 2020; Zinabu and Michael, 2020; Annie and Madan, 2021). The test statistic of the Mann-Kendall test (S) is expressed as

$$S = \sum_{j=1}^{n}\sum_{k=1}^{j-1} \text{sign}\left(x_j - x_k\right)$$

$$\text{where, } \text{sign}\left(x_j - x_k\right) = \begin{cases} 1, & \text{if } \left(x_j - x_k\right) > 0 \\ 0, & \text{if } \left(x_j - x_k\right) = 0 \\ -1, & \text{if } \left(x_j - x_k\right) < 0 \end{cases} \tag{5}$$

Suppose the sample size is n>10 and S follows a normal distribution in a tied group with a mean E(S) and a variance V(S), then the MK test statistic is as follows:

$$E(S) = 0,$$

$$V(S) = \left\{ n(n-1)(2n+5) - \sum_{j=1}^{p} t_j (t_j - 1)(2t_j + 5) \right\} / 18 \qquad (6) \text{ and}$$

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}}, & \text{if } S > 0 \\ 0, & \text{if } S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, & \text{if } S < 0 \end{cases}.$$

Here, the detection of a trend depends on the value of Z. For example, if the Z value is zero, it means that the data does not follow any trend; if the value of Z is positive, it means that the trend is in an upward direction; and if the value of Z is negative, it means that the trend is in a downward direction.

Sen's slope estimator

Assuming that the time series data exhibits a significant trend, i.e., either a positive or a negative trend, then the Sen's slope estimator can be estimated. It means the slope of the trend line or the average rate of change of the trend (Hosseinzadeh, 2014; Guo and Xia, 2014; Gavrilov et al., 2016; Thenmozhi and Kottiswaran, 2016; Zinabu and Michael, 2020; Annie and Madan, 2021). The slope of the trend is estimated using the following test statistic:

$$T_i = \frac{y_j - y_k}{j - k} \quad \text{for } i=1, 2, \ldots, N \qquad (7)$$

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

$$\beta = \begin{cases} T_{\frac{N+1}{2}} & \text{N is odd,} \\ \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}} \right) & \text{N is even} \end{cases} \qquad (8)$$

Here, if the value of β is positive, it means that the trend is in a rising pattern, and if the value of β is negative, it means that the trend is in a declining pattern.

Results and Discussion

In order to explain the characteristics of the data, the researchers analyzed various food grains: rice, wheat, coarse cereals, and pulses, using descriptive statistics. The calculations are presented in Table 1.

Table 1. Statistical information on the production of various food grains (in million tons) from 1950 to 2019.

Food grain	Count	Minimum	Maximum	Mean	S.D.
Rice	70	20.580	118.400	63.432	28.645
Wheat	70	6.180	107.590	46.782	30.808
Coarse cereals	70	15.380	47.500	30.229	7.370
Pulses	70	8.350	25.230	13.109	3.451

The highest production, i.e., 118.4 million tons, was counted for rice in 2019, and the lowest production of rice was recorded in 1950 with a production of 20.580 million tons. The next highest share of food grain production was wheat. The maximum production of wheat was 107.59 million tons in 2019 and the minimum production was 6.180 million tons in 1951; coarse cereals had the highest production (i.e., 47.5 million tons) in 2019 and the lowest production (i.e., 15.38 million tons) in 1950; likewise, pulses had the lowest and highest productions of 8.35 million tons in 1966 and 25.23 million tons in 2017. On average, the production of various food grains such as rice, wheat, coarse cereals, and pulses was 63.432, 46.782, 30.229, and 13.109 million tons, respectively. When comparing all types of food grain production, rice took the top spot, followed by wheat, coarse cereals, and pulses.

FAO acknowledged this as true. It is noteworthy that among all the observed food grains, rice was one of the leading producers from 1950 to 2019.

Table 2 and Figure 1 show there was a shift in rice and wheat production in 1987 by the Buishand's test and the SNH test.

Table 2. Homogeneity test analysis on various food grains in India.

Food grains	PT		BRT		SNH Test	
	Sig.	Shift	Sig.	Shift	Sig.	Shift
Rice	< 0.001	1982*	<0.001	1987*	<0.001	1987*
Wheat	< 0.001	1984*	< 0.001	1987*	< 0.001	1987*
Coarse cereals	< 0.001	1987*	< 0.001	1987*	< 0.001	2002*
Pulses	< 0.001	1987*	< 0.001	1987*	< 0.001	2009*

*Significant at the 95% level.

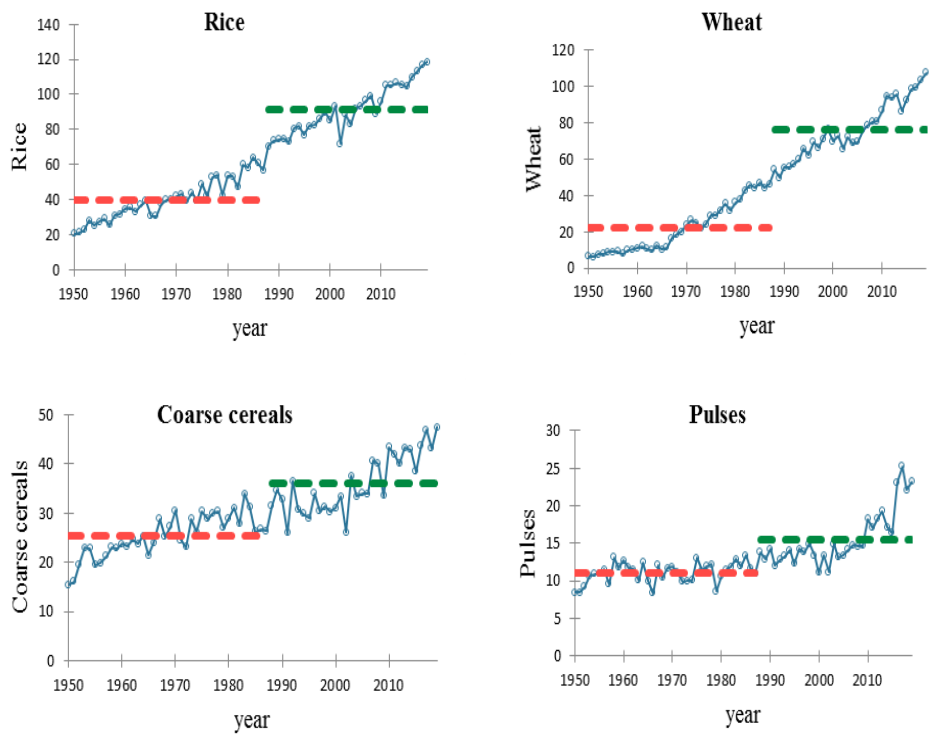

Figure 1. Identified shifts in food grain production in India.

The shifts were also detected for coarse cereals and pulses in the same year (1987) by the Pettit's test and the Buishand's test. Actually, the discrete change points were observed from 1982 to 2009, but the ideal change point, i.e., 1987, was captured in all food grains. In India's history, agricultural production was vulnerable in 1987 due to drought (Radhakrishna, 2002; Wilson, 2005); thus, there is strong evidence for considering methods that are well proven facts.

After detecting the significant change point, the annual data from 1950 to 2019 was divided into two-time intervals according to their shifts. The two periods were time period I (1950 to 1987), and time period II (from 1988 to 2019). The study was continued to analyze the performance of food grain production with different time periods such as period I, period II and overall data by applying trend analysis. The significance of monotonic trends and their magnitude were analyzed by the methods of the MK test and the Sen's slope estimator for three periods.

The data in Table 3 show that a trend analysis of the major types of food grain production and their segmentation year by year was performed. The trend patterns of various food grains such as rice, wheat, coarse cereals, and pulses were detected by the MK test. The results reveal that there was a statistically significant upward trend in the annual production of all food grains. This indicates that the production of food grains was increasing over time. The study was extended to estimate the average rate of change or slope of the trend by using the Sen's slope estimator method.

Table 3. Trend analysis results of various food grain productions.

Food grains	Period	MK test statistic (S)	Sig.	Sen's slope
Rice	1950–1987	0.841	< 0.0001*	1.046
	1988–2019	0.827	< 0.0001*	1.427
	1950–2019	0.918	< 0.0001*	1.387
Wheat	1950–1987	0.915	< 0.0001*	1.169
	1988–2019	0.858	< 0.0001*	1.635
	1950–2019	0.946	< 0.0001*	1.508
Coarse cereals	1950–1987	0.656	< 0.0001*	0.317
	1988–2019	0.587	< 0.0001*	0.512
	1950–2019	0.754	< 0.0001*	0.33
Pulses	1950–1987	0.246	0.031*	0.045
	1988–2019	0.591	< 0.0001*	0.255
	1950–2019	0.642	< 0.0001*	0.107

*Significant at the 95% level.

From the above trend analysis, it can be seen that time period I represents the highest average growth rate of 1.169/year and the lowest average growth rate of 0.045/year for the food grains of wheat and pulses. Within time period II, the highest trend (1.635/year) was observed in wheat and the lowest trend (0.255/year) in pulses. Similarly, when considering the overall time period, it is clear that the maximum change rate was 1.508/year in wheat and the minimum change rate was 0.107/year in pulses. Moreover, in all three observed periods, the rate of change was increasing for all food grains.

In the view of overall trend analysis, the highest magnitude of trend (i.e., 1.635 million tons/year) was observed in wheat, and the lowest magnitude of trend (i.e., 0.045 million tons/year) was identified in coarse cereals. Here, it is noticeable that the trends were greater in time period II than in time period I and for the whole time period. In fact, the utility of food grains was booming based on their health benefits, medical purposes, and ability to sustain human life. For these reasons, the production of food grains failed to meet the needs for food grain utilization in India.

Finally, the surge in food grain production began after 1987, and food grain production has improved in the current scenario when compared to previous years, according to Indian agricultural history and trend analysis.

Conclusion

The present study examined trends and patterns in different major food grains in India. One important point that was noticed from the results is that food grain production, which includes rice, wheat, coarse cereals, and pulses, has increased since 1987, but it is not sufficient to meet human hunger. The gap between the availability of food grains and the requirements of a rising population, as well as the growth rate of food grains, was measured by the Sen's slope estimator. These results reveal that wheat and rice had the highest growth rate among coarse cereals and pulses. This suggests that rice and wheat comprise the predominant share of food grains produced in India.

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EMPIRIJSKA STUDIJA O OCENI TRENDA: PROIZVODNJA HLEBNIH ŽITA U INDIJI

Kalpana Polisetty[1], Christophe Chesneau[2*], Gowthami Paltati[1] i Kiran Kumar Paidipati[3]

[1]School of Applied Sciences & Humanities, Vignan's Foundation for Science, Technology and Research, India
[2]Department of Mathematics, LMNO, Université de Caen-Normandie, Campus II, Science 3, 14032 Caen, France
[3]Area of Decision Sciences, Indian Institute of Management Sirmaur, Paonta Sahib, HP-173025, India

R e z i m e

Razmatranje važnosti određenih hlebnih žita-pirinča, pšenice, ostalih žitarica i leguminoza-od ključnog je značaja za razvoj indijske privrede. Ovaj rad otkriva trenutak promene i analizu trendova za godišnje istorijske serije hlebnih žita u Indiji. Trenuci promena su identifikovani metodama Petitovog testa (PT), Buišanovog testa opsega (BRT) i standardnog normalnog testa homogenosti (SNHT). S druge strane, Men-Kendalov (MK) test je korišćen za utvrđivanje prisustva i odsustva trendova u proizvodnji hlebnih žita, a njihovi nagibi su ocenjeni Senovom ocenom nagiba. Rezultat analize pokazuje značajne tačke promene za hlebna žita na nivou od 95%. Od 1982. do 2009. godine zabeleženi su pojedinačni trenuci promene, ali jedinstven trenutak promene zabeležen kod svih hlebnih žita je 1987. godina. U istoriji Indije, poljoprivredna proizvodnja u 1987. godini bila je ugrožena zbog suše, što je snažan dokaz potrebe da se razmotre metode zasnovane na dokazanim činjenicama. Rezultati Men-Kendalovog testa otkrivaju da je trend proizvodnje hlebnih žita bio statistički značajan i da je imao uzlazni smer u sva tri perioda segmentacije nakon 1987. godine.

Ključne reči: hlebna žita, trenutak promene, trend analiza, statistička analiza, statistička značajnost.

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*Autor za kontakt: e-mail: christophe.chesneau@gmail.com