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Growth and instability analysis of rice production: A district level assessment in Uttar Pradesh and Uttarakhand states of India

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Abstract
Uttar Pradesh and Uttarakhand are the most important states for rice production of the country. It is necessary to study the growth pattern and instability of rice production in these states. Therefore the present study was conducted to examine the growth rate and instability in area, production and yield of rice in Uttar Pradesh including Uttarakhand state. The data was collected for the years 1990-91 to 2019-20 from Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India. The data has been classified into four periods for analysis. Compound annual growth rate and Cuddy-Della Valle Instability index have been computed for the four periods. A new approach has been proposed for classification of instability values under five classes. These classes are very low instability, low instability, medium instability, high instability and very high instability. Highest growth rate for area and production was recorded in Agra district during period I (1990-91 to 1999-2000) and for yield it was observed in Sonbhadra district during the same period. For the state as a whole, the growth rate for area, production and yield was positive for all the periods except in period II where it was observed negative. The growth rate for most of the districts were positive for yield during period I (1990-91 to 1999-2000), III (2010-11 to 2019-20) and IV (1990-91 to 2019-20). The instability for area varies from 0.36 to 71.35 percent, instability for production was varied between 0.84 to 62.80 percent and instability for yield of rice varies from1.25 to 25.24 percent across the districts during the four periods. Most of the districts recorded low instability and very low instability for area, production and yield during all the periods.

Keywords: Rice, production, growth rate, instability, Uttar Pradesh, Uttarakhand

Introduction
Rice is the staple food for about half of the world population and more than two thirds of the Indian population. India ranks first in rice area and second in rice production next to China. In India, rice is grown in more than 45 million hectare area with the production of 124 million tons of milled rice in 2020-21 contributing about 23% of the global rice production. Rice cultivation engages the most of the workforce in the economy as the source of livelihood for those people. Rice accounts for 40% of the total food grain production occupying 35% of the food grain area of the country.

Uttar Pradesh and Uttarakhand jointly are the second highest rice producing states of the country next to West Bengal with the joint production of 16.23 million tons of rice contributing 13.05% rice production of the country in 12.96% of rice area. During the last forty years rice area in Uttar Pradesh (including Uttaranchal) increased 1.13 times, rice production increased 2.9 times and rice yield increased 2.57 times.

For higher growth of agriculture, quantitative assessment of the contribution of different factors of agricultural output growth is important for reorienting the programmes and prioritizing the agricultural development. Various factors affect the growth of agricultural output. Major ones of these factors are area and yield. (Singh, 1981; Cauvey, 1991) [10, 2]. These major sources of output growth have significance in finalizing programmes of agricultural development and priorities of investment in it (Ranade, 1980; Deosthali and Chandrashekhar, 2004) [9, 13]. Hence, it may be vital to find the estimates of the growth rates in various periods, so as to remove the bottlenecks to achieve the fast development of agricultural sector (Sikka and Vaidya, 1985) [11].

The study of instability is also required to identify the fluctuation in the trend for area, production and yield of rice which is severely affecting the production, and indirectly

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employment and income distribution there by affects the economic growth of the state.

District wise growth rate and instability in rice have been computed by researchers for some states (Jambhulkar *et al*, 2020, Jambhulkar *et al*, 2021, Akula *et al*, 2022) [6, 7, 1]. But the district wise analysis of growth rate and instability for rice during the period of last thirty years is not available for Uttar Pradesh (including Uttrakhand) state.

Keeping in view, the present study is undertaken to examine the district wise growth rate and instability in area, production and yield of rice in Uttar Pradesh (including Uttrakhand) state.

Material and Methods
The present study is carried out based on the secondary data of rice of Uttar Pradesh (including Uttarakhand) state collected for the year 1990-91 to 2019-20. The district wise data on area, production and yield of rice of Uttar Pradesh (including Uttarakhand) state have been collected from Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India during the last ten years. Last thirty years data since 1990-91 have been used for the study. Uttarakhand state was a part of erstwhile Uttar Pradesh state and carved out from Uttar Pradesh in 2000. Hence, the study was conducted for all the districts of Uttar Pradesh and Jharkhand. There were sixty two districts during 1990s in the undivided Uttar Pradesh state. Many districts were divided and separated as a new district during the decades 1990s, 2000s and 2010s. All the major rice growing eighty eight districts of Uttar Pradesh (including Uttarakhand) were combined into sixty three districts. For lucidity, the thirty years rice data (1990-91 to 2019-20) is divided into four periods. Period I (1990-91 to 1999-2000), period II (2000-01 to 2009-10), period III (2010-11 to 2019-20) and the overall period as a period IV (1990-91 to 2019-20).

The growth rate of area, production and yield for districts of Uttar Pradesh (including Uttarakhand) state for each period is computed to study the growth pattern in area, production and yield of that districts.

Compound growth rate was estimated using following exponential model Dandekar (1980) [4].

$$Y = ab^t$$

Log Y = log a + t log b
CGR(r) = [Antilog (log b) -1] × 100

where,
CGR = Compound growth rate
t = time period in year
Y = area/ production / productivity
a and b = Regression parameters

The performance of agricultural output affected by climatic factors, the growth rate has been calculated based on three years average data (Dandekar, 1980; Minhas, 1966; Singh and Rai, 1997) [4, 8, 12].

Instability means deviation from the trend. In agriculture, instability is an inherent characteristic due to weather conditions, seasonal variation in area, yields and production of crops from year to year. The instability in area, production and yield of rice is computed to measure the variability using an index of instability called Cuddy-Della Valle index (Cuddy and Della Valle, 1978). This method is used to examine the extent of risk involved in crop production.

The instability in area, production and yield was estimated using the following Cuddy-Della Valle Index.

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

Where,
CDVI = Cuddy-Della Valle Instability index (per cent)
CV= Coefficient of variation (per cent)
Adj. R2= Coefficient of determination from a time trend regression adjusted by the number of degree of freedom

We proposed the classification of instability into five classes as follows

Class	Range of instability
Very low instability	0 to 5
Low instability	5 to 15
Medium instability	15 to 30
High instability	30 to 50
Very high instability	> 50

The districts have been classified as per the proposed classification. Classification.

Results and Discussion
The area, production and yield of rice in Uttar Pradesh (including Uttarakhand) from 1980-81 to 2019-20 is presented in Figure 1. During the last forty years, area increased 1.13 times from 5.25 million hectare in 1980-81 to 5.98 million hectare in 2019-20, production increased 2.9 times from 5.57 million tonnes in 1980-81 to 16.18 million tonnes in 2019-20 and yield increased 2.57 times from 1.05 t/ha in 1980-81 to 2.70 t/ha in 2019-20. Hence, it is vital to study the trend of area, production and yield of rice in Uttar Pradesh (including Uttarakhand).
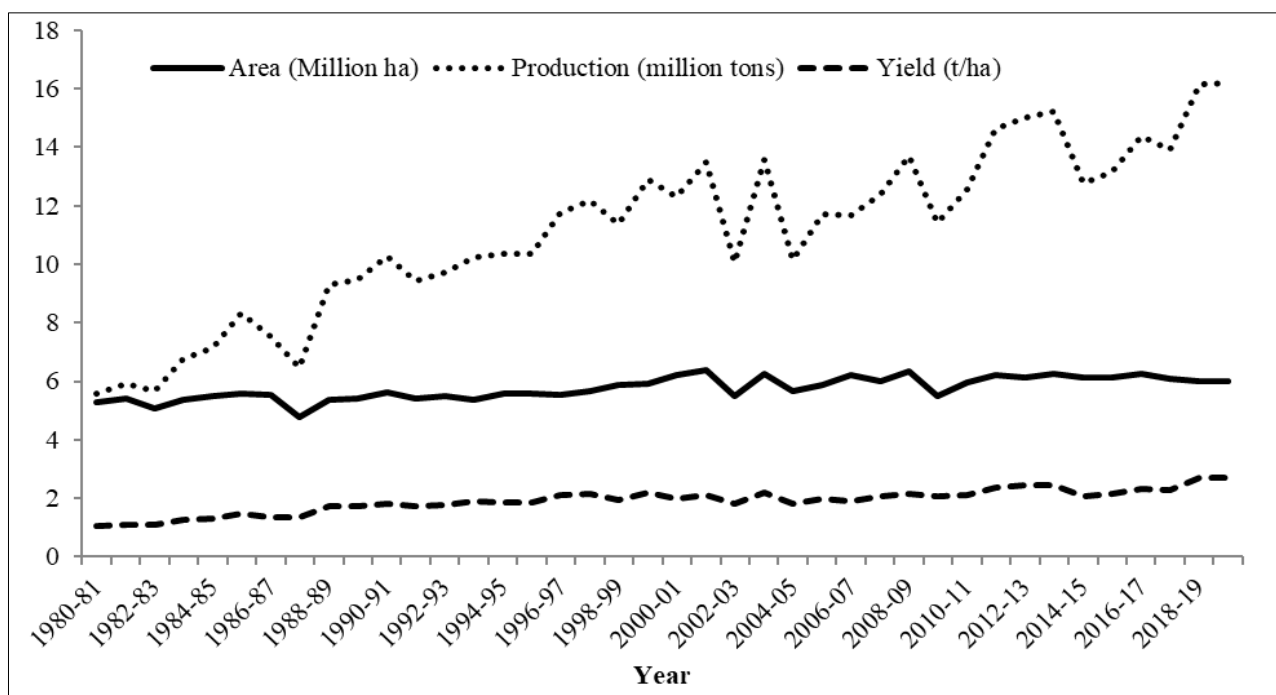
Fig 1: Area (in million hectare), production (in million tons) and yield (t/ha) of rice in Uttar Pradesh (including Uttrakhand) from 1980-81 to 2019-20

Compound Annual Growth Rate

The district-wise compound annual growth rate for area, production and yield of rice in Uttar Pradesh (including Uttarakhand) state is presented in Table 1. It is evident from the result that during period I (1990-91 to 1999-2000), highest growth rate for area (31.72%) and production (35.56%) was recorded in Agra district; and highest growth rate for yield

(9.07%) was observed in Sonbhadra district. Lowest growth rate for area, production and yield was recorded in Gonda (-3.86%), Deoria (-2.21%) and Bijnor (-4.33%) district respectively followed by Lalitpur (-3.73%), Chamoli (-1.18%) and Fatehpur (-0.38%) district respectively. Most of the districts recorded positive growth rate for yield.

Table 1: District wise growth rate of area, production and yield of rice in Uttar Pradesh (including Uttarakhand) for different periods

S.N.	District	Area				Production				Yield			
		P-I	P-II	P-III	P-IV	P-I	P-II	P-III	P-IV	P-I	P-II	P-III	P-IV
1	Bijnor	5.76*	-1.66*	0.09	-0.92*	1.18**	-3.00*	0.80*	-0.99*	-4.33**	-1.37*	0.72*	-0.08
2	Rampur	3.07*	0.11	0.20	1.00**	4.30*	-0.76	2.92*	0.99*	1.19	-0.87**	2.71*	-0.01
3	Muradabad	2.39*	0.58	0.17	1.18*	2.90*	0.30	2.20*	1.08*	0.50	-0.28	2.03*	-0.10
4	Pilibheet	0.08	1.79*	-1.47*	0.34**	0.56	0.59	1.45**	0.69*	0.49	-1.18	2.96*	0.35**
5	Barilei	1.99*	-0.11	-0.73*	0.50*	3.29**	-1.57**	2.14*	0.84*	1.27	-1.46*	2.89*	0.33
6	Kheri	1.68*	-0.33	-0.48	0.12	3.48*	-3.22*	4.47*	0.99*	1.77**	-2.90*	4.97*	0.88*
7	Saharanpur	2.28*	-4.36*	1.88**	-0.89*	2.59*	-4.81*	3.42*	-0.94*	0.30	-0.46	1.51*	-0.05
8	Shajahanpur	2.71*	0.84	-0.20	1.24*	3.62*	0.85	3.98*	2.09*	0.89**	0.01	4.19*	0.84*
9	Muzaffarnagar	0.64	-4.87*	-1.18*	-0.78**	1.95*	-5.12*	0.57	-0.59	1.30*	-0.26	1.77*	0.19**
10	Meerut	5.94*	-4.26*	-0.21	1.21*	7.94*	-3.60**	1.71**	2.13*	1.88*	0.70**	1.92*	0.91*
11	Ghazaibad	9.12*	1.09**	4.29**	5.24*	10.32*	2.92*	4.57**	6.38*	1.10**	1.81*	0.27	1.08*
12	Bulandshahar	17.03*	6.00*	2.27**	10.03*	23.34*	6.69*	5.08*	11.69*	5.40*	0.65**	2.75*	1.51*
13	Badaun	4.92*	-2.59**	-0.28	0.93*	6.59*	-0.99	1.26	2.17*	1.59*	1.64*	1.54**	1.22*
14	Aligarh	9.93*	5.23*	4.06**	8.78*	11.87*	6.52*	7.02*	10.38*	1.77**	1.22**	2.84*	1.47*
15	Etah	2.33*	-1.58**	-1.74**	0.33	4.35*	2.18**	-1.03	1.79*	1.97*	3.82*	0.72	1.46*
16	Manpuri	1.06	3.00*	0.77	0.97*	3.11*	5.82*	2.91*	2.61*	2.03*	2.74*	2.12*	1.62*
17	Mathura	17.10*	1.89	1.16**	6.44*	17.79*	4.40*	-1.52	6.55*	0.59	2.46*	-2.65**	0.10
18	Agra	31.72*	2.49	4.11	16.32*	35.56*	3.57	6.21**	16.89*	2.91**	1.06	2.02*	0.49**
19	Firozabad	3.25**	-2.05	1.98*	2.23*	5.14*	6.26*	0.90	4.66*	1.84*	8.49*	-1.06	2.38*
20	Sitapur	1.77*	-0.44	0.73**	0.75*	4.41*	-0.34	3.28*	2.22*	2.60**	0.10	2.54*	1.45*
21	Hardoi	2.83**	2.54*	0.38	2.10*	5.25*	4.49*	1.99**	3.25*	2.35*	1.90**	1.60*	1.13*
22	Farukhabad	0.25	-1.34**	2.73*	0.89*	2.60*	2.00**	5.05*	2.58*	2.35*	3.38*	2.27**	1.68*
23	Etawah	2.95*	-0.96**	2.15**	1.29*	5.50*	2.01*	3.07**	2.88*	2.47*	3.00*	0.90	1.57*
24	Kanpur (City)	4.29	-1.03	1.23*	3.35*	6.11	0.94	4.14*	5.29*	1.75**	1.99**	2.87*	1.87*
25	Kanpur (Dehat)	-1.63**	2.15	0.07	-2.04*	0.64	2.12	3.66*	-0.37	2.30**	-0.03	3.58*	1.71*
26	Unnao	0.63	-0.88	2.37**	0.36	1.69	2.77*	3.44**	1.74*	1.05	3.68*	1.05	1.38*
27	Lucknow	-0.46	-1.10	1.35**	-0.02	0.71	1.96**	3.83*	1.62*	1.18	3.10*	2.45*	1.64*

No	District	A	P	Y	A	P	Y	A	P	Y	A	P	Y
28	Rae Bareli	-0.62	-0.04	1.39*	0.47*	-0.09	2.01*	2.61*	2.00*	0.54	2.05*	1.20**	1.52*
29	Fatehpur	0.74	-1.98*	2.47*	-0.31	0.36	-1.39	4.58*	1.13*	-0.38	0.60	2.06**	1.44*
30	Allahabad	-0.72	-1.13**	1.56*	0.40**	0.68	-0.13	3.21**	2.04*	1.40**	1.01**	1.62	1.63*
31	Jhansi	3.82	0.71	14.04**	5.99*	5.35	5.61*	12.14**	9.61*	1.48	4.86*	-1.67	3.42*
32	Lalitpur	-3.73**	-9.31*	-10.31*	-8.09*	0.10	-12.55*	-12.17*	-7.71*	3.98*	-3.58	-2.08	0.41
33	Banda	-1.17	-6.38*	1.86**	-0.97*	2.46	-9.73*	7.76*	1.12	3.67**	-3.58**	5.79*	2.12*
34	Hamirpur	7.90**	-18.30*	-4.27	-12.57*	9.75**	-21.78*	1.75	-10.36*	1.72	-4.26*	6.29*	2.53*
35	Jalaun	-2.00	-12.97*	2.07	-4.32*	2.67	-12.02*	6.24	-2.01**	4.77**	1.09	4.09*	2.41*
36	Gonda	-3.86*	0.24	0.83*	0.21	-0.25	2.38**	1.68**	1.87*	3.76*	2.13	0.84	1.66*
37	Baharaich	-1.99*	1.39*	0.46*	0.63*	0.88	2.30*	2.66*	2.85*	2.93*	0.90	2.19*	2.20*
38	Basti	-0.13	0.11	-0.38	-0.21*	1.80	-1.08	1.02	1.33*	1.94**	-1.19	1.40	1.54*
39	Gorakhpur	1.33**	-0.14	-0.14**	0.25*	2.96*	0.62	1.48	1.78*	1.61**	0.76	1.63	1.52*
40	Deoria	-3.53	0.47**	-0.11	0.60**	-2.21	-1.07*	0.06	0.94*	1.37	-1.54*	0.18	0.34
41	Maharajganj nagar	0.32*	-0.02	-0.13	0.07*	2.39*	-1.24*	1.61*	0.62*	2.06*	-1.22*	1.74*	0.55*
42	Sidharthnagar	-0.38	0.97*	0.31	-0.35*	3.52**	3.12	1.80*	2.43*	3.92*	2.13	1.48	2.79*
43	Barabanki	-0.82**	2.19*	0.67**	0.50*	0.40	1.62	2.86*	2.08*	1.23*	-0.56	2.18**	1.57*
44	Faizabad	0.40	-1.03	0.19	0.64*	2.02**	-1.26	1.43	1.63*	1.61*	-0.23	1.23	0.98*
45	Sultanpur	-0.59*	0.09	0.20	-0.34*	1.98**	-0.31	2.41	1.08*	2.59*	-0.40	2.20	1.43*
46	Pratapgarh	-0.41	-1.56*	0.51	-0.44*	0.38	-0.39	1.32**	0.54*	0.79	1.19**	0.81	0.99*
47	Jaunpur	-1.37**	1.09*	1.05*	0.90*	0.97	-0.24	2.41*	1.60*	2.38*	-1.32	1.34**	0.68*
48	Ajamgarh	0.40	0.32	0.54*	0.51*	1.28	-1.26	2.47*	1.30*	0.88	-1.57	1.92*	0.79*
49	Balia	1.31*	-0.34	1.26**	0.10	7.22*	-2.18	4.37*	1.72*	5.83*	-1.84	3.08**	1.61*
50	Ghazipur	-0.37	0.57	0.66**	0.99*	0.52	0.17	2.55*	2.03*	0.89	-0.39	1.88*	1.03*
51	Varanasi	-0.20	0.34	1.61*	0.57*	3.13*	-1.99	4.52*	1.21*	3.34*	-2.31**	2.86*	0.64*
52	Mau	-0.63	-1.06**	0.51**	0.02	-0.04	-3.89*	2.73**	0.88*	0.59	-2.86**	2.21	0.86*
53	Mirzapur	0.78**	-1.90*	1.65*	-0.46**	5.66*	-5.14*	5.25*	0.74	4.84*	-3.31**	3.54*	1.20*
54	Sonbhadra	1.55**	-9.67*	3.85*	-3.82*	10.76*	-14.51*	10.40*	-1.36	9.07*	-5.36*	6.30*	2.55*
55	Uttarkashi	3.13*	-0.93	-0.06	-0.38**	3.97*	1.31	0.98	0.34	0.82	2.27*	1.05	0.72*
56	Chamoli	-1.59**	-1.99*	-0.72*	-2.07*	-1.18	-0.89	-0.68**	-1.96*	0.42	1.13	0.03	0.11
57	Pauri- Garhawal		-1.01*	-4.78*	-3.19*		-0.18	-3.51*	-2.01*		0.83	1.33*	1.22*
58	Tehri - Garhawal	-0.23	-0.84	-1.10*	-2.01*	1.77**	-1.18	1.90*	-1.09*	2.01*	-0.35	3.04*	0.94*
59	Dehradun	-0.40	-2.16*	-2.53*	-1.84*	0.35	-1.45*	-1.14*	-1.05*	0.74	0.72**	1.43*	0.81*
60	Pithoragarh	-0.51	-1.71*	-1.71*	-1.24*	0.46	-0.29	-1.06*	-0.87*	0.98	1.44*	0.66**	0.37*
61	Almora	0.13	-0.16	-2.10*	-0.88*	0.12	-0.33	-0.58	-0.47*	-0.01	-0.17	1.55*	0.41*
62	Nainital	-1.74	1.11*	0.23	0.09	-0.12	0.66	3.01*	1.13*	1.65	-0.45	2.77*	1.03*
63	Haridwar	2.13*	-5.98*	-2.48**	-2.11*	2.26*	-6.30*	-0.40	-2.42*	0.13	-0.34	2.13*	-0.32**
	State	0.44	-0.09	0.27	0.42*	2.38*	-0.14	1.47**	1.37*	1.94*	-0.05	1.20	0.95*

* significant at 1%; ** significant at 5%

P-I: Period I (1990-91 to 1999-2000); P-II: Period II (2000-01 to 2009-10); P-III: Period III (2010-11 to 2019-20); P-IV: Period IV (1990-91 to 2019-20)

A: Area; P: Production; Y: Yield

During period II (2000-01 to 2009-10), the highest growth rate for area (6.0%) and production (6.7%) was observed in Bulandshahar district, and highest growth rate for yield (8.5%) was recorded in Firozabad district. Lowest growth rate for area (-18.3%) and production (-21.8%) was recorded in Hamirpur district while lowest growth rate in yield (-5.36%) was observed in Sonbhadra district. In this period, the growth rates were positive and negative across various districts for area, production and yield.

During period III (2010-11 to 2019-20), the highest growth rate for area (14.04%) and production (12.14%) were observed in Jhansi district and highest growth rate for yield was recorded in Sonbhadra (6.3%) district. Similarly, lowest growth rate for area (-10.31%) and production (-12.17%) was recorded in Lalitpur district whereas lowest growth rate for yield (-2.65%) was observed in Mathura district. In this period most of the districts recorded positive growth rate for yield and production.

During the overall period IV (1990-91 to 2019-20), highest growth rate for area (16.32%) and production (16.89%) was recorded by Agra district and highest growth rate for yield (3.42%) was observed by Jhansi district. Lowest growth rate in area (-12.57%) and production (-10.36%) was observed by Hamirpur district while lowest growth rate in yield (-0.32%) was recorded in Haridwar district. In this period most of the districts recorded positive growth rate for yield. Similar trend was observed in Odisha (Jambhulkar et al, 2020) [6].

Highest growth rate for area and production was recorded in Agra district during period I whereas highest growth rate for yield was observed in Sonbhadra district during the same period.

Cuddy-Della Valle Instability Index
The level of instability cannot be detected by focusing only on growth rates. Growth rate will just explain the rate of growth over time, whereas instability will determine whether the growth performance for the variable under study was stable or unstable over time. In this study, the level of instability in the area, production and yield of rice in Uttar Pradesh (including Uttarakhand) was determined by using Cuddy-Della Valle Index.

Table 2: District wise instability of area, production and yield of rice in Uttar Pradesh (including Uttarakhand) for different periods

SN	Instability District	Area				Production				Yield			
		P-I	P-II	P-III	P-IV	P-I	P-II	P-III	P-IV	P-I	P-II	P-III	P-IV
1	Bijnor	15.85	4.01	1.34	17.36	4.16	4.09	1.93	8.32	12.57	1.25	1.69	10.73
2	Rampur	2.64	1.82	2.13	5.55	5.57	3.10	4.09	8.03	5.26	2.83	2.54	7.06
3	Muradabad	2.82	4.41	1.23	6.26	5.13	4.05	3.01	6.42	3.68	2.33	2.23	4.84
4	Pilibheet	2.10	1.77	3.22	6.06	3.36	2.43	5.04	4.13	3.96	3.79	2.19	6.53
5	Barilei	4.90	6.10	1.80	7.58	9.74	5.65	5.33	8.99	7.52	1.73	6.30	8.95
6	Kheri	3.76	1.66	4.05	4.85	9.41	2.99	6.31	12.31	6.24	2.76	3.16	11.36
7	Saharanpur	3.21	3.83	6.15	10.91	3.05	6.49	5.21	14.37	4.99	2.58	2.72	5.78
8	Shajahanpur	1.47	4.45	4.35	6.04	2.18	5.67	3.99	7.18	2.97	2.76	1.51	9.00
9	Muzaffarnagar	3.43	14.44	3.08	13.67	4.75	14.34	2.80	15.41	2.86	2.77	1.97	4.49
10	Meerut	7.93	12.12	3.07	14.73	9.18	12.13	5.81	14.79	3.27	2.12	3.61	4.55
11	Ghazaibad	5.19	4.04	10.44	13.71	5.61	3.27	11.91	17.53	3.66	3.37	2.21	4.06
12	Bulandshahar	21.15	6.23	8.06	11.88	23.89	5.56	8.19	12.73	6.01	2.31	1.50	7.06
13	Badaun	5.85	10.31	6.83	14.39	7.75	12.32	12.71	13.63	2.08	4.17	6.05	6.52
14	Aligarh	22.92	10.33	7.37	17.08	22.12	7.38	7.65	22.46	6.68	4.64	3.21	5.34
15	Etah	2.73	5.41	5.79	9.25	2.26	6.00	8.27	8.72	3.47	7.76	10.13	8.98
16	Manpuri	6.42	5.58	6.36	9.55	7.21	11.44	4.66	10.56	2.72	6.53	3.03	5.53
17	Mathura	17.85	8.96	4.34	12.29	14.25	10.38	12.33	18.21	6.95	4.36	8.12	8.74
18	Agra	71.35	20.36	17.67	32.46	62.80	19.69	18.38	36.92	9.20	7.02	4.74	10.21
19	Firozabad	8.92	11.72	4.22	11.34	8.10	10.34	4.13	9.83	2.23	8.24	4.76	13.80
20	Sitapur	3.02	4.57	2.28	4.09	10.10	7.00	6.66	12.75	7.53	4.03	5.37	10.24
21	Hardoi	8.27	4.71	2.67	8.19	11.36	7.57	6.53	8.30	3.33	6.89	4.24	5.97
22	Farukhabad	7.48	4.81	7.04	8.22	7.01	6.84	6.11	8.79	3.76	2.81	7.01	6.60
23	Etawah	2.55	3.65	7.17	6.84	4.90	4.75	8.88	7.73	2.89	3.12	3.64	4.18
24	Kanpur (City)	29.00	6.13	2.87	21.52	33.30	11.50	6.70	16.04	6.44	6.60	5.24	8.34
25	Kanpur (Dehat)	6.01	9.40	3.30	10.99	8.23	11.16	7.61	13.51	8.29	4.44	5.01	9.36
26	Unnao	8.88	6.94	6.72	8.10	13.36	6.86	9.54	10.42	5.65	6.20	6.12	6.83
27	Lucknow	2.37	6.35	3.98	6.59	8.51	6.36	3.66	9.56	7.29	5.36	5.61	6.65
28	Rae Bareli	4.93	2.71	3.37	4.68	7.29	2.55	3.67	6.50	3.37	3.35	4.64	4.29
29	Fatehpur	10.01	3.14	4.53	8.46	16.88	7.37	7.02	13.65	7.98	5.77	7.35	9.31
30	Allahabad	4.92	3.97	3.48	8.63	6.45	5.11	9.28	9.64	4.15	3.58	7.95	6.34
31	Jhansi	16.61	8.53	23.34	48.34	24.26	14.60	26.50	61.97	9.45	10.07	7.41	18.69
32	Lalitpur	10.37	3.49	27.55	14.38	10.98	26.17	19.07	27.55	6.48	20.15	12.60	17.24
33	Banda	6.58	8.92	5.29	12.38	16.11	13.46	10.21	25.99	10.69	9.96	9.32	19.24
34	Hamirpur	22.75	13.78	41.73	53.64	27.65	16.07	42.67	60.81	9.98	7.89	11.55	21.16
35	Jalaun	21.95	25.91	30.27	29.23	23.75	30.17	32.15	37.58	16.86	8.55	7.99	25.24
36	Gonda	8.87	4.50	1.59	9.26	6.63	7.82	5.06	7.27	5.62	9.09	6.15	8.16
37	Baharaich	4.31	2.57	0.81	5.29	9.50	4.20	4.19	6.93	5.85	5.35	4.52	5.60
38	Basti	1.44	1.23	2.18	1.94	8.00	9.83	11.04	10.34	6.80	9.96	9.29	10.04
39	Gorakhpur	4.66	1.13	0.44	3.24	5.13	4.29	11.11	8.39	5.05	3.69	11.40	8.39
40	Deoria	13.27	1.53	1.83	9.66	16.97	2.70	12.63	13.44	5.84	3.27	11.46	8.72
41	Maharajganj Nagar	0.76	0.62	0.87	0.91	2.30	3.06	1.40	5.30	2.67	3.03	2.01	5.23
42	Sidharthnagar	3.53	2.05	1.79	4.56	10.75	17.27	4.80	14.48	9.31	16.84	6.08	13.17
43	Barabanki	2.73	3.89	2.24	4.59	3.43	12.17	6.81	10.95	2.51	9.17	5.62	9.09
44	Faizabad	3.53	4.38	1.45	4.47	7.36	7.58	7.64	8.65	4.33	4.83	6.82	5.73
45	Sultanpur	1.30	3.77	2.70	2.86	7.62	3.73	13.84	10.11	6.84	3.70	11.71	9.06
46	Pratapgarh	2.53	1.92	5.34	4.14	4.56	5.42	4.05	6.09	3.09	4.57	6.74	6.04
47	Jaunpur	4.56	2.47	1.75	4.73	5.22	9.87	5.26	8.79	2.72	8.43	5.06	7.92
48	Ajamgarh	3.17	2.05	1.43	2.64	6.85	12.70	5.54	10.46	4.89	12.17	4.47	10.13
49	Balia	2.16	3.31	3.52	4.61	6.63	15.71	9.08	16.56	6.18	16.93	8.45	15.85
50	Ghazipur	5.26	4.90	2.24	6.61	11.47	10.42	5.48	9.76	6.94	10.23	4.22	7.60
51	Varanasi	5.84	5.01	1.91	6.62	7.72	8.35	3.03	10.70	3.43	8.52	2.36	10.27
52	Mau	3.73	3.17	1.44	3.65	9.21	9.93	10.18	13.08	5.80	9.62	10.37	11.24
53	Mirzapur	2.66	4.15	3.99	7.77	6.41	10.70	8.77	17.40	4.91	9.75	6.47	13.52
54	Sonbhadra	4.20	17.57	8.09	25.83	14.43	14.20	11.39	40.09	11.89	12.72	11.41	22.22
55	Uttarkashi	5.25	9.84	3.12	9.12	6.47	13.36	6.93	11.16	3.36	4.71	4.77	5.10
56	Chamoli	5.47	4.99	0.82	9.35	7.75	9.85	2.22	11.36	3.39	6.03	2.04	4.27
57	Pauri- Garhawal		1.84	1.45	4.91		3.68	2.90	5.68		4.21	1.86	3.05
58	Tehri - Garhawal	5.28	4.26	2.33	7.99	5.02	7.64	3.76	9.56	2.09	5.99	2.17	6.17
59	Dehradun	3.77	0.36	2.09	3.67	8.56	2.73	3.05	6.75	9.93	2.65	3.65	5.83
60	Pithoragarh	11.44	2.89	2.05	7.40	15.27	3.03	2.04	9.54	5.52	1.87	1.78	3.96
61	Almora	3.00	2.17	2.03	4.33	5.40	8.35	3.31	5.89	2.93	6.81	2.86	5.07
62	Nainital	23.50	2.28	2.13	14.31	2.44	2.75	0.84	6.40	21.59	2.72	2.36	11.56
63	Haridwar	3.05	7.81	10.04	12.34	4.15	10.33	10.13	14.36	5.81	3.40	3.01	6.33
	State	1.78	2.05	1.72	2.43	4.08	4.86	5.17	5.44	2.55	3.43	4.96	4.85

P-I: Period I (1990-91 to 1999-2000); P-II: Period II (2000-01 to 2009-10); P-III: Period III (2010-11 to 2019-20); P-IV: Period IV (1990-91 to 2019-20)

A: Area; P: Production; Y: Yield

The Cuddy-Della Valle Index for area, production and yield of rice is presented in Table 2. During period I, highest instability for area (71.35%) and production (62.80%) was observed in Agra. Similar trend was observed for growth rate also. Highest instability for yield (21.59%) was recorded in Nainital district. Lowest instability for area (0.76%), production (2.18%) and yield (2.08%) was recorded in Maharajaganj Nagar, Shajahanpur and Badaun districts respectively.

During period II, highest instability for area (25.91%) and production (30.17%) was recorded in Jalaun and for yield (20.15%) was observed in Lalitpur. Lowest instability for area (0.36%), production (2.43%) and yield (1.25%) was recorded in Dehradun, Pilibheet and Bijnor districts respectively.

During period III, highest instability for area (41.73%) and production (42.67%) was observed in Hamirpur, and highest instability for yield (12.60%) was recorded in Lalitpur district. Lowest instability for area, production and yield was recorded in Gorakhpur, Nainital and Bulandshahar districts respectively followed by Baharaich, Maharajajang Nagar and Shahajahanpur districts respectively.

During the overall period IV, highest instability for area, production and yield was recorded in Hamirpur, Jhansi and Jalaun districts respectively followed by Jhansi, Hamirpur and Sonbhadra districts. Lowest instability for area (0.91%), production (4.13%) and yield (3.05%) was observed by Maharajganj Nagar, Pilibeet and Pauri-Garhawal districts respectively.

Instability for area varies from 0.36 to 71.35 percent, instability for production varies from 0.84 to 62.60 and instability for yield varies between 1.25 to 25.24 percent across the districts and periods. The range of instability for the state is observed to be very narrow. The instability for area ranges from 1.72 to 2.43 percent, instability for production ranges from 4.08 to 5.44 percent and instability for yield was varies from 2.55 to 4.96 percent.

Classification of Instability Index
The districts have been classified as very low instability, low instability, medium instability, high instability and very high instability based on the instability value of the area, production and yield of rice in Uttar Pradesh (including Uttarakhand). For area, maximum numbers of districts were classified under very low instability during period I, II and III followed by low instability and medium instability during the same periods. During period IV, highest numbers of districts were classified as low instability districts followed by low instability and then medium instability. The districts classified as high and very high instability are very less or negligible.

For production, maximum numbers of districts were classified as low instability during all the periods followed by very low instability during period I, II, III and medium instability during period IV. Very less or negligible districts were classified as high instability or very high instability during all the periods.

For yield, highest numbers of districts were classified as low instability during period I (32) and period IV (47); very low instability during period II (33) and period III (32). Second highest districts were classified as very low instability during period I (28) and period IV (9); low instability during period II (27) and period III (31). None of the districts were classified as high instability or very high instability during all the periods.
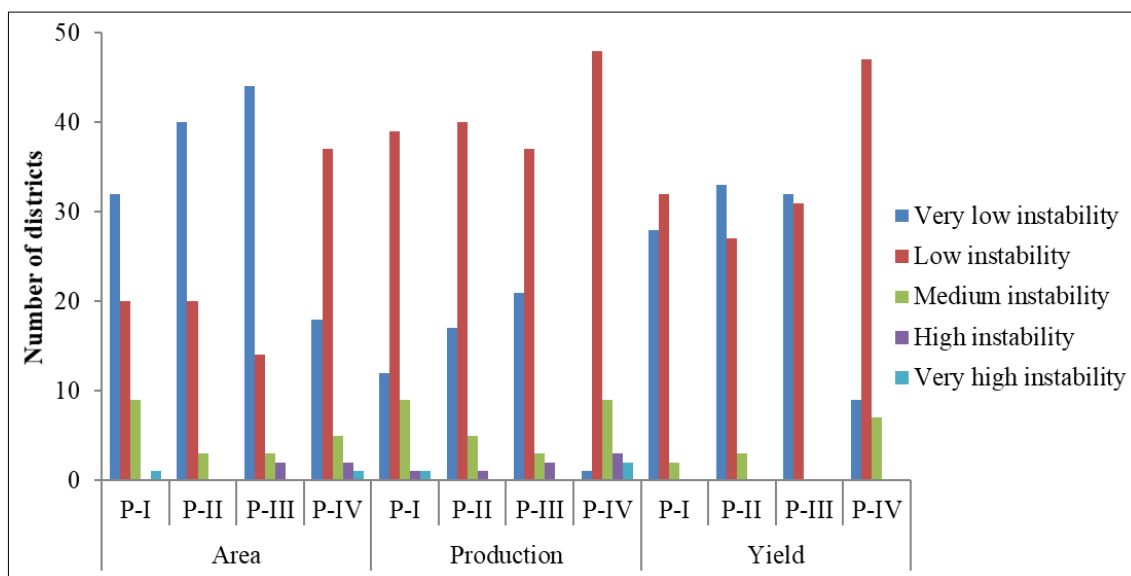
P-I: Period I (1990-91 to 1999-2000); P-II: Period II (2000-01 to 2009-10); P-III: Period III (2010-11 to 2019-20); P-IV: Period IV (1990-91 to 2019-20)

Fig 2: Number of districts under each instability class for area, production and yield of rice during four periods in Uttar Pradesh (including Uttrakhand)

Conclusion
The study revealed that, for the state as a whole growth rate for area, production and yield was negative during period II while it was positive for all other three periods. The highest growth rate for area (0.44), production (2.38) and yield (1.94) was observed during period I. For the state, very low

instability was recorded for area and yield for all the four periods. The instability for area ranged from 1.72 during period III to 2.43 during period IV, instability for yield varies between 2.55 in period I to 4.96 in period III. For yield, two districts recorded very low instability during period I (4.08) and II (4.86) while two districts observed low instability

during period III (5.17) and IV 5.44). The study will helpful for researchers, policy makers and other rice stakeholders of the states for deciding their agricultural policy and effective implementation of agricultural policy in various districts of Uttar Pradesh and Uttarakhand states. Different policies can be modified and reoriented as per the requirement and need of the rice stakeholders of these states.

Acknowledgements

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