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Research Paper

Decomposition of production growth and identification of efficient cropping zones for major pulse crops in Uttar Pradesh and Uttarakhand

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ABSTRACT

The study's goal is to decompose pulse production growth in Uttar Pradesh and Uttarakhand and identify efficient copping zones for both states. The total change in production was decomposed into three effects, i.e., the area effect (ΔA. Y0), the yield effect (ΔY. A0.), and the interaction effect (ΔA. ΔY). The relative spread index (RSI) and relative yield index (RYI) were computed to identify the potential cropping districts for different pulses grown in Uttar Pradesh and Uttarakhand. We classified districts into four zones: most efficient, efficient, not efficient, and highly inefficient. A higher RYI corresponds to higher yield districts, and a higher RSI indicates a more cultivated area. Districts with a high relative spread index and a low relative yield index indicate that a particular pulse is not suitable for that district. We suggest addressing production issues through research, marketing, and extension services to enhance the productivity level of pulse crops. The results from Uttar Pradesh are highly encouraging, indicating that the yield effect has primarily contributed to the growth in pulse production. The government's policies, schemes, and initiatives to promote pulse production and decrease imports are moving in the right direction. According to the methodological analysis, 57 districts are among the most efficient cropping zones for all selected pulse crops in Uttar Pradesh. In the case of Uttarakhand, for all selected pulses, 20 percent of districts come under the most efficient cropping zone, and 20 percent of districts come under the most efficient cropping zone. The highest 40 percent of districts fell under highly inefficient cropping zones. Lack of high-quality inputs, technology adoption, and poor market and extension services may be the reasons for low productivity in these districts. An increase in productivity with low costs could help the country reduce imports of pulses and check the flow of foreign currency.

Key words: Decomposition analysis, Relative Spread Index (RSI), Relative Yield Index (RYI), Pulses

INTRODUCTION

Agriculture in India stands as a cornerstone of its economy, providing livelihoods for a significant portion of the population and ensuring food security across the nation. Two key states in northern India, Uttar Pradesh, and Uttarakhand, play pivotal roles in agricultural production, particularly in the cultivation of major pulse crops. In Uttar Pradesh, the 2380-thousand-hectare area is occupied by the pulses with 2476-thousand-ton production (GoI 2022). In Uttarakhand, pulses are cultivated only on 63 thousand hectares of area and produce merely 61 million tone pulses (Agriculture 2021). The contribution of Uttar Pradesh is about ten percent in the production and more than eight percent in the area to national production and cultivated area under pulses. The share of Uttarakhand in the area and production of pulses is less than one percent (GoI 2021).

Pulses are crucial for both nutritional security and economic sustainability, making the productivity and efficiency of their cultivation a matter of paramount importance. The production of total pulses in both the selected states has been registering improvement in recent decades. A myriad of factors influences production growth in pulse crops. These include the expansion of cultivated areas, technological advancements, access to quality seeds, efficient irrigation systems, soil fertility management, and pest and disease control measures. A comprehensive analysis of these factors is essential to understand their

contributions to production growth and to devise strategies for sustainable agricultural development. The high level of fluctuation in production and prices may divert farmers from pulse production to other cash crops like cotton and sugarcane (GoI 2018). Therefore, it is important to decompose the production growth of pulses into area, yield, and interaction effect.

To study the district-wise scenario of production growth, it is important to identify the efficient cropping zone for different pulse crops of the study area. The identification of potential cropping zones would be helpful for enhancement and sustainable productivity. This information allows using the natural resources to the maximum extent possible without any degradation (Agriculture 2021). Kokilavani and Geethalakshmi (2013) delineated efficient cropping zones for rice, maize, and groundnut in Tamil Nadu (Kokilavani and Geethalakshmi 2013). Delineation of Efficient Cropping Zone for Sugarcane over the Southern Indian States was reported by Gowtham *et. al.* (2019). Yadu and Das (2021) identified efficient cropping zones for major field crops in 27 districts of Chhattisgarh (Gowtham *et al.* 2019). In the present study, we have identified efficient cropping zones for all 75 districts of Uttar Pradesh and 13 districts of Uttarakhand for all major pulse crops.

In recent years, studies by Prabhakar (Kumar *et al.* 2003) on the economics of pulse production in the Bundelkhand region and Devegowda (Kumari *et al.* 2018) on growth trends in major pulses in India have provided valuable insights into current challenges, opportunities, and policy implications. These studies emphasize the significance of efficient cropping zones, technological advancements, market linkages, and policy support for enhancing pulse crop production, profitability, and sustainability. Minhas and Vaidyanathan conducted a decomposition analysis to assess the contribution of different factors to crop output growth, shedding light on the roles of area expansion, yield improvements, and cropping pattern changes (Minhas and Vidhyanathan 1965). Their findings underscored the importance of holistic approaches to agricultural growth. Similarly, Shetty (1970) and Narula and Vidyasagar (1973) focused on the roles of area, yield, and cropping patterns in production growth, emphasizing the need for technological interventions and policy measures to enhance productivity and sustainability (Shetty 1970, Narula and Sagar 1973).

This study contributes valuable insights and data-driven strategies for sustainable agriculture and food production in India. By examining the factors influencing production growth and identifying efficient cropping zones, the study can inform policymakers, researchers, and farmers about optimizing agricultural practices, resource allocation, and policy formulation. Understanding the dynamics of production growth and efficiency is crucial for addressing challenges such as food security, environmental sustainability, and economic development in the agricultural sector. This study delves into the decomposition of production growth and the identification of efficient cropping zones for major pulse crops in these states, aiming to provide insights into enhancing agricultural sustainability, productivity, and economic well-being.

MATERIALS AND METHODS

The data on the area and production of chickpea, pigeonpea, lentil, green gram, and black gram for all districts of Uttar Pradesh and Uttarakhand were collected from the Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, New Delhi.

Decomposition analysis

Decomposition analysis was carried out to estimate the percentage contribution of area, yield, and the interaction of area and yield in increasing production of pulses (Minhas and Vidhyanathan 1965). The total change in production was decomposed into three effects i.e. area effect ($\Delta A. Y_0$), yield effect ($\Delta Y.A_0$.), and the interaction effect ($\Delta A.\Delta Y$) and represented through the following additive scheme of decomposition;

$$\Delta P = \Delta A. Y_0 + \Delta Y. A_0 + \Delta A. \Delta Y$$

Where,

ΔP = Differences in average triennium production over two periods i.e. 2004-05 to 2006-07 and 2018-19 to 2020-21

A_0 = Average area of triennium 2004-05 to 2006-07

Y_0 = Average yield of triennium 2004-05 to 2006-07

ΔA = Change in the average area between two periods

ΔY = Change in average yield between two periods

Relative Spread Index and Relative Yield Index were computed to identify the efficient cropping zones for selected pulses using Kanwar (1972) formula (Kanwar 1972).

2.2 Relative Spread Index (RSI)

$$RSI = \frac{Area\ of\ particular\ crop\ expressed\ as\ \%\ of\ total\ cultivable\ area\ in\ the\ district}{Area\ of\ crop\ expressed\ as\ percentage\ to\ the\ total\ cultivable\ area\ in\ the\ state} \times 100$$

2.3 Relative Yield Index (RYI)

$$RYI = \frac{Mean\ yield\ of\ \ a\ particular\ crop\ in\ the\ district\ \left(\frac{kg}{ha}\right)}{Mean\ yield\ of\ the\ crop\ in\ the\ state\left(\frac{kg}{ha}\right)} \times 100$$

Table 1. Criteria for efficient cropping zone

RSI	RYI	Cropping Zone
>100(High)	>100(High)	Most Efficient Cropping Zone (MECZ)
<100(Low)	>100(High)	Efficient Cropping Zone (ECZ)
>100(High)	<100(Low)	Not Efficient Cropping Zone (NECZ)
<100(Low)	<100(Low)	Highly Inefficient Cropping Zone (HICZ)

RESULTS AND DISCUSSION

Decomposition analysis

The results for Uttar Pradesh showed that growth in pulse production was mainly contributed by the yield effect. The production of pulses namely chickpea, lentil, and black gram has increased due to yield parameters like improved seeds, enhancement of technology, innovations, improved practices, and infrastructural improvements. In the case of pigeonpea, the area effect is higher than the yield effect indicating that the production increase was solely due to area expansion. All three effects are positive for black gram and green gram. The area effect and yield effect shared almost equal (46%) contributions in the case of green gram. The interaction effect came positive for pigeon pea, black gram, and green gram for Uttar Pradesh. The contribution of area effect, yield effect, and interaction effect is 26%, 70.4%, and 3.6% respectively for black gram production in Uttar Pradesh (Table 2).

The area effect is positive and significantly contributed to the production growth of almost all selected pulses in Uttarakhand. The area effect is positive and higher than the yield effect for chickpeas, pigeonpea, and black gram. For total pulses and lentils, the yield effect is higher than the area effect. The production of lentils increased due to the yield effect only. The contribution of the interaction effect is as high as 82% for the black gram in the state.

Identification of cropping zone

The districts with high RSI and high RYI come under the most efficient cropping zone, with low RSI and high RYI fall under the efficient cropping zone, with high RSI and low RYI classified under not efficient cropping zone, and with low RSI and low RYI found to be highly inefficient cropping zone for Uttar Pradesh. The most efficient cropping zone share ranges from 8 to 25 percent for different pulse crops (Figure 1). The contribution of efficient cropping zone ranges from as low as 16% for piegonpea and as high as 67% for black gram. The share of efficient cropping zone is lower than the not efficient zone for chickpea and pigeon pea which implies both of these pulse crops occupied larger cultivated areas but yield is low. The use of better and innovative technologies, and improved market and extension services could bring these zones to efficient zones. For lentils, green gram, and black gram the share of efficient zones is more than the share of not efficient zones implying lower areas under cultivation produce higher yields.

Efficient cropping zone for chickpea

A high relative spread index (RSI) is the indicator to identify the districts with highly cultivated areas under a particular crop. It is found that the calculated relative spread index for chickpeas was maximum in the Chitrakoot district followed by the Hamirpur, Banda, Mahoba, and Jhansi districts (Table 3). Higher RSI shows that natural and climatic conditions are favorable to cultivating chickpeas in these districts. Agra recorded the maximum relative yield index (RYI) followed by Firozabad, Mainpuri, Mathura, and

Table 2. Decomposition of production growth of major pulses in Uttar Pradesh and Uttarakhand

Pulses	Uttar Pradesh			Uttarakhand		
	Area Effect	Yield Effect	Interaction Effect	Area Effect	Yield Effect	Interaction Effect
Chickpea	-58.07	188.67	-30.60	83.45	27.59	-11.04
Pigeonpea	145.47	-64.25	18.78	80.29	8.76	10.95
Lentil	-645.76	970.86	-225.10	-103.78	291.88	-88.10
Black gram	26.00	70.38	3.62	156.89	-139.07	82.18
Green gram	46.14	46.12	7.74	---	---	---
Total Pulses	-130.23	270.70	-40.47	19.49	69.95	10.56

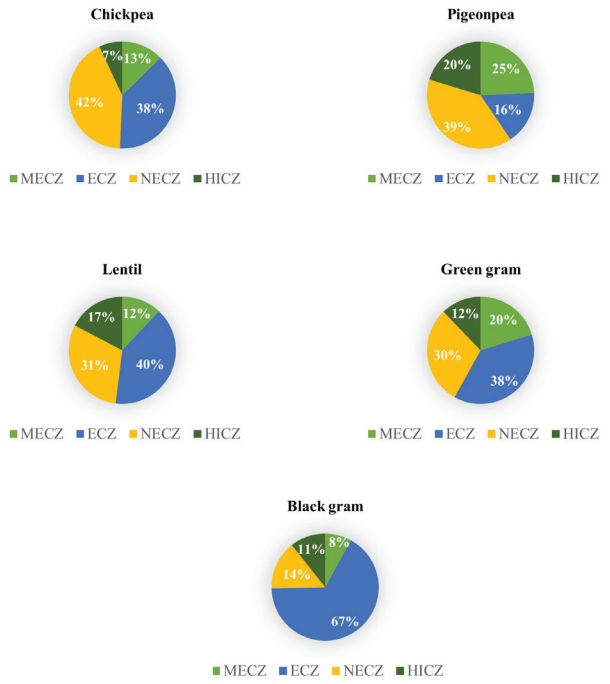

Fig. 1. Distribution of potential cropping zone for different pulse crops in Uttar Pradesh

Ghazipur districts. Higher RYI indicates that productivity is higher in these districts.

The analysis of chickpea area and productivity data showed that nine districts namely Fatehpur, Jalaun, Jhansi, Kanpur Dehat, Kanpur Nagar, Kaushambi, Lalitpur, Merzapur, Sonbhadra were the districts which recorded high RSI and high RYI and classified as Most Efficient Cropping Zone (MECZ) for chickpea cultivation in Uttar Pradesh (Table 4). The districts such as Agra, Aligarh, Auraiya, Azamgarh, Bahraich, Ballia, Balrampur, Bulundshahr, Chandauli, Etawah, Farrukhabad, Firozabad, Ghazipur, Gonda, Hapur, Jaunpur, Kannauj, Mainpuri, Mathura, Mau, Rampur, Sant Ravidas Nagar, Shamli, Shravasti, Siddhart Nagar, Unnao, and Varanasi fell under Efficient Cropping Zone (ECZ) with high RYI and low RSI values. Allahabad, Banda, Chirakoot, Hamirpur, and Mahoba districts registered high RSI and low RYI values and come under the Not Efficient Cropping Zone (NECZ) whereas the remaining districts namely Ambedkar Nagar, Amethi, Bagpat, Barabanki, Bareli, Basti, Bijnor, Budaun, Deoria, Faizabad, Gorakhpur, Hardoi, Hatras, Kashganj, Kheri, Kausinagar, Lucknow, Maharazganj, Meerut, Muradabad, Muzaffarnagar, Pilibhit, Partapgarh, Rae Bareli, Saharanpur, Sambal, Sant Kabeer Nagar, Sahajahanpur, Sitapur, and Sultanpur district fell under Highly-Inefficient Cropping Zone (HICZ) where both RSI and RYI values were below 100 percent. In Uttar Pradesh, the study found that nine districts come under MECZ, twenty-seven districts under ECZ, five districts under NECZ and thirty districts under HICZ for chickpea pulse crop. Four districts could not be classified due to insufficient data availability.

Efficient cropping zone for pigeonpea

The data of the relative yield spread index for pigeonpea showed that among all districts, the RYI was maximum in Kanpur Nagar followed by Etawah, Kanpur Dehat, Sant Ravidas Nagar and Sitapur. Higher RYI shows those districts have higher yields in comparison to other districts. The relative spread index was recorded maximum for Chitrakoot and followed by Sonbhadra, Mirzapur, Kaushambi, and Hamirpur (Table 3). Higher RSI indicates that these districts covered more area under pigeonpea.

The analysis of the identification of the potential zone of pigeonpea revealed that Allahabad, Auraiya, Azamgarh, Ballia, Banda, Chandauli, Ghazipur, Jalaun, Jaunpur, Kanpur Dehat, Kanpur Nagar, Kaushambi, Mau, Mirzapur, Pratapgarh, Sant Ravidas Nagar, Sultanpur, and Varanasi districts of Uttar Pradesh registered high RSI and high RYI and classified as the Most Efficient Cropping Zone (MECZ). The districts such as Agra, Ambedkar Nagar, Etah, Etawah, Faizabad, Farrukhabad, Firozabad, Hapur, Kannauj, Mainpuri, Sitapur, and Unnao fell under the Efficient Cropping Zone (ECZ) with high RYI and low RSI values. Aligarh, Amethi, Balrampur, Bulandshahr, Chitrakoot, Deoria, Fatehpur, Gautam Buddha Nagar, Gonda, Hamirpur, Hathras, Mahoba, Rae Bareli, Sant Kabeer Nagar, and Sonbhadra, comes under Not Efficient Cropping Zone (NECZ) where the districts registered high RSI and low RYI values. Amroha, Baghpat, Bahraich, Barabanki, Bareilly, Basti, Bijnor, Budaun, Ghaziabad, Gorakhpur, Hardoi, Jhansi, Kashganj, Kheri, Kaushi Nagar, Lalitpur, Lucknow, Maharajganj, Mathura, Meerut, Moradabad, Mazaffarnagar, Pilibhit, Rampur, Sambal, Shahjahanpur, Shamli, Shravasti, Siddharth Nagar district fell under Highly-Inefficient Cropping Zone (HICZ) where both RSI and RYI values were below 100 percent (Table 4). In the case of pigeonpea, 18 districts come under MECZ, 12 districts under ECZ, 15 districts under NECZ and 29 districts under HICZ for Uttar Pradesh.

Table 3. Computed value of RSI and RYI for major pulse crops in all districts of Uttar Pradesh (2010-11 to 2019-20)

Districts	Chickpea		Pigeonpea		Lentil		Green gram		Black gram	
	RSI	RYI	RSI	RYI	RSI	RYI	RSI	RYI	RSI	RYI
Agra	12.84	166.87	16.98	107.72	9.02	135.11	31.82	116.55	2.82	96.84
Aligarh	0.18	103.18	149.94	90.69	15.09	143.53	213.81	97.64	6.90	104.31
Allahabad	140.53	94.48	253.90	107.91	95.39	81.99	202.64	126.94	33.56	124.25
Ambedkar Nagar	22.87	99.65	78.92	103.38	8.25	87.58	23.79	86.78	35.07	99.66
Amethi	52.48	99.96	124.25	91.61	41.81	87.57	72.31	81.47	145.46	89.62
Amroha	---	---	12.08	91.54	1.57	106.90	4.63	66.90	50.30	153.12
Auraiya	96.30	136.23	111.36	119.87	0.82	100.39	336.74	142.42	43.49	154.58
Azamgarh	29.15	126.21	141.58	108.15	2.95	146.25	3.67	124.18	3.09	107.31
Baghpat	0.10	93.02	34.82	95.38	2.90	99.67	10.21	120.88	19.13	122.90
Bahraich	1.99	101.36	63.14	57.91	483.68	115.46	2.87	124.73	14.78	103.59
Ballia	39.94	152.44	142.92	104.03	285.28	146.32	15.10	120.34	0.78	117.01
Balrampur	7.49	100.96	222.33	58.43	416.84	102.60	0.13	62.50	19.90	98.76
Banda	875.17	81.70	355.98	113.25	397.95	75.22	210.64	67.85	44.17	76.19
Barabanki	6.01	99.68	27.76	92.60	114.27	92.83	6.71	80.51	82.15	86.14
Bareilly	0.20	95.73	5.37	88.28	42.02	120.91	0.25	49.50	56.13	138.01
Basti	13.12	93.47	89.79	75.50	34.63	99.99	6.35	131.06	5.79	104.47
Bijnor	0.38	97.42	0.24	90.27	10.84	113.21	1.17	118.51	19.68	156.61
Budaun	0.36	94.07	9.87	89.30	34.67	146.97	7.79	76.09	250.08	166.25
Bulandshahr	0.42	107.27	141.27	79.72	10.25	100.01	97.58	116.84	15.35	124.33
Chandauli	28.75	115.56	113.90	102.16	217.67	91.79	10.15	130.28	2.25	123.90
Chitrakoot	1118.61	80.11	711.20	87.71	509.14	63.15	279.58	55.20	38.11	68.15
Deoria	2.27	98.34	126.64	70.57	8.13	83.26	8.14	131.03	0.14	106.17
Etah	---	---	65.43	110.78	36.26	143.54	334.40	132.17	17.22	113.78
Etawah	33.06	127.74	71.11	179.67	0.17	96.92	601.78	146.45	25.88	142.02
Faizabad	28.83	99.66	58.86	103.38	45.88	89.34	57.06	83.03	68.67	83.42
Farrukhabad	14.84	127.73	48.21	120.11	30.62	97.81	122.37	131.55	58.28	142.30
Fatehpur	466.69	107.73	360.12	96.22	11.61	80.25	396.18	119.46	83.29	104.42
Firozabad	7.46	166.74	34.21	103.75	0.76	134.88	147.56	130.26	20.65	154.25
Gautam Buddha Nagar	---	---	158.59	99.46	3.56	100.95	119.64	137.99	3.33	119.81
Ghaziabad	---	---	86.50	92.39	3.80	99.84	14.68	131.88	9.71	125.75
Ghazipur	48.33	156.26	119.64	105.77	126.55	123.29	24.71	140.14	13.25	124.42
Gonda	7.34	101.02	106.04	60.29	170.98	104.56	13.99	124.13	12.18	107.07
Gorakhpur	6.71	98.55	84.73	67.80	16.93	83.26	6.30	129.64	0.49	109.70
Hameczrpur	979.94	82.38	363.83	94.94	441.44	79.08	401.81	61.29	229.42	71.87
Hapur	0.01	104.67	50.24	101.36	8.39	101.47	54.98	114.75	26.42	125.38
Hardoi	5.14	84.79	21.15	83.55	64.44	112.97	14.25	91.82	167.91	105.73
Hathras	0.28	96.28	143.75	94.02	11.12	143.57	184.26	113.21	3.56	114.33
Jalaun	406.15	112.85	104.30	100.61	363.72	124.03	87.44	96.63	82.39	91.12
Jaunpur	46.77	137.72	195.40	101.28	3.45	107.68	53.36	145.50	65.73	139.18
Jhansi	495.85	106.76	30.87	67.84	277.70	91.94	346.02	54.52	541.56	63.95
Kannauj	18.51	127.73	48.85	120.13	4.14	100.37	140.89	114.51	30.67	153.00
Kanpur Dehat	220.73	125.33	221.63	169.45	7.46	100.15	99.24	123.24	92.59	130.90
Kanpur Nagar	286.35	125.41	177.82	181.71	15.60	105.12	136.42	117.19	133.76	110.35
Kasganj	0.63	97.47	50.19	98.93	30.03	143.57	143.91	106.18	24.49	115.11
Kaushambi	252.57	104.73	367.58	117.93	4.57	79.84	88.85	126.14	32.49	113.42
Kheri	1.35	84.66	12.23	83.50	110.31	101.88	31.74	87.64	21.33	133.12
Kushi Nagar	0.07	90.75	20.16	68.29	55.20	83.27	14.92	130.63	2.17	116.41
Lalitpur	179.80	123.71	0.53	67.02	214.53	127.25	363.10	78.01	1501.34	93.71
Lucknow	21.18	84.85	29.19	83.54	53.03	108.83	34.11	89.07	145.14	89.75
Maharajganj	0.43	86.30	9.81	68.26	137.56	81.77	5.22	132.08	0.87	111.60
Mahoba	830.69	80.47	109.01	81.29	449.19	60.52	859.02	47.42	732.09	65.59
Mainpuri	13.16	166.73	24.49	107.74	1.73	135.16	322.21	176.64	23.48	159.74
Mathura	0.72	162.98	48.32	99.92	0.82	134.83	143.10	114.71	1.88	96.60
Mau	31.55	126.12	102.41	107.37	8.45	146.28	11.06	131.42	0.62	115.86
Meerut	0.55	93.48	29.11	95.36	7.76	100.03	12.15	114.16	20.08	126.97
Mirzapur	213.60	113.91	371.44	100.65	102.20	95.03	11.44	67.94	11.12	130.57
Moradabad	0.54	93.44	4.29	92.17	11.71	106.98	4.94	73.05	90.16	154.01
Muzaffarnagar	0.63	99.21	1.40	79.75	4.74	89.89	5.02	128.62	19.23	115.08
Pilibhit	0.25	94.78	0.59	91.19	27.02	117.24	1.36	134.71	2.15	135.44
Pratapgarh	49.99	98.74	172.29	110.09	1.40	79.60	131.25	102.31	135.27	113.41
Rae Bareli	75.86	75.22	131.44	67.40	1.08	94.48	103.57	87.93	201.48	60.56
Rampur	0.02	126.70	2.84	95.09	18.92	111.40	0.87	71.07	52.22	157.83
Saharanpur	0.14	96.38	0.00	0.00	23.47	89.83	0.56	120.56	29.09	114.73
Sambhal	0.03	82.28	9.06	94.33	12.44	105.18	15.82	63.29	143.06	159.66
Sant Kabeer Nagar	9.35	97.25	127.24	75.54	30.38	99.98	0.33	75.83	0.21	100.23
Sant Ravidas Nagar	34.30	102.07	359.75	129.78	0.16	111.94	8.68	119.53	32.35	122.77
Shahjahanpur	0.67	96.74	4.97	88.63	196.23	115.62	6.34	91.29	70.12	113.83
Shamli	0.44	127.33	0.05	92.16	1.88	97.87	4.97	123.05	25.01	117.45
Shravasti	2.53	101.10	89.27	56.63	524.98	86.68	0.40	130.81	11.32	99.09
Siddharth Nagar	0.15	108.89	51.72	75.51	50.56	99.99			2.73	98.27
Sitapur	3.82	84.86	42.99	128.51	149.71	84.65	1.95	85.64	88.93	103.74
Sonbhadra	239.91	114.70	410.91	92.60	251.09	85.82	4.81	77.47	59.17	120.66
Sultanpur	51.53	95.99	179.02	111.61	100.69	98.57	77.23	87.24	101.15	97.74
Unnao	28.51	106.18	43.12	100.09	7.90	87.67	288.95	89.08	265.99	102.40
Varanasi	63.45	128.41	231.89	100.04	10.43	96.67	60.08	85.89	60.19	123.35

Efficient cropping zone for lentil

The data of the relative yield spread index for lentils indicated that among all 75 districts, the RYI was maximum in Budaun followed by Ballia, Mau, Azamghar and Hathras. The relative spread index was recorded maximum for Shravasti and followed by Chitrakoot, Bharaich, Mahoba, and Hamirpur.

The examination of lentil crop area and productivity data observed that the Most Efficient Cropping Zone (MECZ) was found in Bahraich, Ballia, Balrampur, Gazipur, Gonda, Jalun, Kheri, Lalit Pur, and Sahajahanpur districts of Uttar Pradesh. The districts such as Agra, Aligarh, Amorha, Auraiya, Azamgarh, Bareilly, Bijnor, Budaun, Bulandsahar, Etah, Firozabad, Gautam Buddha Nagar, Hapur, Hardoi, Hathrs, Jaunpur, Kannauj, Kanpur Dehat, Kanpur Nagar, Kashganj, Lucknow, Mainpuri, Mathura, Mau, Meerut, Muradabad, Pilibhit, Rampur, Sambal, Santravi Das Nagar fell under Efficient Cropping Zone (ECZ) with high RYI and low RSI values. Banda, Barabanki, Chandauli, Chitrakoot, Hamirpur, Jhansi, Marajganj, Mahoba, Mirzapur, Sarasvasti, Sitapur, Sonbhadra, Sultanpur come under Not Efficient Cropping Zone (NECZ) where the districts registered high RSI and low RYI values. Allahabad, Ambedkar Nagar, Amethi, Baghpat, Basti, Deoria, Etawah, Faizabad, Farrukhabad, Ghaziabad, Gorakhpur, Kheri, Kaushi Nagar, Muzzafarnagar, Paratapgarh, Rai Bareli, Saharanpur, Sant Kabeer Nagar, Shamli, Siddharth Nagar, Unnao, and Varanasi district fell under Highly-Inefficient Zone (HICZ) where both RSI and RYI values were below 100 percent. In context to Uttar Pradesh, 9 districts come under MECZ, 30 districts under ECZ, 13 districts under NECZ, and 23 districts under HICZ for lentil crops.

Efficient cropping zone for green gram

The data of the relative yield spread index for green gram indicated that RYI was maximum in Mahoba followed by Etawah, Hamirpur, Fatehpur, and Lalitpur whereas the relative spread index was recorded as maximum for Mainpuri, followed by Etawah, Jaunpur, Auraiya, and Ghazipur. It is interesting to observe that Etawah district registered higher RYI and higher RSI for green gram.

Allahabad, Auraiya, Etah, Etawah, Farukkhabad, Fatehpur, Firozabad, Gautam Buddha Nagar, Hathras, Kannauj, Kanpur Nagar, Kashganj, Mainpuri, Mathura, and Partapgarh district of Uttar Pradesh observed high RSI and high RSI and classified into the Most Efficient Cropping Zone (MECZ). The districts such as Agra, Azamgarh, Baghpat, Bahrich, Ballia, Basti, Bijnor, Bulundsahar, Chaundauli, Deoria, Ghaziabad, Gajipur, Gonda, Gorakhpur, Hapur, Jaunpur, Kanpur Dehat, Kaushambi, Kushi Nagar, Marahjganj, Mau, Meerut, Muzzafarnagar, Pilibhit, Saharanpur, Sant Ravi Das Nagar, Shamli, Saravasti come under Efficient Cropping Zone (ECZ) class with high RYI and low RSI values. Aligarh, Banda, Chitrakoot, Hamirpur, Jhansi, Lalitpur, Mahoba, Rai Bareli, Unnao, and come under Not Efficient Cropping Zone (NECZ) with high RSI and low RYI values. Ambedkar Nagar, Amethi, Amroha, Balrampur, Barabanki, Bareilly, Bundau, Faizabad, Hardoi, Jaluan, Kheri, Lucknow, Mirzapur, Muradabad, Rampur, Sambal, Sant Kabeer Nagar, Sahajanpur, Sitapur, Sonbhadra, Sultanpur and Varanasi district fell under Highly-Inefficient Cropping Zone (HICZ) where both RSI and RYI values were below 100 percent. In the case of green gram, 15 districts come under MECZ, 28 districts under ECZ, 9 districts under NECZ and 22 districts under HICZ and Siddharatnagar district could not be classified due to lack of negligible data.

Efficient cropping zone for black gram

Budaun district recorded the maximum RYI for black gram which was followed by Manipur, Sambhal, Rampur, and Bijnor. The relative spread index was recorded maximum for Lalitpur and followed by Mahoba, Jhansi, Unnao, and Budaun. Budaun district figures out in in top five districts with maximum RYI and maximum RSI (Table 3).

The Most Efficient Cropping Zone (MECZ) includes Budaun, Hardoi, Kanpur Nagar, Paratap Garh, Sambal, and Unnao, districts of Uttar Pradesh. The Districts such as Aligarh, Allahabad, Amroha, Auraiya, Azamgarh, Baghpat, Baharich, Ballia, Bareilly, Basti, Bijnor, Bulandshar, Chaundauli, Deoria, Etah, Etawah, Farrukhabad, Fathepur, Firozabad, Gautam Buddha Nagar, Ghaziabad, Ghazipur, Gonda, Gorakhpur, Hapur, Hathras, Jaunpur, Kannuj, Kanpur Dehat, Kasganj, Kausambi, Kheri, Kaushi Nagar, Marahganj, Mainpuri, Mau, Meerut, Mirzapur, Muradabad, Mujjafarnagar, Pilibhit, Rampur, Saharanpur, Sant Kabeer Nagar, Sant Ravi Das Nagar, Sahajanpur, Shamli, Sitapur, Sonbhadra, and Varanasi come under Efficient Cropping Zone (ECZ). Amethi, Hamirpur, Jhansi, Lalitpur, Lucknow, Mahoba, Rai Bareli, and Sultanpur fell under the Not Efficient Cropping Zone (NECZ) with high RSI and low RYI values. Agra, Ambedkar Nagar, Balrampur, Banda,

Barabanki, Chitrakoot, Faizabad, Jalaun, Matura, Sarasvati and Siddharth Nagar districts are covered under the last category of Highly-Inefficient Cropping Zone (HICZ) (Table 4). For black gram, out of all 75 districts, 6 districts come under MECZ, 50 districts under ECZ, 8 districts under NECZ and 11 districts under HICZ (Table 4).

Identification of the cropping zone of Uttarakhand

The most efficient cropping zone share ranges from 7 to 40 percent for different pulse crops (Figure 2). The contribution of an efficient cropping zone ranges from as low as 8% for pigeonpea and as high as 40% for green gram. The share of the efficient cropping zone is lower than the not efficient zone for pigeonpea and lentils which implies both of these pulse crops occupied larger cultivated areas but the yield is low. The use of better and innovative technologies, and improved market and extension services could bring these zones to efficient zones. For chickpeas, the share of efficient and not efficient zones is equal. For green gram and black gram, the share of efficient zones is more than the share of not efficient zones implying that lower areas under cultivation produce higher yields. Most of the districts are marked as highly in-efficient cropping zones for pulse crops of Uttarakhand (Figure 2).

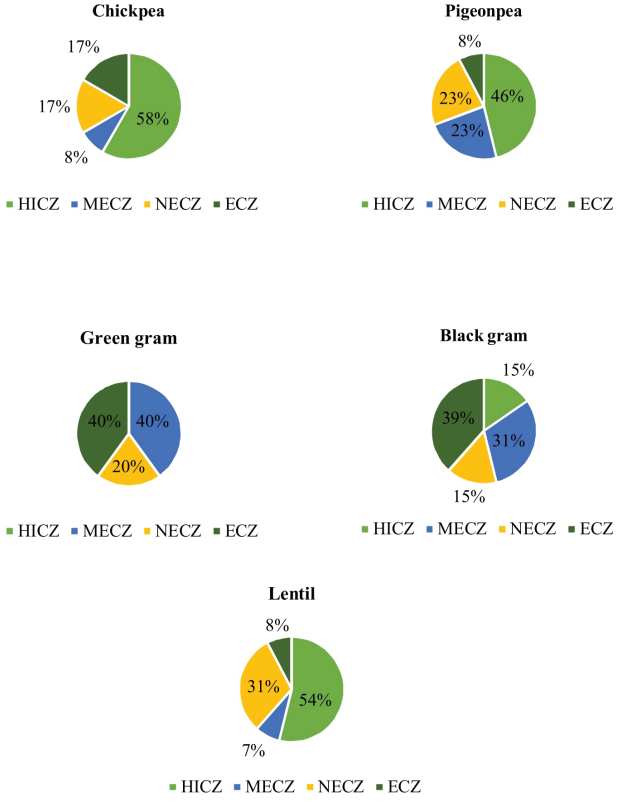

Fig. 2. Distribution of potential cropping zone for different pulse crops in Uttarakhand

Efficient cropping zone for chickpea

Examination of RSI and RYI of chickpea for Uttarakhand found that both indices are at maximum for the Nainital district (Table 4). It shows that natural and climatic conditions are favorable to cultivating chickpea in this district and productivity is also high here.

Only one district namely Nainital recorded high RSI and RYI for chickpea and came under the most efficient cropping zone (MECZ). Chamoli and Dehradun registered high RYI and low RSI and fell under efficient cropping districts (ECZ) for chickpea in Uttarakhand. The yield of the crop in these regions is high and hence the crop may be promoted by better extension methodologies or the reasons for the low spread may be examined. The districts such as Champawat and Pauri Garhwal fell under inefficient cropping zone (NECZ) with high RSI and low RYI values. The rest of the districts fell under a highly in-efficient cropping zone (HICZ). On the whole, one district comes under MECZ, two districts under ECZ, two districts under NECZ, and seven districts under HICZ.

Efficient cropping zone for pigeonpea

Tehri Garhwal registered the maximum area under pigeonpea with the highest value of RSI. Uttar Kashi is next to Tehri Garhwal. Tehri Garhwal and Rudra Prayag recorded the maximum RYI for pigeonpea (Table 4). The perusal of pigeonpea crop area and productivity data revealed that the Most Efficient Cropping Zone (MECZ) for pigeon pea was found in Deharadun, Rudra Prayag and Tehri Garhwal districts. Only the Udam Singh Nagar district fell under the Efficient Cropping Zone (ECZ) with high RYI and low RSI values. Chamoli, Pauri Garhwal, and Uttar Kashi come under the Not Efficient Cropping Zone (NECZ) where the districts registered high RSI and low RYI values. Almora, Bageshwar, Champawat, Haridwar, Nainital and Pithoragarh district fell under Highly In-efficient Cropping Zone (HICZ) where both RSI and RYI values were below 100 percent. In the context of Uttarakhand, three districts come under MECZ, one district under ECZ, three districts under NECZ, and six districts under HICZ.

Efficient cropping zone for lentil

Computed RSI is maximum in Bageshwar

Table 4. Computed value of RSI and RYI for major pulse crops in all districts of Uttarakhand

Districts	Chickpea		Pigeonpea		Lentil		Green gram		Black gram	
	RSI	RYI	RSI	RYI	RSI	RYI	RSI	RYI	RSI	RYI
Almora	67.31	68.72	20.42	83.90	92.97	83.49	---	---	84.22	116.98
Bageshwar	14.10	89.98	3.83	88.30	370.85	87.78	---	---	24.16	81.82
Chamoli	1.34	102.08	128.85	64.14	16.79	96.23	---	---	87.07	122.41
Champawat	104.82	78.02	70.17	56.97	30.23	96.23	44.35	117.12	137.25	105.54
Dehradun	49.74	102.16	227.20	105.39	79.10	99.99	215.73	111.77	106.55	103.74
Haridwar	3.03	80.75	0.12	97.52	23.52	83.05	41.27	131.76	8.97	86.37
Nainital	1053.36	107.38	7.26	84.63	55.60	95.43	265.90	104.11	138.98	100.07
Pauri Garhwal	108.04	84.59	161.59	88.74	103.87	78.25	---	---	388.86	85.62
Pithoragarh	92.94	88.17	15.53	81.59	626.16	115.84	---	---	94.95	106.38
Rudra Prayag	---	---	130.67	111.25	11.22	94.22	---	---	61.71	100.68
Tehri Garhwal	23.87	77.88	653.77	110.63	132.08	93.84	---	---	273.15	99.27
Udam Singh Nagar	5.46	98.80	0.27	100.13	10.28	101.12	270.82	90.83	9.93	109.35
Uttar Kashi	11.99	97.99	345.55	96.85	69.83	99.32	---	---	191.04	116.59

district followed by Pithoragarh as RYI is maximum for Pithoragarh followed by Udam Singh Nagar district (Table 4). The MECZ for lentils was found only in Pithoragarh district in Uttarakhand. Udam Singh Nagar district comes under the Efficient Zone (ECZ). Four districts namely Bageshwar, Champawat, Pauri Garhwal, and Tehri Garhwal fell under NECZ and the rest of the districts fell under HICZ.

Efficient cropping zone for green gram

It has been observed that data for green gram is reported for only five districts of Uttarakhand. Udam Singh Nagar recorded the highest RSI whereas Haridwar recorded the highest RYI (Table 4). Out of five districts two districts namely Dehradun and Nainital registered high RSI and high RYI and are the most efficient districts for green gram in Uttarakhand. Champawat and Haridwar are the efficient zones with RYI whereas Udam Singh Nagar district fell under NEZ with high RSI and low RYI.

Efficient cropping zone for black gram

Pauri Garhwal registered the highest RSI and Chamoli occupied the highest RSI in the case of black gram for Uttarakhand. Champawat, Dehradun, Nainital and Uttar Kash districts recorded high RSI and high RYI and came under MICZ. Almora, Chamoli, Pithoragarh, Rudra Prayag and Udam Singh Nagar districts fell under ECZ with high RYI and low RSI. Pauri Garhwal and Tehri Garhwal come under NEZ with high RSI and low RYI. The remaining two districts come under the highly inefficient cropping zone category. In total four districts come under most MECZ, five fell under ECZ, two under NEZ and two under HICZ for black gram in Uttarakhand.

CONCLUSION

The results of Uttar Pradesh are very encouraging and show that growth in pulse production has been mainly contributed by yield effect which implies growth in pulse production is mainly due to yield effect. The government policies, schemes and initiatives to promote pulse production and decrease imports are moving in the right direction. It is a welcoming sign that the yield effect is positive and higher than the area effect as the land resources are limited. The methodological analysis found that 57 districts come under the most efficient cropping zones for all selected pulse crops of Uttar Pradesh. These zones may have optimum climatic conditions and favourable natural resources for pulse crop production which leads to high yields. Around 150 districts are classified under efficient cropping zones registering high RYI with low RSI. 115 districts recorded low RYI and high RSI comes under not-efficient zones. In the case of Uttarakhand for all selected pulses 20 per cent of districts come under the most efficient and 20 percent of districts come under the efficient cropping zone. The highest 40 percent of districts fell under highly in-efficient cropping zone. Lack of good quality inputs, technology adoption and poor market and extension services may be the reasons for low productivity in these districts. There is a need to develop inclusive and environmentally friendly production systems, which emphasize

sustainable farming practices and increase farmers' income. An increase in productivity with low cost could help the country to reduce imports of pulses and check the flow of foreign currency.

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