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Growth Dynamics and Sustainability of Major Crops in Haryana, India

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HIGHLIGHTS

- Rice cultivation shows significant groundwater dependence, posing sustainability challenges.
- Government policies like "Mera Pani Meri Virasat" promoted water-efficient crops post-2015.
- Instability is low for wheat and rice, high for sugarcane and gram.

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ABSTRACT

The study examined the nexus between crop growth, instability, and groundwater depletion in Haryana, India. Data was collected for 2002 to 2022 to examine the trends of cropped area, production, and productivity by calculating compound annual growth (CAGR). The drivers of crop growth and instability in area, production, and productivity using decomposition analysis and the Cuddy-Della Valle Instability index, were examined respectively. Finally, the Pearson and Spearman correlation methods to investigate the relationship between groundwater depletion and crop yield were employed. Consistent production growth in wheat and rice but negative growth in gram and cotton production observed. After 2015, bajra and rapeseed-mustard showed big improvements, indicating success of programs like "Mera Pani Meri Virasat" that encourage water-efficient farming. Instability analysis indicated low variability in wheat and rice yields but high instability in sugarcane and gram. Gram's resistance to low water levels and rice's strong reliance on groundwater were both brought to light by correlation analysis. The findings stress the importance of crop diversification, especially promoting gram production, and suggest targeted interventions in yield enhancement for sustainable agricultural development.

INTRODUCTION

In India, agriculture and its related sectors offer the majority of livelihoods, especially in the country's vast rural areas. Agriculture remains a cornerstone of India's rural economy, contributing approximately 17.70 per cent to the country's Gross Value Added (GVA) in 2023-24 (GoI, 2024). According to the Periodic Labour Force Survey (PLFS), the proportion of India's workforce engaged in agriculture and allied sectors was 45.50 per cent in 2022–23 (MoSPI, 2023). In the last few years, India has also become a net exporter of agricultural products. Haryana, known for its extensive fertile land, has emerged as a significant contributor to India's agricultural and industrial sectors. Agriculture directly employs about 70 per cent of people in the agrarian state of Haryana (Swati, 2024). One of its primary crops is wheat. It significantly contributes to the country's food basket.

The state has achieved substantial progress in its agricultural development, making it self-sufficient in food grain production and making it the second-largest contributor to the central food grain pool in India (Sihmar, 2014; Nisha et al., 2019). Haryana alone accounts for almost 60 per cent of the world's exports of basmati rice. Wheat and paddy crops accounted for 61.40 per cent of the state's total gross area in 2022–2023, according to the Economic Survey of Haryana, 2024. In the Indo-Gangetic Plain region of India,

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farmers have used climate-smart agriculture practices, such as improved crop varieties, laser field levelling, and zero tillage, which have raised farm output and reduced production costs (Jatav & Mubeena, 2024). However, agriculture in the region, including Haryana, faces severe challenges, including imbalances in water resources, degraded land, inefficient input utilization, declining factor productivity, high production costs, a lack of workforce, and low farmer returns (Bishnoi et al., 2015). Therefore, the Haryana government has launched an ambitious programme called “Mera Pani Meri Virasat” to diversify the cropping pattern from water-intensive crops (i.e., wheat, rice, and sugarcane) to water-efficient crops (i.e., pulses, bajra, maize, and cotton) to maintain the state’s groundwater level (Kumar & Phougat, 2022).

Lastly, it is evident that cropped area and production are fluctuating over the year, and to control the fluctuations, farmers are using relatively more groundwater. This leads to a severe water crisis for both agriculture and domestic use. Therefore, it is a prerequisite to examine the nexus between cropped growth, instability, and groundwater depletion in most food-producing state of India, namely Haryana. Further, identification of drivers of crop growth is also vital for sustainable agricultural practices; therefore, this study uses large-scale data from 2002 to 2022 to identify the key drivers of crop growth in Haryana using decomposition analysis. The findings from this study provide critical insights for policymakers and stakeholders to develop strategies that enhance productivity while ensuring long-term resource sustainability.

METHODOLOGY

The present study used secondary data collected from the Department of Agriculture and Farmer Welfare, Haryana, covering major food and non-food crops for the period of twenty-one years ranging from 2002 to 2022. The data on growth of cropped area, production and productivity was analysed using compound annual growth rate. Further, instability in cropped area, production and productivity was measured using the coefficient of variation and the Cuddy-Della Valle Index (eq. 1).

$$\text{Cuddy-Della Valle Index} = C.V \times \sqrt{(1-R^2)} \qquad ...(1)$$

Where, C.V. stands for Coefficient of Variation and $R^2$is the coefficient of determination obtained from a regression analysis on the time series data. The instability classification followed Sihmar (2014), categorizing instability as low (0-15), medium (15-30), and high (>30).

To assess the contribution of area, productivity, and their interaction to total production, the decomposition method was applied (Kalia et al., 2021), Several studies used this decomposition analysis and studied growth performance of crops (Bhatnagar & Saxena, 2000; Siju & Kombairaju, 2001).

$$P_n - P_o = (Y_n - Y_o) A_o + (A_n - A_o) Y_o + (Y_n - Y_o) (A_n - A_o) \qquad ...(2)$$

$$\Delta P = (\Delta Y) A_o + (\Delta A) Y_o + (\Delta Y) (\Delta A) \qquad ...(3)$$

Where, P_n, Y_n and A_n are the production, yield and area under crop in the current period respectively and P_o, Y_o and A_o are the production, yield and area under crop in the base period, respectively. ΔA = change in area between current year and base year, ΔY = change in yield between current year and base year.

To examine the relationship between groundwater depth and crop production, Pearson’s correlation coefficient and Spearman’s rank correlation was used. Further, Pearson’s correlation coefficient was used to examine correlation between yield of rice, bajra, wheat, gram and cotton with groundwater depth, as data is normally distributed, while spearman’s rank correlation was used to examine relationship between yield of rapeseed & mustard & sugarcane with groundwater depth.

RESULTS

Growth in the area, production, and productivity of major crops

The Compound Annual Growth Rate (CAGR) has been examined to evaluate the long-term trends in the area, output, and productivity of key crops from 2002 to 2022. The investigation is segmented into three separate stages to enhance comprehension of development variances. Table 1 displays the CAGR estimates, emphasizing both favourable and unfavourable trends across various crops, shaped by factors such as policy interventions, environmental circumstances, and technology improvements. The analysis of the CAGR for the region indicates, as shown in Table 1, that the CAGR is positive for rice, wheat, and rapeseed & mustard, while it is negative for sugarcane, bajra, gram, and cotton. The region exhibits the most significant positive increase for rice, whereas the most pronounced negative growth is seen for gram. Since 2015, there has been notable expansion in the area, output, and productivity of gram.

Similarly, the compound annual growth rate (CAGR) of production is positive from 2002 to 2022 for rice, wheat, sugarcane, bajra, rapeseed, and mustard, whereas production growth is negative for gram and cotton (Table 1). Rice output has the most significant positive development, followed by rapeseed and mustard, while grams show the most substantial negative decline. Moreover, there has been a significant increase in the area, productivity, and production of rapeseed and mustard attributed to the promotion of water-intensive crops since 2015. In contrast, bajra has experienced a positive growth rate in area and production due to government initiatives and encouragement for millet cultivation.

All crops under examination have shown favourable growth, with the exception of cotton. The yield of cotton has decreased throughout time. The most significant productivity gain is recorded in rapeseed and mustard, whereas the least favourable rise is noted in wheat (Table 1). Groundwater shortage, environmental stress, and stagnant practices have led to the decline in rice production (Dhanda et al., 2022). The exhaustion of water resources for rice production may result in soil quality deterioration and diminished agricultural yield (Pathak et al., 2011). Excessive use of water resources might exacerbate salinization and waterlogging, hence diminishing agricultural production (Surendran et al., 2021).

Instability in area, production, productivity of major crops

Agricultural instability denotes variations in output, yield, and arable land, which profoundly affect food security, economic stability, and livelihoods (Dalal et al., 2024). Analyzing instability is crucial for comprehending the resilience of various crops due to its significant influence (Tripathi et al., 2023). Table 2 illustrates

Table 1. CAGR of Major Crops

Periods	Rice	Wheat	Bajra	Gram	Rapeseed & Mustard	Cotton	Sugarcane
CAGR in per cent (Area)							
Phase – I	1.58	1.05	2.15	2.02	-0.46	2.32	-4.27
Phase – II	0.68	-0.73	-8.70	-9.72	-0.08	-5.37	2.88
Phase – III	2.40	-1.69	5.31	0.74	8.10	-2.25	0.71
Overall	2.49	0.40	-1.60	-6.36	0.25	-1.32	-2.38
CAGR in per cent (Production)							
Phase – I	1.05	1.27	8.80	-4.20	-2.78	-15.55	-1.58
Phase – II	-0.73	0.19	-6.98	-12.91	-2.49	-1.95	17.86
Phase – III	-1.69	-1.51	11.08	6.62	10.19	-5.68	1.95
Overall	0.40	1.44	1.52	-4.24	2.63	-2.12	0.00
CAGR in per cent (Yield)							
Phase – I	4.22	0.23	6.54	-6.18	-2.38	-18.27	2.81
Phase – II	2.62	0.93	1.95	-3.51	-2.41	3.24	14.55
Phase – III	2.64	0.18	5.53	5.79	1.90	-3.30	1.23
Overall	1.14	1.03	3.17	2.27	2.37	-0.79	2.44

Source: Author's calculation, 2024.

Note: Phase – 1 covers period of 2001-2002 to 2007-08, Phase – II covers of 2008-09 to 2014-15, Phase – III covers of 2015-16 to 2021-22, and overall indicates period of 2001-02 to 2021-22.

the projected volatility for principal crops, indicating diverse levels of variation in area, output, and yield during the research period. The research revealed that during its duration, there was little volatility in the area of wheat, rice, and bajra. Cotton, rapeseed, mustard, sugarcane, and gram followed, demonstrating a moderate degree of fragility. The cultivation of rice and wheat has a consistent pattern. The analysis indicated little variation in the production of rice and wheat over this period, whereas cotton, bajra, rapeseed, and mustard exhibited moderate levels of volatility. Sugarcane and gram had significant volatility over the mentioned period. The research demonstrates little variation in the yields of wheat, rice, bajra, rapeseed, and mustard over the study period, but cotton, sugarcane, and gram exhibited a moderate degree of instability.

Decomposition analysis of production of major crops

To examine the influence of area, productivity, and their interaction on the variability of total output, decomposition methods were used to analyze production variability into its constituent elements. The decomposition study of production variations across principal crops from 2002 to 2022 underscores the substantial impacts of area and yield effects, whereas interaction effects are comparably negligible. In the case of crops such as rapeseed-mustard and bajra, the area impact was a crucial factor, considerably influencing Phase-I and Phase-III (Table 3). Likewise, sugarcane exhibited a remarkably significant area impact during the whole duration, signifying that production increase was mostly propelled by the enlargement of farmed regions (Table 3). Conversely, wheat had significant contributions from both yield and area impacts, indicating balanced growth determinants. Nonetheless, crops such as sugarcane had a significant adverse influence on yields, highlighting difficulties in enhancing productivity for specific crops. This highlights the need of focused interventions in yield improvement and optimal land use to maintain long-term production growth.

Major crop production and groundwater depth

Two correlation approaches were used to examine the association between groundwater depth obtained from the Central Ground Water Board and the Ground Water Cell of the Irrigation and Water Resource Department of Haryana (2023), and crop production. We used the Pearson correlation coefficient and the Shapiro-Wilk test, contingent upon the normality of the data. Rice exhibited a robust positive and significant connection with groundwater depth, indicating its substantial reliance on groundwater and the need for considerable water for cultivation (Table 4). Wheat exhibited considerable water dependency, demonstrating a positive and significant connection. Gram had a significant negative association, suggesting it thrives with less water

Table 2. Instability in Area, Production and Productivity of major crops

Crops	Area	Intensity	Production	Intensity	Yield	Intensity
Rice	4.14	Low	5.28	Low	6.16	Low
Wheat	3.78	Low	8.36	Low	6.56	Low
Bajra	14.67	Low	23.24	Medium	12.18	Low
Sugarcane	18.57	Medium	36.20	High	29.99	Medium
Gram	27.27	Medium	34.78	High	20.91	Medium
Rapeseed & Mustard	15.95	Medium	18.66	Medium	11.86	Low
Cotton	10.40	Medium	24.30	Medium	27.53	Medium

Source: Author's calculation, 2024.

Table 3. Decomposition of Production of major crops

Decomposition (in Percentage)	Rice	Wheat	Bajra	Gram	Rapeseed & Mustard	Cotton	Sugarcane
Phase – I							
Area effect	13.58	18.64	83.00	44.25	29.38	-14.53	285.08
Yield effect	82.79	75.85	15.89	74.00	76.31	149.43	-212.53
Interaction effect	3.63	5.51	1.11	-18.25	-5.69	-34.89	27.45
Phase – II							
Area effect	0.26	96.54	-85.14	70.66	28.74	1012.23	13.05
Yield effect	0.70	5.39	173.40	56.64	76.31	-643.05	83.24
Interaction effect	0.04	-1.93	11.74	-27.30	-5.05	-269.18	3.72
Phase – III							
Area effect	40.49	-0.83	133.65	-12.60	68.96	4.90	58.74
Yield effect	52.47	101.09	-37.52	124.31	18.04	92.51	35.98
Interaction effect	7.04	-0.26	3.86	-11.70	13.00	2.59	5.28
Overall (2002-22)							
Area effect	48.24	-42.08	4.28	116.77	57.70	0.38	591.57
Yield effect	34.66	168.69	95.27	-62.81	25.91	99.19	-742.88
Interaction effect	17.10	-26.61	0.45	46.04	16.38	0.44	251.31

Source: Author's calculation, 2024.

Note: Phase – 1 covers period of 2001-2002 to 2007-08, Phase – II covers of 2008-09 to 2014-15, Phase – III covers of 2015-16 to 2021-22, and overall indicates period of 2001-02 to 2021-22.

Table 4. Correlation matrix between crops production and groundwater depth

Pearson Correlations	Groundwater Depth (meters)
Rice	0.796**
Bajra	0.318
Wheat	0.563**
Gram	-0.639**
Cotton	0.252
Spearman's rho Correlations	
Rapeseed & Mustard	0.519*
Sugarcane	-0.051

Source: Author's Calculations, 2024. * & ** indicates 5 per cent and 1 per cent level of significance

availability; hence, it serves as a valuable alternative to wheat and rice for enhancing groundwater levels. Rapeseed and mustard have moderate water demands, but sugarcane and bajra demonstrate little or negligible reliance on groundwater. These results underscore rice as the most water-intensive crop among those examined.

DISCUSSION

Sustainability in agriculture is a multifaceted concept encompassing economic viability (a sustainable farm must be a profitable enterprise that bolsters the economy), social equity (it should treat its workers justly and foster a mutually advantageous relationship with the local community), and environmental stewardship. Sustainability entails the ethical management of natural systems and resources essential for agriculture by fostering and preserving good soil, judiciously managing water, reducing pollution in air, water, and climate, and enhancing biodiversity. Haryana is a classical case for sustainable farm practices, as it is rich in water and soil resources and suitable for high-value crops. The post-green revolution (1960-1990s) and post-economic reform periods (1991-2000s) further validated this. Crop areas under high-yield varieties in Haryana needed more water, fertilizer, and pesticides. Singh et al., (2021) found that Haryana's per-hectare consumption of fertilizers was 56 percent higher than that of the country as a whole. The results of this study aligned with the findings of Bishnoi et al., (2015). Their findings revealed that agriculture in Haryana faces significant challenges, including imbalances in water resources, soil degradation, inefficient input utilisation, declining factor productivity, elevated production costs, labour shortages, and minimal returns for farmers.

With subsidized chemical fertilizers and a free water supply, farmers tend to grow more water-intensive crops like wheat, rice, and sugarcane, leading to fluctuation in the cropped area and yield of minor cereals and pulses. Panwar & Dimri (2018) have confirmed this. They have used large-scale data from 1966–67 to 2015–16 on cropping area, production, and yield. They found that the yield of major crops like wheat, rice, sugarcane, and cotton increased progressively due to the adoption of high-tech agricultural practices. Further, the current study analyzed the instability in the cropped area, production, and productivity of major crops, concluding that there is significant instability in all of them. These findings were also aligned with those of Swati (2014). She found that a decrease in yield instability can lead to a reduction in both area instability and production instability. It was also in line with what Kalia et al., (2021) found, which is that area and yield effects have the most impact on production growth, while interaction effects have a smaller impact.

CONCLUSION

This study highlights the nexus between agricultural growth, instability issues in yield, and the rise in groundwater issues. The findings revealed that major food crops, viz., rice, wheat, and bajra, are maintained in stable cultivation, while non-food crops, viz., cotton and sugarcane, exhibited moderate to high fluctuations, indicating vulnerability to external factors, especially rainfall and temperature. Similarly, the correlation between crop production and groundwater depth reinforces this challenge, with rice showing a strong dependence on water resources, while gram was more resilient under limited water availability. Therefore, the evidence suggests that there is a need for a grassroots-level water management policy that enables addressing regional issues. Further, for long-term agriculture sustainability, a shift toward yield enhancement strategies, efficient resource utilization, and targeted interventions to balance productivity with environmental conservation are vital for sustainable development agriculture planning.

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