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Identification of Mutation Point and Trend Analysis of Wheat Crop in Western Uttar Pradesh

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ABSTRACT

The objectives of present study were to identify the mutation point and trend analysis of wheat crop in western Uttar Pradesh. The time series data on area, production and yield of wheat crop from 1997-98 to 2019-20 of Meerut district was used which were obtained from the Area Production Statistics Information System, Ministry of Agriculture and Farmers Welfare, New Delhi. For identification of mutation point, we have applied various prominent non-parametric methods as Pettitt's test, Standardnormal homogeneity test and Buishand's range test. Sen's slope estimator was applied to measure the magnitude of the trend of wheat crop and their significances were examined through Mann Kendall test. The year 2010 was identified as significant mutation point for production and yield by two tests as Pettitt's test ($p < 0.05$) and SNH test (0.10) and for wheat area, mutation point was identified as year 2011. From the Sen's slope analysis, it is observed that statistically significant ($p < 0.05$) highest growth of production was observed as 2107.16 tonnes/year during 1997-2019. A significant increasing trend was also experienced in the yield of whole time series (43.70 kg ha^{-1}/year) and second sub-time series (53.00 kg ha^{-1}/year) which were significant @ 1% and 5% level of significance, respectively. The statistical analysis showed that in spite of decreasing in the area under wheat crop, the production and yield was positively increased during the study period.

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

INTRODUCTION

Wheat (*Triticum aestivum*) the world's largest cereal crop belongs to Graminae (Poaceae) family of the genus Triticum. It is also most important cereal crop in India occupying second place next to rice in production and it plays a critical role in food security. Wheat has been described as the "King of cereals" because of the acreage it occupies, high productivity and the prominent position in the international food grain trade. Wheat is consumed in a variety of ways

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such as bread, chapatti, porridge, flour, suji. Wheat has good nutrition profile with 12.1% protein, 1.8% lipids, 1.8% ash, 2.0% reducing sugars, 6.7% pentosans, 59.2% starch, 70% total carbohydrates and provides 314 Kcal/100g of food. It is also rich source of minerals and vitamins (Singh, *et al.* 2020). Wheat is the second most important cereal crop after rice, contributing 39.08 % of the total cereal production in the country (Anonymous 2020). On an average, India produces around 102.19 million tonnes of wheat annually on the area of 29.14 million hectare with productivity 3507 kg per hectare (2018-19). Rice-Wheat is a major cropping system of the Uttar Pradesh. Uttar Pradesh is the first position with maximum contribution towards national production (32.04 %) of wheat from a largest area (32.74 %), but with productivity on a lower side of 3.40 tonnes/ha (Anonymous 2020). In Uttar Pradesh, area under wheat is 9.54 million ha with a production of 32.74 million tonnes (2018-19). In Uttar Pradesh, all the resources related to the production of wheat are available of high quality, so that Uttar Pradesh can fulfill the wheat requirement of the citizens of the entire country. To meet this requirement, we need to know the status of wheat crop at the regional level i.e. district level. Therefore, it is necessary to identify the mutation point and trend analysis of wheat crop in Meerut district of Uttar Pradesh 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 Meerut district of Uttar Pradesh during the last two decades where a drastic change appears.

MATERIALS AND METHODS

Meerut district is located in the Western part of Uttar Pradesh situated between 28.740 N and 29.270 N latitudes and 77.440 and 78.140 E longitudes and known for its historical importance as it has many sites that can be traced back to the Epic Mahabharata period. It has an area more than 2500 km^2 (Anonymous 2011), majorly dominated by agriculture land use. It is bounded by Muzaffarnagar district is in the north, Ghaziabad, Bulandsahar and Gautam Budh Nagar districts in the south, Bijnore and Jyotibaphule Nagar in the east and Baghpat in the west (Anonymous 2013). It has 3 tehsils and 12 blocks. Naturally, Meerut is a water rich region as India's two major annual rivers Ganga and Yamuna forms the eastern and western borders of the district distinguishing it from the surrounding area. The land is very fertile and therefore agriculture has been the main occupation for people in the area. The present study deals with identification of mutation point and trend analysis of wheat crop in Meerut district of Western Uttar Pradesh. To full fill the objectives of the study, a secondary data on area, production and yield of wheat crop of Meerut district covering the period 1997-98 to 2019-20 have been obtained from Area Production Statistics Information System, Ministry of Agriculture and Farmers Welfare, New Delhi (https://www.aps.dac.gov.in/APY/ Public_ Report 1.aspx). The time series data were analyzed by using Microsoft Office Excel 2007 and XLSTAT 2021. Descriptive statistics used graphical and numerical summaries to describe the main features of a collected in quantitative terms.

Identification of mutation point

The analysis of mutation point, generally called change point tries to find out where significant changes occur in the wheat crop. Many different techniques were applied to find out the change points in the time series data by the several researchers (Buishand 1982, Bryson *et al*. 2012, Sharma *et al.* 2016, Polisetty and Paidipati 2020). The Pettitt's test, a distribution-free test, developed by Pettitt (1979) which is valuable for evaluating the occurrence of abrupt changes in time series data (Mu *et al.* 2007). Several research workers have been applied different distribution-free statistical methods to find the change points in the time series data (Jaiswal *et al.* 2015, Sharma *et al.* 2016 and Kalpana and Kiran 2019 ; Polisetty and Paidipati 2020). The details methods of change point detection are given below. For identification of mutation point, we have been applied three non-parametric tests namely Pettitt's Test (Pettitt, 1979), Buishand's Range Test (Buishand 1982) and Standard Normal Homogeneity (SNH) Test (Alexandersson 1986). For confirmation of mutation point, the results of at least two tests out of three tests should be same. That point will

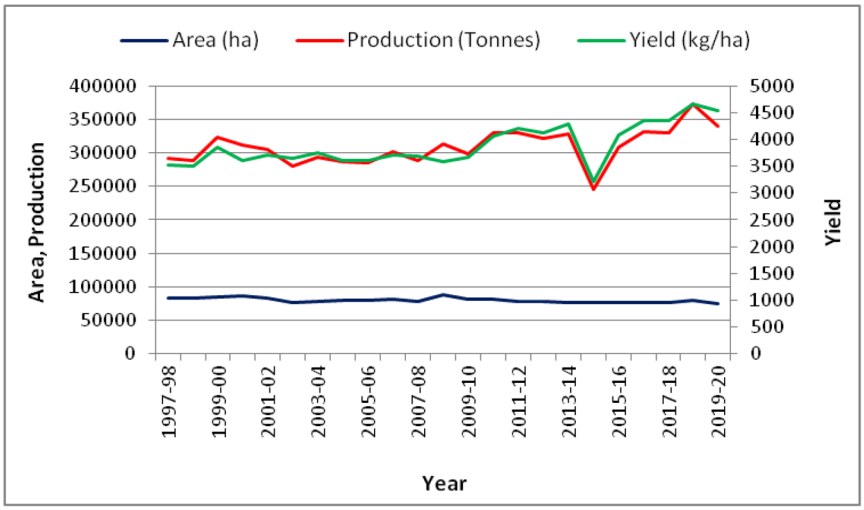

Fig. 1. Trend in area, production and yield of wheat crop during 1997-98 to 2019-20.

be considered as the true mutation point. For trend analysis, we use of statistics such Mann-Kendall's test and sen's slope.

Trend Analysis

The amount of the trend in the time series data was estimated by Sen's estimator (Sen 1968) and significance of the trend in the time series was tested by Mann-Kendall (M-K) test (Mann 1945 ; Kendall 1975). Sen's slope method is a non-parametric approach frequently used for environmental data analysis because it gives a robust estimation of trend (Yue *et al.* 2002). Sen's method calculates the slope as a change in measurement in consonance to the change in time. Mann-Kendall test checks the null hypothesis (H_0) of no trend versus alternative hypothesis (H_1) of the presence of increasing or decreasing trend. The Mann-Kendall test plays a crucial role to identify the significant nature of linear trends in the time series data (Polisetty and Paidipati 2020). The details of M-K test are given by Salas (1993) and Hirsch *et al.* (1993).

RESULTS AND DISCUSSION

Several statistical tools have been used to present the summary statistics for wheat crop in Meerut district during 1997-98 to 2019-20. The highest yield of wheat was recorded in the years of 2018-19 with the value of 4664 kg/ha (Table 1) while the lowest wheat yield recorded in 2014 with the value of 3223 kg/ha (Fig. 1). The maximum wheat production in Meerut district was 8373423.00 tonnes with a standard deviation of 26409.83 tonnes and coefficient of variation of 8.54 % (Table 1). The maximum area under wheat was 87795.00 ha with a standard deviation of 3535.64 ha and coefficient of variation of 4.44% along with average productivity of 3893.00 kg/ha during the study period 1997-98

Table 1. Summary statistics of wheat crop during 1997-98 to 2019-20.

Variable	Minimum	Maximum	Mean	SD	CV
Area (ha)	74650.00	87795.00	79620.13	3535.64	4.44
Production (tonnes)	245180.00	373423.00	309426.96	26409.83	8.54
Yield (kg/ha)	3223.00	4664.00	3893.00	377.38	9.69

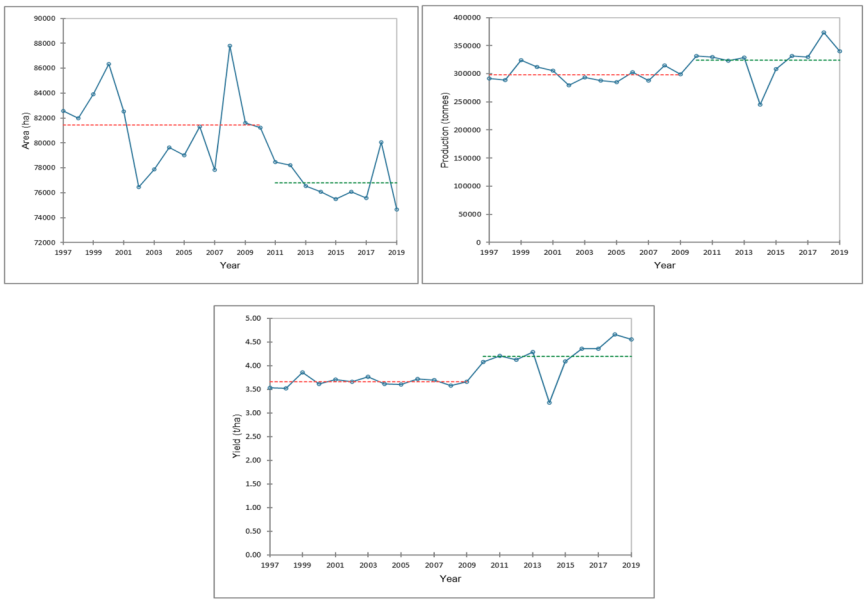

Fig. 2. Identified mutation points in area, production and yield wheat crop.

to 2019-20. The overall average area, production and yield of wheat were 79620.13 ha, 309426.96 tonnes and 3893.00 kg/haduring 1997-98 to 2019-20. 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 productivity from 1997-98 to 2019-20. From the Table 2 and Fig. 2, the results exhibits the significant ($p < 0.0001$) mutation points i.e., 2011 year is captured for area by all three tests such as Pettitt's, Buishand's range and SNH tests. A the significant mutation points 2010 year was captured for production by two tests as Pettitt's test ($p < 0.05$) and SNH test (0.10) while year 2016 was identified significant ($p < 0.05$) mutation point by Buishand's range test. Thus, year 2010 was considered as true mutation point. In the case of yield of wheat crop, the significant ($p < 0.01$) mutation points was captured as 2010 year by the two tests such as Pettitt's and SNH test while year 2016 was identified as significant (0.01) mutation point by Buishand's range test. Therefore, also here year 2010 was considered as significant ($p < 0.01$) mutation point. These mutation points play a very crucial role to analyse the monotonic trends in the area, production and yield of wheat in time series data.

After, identification of mutation point, the whole

Table 2. Analysis of mutation point of wheat crop during 1997-98 to 2019-20. *Significant @ 10 % level of significance , **Significant @ 5% level of significance and ***Significant @ 1 % level of significance.

Variable	Pettitt's Test p-value	Buishand's range test Change point	p-value	SNH test Change point	p-value	Change point
Area	0.006	2011***	0.017	2011**	0.005	2011***
Production	0.012	2010**	0.011	2016**	0.053	2010*
Yield	0.003	2010***	0.002	2016***	0.001	2010***

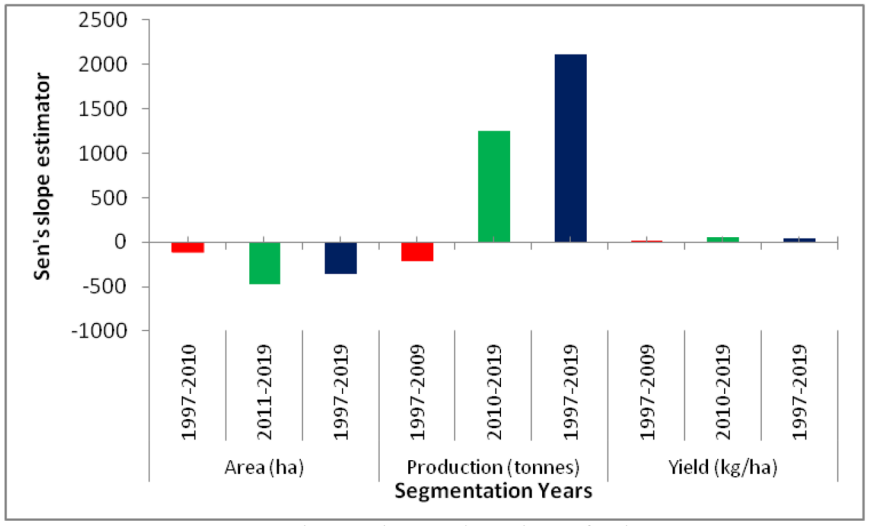

Fig. 3. Segmentation year wise Sen's slope estimators for wheat crop.

time series (1997-2020) were divided into three parts i.e., first-time series (before mutation point), second-time series (after mutation point) and whole-time series (1997-2020). For segmentation period of wheat area, mutation point was identified as 2011. Thus, a time series 1997-2010 was observed as first-time series and series 2010-2019 detected as second-time series. Similarly, mutation point for both production and yield of wheat was observed as 2010. Hence, the time series 1997-2009 and 2009-2019 were identified as first-time series and second-time series, respectively (Table 3). Sen's slope estimators have been used to compute the degree of monotonic trends. Further, the trend analysis was extended based on segmentation time period. Here, the M-K test has been applied to analysis the significant monotonic trends for indicator wise and segmentation period wise for wheat crop. A declined trend was observed for wheat area while raising trends was seen for production and yield of wheat in the segmentation year wise (Table 3 and Fig. 3).

From the Sen's slope estimator analysis, it is observed that statistically significant ($p < 0.05$) highest growth of production was observed as 2107.16 tonnes/year during 1997-2019 i.e. whole-time period and lowest non-significant growth was experienced as -465.40 ha/year in the second sub-time

Table 3. Mann-Kendall test and Sen's slope estimators of wheat crop during 1997-98 to 2019-20. **Significant @ 5 % level of significance and *** Significant @ 1 % level of significance.

Variable	Segmentation year	MK-Stat	Kendall's tau	p-value	Sen's slope
Area (ha)	1997-2010	-15.00	-0.165	0.4434	-105.92
	2011-2019	-16.00	-0.444	0.1179	-465.40
	1997-2019	-133.00	-0.526***	0.0005	-348.33
Production (tonnes)	1997-2009	-4.00	-0.051	0.8548	-207.33
	2010-2019	11.00	0.244	0.3711	1248.50
	1997-2019	103.00	0.407**	0.0071	2107.16
Yield (kg/ha)	1997-2009	6.00	0.209	0.7604	3.77
	2010-2019	27.00	0.600**	0.0200	53.00
	1997-2019	137.00	0.542***	0.0003	43.70

series of area (Table 3 and Fig. 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 productivity in first and second series and also in whole time period. A significant increasing trend was also experienced in the yield of whole time series (43.70 kg ha^{-1}/year) and second sub-time series (53.00 kg ha^{-1}/year) which was significant @ 1 % and 5% level of significance, respectively (Table 3). From the above analysis and discussion, it is clear that the Sen's slope estimator has given accurate results to the researchers for the trend analysis. The statistical analysis showed that in spite of decreasing in area under wheat crop, the production and yield was positively increased during the study period. However, at present, the population is increasing continuously along with the production and productivity of wheat can fulfill the wheat requirement of the citizens of the entire country.

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