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Trends and Decomposition of Wheat Production in Western Maharashtra

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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

The study was aimed to investigate the production performance of wheat in western Maharashtra. The data of 20 years regarding area, production and productivity of wheat was made available through the secondary source for all the districts of the western Maharashtra region. The study period of 1996-97 to 2015-16 was split into two sub periods i.e. period-I (1996-97 to 2005-2006), period-II (2006-07 to 2015-16) and overall period. The growth rates were calculated using the exponential function. The instability in area, production, and productivity was measured with a coefficient of variation (CV) and Cuddy Della Valle's Instability index. The relative contribution of area and yield to change in output was estimated by Minhas decomposition model. The district-wise analysis was carried out which resulted that, during the period-I and period-II, almost all districts in the western Maharashtra region registered negative growth including the region as a whole. The area and productivity showed stability in wheat crop in almost all the districts of western

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Maharashtra region. In the western Maharashtra region, among all the parametric models fitted to the area, production and productivity of wheat crop, the maximum R^2 was observed in the case of cubic model in all the districts of Western Maharashtra region with the region as a whole. The region as a whole recorded 59 per cent which marked as the highest R^2 in productivity as compared to area and production. The decomposition analysis for western Maharashtra region depicted the largest area effect on wheat production. It was also observed that for both periods the area effect was more pronounced than the yield effect and interaction effect. Hence, there is need for policy maker to formulate development-oriented policies and the researchers to design an investigative research activity for promoting a sustainable wheat production system in the region for expansion of area under wheat cultivation.

Keywords: Wheat; growth rate; instability; trend; decomposition.

1. INTRODUCTION

Wheat (*Triticum aestivum*) is a self-pollinated hexaploid (2n=6x=42) cereal which belongs to family Graminea. The three species of wheat namely, *Triticum aestivum* (bread wheat), *Triticum durum* (macaroni wheat) and *Triticum dicoccum* (Emmer or Khapli wheat) are grown on commercial basis in the Indian subcontinent from pre-historic times with share of production in percent 95 per cent, 4 per cent and 1 per cent respectively [1-3]. Wheat is a staple food of millions of people. Approximately one-sixth of the total arable land in the world is used for wheat cultivation. Wheat has a distinct place among the food grain crops. As per projected by FAO cereal supply, global wheat production touched 761.5 million tonnes in 2018-19. India is the second largest producer of wheat after China. According to India-stat, India accounts for about 8.7 per cent of the total wheat production in the world with 101.20 million tonne. China, India and Russia are first, second and third, respectively in wheat production [4-6]. In addition to these, other countries are Canada, Argentina, Australia, France and Italy where wheat is cultivated at a larger scale. Wheat is grown in India in an area of about 29.8 million ha. The normal national productivity is about 3.39 tones/ha. The major Wheat producing States are Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan, Bihar and Maharashtra [7-9]. These States contribute about 94.09 per cent of total Wheat production in the country.

According to Department of Agriculture, Government of Maharashtra (2018-19), wheat is grown in Maharashtra in an area of about 834.4 thousand hectare having production of 1249.2 thousand tonnes and productivity of 1497.1 kg/ha. Maharashtra contributes about 1.51 per cent of the total wheat production of the country (area 3.06 per cent). Ahmednagar, Nashik, Pune and Satara districts of the black cotton soils are the main producers in Western Maharashtra region [10,11]. Hence, the paper has worked out the subsequent objectives: To estimate district wise growth rates of area, production and productivity of wheat in western Maharashtra, To workout district wise instability of wheat, To assess trends in area, production and productivity and lastly to estimate relative contribution of area and yield to change in the output of wheat in western Maharashtra.

2. METHODOLOGY

The study has been undertaken to examine the growth pattern in area, production and yield of wheat crop. Also, the relative contribution of area and yield on production has to be estimated. The study even further attempts to assess the direction of trend. So as to obtain the required results of the study following methodology was used.

2.1 Selection of Study Area

Wheat crop is grown in the entire Western Maharashtra region of Maharashtra. Western Maharashtra region included Nashik, Pune and Kolhapur division. The study was confined to seven districts of Western Maharashtra region namely Satara, Solapur, Pune, Ahmednagar, Jalgaon, Dhule and Nashik, except Nandurbar (Because Nandurbar was announced as a separate district on 1st July 1998).

2.2 Selection of Period

The data were collected on area, production and productivity of Wheat grown in Western Maharashtra region pertaining to the period from 1996-97 to 2015-16 (20 years). For the analysis

of growth and instability, the entire study period was split into two sub-periods and overall as follows.

Period-I	: 1996-97 to 2005-06
Period-II	: 2006-07 to 2015-16
Overall	: 1996-97 to 2015-16

2.3 Source of Data

The time-series data as per required for study regarding the area, production and productivity of wheat crop were collected from Government publications; website of the Government of Maharashtra.

2.4 Analytical Tools

The present study was based on time series secondary data of Wheat growing districts in Western Maharashtra region. The analysis was done on the following aspects.

2.4.1 Growth rate

The compound growth rates of area, production and productivity of wheat were estimated for the last 20 years. The district-wise compound growth rates of area, production and productivity were estimated by using following exponential model.

$$Y = a.b^t \quad (1)$$

Where,

Y = Depended variable for which growth rate is to be estimated
a = Intercept
b= Regression Coefficient
t = Time Variable

This equation was estimated after transforming (1) as follows

$$\text{Log } y = \log a + t \text{ Log } b \quad . \quad (2)$$

Then the per cent compound growth rate (g) was computed using the relationship.

$$\text{CGR (r)} = [\text{Antilog (log b)} - 1] \times 100 \quad (3)$$

The significance of the regression coefficient was tested using the student's t- test.

2.4.2 Instability

To measure the instability in area, production and productivity, an index of instability was used as a measure of variability through Coefficient of Variation (CV) and Cuddy Della Valle's instability indices.

2.4.2.1 Coefficient of variation (CV)

$$\text{Coefficient of variation (CV)} = \frac{\sigma}{x} \times 100$$

Where,

σ = Standard deviation
$\overline{X}$ = Arithmetic mean

The simple Coefficient of Variation (C.V) often contains the trend component and thus over estimates the level of instability in time series data characterized by long term trends and Cuddy Della Valle's instability was estimated as follows.

2.4.2.2 Cuddy Della Valle's Instability Indices (CDVI)

It was used to measure instability of wheat which was close to an approximation of the average year to year per cent variation adjusted for trend. The algebraic form of it was;

$$\text{Instability Index} = CV\sqrt{(1 - R^2)}$$

Where,

CV = Simple Estimates of the coefficient of variation in per cent and

R^2 = Coefficient of determination from a time trend regression (linear) adjusted by the number of degree of freedom.

2.4.3 Trend analysis

The trend in area, production and productivity of wheat was computed for the series data of the last 20 years. To trace the path of process different parametric trend models as given in the Table 1 were used.

Among the competitive trend models, the best function was selected based on their goodness of fit (measured in terms of R^2) value and significance of the coefficients.

Table 1. List of different parametric models with their equations

Sr. no.	Name of model	Equation
I	Linear	$Y_t = a+bt$
II	Quadratic	$Y_t = a+b_1t+b_2t^2$
III	Cubic	$Y_t = a+b_1t+b_2t^2+b_3t^3$
IV	Exponential	$Y_t = a+Exp(bt)$
V	Logarithmic	$LogY_t = a+b\ Log(t)$

Where, a, b and t represent constant, coefficient and time respectively in the model

2.4.4 Decomposition of output growth

To measure the relative contribution of area and yield to the total output of the wheat crop, Minhas (1964), Decomposition analysis model was used which is given below.

Po = Ao x Yo and

$$Pn = An \times Yn \quad (1)$$

Ao, Po and Yo are area, production and productivity in base year and An, Pn and Yn are values of the respective variable in n^{th} year item respectively.

Where,

Ao and An = Area
Yo and Yn = yield in the base year and n^{th} year respectively.
$Pn - Po = \Delta P$
$An - Ao = \Delta A$
$Yn - Yo = \Delta Y \quad (2)$

For equation (1) and (2) we can write

$Po + \Delta P = (Ao + \Delta A)(Yo + \Delta Y)$

Hence,

$$P = \frac{Ao\ \Delta Y}{\Delta P} x\ 100 + \frac{Yo\ \Delta A}{\Delta P} x\ 100 + \frac{\Delta Y\ \Delta A}{\Delta P} x\ 100$$

Production = Yield effect + area effect + interaction effect.

Thus, the total change in production can be decomposed into yield effect area effect and the interaction effect due to change in yield and area.

3. RESULTS AND DISCUSSION

3.1 Growth Rate of Wheat in Western Maharashtra Region

The district-wise compound growth rates of area, production and productivity of Wheat in Western Maharashtra region for two periods and overall were also worked out and presented in Table 2.

Table 2 showed that, during the period I, almost all districts in Western Maharashtra region registered negative growth including the region as whole for area, production and productivity, except Dhule. The highest growth rate was recorded in Dhule district for area i.e. 7.10 and statistically significant at 5 per cent level. Whereas highest decline in growth rate of production was registered in Dhule district (-15.97 per cent) which was found to be significant at 5 per cent level. The compound growth rates for area were negative indicating decline in area of Western Maharashtra region during period I.

During period II, almost all districts in Western Maharashtra region registered negative growth including the region as whole for area, production and productivity, except area and production of Dhule district. The highest growth rate was recorded in Dhule district for area i.e. 5.72 per cent and positively significant at 5 per cent level. Whereas highest decline in growth rates of area and production were registered in Ahmednagar district i.e. -15.20 per cent and -17.66 per cent, respectively and found to be significant at 1 per cent level. The compound growth rates for area and production of wheat in Western Maharashtra region as whole were negative i.e. -5.13 per cent and -6.38 per cent, respectively but statistically significant at 5 per cent level, while the growth rate of productivity was -1.39 per cent but not significant statistically.

The growth rates were also worked out for overall period of 20 years. During this period, the compound growth rates of area and production were positive in almost all districts except area of Nashik (-0.07 per cent), Ahmednagar (-3.03 per cent) and Solapur district (-1.44 per cent) but not significant statistically. The growth rates of area, production and productivity were highest in Dhule i.e. 8.51 per cent, 11.68 and 3.07, respectively and found statistically significant at 1 per cent level. The compound growth rate of productivity in Western Maharashtra region as whole was 1.33 per cent and found statistically significant at 1 per cent level.

Table 2. District wise compound growth rate of wheat in Western Maharashtra Region (per cent)

Sr. no.	Name of District	Particular	Period-I	Period-II	Overall
1	**Nashik**	Area	-5.55	-4.09	-0.07
		Production	-15.97*	-5.72	1.59
		Yield	0.90	-1.69	1.49**
2	**Dhule**	Area	7.10**	5.72*	8.51**
		Production	9.52	4.12	11.68**
		Yield	2.30	-2.15	3.07**
3	**Jalgaon**	Area	-1.77	-3.69	0.55
		Production	0.46	-7.01	2.00
		Yield	2.27	-3.45	1.44
4	**Ahmednagar**	Area	-3.24	-15.20**	-3.03
		Production	-2.78	-17.66**	-2.16
		Yield	0.47	-2.90	0.90
5	**Pune**	Area	-1.67	-1.07	0.30
		Production	-0.22	-1.19	2.34*
		Yield	1.48	-0.12	2.03**
6	**Solapur**	Area	-1.66	-9.07*	-1.44
		Production	-3.87	-14.07*	-1.71
		Yield	-2.24	-5.20	0.15
7	**Satara**	Area	0.43	-3.46**	0.52
		Production	0.40	-4.99**	0.83
		Yield	-0.03	-1.49	0.32
Western Maharashtra Region		Area	-1.73	-5.13*	0.21

*Note: **Significant at 1% level, * Significant at 5% level*

3.2 Instability in Area, Production and Productivity of Wheat

One should not rely just on growth rate for instability analysis, because the growth rate will explain only the rate of growth over the period, whereas, instability judges, whether the growth performance was stable or unstable for the period for the pertinent variable. In order to know the instability in area, production, and productivity of the crop, the fluctuation measured with the help of coefficient of variation and mean. To facilitate a better understanding of the magnitude and pattern of changes in the level of production, cropped area and productivity of crop in the different wheat-growing region, instability of production, area and productivity of wheat crop have been worked out as per the period discussed in methodology.

It is observed from the Table 3 that, during period I, relatively speaking, the coefficient of variation and Cuddy Della Valle's instability with regard to both area (13.12 and 12.96 per cent) and production (21.47 and 21.30 per cent) were lowest in Satara district among the wheat growing district of Western Maharashtra Region. As regards to productivity, Nashik district recorded the lowest instability indices estimated by CV and CDVI i.e. 11.17 and 10.73 per cent, respectively. Whereas region as whole recorded medium instability in area and production i.e. (19.04 and 18.43 per cent for CV and CDVI, respectively) and (24.24 and 23.89 per cent for CV and CDVI, respectively). While yield was observed to be low (10.44 and 9.96 per cent) for CV and CDVI, respectively.

During period II, the lowest coefficient of variation of area was observed in Pune district (11.41 per cent for CV) and Satara (6.74 per cent for CDVI) while, the highest variation was observed in Ahmednagar district (52.04 per cent for CV) and Jalgaon district (32.16 per cent for CDVI). The lowest coefficient of variation for production was observed in Satara district (19.33 and 11.98 per cent for CV and CDVI, respectively) and the highest coefficient of variation was observed in Ahmednagar district (57.56 per cent for CV) and Solapur district (38.8 per cent for CDVI). The lowest coefficient of variation in yield was observed in Satara district (9.87 and 8.68 per cent) for CV and CDVI, respectively. Whereas, the region as a whole recorded medium instability in area (22.15 and 15.44 per cent) for CV and CDVI, respectively and production (26.78 and 18.35 per cent for CV and CDVI, respectively). While yield was observed to be low (9.68 and 8.74 per cent) for CV and CDVI, respectively.

Table 3. District wise instability indices of wheat in Western Maharashtra Region

Sr. no	Name of District	Particular	Period-I			Period-II			Overall		
			A	P	Y	A	P	Y	A	P	Y
1	Nashik	CV	35.36	51.99	11.17	22.67	25.82	11.05	28.90	42.07	15.25
		CDVI	30.92	34.19	10.73	19.20	19.61	9.93	28.86	41.39	12.56
2	Dhule	CV	29.28	45.40	17.63	21.01	22.75	13.97	48.17	61.68	25.04
		CDVI	18.19	31.76	15.92	13.66	20.55	12.47	16.78	28.10	18.39
3	Jalgaon	CV	23.41	30.01	13.32	33.91	41.74	17.15	31.07	43.27	18.99
		CDVI	22.64	30.00	11.65	32.16	35.30	14.39	30.75	41.79	16.98
4	Ahmednagar	CV	27.93	33.51	18.08	52.04	57.56	17.84	40.81	49.12	19.35
		CDVI	26.73	33.18	18.02	24.13	27.28	15.87	38.82	48.75	18.60
5	Pune	CV	15.68	27.58	18.44	11.41	16.55	11.17	13.80	25.93	18.52
		CDVI	15.00	27.57	17.79	10.89	16.02	11.17	13.71	22.77	14.60
6	Solapur	CV	21.84	35.29	24.97	40.28	55.07	29.73	32.04	47.23	28.13
		CDVI	21.34	34.53	24.49	29.35	38.08	26.73	31.51	46.94	28.06
7	Satara	CV	13.12	21.47	11.44	12.28	19.33	9.87	13.73	21.84	10.89
		CDVI	12.96	21.30	11.44	6.74	11.98	8.68	13.39	21.35	10.75
Western Maharashtra Region		CV	19.04	24.24	10.44	22.15	26.78	9.68	21.78	31.60	13.46
		CDVI	18.43	23.89	9.96	15.44	18.35	8.74	21.73	30.12	11.10

Note: CV =Coefficient of variation (per cent per annum), CDVI = Cuddy Della Valle's Instability (per cent per annum) (A=Area, P=Production and Y=Yield)

Table 4. Trend in area production and productivity of Western Maharashtra Region

Sr. no.	District	Particulars	Function	Constant	Coefficients			R^2
				a	b_1	b_2	b_3	(%)
1	**Nashik**	Area	Cubic	960.99	-145.29	15.33	-0.46	0.17
		Production	Cubic	1578.51	-358.87*	40.82*	-1.25*	0.29
		Yield	Cubic	1620.39	-182.09**	26.60**	-0.91**	0.74
2	**Dhule**	Area	Cubic	221.45	-32.58	6.17*	-0.17	0.91
		Production	Cubic	501.98	-182.09*	28.77**	-0.91**	0.90
		Yield	Cubic	1808.56	-321.17**	48.34**	-1.65**	0.86
3	**Jalgaon**	Area	Cubic	439.91	-43.76	5.60	-0.18	0.08
		Production	Cubic	845.45	-159.52*	24.42*	-0.87**	0.30
		Yield	Cubic	1906.63	-196.23**	33.75**	-1.24**	0.65
4	**Ahmednagar**	Area	Cubic	1097.87	-104.98	17.62	-0.73	0.37
		Production	Cubic	1694.20	-272.22	46.06	-1.82	0.40
		Yield	Cubic	1638.00	1638.00	24.04	-0.84*	0.33
5	**Pune**	Area	Cubic	592.62	5.22	-0.73	0.03	0.02
		Production	Cubic	871.11	-21.67	5.34	-0.18	0.24
		Yield	Cubic	1497.53	-67.01	12.33	-0.41	0.42
6	**Solapur**	Area	Cubic	576.75	-32.84	6.12	-0.26	0.21
		Production	Cubic	765.46	-109.65	17.44	-0.67	0.27
		Yield	Cubic	1476.15	-215.01	28.56	-0.98*	0.25
7	**Satara**	Area	Cubic	356.28	-17.50	3.31	-0.13	0.40
		Production	Cubic	648.83	-60.53	10.23	-0.38*	0.38
		Yield	Cubic	1836.24	-94.82	13.25	-0.46	0.19
Western Maharashtra Region		Area	Cubic	4591.89	-388.83	56.56	-2.02	0.18
		Production	Cubic	7473.18	-1204.58	181.07	-6.37*	0.38

*Note: **Significant at 1% level, * Significant at 5% level*

For the overall period, the lowest coefficient of variation for area was in Satara district (13.73 and 13.39 per cent) for CV and CDVI, respectively while, the highest variation was in Dhule district (48.17 per cent for CV) and Ahmednagar district (38.82 per cent for CDVI). The lowest coefficient of variation for production was observed in Satara district (21.84 and 21.35 per cent for CV and CDVI, respectively) while, the highest coefficient of variation was observed in Dhule district (61.68 per cent for CV) and Ahmednagar district (48.75 per cent for CDVI). The lowest coefficient of variation in yield was in Satara (10.89 and 10.75 per cent) for CV and CDVI, respectively. Whereas, Western Maharashtra region recorded medium instability in area (21.78 and 21.73 per cent) for CV and CDVI, respectively and production (31.60 and 30.12 per cent) for CV and CDVI, respectively. While in yield it was observed low i.e. (13.46 and 11.10 per cent) for CV and CDVI, respectively.

The area and productivity was indicating stability in wheat crop in all most all the districts in Western Maharashtra region.

3.3 Trend in Area Production and Productivity of Wheat in Western Maharashtra Region

Trends in area, production and productivity of wheat in Western Maharashtra region is presented in the Table 4.

It could be observed from the Table 4 that, among the parametric models fitted to the area, production and productivity under wheat crop, the maximum R^2 was observed in the case of cubic model in all the districts of Western Maharashtra region including region as a whole in comparison to that of other parametric models.

As regard the trend in area, production and productivity the highest R^2 was observed in Dhule district i.e. 91 per cent, 99 per cent and 86 per cent respectively in comparison to that of other districts of Western Maharashtra region. However, the region as a whole recorded highest R^2 in productivity i.e. 59 per cent than area and production.

Table 5. Per cent contribution of area, yield and their interaction for change in production of wheat in Western Maharashtra Region

Sr. no.	Name of District	Particular	Period-I	Period-II	Overall
1	**Nashik**	Area Effect	-47.83	69.84	77.64
		Yield Effect	154.53	42.28	27.51
		Interaction	-6.70	-12.12	-5.14
2	**Dhule**	Area Effect	67.45	161.98	89.20
		Yield Effect	18.75	-39.33	3.20
		Interaction	13.80	-22.65	7.60
3	**Jalgaon**	Area Effect	88.99	38.66	-42.73
		Yield Effect	12.11	73.66	134.29
		Interaction	-1.10	-12.33	8.44
4	**Ahmednagar**	Area Effect	1265.31	91.86	80.33
		Yield Effect	-1005.94	30.48	42.58
		Interaction	-159.37	-22.34	-22.92
5	**Pune**	Area Effect	32.25	858.76	22.47
		Yield Effect	61.45	-892.16	69.53
		Interaction	6.30	133.40	8.00
6	**Solapur**	Area Effect	302.54	60.94	22.43
		Yield Effect	-161.96	65.64	88.46
		Interaction	-40.58	-26.58	-10.89
7	**Satara**	Area Effect	85.22	85.90	49.97
		Yield Effect	12.25	20.47	54.75
		Interaction	2.53	-6.36	-4.72
Western Maharashtra Region		Area Effect	74.99	82.42	56.07
		Yield Effect	22.11	26.81	46.87
		Interaction	2.90	-9.23	-2.93

3.4 Decomposition Analysis in Wheat Production

It is evident from Table 5 that, during period-I, area effect was the most responsible factor for change in production in Ahmednagar district i.e. 1265.31 per cent. On the other hand, in Nashik district yield effect was the most powerful factor for change in the production of wheat with 154.53 per cent. As regard to region as whole area effect (74.99 per cent) was found most responsible for change in production in the region.

Hence, area effect indicating that the area has been playing a driving force in the differential of wheat production. During period II, it was observed that area effect (858.76 per cent) playing major role in change in the production of wheat in Pune district and the yield effect was negative -892.16 per cent per annum. In this period area effect was the most responsible to change in production for all the districts and region as whole i.e. 82.42 per cent.

At overall period, the area effect was the most responsible factor for change in production of wheat in Dhule district i.e. 89.20 per cent with a yield interaction effect 7.60 and yield effect 3.20 per cent. As regard to region as whole area effect almost show positive 56.07 per cent and played major role for the change in production of wheat in Western Maharashtra region and interaction effect almost show negative i.e. -2.93, respectively.

4. CONCLUSION

The results indicated that during the period I and period II, almost all districts in Western Maharashtra region registered negative growth including the region as a whole. The area and productivity was indicating stability in wheat crop in all most all the districts in Western Maharashtra region. In Western Maharashtra region, among the parametric models fitted to the area, production and productivity under wheat crop, the maximum R^2 was observed in case of cubic model in all the districts of western Maharashtra region including region as a whole. The region as a whole recorded highest R^2 in productivity i.e. 59 per cent than area and production. The decomposition analysis for Western Maharashtra region has estimated the largest area effect on wheat production. It was also observed that for both the periods area effect was more pronounced than yield effect and interaction effect. Hence, there is a need for policy makers to formulate development-oriented policies and researchers to design investigative research activities for promoting sustainable wheat production system in the region for expansion of area under wheat cultivation. The efforts need to be made to increase the area under wheat. Ensuring the remunerative prices to the farmer and supplying the significant amount of input especially fertilizer at the subsidized prices, has been the most important factor to promote the farmer to increase the production of wheat.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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