IDENTIFICATION OF MUTATION POINT AND TREND ANALYSIS OF AREA, PRODUCTION AND YIELD OF WHEAT CROP IN GUJARAT

ABSTRACT

The objectives of present study were to identify the mutation point and trend analysis of wheat crop in Gujrat state. The time series data on area, production and yield of wheat crop from 1973-74 to 2022-23 of Gujarat state was used which were obtained from the CMIE (Centre for Monitoring Indian Economy). For identification of mutation point, we have applied various prominent non-parametric methods as Pettitt's test, Standard normal homogeneity test and Buishand's range test. Sen's slope estimator was used to calculate the wheat crop's magnitude trend, and the Mann-Kendall test was used to assess the significance of the results. The result revealed of identification of mutation point of Buishand range test and the SNH test both identified 2004 as an important mutation point for the wheat area. The Pettitt's test and the Buishand range test both identified 2002 as an important mutation point for the wheat production. The year 2002 was identified as significant mutation point for yield all three tests such as Pettitt's test, Buishand range test and SNH test. From the Sen's slope analysis, it is observed that statistically non-significant ($p < 0.012$) highest growth of production was observed as 61.33 thousand tonnes/year during 2002-2023 and the lowest growth of area was observed as -3.52 thousand ha/year during 1973-2003. The analysis provided a clear idea about the trends of wheat cultivation over Gujarat state. It is recommended to focus on enhancing agricultural practices and resource management to counter the declining trend in wheat cultivation area, while leveraging the positive growth in production and yield to ensure sustainable agricultural development.

Keywords: Mutation point, Trend analysis, Wheat, M-K test, Sen's slope.

1. INTRODUCTION

Wheat is the most consumed crop globally, next to rice and maize. It is the main grain used in Old World agriculture. Wheat belongs to Graminace family. Wheat can be consumed in a variety of ways, such as in bread, chapatti, porridge, flour, and suji The nutritional profile of wheat is fairly good: it contains 12.1% protein, 1.8% fats, 1.8% ash, 2.0% reducing sugars, 6.7% pentosans, 59.2% starch, 70% total carbohydrates, and 314 kcal per 100g of meal [1]. It is commonly grown in North American continent, Latin American including Europe, West Asia, North Africa, South Africa, East Africa, South Asia and Australia. In 2022, the total global production of wheat was 771 million tons. Representing over 41% of global wheat production, China, India, and Russia are the three leading producers of wheat on a per capita basis [2]. Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan, Bihar and Gujarat are the major wheat-growing states in India. Among all the wheat growing states, Gujarat occupies 7th position in respect to area and production. In Gujarat, area under wheat is 1.06 million ha with a production of 3.46 million tonnes (2022-23) and it is mostly grown in Bhal region consisting of some parts of Kheda, Ahmedabad, Bhavnagar and Surendranagar districts [3].

Understanding the fluctuations in wheat production is very essential for developing countries like India. It is required to enhance the level of wheat production in the face of the rapid growth of population and declining production of wheat. There is a need to determine monotonic trends of production and it helps to know the current situation of wheat production. To meet this requirement, we need to know the status of wheat crop at the state level. Therefore, it is necessary to identify the mutation point and trend analysis of wheat crop in Gujarat state in order to inject policy innervations for sustainable growth of wheat production in the State. In view of the above facts, an attempt has been made to investigate the mutation point and trend analysis

of wheat crop in Gujarat during the last five decades where a drastic change appears.

2. METHODOLOGY

Gujarat, a state on the western coast of India, is strategically located between latitudes 20°1'N and 24°7'N and longitudes 68°4'E and 74°4'E. It is bordered by the Arabian Sea to the west, providing an extensive coastline of over 1,600 kilometers, which is crucial for its maritime trade. To the northeast, Gujarat shares its boundary with Rajasthan, to the east with Madhya Pradesh, and to the southeast with Maharashtra. It has an area of 196024 km^2, majorly dominated by agriculture land use. Agriculture has historically been the primary industry in the area due to the abundance of rich land. To The present study deals with identification of mutation point and trend analysis of wheat crop in Gujarat state. To full fill the objectives of the study, a secondary data on area, production and yield of wheat crop of Gujarat state covering the period 1973-74 to 2022-23 have been obtained from CMIE (Centre for Monitoring Indian Economy). The time series data was analyzed by using XLSTAT trial version.

2.1 Identification of mutation point

The purpose of the mutation point analysis (also called the change point analysis) is to determine where significant changes in the wheat crop take place. To determine the change points in the time series data, multiple researchers employed a variety of methodologies. The distribution-free Pettitt's test was created by Pettitt (1979) and is useful for determining whether sudden changes in time series data occur. Different distribution-free statistical techniques have been used by numerous researchers to identify the change points in time series data [4]. Below are specific approaches for detecting change points in data[5,6]. For identification of mutation point, we have been applied three non-parametric tests namely Pettitt's Test [7], Buishand's Range Test [8] and Standard Normal Homogeneity (SNH) Test [9]. For confirmation of mutation point, the results of at least two tests out of three tests should be same. That point will be considered as the true mutation point. For trend analysis, we use of statistics such Mann-Kendall's test and sen's slope.

2.2 Trend Analysis

The amount of the trend in the time series data was estimated by Sen's estimator [9] and significance of the trend in the time series was tested by Mann-Kendall (M-K) test [10]. Sen's slope method is a non-parametric approach frequently used for time series data analysis because it gives a robust estimation of trend[11]. Sen's method calculates the slope as a change in measurement in consonance to the change in time. The Mann-Kendall test compares the presence of an increasing or decreasing trend (H1) to the null hypothesis (H0) that there is no trend.

3. RESULTS AND DISCUSSION

Data of Gujarat wheat crop obtained from the CMIE website covering the last 50 years, from 1973-1974 to 2022-23. The table 1 presents statistical data for three agricultural variables: Area, production and yield. The area, measured in thousands of hectares, ranges from a minimum of 192.40 to a maximum of 1442.00 with an average of 758.23 and a standard deviation of 288.57. This indicates that while there is some variability in the size of the agricultural areas, it is relatively moderate. Production, also in thousands of tonnes, has a much wider range, from 351.20 to 4694.00 with a mean of 1919.26 and a high standard deviation of 1071.36 suggesting significant fluctuations in production levels. Yield, measured in kg. per hectare, varies from 1474.90 to 4694.00 with an average of 2391.50 and a standard deviation of 499.48, indicating moderate variability. Overall, the data show substantial variability in production and yield, possibly due to differing agricultural conditions and practices. (Table 1).

Table 1. Summary statistics of wheat crop during 1973-74 to 2022-23 for Gujarat

Variable	Minimum	Maximum	Mean	Std. deviation

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Area	192.40	1442.00	758.23	288.57
Production	351.20	4694.00	1919.26	1071.36
Yield	1474.900	3268.00	2391.50	499.48

In the current study, the non-parametric tests Pettitt's, SNH and Buishand's range tests have been applied to identify the mutation point for year wise wheat area, production and yield from 1973-74 to 2022-23. From the Table 2. the results exhibits the significant ($p < 0.0001$) mutation points i.e., 2004 year is captured for area by two test such as Buishand range test and SNH tests while year 2002 was identified significant ($p<0.001$) mutation point by pettitt's test. Thus, year 2004 was considered as true mutation point for area. A the significant mutation points 2002 year was captured for production by two tests as Pettitt's test ($p < 0.0001$) and Buishand range test ($p < 0.0001$) while year 2004 was identified significant ($p < 0.0001$) mutation point by SNH test. Therefore, year 2002 was considered as significant ($p < 0.0001$) mutation point for production. In the case of yield of wheat crop, the significant ($p < 0.0001$) mutation points was captured as 2002 year by the all three tests such as Pettitt's test, Buishand range test and SNH test. Therefore, year 2002 was considered as significant ($p < 0.0001$) mutation point for yield. These results collectively highlight notable shifts in area, production and yield around the early 2000s, with changes in area and production showing some variation in the exact year of change among the different tests.

Table 2. Analysis of mutation point of wheat crop during 1973-74 to 2022-23 for Gujarat

Variable	Pettitt's test		Buishand range test		SNH test	
	Change point	p-value	Change point	p-value	Change point	p-value
Area	2002***	<0.0001	2004***	<0.0001	2004***	<0.0001
Production	2002***	<0.0001	2002***	<0.0001	2004***	<0.0001
Yield	2002***	<0.0001	2002***	<0.0001	2002***	<0.0001

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

After, identification of mutation point, the whole time series (1973-2023) were divided into three parts i.e., first-time series (before mutation point), second-time series (after mutation point) and whole time series (1973-2023). For segmentation period of wheat area, mutation point was identified as 2004. Thus, a time series 1973-2003 was observed as first-time series and series 2004-2023 detected as second-time series. Similarly, mutation point for both production and yield of wheat was observed as 2002. Hence, the time series 1973-2001 and 2002- 2023 were identified as first-time series and second- time series, respectively (Table 3). Using Sen's slope estimators, the degree of monotonic trends has been calculated. Further, the trend analysis was extended based on segmentation time period. In this case, the wheat crop's substantial monotonic trends have been analyzed indicator- and segmentation-wise

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using the M-K test. (Table 3).

Table 3. Mann-Kendall test and Sen's slope estimators of wheat crop during 1973-74 to 2022-23 for Gujarat

Variable	Segmentation year	MK-test	Kendall's tau	p-value	Sen's slope
Area	1973-2003	-63	-0.135	0.292	-3.52
	2004-2023	-6	-0.035	0.861	-1.00
	1973-2023	516	0.421***	<0.0001	11.08
Production	1973-2001	58	0.143	0.285	11.33
	2002-2023	84	0.400**	0.012	61.33
	1973-2023	701	0.572***	<0.0001	52.05
Yield	1973-2001	252	0.621***	<0.0001	24.03
	2002-2023	121	0.578***	0.000	40.51
	1973-2023	930	0.759***	<0.0001	30.57

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

From the Sen's slope estimator analysis, it is observed that statistically significant ($p < 0.0001$) highest growth of production was observed as 61.334 thousand tonnes/year during 2002-2023 i.e. second sub series time period and lowest non-significant ($p= 0.292$) growth was experienced as -3.52 (thousand ha/year) in the first sub-time series of area (Table 3). The whole-time series results shown the upward significant ($p <0.001$) trends were seen in the segment of production and yield while downward non-significant trend was observed in the area. Thus, production of wheat showed the highest increasing trend as compared to area and yield in second sub series and whole time period. A significant increasing trend was also experienced in the yield of first sub-time series (24.03 kg ha-1/year), second sub-time series (40.51 kg ha-1/year) and whole time series (30.57 kg ha-1/year) which was significant @ 1 per cent level of significance (Table 3).

Overall, the results show that while the area under consideration did not exhibit significant trends in the segmented periods (1973-2003 and 2004-2023), there was a significant overall increase from 1973 to 2023. Both production and yield showed significant positive trends, particularly after 2002 suggesting improvements in productivity and efficiency.

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4. CONCLUSION

The study highlights variability and long-term trends in wheat cultivation in Gujarat. Using nonparametric methods, significant changes between 2002 and 2004 were identified, influenced by climatic conditions, industrialization, and human activities. Trend analysis showed an upward trend in wheat production and yield, but a declining trend in the cultivated area. Notably, wheat production grew by 61.33 thousand tonnes/year in the second sub-time series, while the area declined by 3.52 thousand hectares/year in the first sub-time series. The study recommends improving agricultural practices and resource management to address the declining cultivation area and sustain positive growth in production and yield.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

Details of the AI usage are given below:

1. ChatGPT has been used while editing conclusion, abstract and R& D. once the text has been written by author then to improve its language and editing purpose ChatGPT has been used.

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