Full Length Research Article

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Research Journal of Agricultural Sciences
Volume 15; Issue 03 (May–Jun 2024); pp 796–800

ISSN: 0976-1675 (P)
ISSN: 2249-4538 (E)

Growth and Instability in Subsistence Agriculture of Uttar Pradesh: Evidence from Major Crops

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Received: 29 Feb 2024; Revised accepted: 22 May 2024

Abstract

Instability is an essential characteristic of agriculture; since agriculture depends on weather conditions, the crop area, production and productivity are subject to significant variation over time. Measuring instability and persistently identifying sources of instability are essential areas of research. The present study pertains to Uttar Pradesh, which occupies an essential place in the country's agricultural production. The study was undertaken to examine the trend in growth and instability in the output of major crops over the last 32 years, from 1990 to 2022. A semi-log regression model was used to analyze major crops' growth and trend (rice, wheat, coarse, oilseed, sugarcane), and instability was performed by generating the Cuddy Dell instability index. The study observed that most crops had a positive but low growth rate in area and production. Moreover, most crops were found instable in terms of area, production and productivity over time. Therefore, proper policies should be formulated to make the state self-sufficient in the agriculture sector, which resorts to imports, by reducing instability and increasing the production of major crops.

***Key words*:** Agriculture, Subsistence agriculture, Instability index, Growth rate, Major crops

Despite intense study at the national level, there are contradictory views on the impact of the green revaluation on the instability in production and productivity of Indian agriculture. While some studies [1-4] indicate that the adoption of modern technology has contributed to instability in production, others show a decline [5-7]. In 1981, Mehra conducted a comparative analysis of production instability before and after introducing new farm technology. The study covered 1950 to 1965 and 1968 to 1978. The study concluded that production instability increased during the later period, and fluctuations in productivity were the primary factor contributing to this instability. Hazell [8] conducted a study to examine the factors that contributed to the change in variation of India's total cereal production during two periods covering 1955 to 1965 and 1968 to 1978. The study found that in the II period, the simultaneous changes in the area, productivity and cropping pattern were responsible for increased instability in cereal production.

The cropping pattern indicates that paddy and wheat are the most essential crops in Uttar Pradesh. Most of the area is used to cultivate food grains, of which only 13.8 per cent is covered under pulses—about 79.8 per cent of the total cropped area dedicated to the production of food grains, sugarcane, potato, mustard, groundnut, gram, pea and lentil are other important crops grown in the state [9]. On the other hand, evidence from the studies, Deshpande [10] discovered that instability decreased as growth rates increased in Maharashtra. Dev [11] conducted an inter-state analysis, revealing that wheat crop instability declined in most states with high growth rates. The objective of the present study are as follows. (i) To analyze the growth and trend in the area and the production and productivity of major crops in Uttar Pradesh. (ii) To examine the instability of major crops in the area and their production and productivity in Uttar Pradesh.

MATERIALS AND METHODS

The present study is based on secondary data from the last 30 years, i.e., from 1991 to 2022, regarding the area, production, and yield of food grains and major commercial crops in Uttar Pradesh. The data were collected from the Handbook of Statistics on India States published by the Reserve Bank of India, Agricultural Statistics at a Glance. The data on area, production and yield of food grains and major commercial crops were collected from 1990-91 to 2021-22. To understand the decadal viz. 1990-91 to 1999-00 (Period I), 2000-01 to 2009-2010 (Period II), 2010-11 to 2021-22 (Period III) and 1990-91 to 2021-22 (overall period) of food grains and commercial crops.

Trend and growth rate analysis

The annual compound growth rate was estimated for the area, production and yield of the major crops as follows:

$$Yt = ab^t e^u$$

$$\ln Yt = \ln a + tln\ b + u$$

$$\text{CAGR} = \{\text{Antilog } (\ln b) - 1\} * 100$$

The significance of the estimated compound annual growth rate was tested with the help of a student's t-test.

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Citation: Singh P. 2024. Growth and instability in subsistence agriculture of Uttar Pradesh: Evidence from Major Crops. *Res. Jr. Agril. Sci.* 15(3): 796-800.

Instability analysis

Measuring instability and persistently identifying sources of instability are essential areas of research. The degree of variability in area, production and yield of food grains, major commercial crops, vegetables and fruits was estimated using the instability index given by the Cuddy-Della Valle [12], which estimates variability in time series data. A low value of this index shows low instability in production and prices [13-14]. Meanwhile, the coefficient of variation (CV) estimates the variability in time series data due to a trend.

The coefficient of variation can be used following the formula with equation (1) to study the instability of different major crops in Uttar Pradesh with respect to production, area, and yield.

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

Cuddy-Della Valle index

$$CDVI = CV \times \sqrt{(1 - \bar{R})^2}$$

CV = Coefficient of Variation
R^2 = Adjusted Coefficient of Determination
CDVI = Cuddy Dell Valle Index
Low instability = between 0 to 15,
Medium instability = 15< CDVI < 30
High instability = greater than 30

RESULTS AND DISCUSSION

Annual compound growth rate of area, production and productivity of food grains

The growth rates of area, production, and productivity of major crops and oilseeds for periods I, II, and III, as well as for the overall periods, are presented in (Table 1). The compound growth rates of area, production and productivity of food grains were computed and presented in (Table 1) for 1990 to 2022. The growth rate was specified for decal periods and overall periods. Compound annual growth rates for area, production, and productivity for the whole period were found to be -0.60, 2.13 and -3.20 per cent, respectively, significant at 10 per cent and 1 per cent. During the first period (1990-2000), the CAGR of area, production and yield of food grains in Uttar Pradesh was -0.60 per cent, 2.13 per cent, and 2.26 per cent.

Instability in area, production and productivity of foodgrains

Medium instability (27.09%) with respect to overall foodgrains productivity in the state was estimated over the study period (1990-22), with variations from 3.57 per cent in period I to 14.97 per cent in period III. However, the instability index for overall area coverage under foodgrains was observed to be low in all period, period I (2.05%), period II (2.32%), period III (1.27%) and overall period (0.32%). In similar lines, the instability index of production was noted to be low (3.32%) for the period I (1990-00).

Table 1 Growth and instability in area, production and yield of foodgrains in Uttar Pradesh

Period	CAGR (%) of food grains			Instability index		
	Area	Production	Yield	Area	Production	Yield
Period I (1990 to 2000)	-0.60** (0.02)	2.13*** (0.00)	2.26*** (0.00)	2.05	3.32	3.57
Period II (2001 to 2010)	-0.41^{ns} (0.14)	0.51^{ns} (0.51)	0.92^{ns} (0.15)	2.32	6.74	5.28
Period III (2011 to 2022)	-0.15^{ns} (0.23)	1.87 *** (0.01)	3.17** (0.05)	1.27	8.93	14.97
Overall Period (1990 to 2022)	-0.60** (0.02)	2.13***(0.00)	-3.20***(0.00)	0.32	7.83	27.09

Note: figures in parentheses indicate the p-value of respective values
*** and ** denotes significant at 1 and 10 levels; ns: non-significant

Growth rates of area, production and productivity of major crops

While interpreting the results of Period I, it is crucial to remember the agricultural situation that prevailed in India at that time. The condition of agriculture in Uttar Pradesh was no different from the agriculture of the whole nation. As is evident from (Table 2), the production of all crops either stagnated or declined significantly during Period I (1990-91 to 1999-00). The crop instability depicted a declining trend in the post-period; a trend has also been observed in production. The compound growth rate of productivity in the case of rice was 2.21 per cent per annum, whereas the growth rate in the area was only 0.94 per cent. The wheat crop registered a growth rate of 2.24 and 0.91 per cent per annum in productivity and area, respectively. However, oilseed and cereals witnessed negative growth rates in the area against the productivity growth rates of 0.67 and 1.97 per cent, respectively, during the overall period. However, a significantly declining trend was observed in the area of coarse cereals, pulses and total foodgrains during the initial period. Yield expansion under some crops like rice, wheat, pulses, and total foodgrains could increase the production of these crops perceptibly, except if they failed to increase the production of pulses.

Interestingly, the productivity rate of rice, wheat, cereals, and total foodgrains, except for oilseed, was positive during the period I. Most of the increase in food grain production was mainly due to productivity improvement. The area under wheat and oilseed registered a growth rate of 0.39 and 0.16 per cent per annum, respectively, in period II. Oilseed, which registered a negative growth rate in area and productivity in period I, has shown considerable improvement in period II.

During period II (2001 to 2010), the decrease in rice production in general and wheat production, in particular, was mainly due to the decrease in productivity rather than the decrease in area. However, the scenarios changed during the overall period (1990 to 2022). The increase in cereals and oilseeds production is mainly due to increased productivity. The compound growth rates of productivity in the case of oilseed, cereals and total foodgrains were 2.68, 2.91 and 3.17 per cent annum, respectively. In contrast, the growth rates in the area were negative growth per annum except for oilseeds.

The table indicates that the area under sugarcane registered a significant and positive growth rate as a whole during 1991-22. The highest growth rate in the sugarcane area was observed in Period I, and the lowest was in Period III. The sugarcane acreage registered a compound growth rate of 0.58 per cent per annum in Uttar Pradesh.

Sugarcane production registered significant and positive growth in the two periods and overall. The highest growth rate was observed in period III, followed by I and II. The state

registered a growth rate of 1.53 per cent per annum in production. Sugarcane productivity registered significant and positive growth rates in different periods. Both periods I and II registered growth rates of equal magnitude, while the growth rate in period III registered the highest growth rate. The state as a whole registered a growth rate of 0.95 per cent per annum.

Table 2 Growth and instability indices of area, production and yield of major crops, 1990-91 to 2021-22

Period	CAGR (%)			Instability Index		
	Area	Production	Yield	Area	Production	Yield
			Rice			
1990-2000	0.94**	3.18***	2.21***	2.65	5.72	3.2
2001-2010	-0.44	0.08	0.52	2.60	12.0	7.11
2011-2022	-0.24	1.67**	0.34***	1.90	7.72	7.75
1990-2022	0.56	1.30***	1.14***	4.09	9.59	7.94
			Wheat			
1990-2000	0.91***	3.17***	2.24***	1.09	3.69	1.96
2001-2010	0.39	1.23	0.84	1.94	6.17	4.74
2011-2022	-0.82	1..85	0.41***	1.44	10.4	10.52
1990-2022	0.36***	1.61***	1.24***	1.98	8.21	7.88
			Coarse cereals			
1990-2000	-1.58***	-0.16	1.45	2.80	9.28	7.82
2001-2010	-2.27***	-1.47	0.42***	4.14	7.85	6.40
2011-2022	-0.26	2.65***	2.91***	1.73	5.10	4.47
1990-2022	-1.74***	-0.19	1.97***	7.92	12.96	8.24
			Oilseeds			
1990-2000	-1.19	-1.59	-0.41	4.59	12.47	13.13
2001-2010	0.16***	-0.28	0.23	10.96	12.46	8.59
2011-2022	0.89**	3.60***	2.69**	4.95	11.13	12.56
1990-2022	-1.42***	-0.76	0.67***	11.59	16.39	12.02
			Pulses			
1990-2000	-6.06***	-5.77***	1.70	10.20	8.30	12.90
2001-2010	-1.75	-2.80**	-1.07	7.41	9.63	7.80
2011-2022	-0.03	1.87**	2.52	7.13	8.93	17.04
1990-2022	-1.96***	-1.69***	0.43	15.00	20.34	14.32
			Total Foodgrains			
1990-2000	-0.60**	2.13***	2.26***	2.05	3.32	3.57
2001-2010	-0.41	0.51	0.92	2.32	6.74	5.28
2011-2022	-0.15	1.87 ***	3.17**	1.27	8.93	14.97
1990-2022	-0.60**	2.13***	-3.20***	0.32	7.83	27.09
			Sugarcane			
1990-2000	1.11**	1.89**	0.77	4.35	6.10	4.33
2001-2010	0.50	0.65	0.77	5.11	7.06	4.67
2011-2022	0.15	4.17***	4.00	1.61	6.03	5.07
1990-2022	0.58***	1.53***	0.95***	3.75	10.61	10.28

Note: Area in thousand hectares; production in thousand tonnes; Yield in kg. Per hectare,
*** and ** denotes significant at 1 and 10 levels; ns: non-significant results.

Instability in crop production

Instability indices in area, production and productivity of major crops from 1990-91 to 2021-22 were computed using the coefficient of variation, Cuddy-Della Valle Index. Instability is one of the critical decision parameters in the development of dynamics and more so in the context of agricultural production. The results of the analysis are presented in (Table 2). The results revealed instability measures of area, production and productivity (Yield) of major crops in Uttar Pradesh from 1990-91 to 1999-2000, 2001 to 2010, 2010-11 to 2022 and 1990 to 2022. In period I, the output of the oilseed, coarse cereals, and rice registered low instability, and total foodgrains and wheat were also low. As the variation in output is the compound result of fluctuation in crop area and crop yield, productivity contributed more relative to the area. The magnitude of instability in the productivity of all major crops except rice, wheat and foodgrains declined during period II compared to period I. During the II period, movements in area productivity were responsible for increased instability in oilseed, coarse cereals, and rice production. Data depicted in (Table 2) further reveals that during the period 2010-11 to 2021-22, the magnitude of fluctuations was the highest in the case of foodgrains and wheat and the lowest for rice, followed by coarse cereals and oilseeds in production. [15] showed that irrigation causes a substantial reduction in instability in areas, production, and productivity.

Medium instability (20.34%) concerning overall pulse production in Uttar Pradesh was estimated over the study period (1990-2022), with variations from 8.30 per cent in period I to 9.63 per cent in period II. However, the instability index for overall area coverage under pulse crops was observed to be low in all periods I (10.20%), period II (7.41%), period III (7.13%) and overall (15.0%). Along similar lines, the instability index of productivity was noted to be low (12.90%) for the period 1990-00. Sugarcane had low instability under acreage, production, and productivity in Uttar Pradesh. In contrast, during period III, area coverage under sugarcane declined by 5.11 per cent in period II. The instability varies around 11 per cent under production and productivity in sugarcane. Overall, the pulse crops in Uttar Pradesh showed medium instability in production but low instability in area coverage and productivity. Sugarcane maintained low instability in all aspects but faced a slight reduction in area coverage. These trends indicate that both crops have relatively stable production patterns, pulses are more susceptible to fluctuations in production compared to sugarcane.

Table 3 Changing patterns of input use and other factors in Uttar Pradesh

Year	Net sown area ('000 ha)	Gross sown area ('000 ha)	Gross irrigate area ('000 ha)	Net irrigated area ('000 ha)	Cropping intensity (%)	Fertilizer use (NPK) (kg/ha)
1990-91	17299	25480	14771	10542	147.3	88.7
1995-96	17399	25793	16972	11675	148.2	102.0
2000-01	16825	25304	17690	12401	150.4	115.3
2005-06	16633	25307	18970	13075	152.2	140.4
2009-10	16589	25440	19354	13383	153.4	171.0
2015-16	16469	26203	20882	14231	159.1	155.5
2020-21	16368	27109	22994	14334	165.6	189.0

Source: compiled from various issues of Handbook of Statistics on India States, RBI

Sources of low growth rates

The input use patterns and other factors are presented in Table 3; the results of the area under cultivation, including net sown area and gross sown area, have marginally changed after 2001. However, if we compare the data between 1990 and 2020, then the gross sown area was 17399 thousand hectares in 1980, which, after ups and downs in between, decreased to 16368 thousand hectares in 2020-21, depicting an increase of 6.39 per cent after nearly three decades. In the case of the net irrigated area, there was an increasing trend, and the percentage increase was 35.97 per cent. The ratio of gross irrigated area to gross sown area presents a depressing picture. It was 57.9 per cent in 1990 and increased to 69.9 per cent in 2000.

However, again, it increased to 76.0 per cent in 2010 and reached 84.8 per cent. The area under irrigation can be expanded by more than 3 per cent per annum in Madhya Pradesh, Maharashtra, Himachal Pradesh and West Bengal. The Scope for Irrigation Expansion in Uttar Pradesh was 1.67 per cent [16]. However, compared with other states like Bihar, Madhya Pradesh, West Bengal, Tamil Nadu, Andhra Pradesh and Assam, they have a higher proportion of cultivated area under assured irrigated [17].

Fertilizer, measured as the amount of nitrogen, phosphorous, and potassium used, is regarded as one of the yield-augmenting technologies; results show its use persistently increased from 1990 but declined to 9.06 from 2010 to 2015 [18]. A comparison of fertilizer use in other Indian states shows that fertilizer use is as low as 28kg/ha in Assam and as high as 328kg/ha in the net sown area in Punjab. Similarly, fertilizer use is below 40kg/ha in Rajasthan and Madhya Pradesh and 55kg/ha in Orissa. Increasing fertilizer use is a significant option for increasing agriculture output in most states [19].

CONCLUSION

Agriculture is susceptible to instability due to its dependence on several factors, such as weather conditions, crop area, production and productivity. Therefore, it is important to study and identify the sources of instability. The result was a notable increase in instability and growth rates of area, production and productivity in most crops during the period. Thus, from 2010-11 to 2021-22, the crop output recorded an unprecedented annual growth rate of 3.60 per cent compared with a growth rate of -1.59 per cent from 1990-91 to 1999-00. There are different reasons for the slowdown in production growth and productivity in different crops. The instability index for overall area coverage under major crops was observed to be low to medium overall. However, the productivity rate of most crops in Uttar Pradesh is comparatively lower than in the country. This may be due to the low use of scientific methods of cultivation techniques, weather conditions, lack of irrigation facilities, poor infrastructure, etc. The growth rate of acreage, production and productivity under sugarcane is positive and significant overall. At the same time, instability in the area, production, and productivity under sugarcane have been found to be low in Uttar Pradesh. Other hand, changing patterns of input use and other factors such as net sown area, net irrigation, cropping intensity and fertilizer use (NPK). It was observed that fertilizer use increased after 2000-01, and cropping intensity marginally fluctuated at the same time.

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