



RESEARCH ARTICLE

Profitability and cost efficiency of paddy and bajra cultivation in Haryana

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Abstract

Agricultural sector in India has experienced significant growth and plays an important role in Haryana's economy, employing more than half of the state's workforce and contributing substantially to their income. The study uses secondary data from official agricultural statistics from 1996–97 to 2021–22 to compare the profitability and productivity of 2 major crops grown in the state, paddy and bajra. Profitability was assessed through cost-benefit analysis, while cost efficiency and efficiency were evaluated using the stochastic frontier approach. The results showed that paddy remained more profitable throughout the study period, with the value of output increasing sevenfold, whereas bajra's profitability declined due to a sharp rise in input costs. The mean technical efficiency was found to be 98.5 % for paddy and 92 % for bajra, indicating that both crops were highly cost-efficient in production indicating that cost efficiency differences are unlikely to be the primary driver of profitability differences between rice and bajra. However, the dominance of paddy cultivation is associated with intensified groundwater depletion and reduced soil fertility, posing sustainability challenges. The findings suggest the need for policy measures to encourage millet production through competitive support prices, assured procurement and farmer awareness programs. Promoting bajra as a sustainable alternative can reduce environmental stress, enhance income stability and contribute to long-term agricultural resilience in Haryana.

Keywords: bajra; Haryana; paddy; profitability; stochastic frontier analysis; sustainability; technical efficiency

Introduction

The agricultural sector in India has seen a remarkable change and has contributed significantly to the security of food and economic development. Nearly 41 % of the total income of the Indian economy accounts for agriculture and it continues to be the principal source of livelihood for the rural households (1). The contribution of agricultural sector has been increasingly recognised over the decades majorly emphasising on inclusive growth particularly in resource-constrained economies like India.

Agriculture sector continues to provide employment to about 51 % of the workforce in the state of Haryana and contributes approximately 14.5 % to the state's gross domestic product (2). The state's population majorly depends on agriculture and allied activities either directly or indirectly. Historically in the pre and post independent era, millets were consumed by the majority households and considered as a vital dietary pattern. Prior to Green Revolution, nearly 40 % of India's total grain production constituted of millets, which contributed about 170 lakh tonnes, which is equivalent to 20 % of global output (3). Millets were among the crops that were domesticated early in India and continued to be valued for their nutritional benefits and plasticity to climatic stress.

In the mid-1960s, the agriculture sector experienced its turning point with the advent of the Green Revolution. The state of Haryana became a food-secure state because of the introduction of high-yielding varieties (HYVs) seeds of wheat and paddy, along with

institutional support such as subsidies on inputs, procurement policies and the infrastructure facilities like irrigation. However, these achievements had a cost associated with it that is in terms of environment. There was increased emphasis on monocropping of paddy and wheat which caused degradation of soil, pest infestation and above all, the groundwater extraction. The groundwater resources started depleting thereby declining soil fertility posing threat to the sustainability of agricultural system of Haryana.

The area cultivated under paddy has consistently surpassed the area under of bajra (pearl millet) over the past 2 decades. As per the data of 2021–22, paddy covered 1327.2 thousand hectares relative to 569.2 thousand hectares under bajra cultivation (4). Districts such as Bhiwani, Mahendergarh, Hisar and Rewari remain key bajra-producing regions, with Jhajjar being the major contributor (5). The increased paddy cultivation in the state has increased the dependence of farmers on production systems which are more water intensive, causing exploitation of groundwater. According to the Central Ground Water Board, 13 out of 22 districts in Haryana have been categorised as “over-exploited” (1). This unsustainable practice can lead to serious outcomes for agricultural viability and ecological balance.

The Government of Haryana has recognised these challenges and has started undertaking several initiatives to encourage agricultural practices that are sustainable. The Bhavantar Bharpai Yojana was launched to provide farmers with

assured returns on bajra, while the Mera Pani Meri Virasat scheme has focussed on promoting the substitution of paddy with crops which are less water intensive such as maize, pulses and cotton. Despite these initiatives and a primary focus on millets, farmers resist to substitute paddy and wheat with millets. This resistance is mainly driven by farmers' preference for short-term income security and risk minimisation over long-term environmental sustainability.

The primary focus on these 2 sets of crops namely paddy and wheat has marginalised and sidelined the traditional coarse cereals like bajra. This has led to an increased vulnerability of farming systems to climate variability. The Green Revolution was a revolutionary initiative to achieve self-sufficiency in food, but it has also left a mixed legacy by undermining crop diversity and sustainability. Since the environmental stress has been on an increase, there is a dire need to re-evaluate the crop choices to promote sustainability in agricultural system.

Bajra production is a promising alternative to paddy. Bajra holds the advantage of being nutritionally superior and sustainable and requires less water and chemical input. Empirical studies that examine efficiency in terms of profitability and productivity of bajra to that of paddy is limited. This research gap underlines the need for an economic assessment to guide policies for sustainable production systems.

Accordingly, the present study aims to conduct a comparative analysis of the profitability and cost efficiency of paddy and bajra in Haryana over the period 1996–97 to 2021–22.

The objectives of the study are to:

- To evaluate the trends in profitability of paddy and bajra cultivation.
- To estimate their relative technical cost efficiency using the stochastic frontier approach.
- To assess their potential for sustainable income generation and long-term agricultural viability.

The analytical framework of this study draws upon the economic theory of production to understand how resource use efficiency, profitability and sustainability can be aligned to promote balanced agricultural development in Haryana.

Materials and Methods

The study is based on secondary data collected from official sources including the Directorate of Economics and Statistics (DES), Government of India and published statistical reports for the period 1996–97 to 2021–22. The analysis focuses on 2 major crops grown in Haryana, namely paddy and bajra. The analysis was performed using R software version 4.4.1. The profitability and productivity have been analysed for both the crops: paddy and bajra using the approach as given.

Profitability analysis

For analysing the profitability, cost and benefit analysis was done using tabular analysis for different crops separately. The profit equation of the following form is used (6).

$$\pi_i = Y_i - \sum_{j=1}^n (P_{xji} \cdot X_{ji}) - TFC \quad (\text{Eqn. 1})$$

Where:

π_i = profit per acre from i^{th} output

Y_i = value of main product

P_{xj} = per unit price of j^{th} input used in producing i^{th} output

X_{ji} = total quantity of j^{th} input used for the production of per acre i^{th} output

TFC = total fixed costs involved in producing per acre i^{th} output

i = the number of individual crops produced by the farmers

j = the number of individual inputs used for producing the relevant product, where $j=1, 2, 3, \dots, n$

Profitability refers to the ability of a crop to generate profit relative to its cost of production. It is expressed as:

$$\text{Profitability} = \frac{\text{Profit}}{\text{cost of cultivation}} \times 100 \quad (\text{Eqn. 2})$$

Cost efficiency

Technical efficiency was estimated using a stochastic production frontier approach, which accounts for random shocks and measurement errors inherent in agricultural production (6). A translog production function was employed due to its flexibility in capturing input interactions and variable elasticities. Empirically, the trans log production function is expressed as:

$$\ln y_i = \beta_0 + \sum_{i=1}^5 \beta_i \ln x_i + v_i - \mu_i \quad (\text{Eqn.3})$$

Where y_i denotes the total cost of production per hectare (in quintals), x_1 is the cost of seed, x_2 is the cost of fertiliser, x_3 represents irrigation charges, x_4 corresponds to human labour and x_5 corresponds to machine labour, $\ln$ represents natural logarithm, v_i represents the random error term and μ_i is the one-sided error term with a non-zero mean representing the technical inefficiency.

Maximum likelihood procedure has been used to estimate the model. Likelihood ratio test has been used in the stochastic frontier model for hypothesis testing which can be written as:

$$\lambda = -2[l(H_0) - l(H_1)] \quad (\text{Eqn. 4})$$

Where $l(H_0)$ represents log-likelihood value in the restricted model of stochastic frontier analysis under null hypothesis and $l(H_1)$ in the general unrestricted model under alternate hypothesis with degree of freedom 1 representing imposed restriction. The maximum likelihood estimation parameters of variance is $\sigma^2 = \sigma_{\mu}^2 + \sigma_v^2$ and $\gamma = \sigma_{\mu}^2 / \sigma^2$ where γ shows the variation in output accounted for by technical inefficiency and the value of which lie between 0–1, where close to one implies that much variation is caused by technical inefficiency (7).

Results and Discussion

Status of paddy and bajra in Haryana

The average yield per hectare of paddy in Haryana is 2689.33 kg ha⁻¹ from 1996–97 to 2021–22 (Table 1). In contrast, the average yield of bajra per hectare is 1396.55 kg ha⁻¹ which is 61.14 % lower during the same period. Initially just before 1960s, the area under bajra

cultivation was higher than paddy cultivation, but after green revolution that focused on increasing the yield of wheat and paddy, the area under cultivation for paddy gradually increased and surpassed the area under bajra (Table 1).

Profitability of paddy and bajra

It is found that profitability of paddy is significantly higher than profitability of bajra from a period of 1996–97 to 2021–22. The value of output each year has increased significantly over years (Table 2) and the difference of profitability has increased 22.5 % for paddy relative to bajra from 1996–97 to 2021–22. The yield and cost of production for paddy is significantly higher than that of bajra. An analysis of the period from 1996–97 to 2021–22 showed that the value of output per hectare increased nearly 7 times for paddy and 7.6 times for bajra. However, the cost of production per hectare over the same period revealed a contrasting trend: while production costs for paddy increased by about 4.6 times, those for bajra shot up by 9.7 times. The cost of production for bajra has been less than paddy till 2019, but post that, the cost of cultivation per quintal for bajra has been higher to that of paddy (Fig. 1). This is attributed to

reasons like high input cost, climate variability and market dynamics. The value of output for paddy is 3.8 times to that of bajra in 2021 whereas the cost of production of paddy is 1.33 times less than that of bajra. The profitability difference between paddy and bajra has increased significantly over the years, rising from 19.04 % in 1996 to 61.99 % in 2021. Bajra growing farmers were exposed to price risk and limited market linkages, making negative profits in years like 2000–2005 and parts of 2014–18 period. The profitability difference of paddy and bajra over the years 1996–97 to 2021–22 has been shown in Table 3 and in Fig. 1.

Efficiency results

The validity of the trans log production function is verified by the rejection of the null hypothesis ($H_0: \beta_0 = \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5$) at the 5 % significance level. As a result, only the trans log function's is shown. Table 4 displays the outcomes of the trans log model utilised in the stochastic frontier technique. The estimated coefficients are found to be statistically efficient. The estimated value of gamma (γ) and sigma square (σ^2) are significant at 10 % significance level indicating

Table 1. Area, production and average yield paddy and bajra in Haryana

Years	Paddy			Bajra		
	Area (ha)	Production (tonnes)	Yield (kg)	Area (ha)	Production (tonnes)	Yield (kg)
1966–67	192	223	1161	893	373	418
1970–71	269.2	460	1697	879.6	826	939
1980–81	483.9	1259	2606	870.3	474	544
1990–91	661.2	1834	2775	608.6	526	864
2000–01	1054.3	2695	2557	608.3	656	1079
2010–11	1243.3	3465	2788	659.6	1183	1792
2019–20	1559	5198	3334	492.9	1101	2235
2020–21	1525.8	5633	3692	594.1	1411	2378
2021–22	1534.5	5514	3594	493.1	1144	2320

Source: Statistical abstract of Haryana 2021–22.

Table 2. Data for value of output and cost of production per hectare of bajra and paddy in Haryana

Years	Paddy		Bajra	
	Value of output (in ₹ ha ⁻¹)	Cost of production (₹ qtl ⁻¹)	Value of output (in ₹ ha ⁻¹)	Cost of production (₹ qtl ⁻¹)
1996	19873	197.49	4560.57	126.73
1997	20347.93	230.3	5014.81	135.04
1998	21749.17	270.14	4958.56	143.48
1999	23159.79	273.24	5785.34	204.83
2000	28418.8	261.29	5350.38	171.85
2001	27653.46	278.84	4650.02	156.23
2002	30319.06	346.34	6282.99	290.47
2003	32197.99	349.8	5432	203.17
2004	36123.33	368.1	5770.43	239.56
2005	35099.46	314.94	5987.03	286.15
2006	40189.05	304.25	9471.92	296.6
2007	66220.14	304.25	11435.88	215.03
2008	59752.73	461.45	17320.56	283.85
2009	70844.67	488.03	14914.24	298.44
2010	72711.13	594.43	14881.14	345.39
2011	63801.5	650.13	14738.92	439.44
2012	84748.26	604.25	20229.76	438.41
2013	121468.8	640.93	23441.88	475.84
2014	117530.8	677.44	20109.02	533.06
2015	89315.14	668.09	20218.77	674.37
2016	100615.5	654.15	27489.33	624.51
2017	122202.38	628.66	22625.87	671.45
2018	125308.76	806.27	28296.32	751.68
2019	143742.26	831.43	39015.08	769.06
2020	117602.14	856.82	28900.26	1024.4
2021	134921.31	927.14	35007.03	1239.71

Source: Directorate of Economics and Statistics: MOA.

Table 3. Profitability difference of paddy and bajra over the years 1996–2021

Years	Profitability of paddy	Profitability of bajra	Difference
1996	47.39	28.35	19.04
1997	47.66	14.94	32.72
1998	49.49	15.83	33.66
1999	47.60	24.85	22.75
2000	95.45	-19.21	114.66
2001	69.85	-20.85	90.70
2002	32.77	-10.04	42.80
2003	37.12	11.83	25.30
2004	44.78	-1.91	46.69
2005	47.42	-16.82	64.24
2006	77.20	5.89	71.31
2007	213.53	37.27	176.26
2008	102.76	56.29	46.47
2009	124.35	15.46	108.89
2010	126.20	12.77	113.43
2011	51.44	-12.10	63.53
2012	117.45	20.59	96.86
2013	200.81	14.04	186.77
2014	142.31	-7.99	150.31
2015	53.28	-18.08	71.36
2016	90.48	-13.76	104.24
2017	130.48	-35.94	166.42
2018	126.98	-10.27	137.26
2019	145.54	32.17	113.38
2020	60.98	12.55	48.43
2021	82.97	20.98	61.99

the presence of technical inefficiency. The value of gamma (γ) represents the one-sided error component which implies that it indicates the difference between observed and estimated cost or output from the frontier. Here, its value is 8.4 % which implies that

this variation is caused by factors under farmer's control (Table 4). 91.6% variation is attributed to random noise.

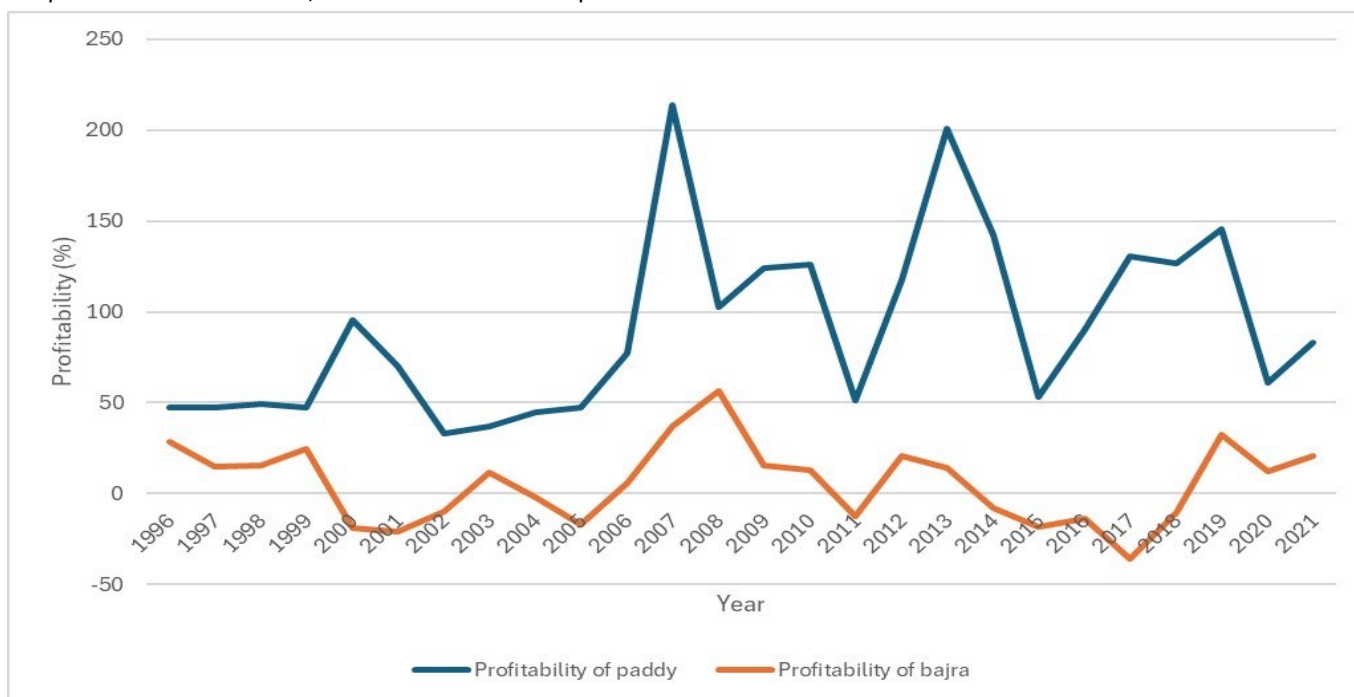
The mean efficiency score of paddy obtained from stochastic production frontier is 98.5 % whereas that of bajra is 92 %. This analysis clearly states that the cost efficiency difference in both the crops is not very large unlike the profitability.

Kernel density estimation (KDE) is a non-parametric technique particularly useful to visualise the distribution of efficiency scores and compare the distributional characteristics of technical inefficiency scores for paddy and bajra producers (8). Kernel density estimation for inefficiency of crop paddy and bajra is plotted as shown in Fig. 2 and Fig. 3 respectively. Values clustered around 0 indicate high technical efficiency among producers, while values farther from 0 suggest increasing levels of inefficiency.

The KDE for paddy farmers indicates that the majority exhibit high technical efficiency, with density peaking near an efficiency score of 0.99.

Conclusion

The present investigation assessed profitability and productivity of paddy and bajra in Haryana for the period 1996–97 to 2021–22 using stochastic frontier analysis. The results revealed that growing paddy has been consistently more profitable than bajra mainly due to higher prices, assured government procurement and comparatively slow increase in production cost. In contrast, bajra

**Fig. 1.** Profitability percent difference of paddy and bajra.**Table 4.** Maximum likelihood estimates (MLE) of the stochastic production function

Parameter	Estimate	Std. error	z value	Pr(> z)
(Intercept)	-0.88	0.14	-6.47	1.0×10^{-10}
Log (seed)	0.07	0.10	0.72	0.47
Log (Fertiliser)	1.08	0.17	6.31	2.8×10^{-10}
Log (human labour)	1.42	0.21	6.85	7.3×10^{-12}
Log (Irrigation)	0.42	0.08	5.46	4.8×10^{-8}
Log (Machine labour)	0.99	0.20	4.89	1.0×10^{-6}
sigma sq (σ^2)	4.0×10^{-4}	1.0×10^{-4}	2.84	4.47×10^{-4}
Gamma (γ)	0.08	0.23	0.36	0.07
time	3.10	1.43	2.17	0.03

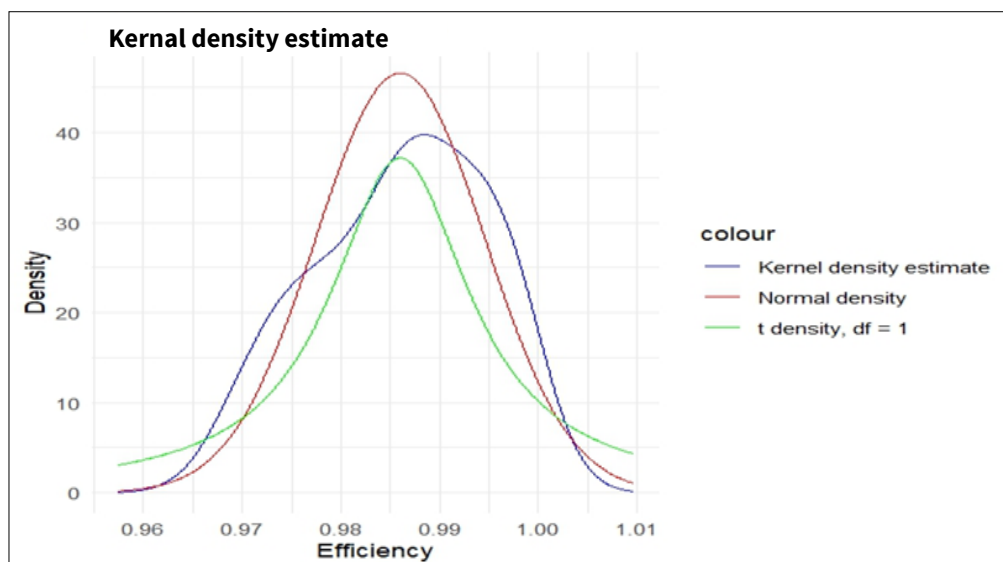


Fig. 2. Kernel density estimate (KDE) for paddy.

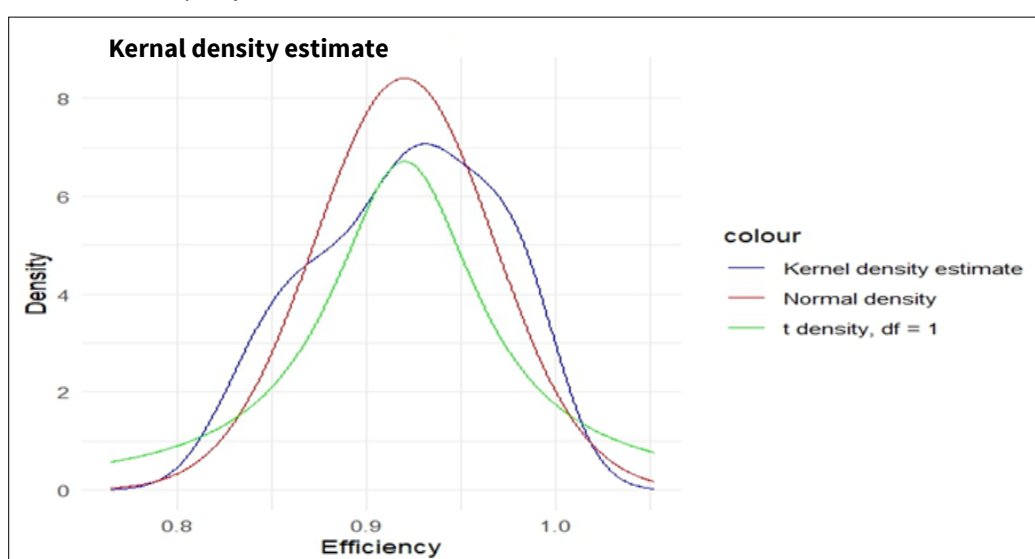


Fig. 3. Kernel density estimate (KDE) for bajra.

profitability declined over time exposing farmer to market risk and price fluctuations resulting negative returns in some years.

The stochastic frontier estimates revealed high technical efficiency of 98.5 % and 92 % for paddy and bajra respectively. Paddy showed a marginally higher efficiency level; the difference is small when compared to substantial divergence in profitability. This shows that poor performance of bajra in terms of profits is not primarily driven by technical inefficiency but rather by market-related and institutional factors such as poor price support, limited government procurement and poor market linkages.

The long dominance of paddy cultivation in Haryana has raised concerns regarding sustainability in the context of groundwater levels and environmental stress. Bajra on other hand has agronomic and climatic advantages, including low irrigation requirements and robust response to stress conditions. The study therefore highlights a need of balancing act between short-term income gain and long-term sustainability. Addressing this imbalance needs policy interventions that targets the economic constraints faced by bajra producers rather than focusing solely on productivity enhancement. Minimising market risks, improving price incentives and increased demand-side support for bajra are essential for sustainable crop diversification in the Haryana state.

Policy implications

The insights of the study offer several policy recommendations for promoting sustainable cropping system in Haryana. First, the high technical efficiency of bajra revealed that farmers are already using resources well and productivity interventions alone will not improve the situation. Policy efforts should be made to prioritise increment in profitability through institutional support.

Second, the wide profitability gap between paddy and bajra highlights the critical role of price assurance and procurement policies. Paddy growers get benefit of effective minimum support price and assured government procurement while bajra growers remained exposed to market risk. The MSP for bajra needs to be re-examine and procurements in major bajra growing districts will mitigate price risk and enhance income stability for farmers.

Third, given the relationship between paddy cultivation and groundwater stress in Haryana, crop diversification policies should be region-specific. In arid and semi-arid districts where water scarcity is acute and the bajra comparative advantage is strongest promotion of its cultivation should be done. Bajra cultivation should be supported by direct benefit transfers or input subsidies.

Fourth, the limited market integration of bajra requires action for strengthening collective marketing and value addition

through Farmer Producer Organizations (FPOs) and cooperatives. Improved aggregation, storage and market access can enhance price realisation for bajra growers. Production incentives can be reinforced by integrating bajra with public distribution system and midday meal schemes thereby generating institutional demand.

Extension initiatives like awareness campaigns highlighting the nutritional, agronomic and environmental benefits of bajra will change farmer view in addition to steps like credible price assurance and risk mitigation mechanisms. All these steps combined will generate an economically viable shift towards more sustainable and diverse cropping patterns, balanced farm income security with long-term resource conservation in Haryana.

Future scope of the study

This study opens several avenues for future research and policy development. While it has provided a comparative analysis of paddy and bajra in terms of profitability and productivity, future studies can amplify this analysis by incorporating a wider range of crops to examine variations in profitability, efficiency and sustainability. Additionally, further research could focus on identifying the inefficiencies in bajra production relative to paddy and suggest recommendations to work on them. Qualitative studies which focus on farmer preferences, education, awareness, training would complement the quantitative results and provide richer insights for designing effective and inclusive agricultural policies.

Eco-friendly agricultural practices support the preservation of valuable natural resources and are consistent with India's commitment to sustainable agriculture.

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Authors' contributions

GG did the conceptualisation and design of the study and performed the statistical analysis and wrote the paper. KI participated in its design and co-ordination. Both authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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