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Resource Use Efficiency and Marginal Productivity of Potato Cultivation in Haryana

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HIGHLIGHTS

- Analysed resource use efficiency in Haryana's potato production using Cobb Cobb-Douglas model.
- Identified major inefficiencies in human labour, fertiliser and irrigation use.
- Recommended optimized input allocation to enhance productivity and profitability.

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ABSTRACT

The study conducted in 2024 aimed to analyse the efficiency of resource utilisation and the marginal value productivity (MVP) of inputs in potato farming across three prominent districts of Haryana–Sonipat, Karnal, and Kurukshetra. A sample of 120 farmers cultivating potatoes was chosen through convenience sampling. To evaluate the impact of various inputs on yield variation, the Cobb-Douglas production function was applied to estimate the respective regression coefficients. Marginal Value Productivities were derived and compared with Marginal Factor Cost (MFC), taken as unity due to monetary standardisation of variables. The results revealed that seed and manure & fertilizers were significantly underutilised in all districts, indicating potential for increased productivity through better input management. In contrast, human labour and irrigation were overutilized, often yielding negative MVPs, suggesting inefficiencies in labour deployment and water use. Mechanization, reflected through machine labour, was also found to be underutilized across all districts, indicating the need for greater adoption of efficient farm machinery. The overall coefficients indicated decreasing returns to scale, underscoring the need for balanced and efficient resource allocation. The findings provide actionable insights into optimizing input use to improve farm-level productivity and profitability in potato cultivation in Haryana.

INTRODUCTION

Potato is the edible tuber of *Solanum tuberosum*, a perennial plant belonging to the Solanaceae family. Recognized as a staple food across various continents, potato plays a critical role in global nutrition and food systems. As per the Food and Agriculture Organization, global potato production reached around 383 million tonnes in 2023, ranking it as the fourth most significant food crop after maize, wheat, and rice. Despite a reduction in harvested area from 18.1 to 16.8 million hectares, global production increased by 7 million metric tons compared to 2022 (FAOSTAT, 2024). This achievement underscores the success of modern farming techniques and technological innovations.

Potato yields are influenced by several factors, including varietal characteristics, seed quality, agronomic practices, and environmental conditions. Improving these factors and narrowing the yield gap has the potential to significantly strengthen global

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food security and enhance the livelihoods of farmers, particularly in developing countries (Foley et al., 2011). In India, Haryana is one of the major potato-producing states, with an output of approximately 843.23 thousand metric tonnes in 2023 (National Horticulture Board, 2023).

The crop is cultivated throughout Haryana, with significant production concentrated in districts such as Kurukshetra, Yamuna Nagar, Karnal, Ambala, Sonipat, Panchkula, Panipat, Rohtak and Sirsa (Directorate of Horticulture, Haryana, 2018). Haryana's favourable agro-climatic conditions enable two potato-growing seasons: the spring season, with sowing in January, and the main season, beginning in early October. Despite its high production potential, there is considerable scope to improve productivity by optimizing the use of agricultural inputs and ensuring efficient resource allocation. Better management of existing resources can contribute to increased income and savings for farmers (Shankar & Naidu, 2017). As noted by Kharumnuid et al., (2023), the efficient and balanced use of inputs such as human and machine labour, quality seed, fertilizers, irrigation, and plant protection chemicals are vital for enhancing overall farm performance.

Resource use efficiency (RUE) and marginal value productivity (MVP) are essential indicators of how well resources contribute to output. Among the essential inputs required in agriculture are human labour, quality seeds, bullock power, working capital, agricultural machinery, irrigation facilities, fertilisers–both organic and chemical–and crop protection practices (Shelke et al., 2016). The Studies conducted in various regions have highlighted suboptimal input usage. For instance, Sujan et al., (2017) in Bangladesh reported that human labour, land preparation, insecticides, and irrigation were underutilized. Kumar et al., (2018) observed that medium farms in Haryana benefited from economies of scale owing to better management, stronger financial capabilities, and more efficient input use. Similar insights were reported by Mukherjee et al., (2024) in the Surguja district of Chhattisgarh, where economic analysis of potato cultivation highlighted variation in input costs and profitability among farm categories.

METHODOLOGY

On the basis of highest potato production, three districts of Haryana state namely Kurukshetra, Karnal and Sonipat were selected purposively as these districts collectively contribute most to the state's potato production (Directorate of Horticulture, Haryana, 2018). From each district, 40 potato growers were selected by convenience sampling for collecting the required information. Thus, in total 120 potato growers were interviewed to collect the required information.

The Cobb-Douglas production function was used to analyze the relationship between output and input utilization among the sampled farmers. From the estimated model, regression coefficients and standard errors were obtained, and Marginal Value Productivities (MVPs) were computed for inputs with statistically significant effects. The coefficient of multiple determination (R^2) was used to assess the explanatory power of the model in accounting for yield variation.

To assess resource use efficiency in potato cultivation, the present study utilized a production function approach. Specifically, the Cobb-Douglas production function was employed in the following form:

$$Y = aX_1^{b1}.X_2^{b2}.X_3^{b3}.X_4^{b4}.X_5^{b5}.X_6^{b6}$$

Where, Y = Gross Returns (Rs/ha), X_1 = Expenditure on human labour (Rs/ha), X_2 = Expenditure on machine labour (Rs/ha), X_3 = Seed cost (Rs/ha), X_4 = Manure and Fertilizers cost (Rs/ha), X_5 = Plant protection chemicals cost (Rs/ha), X_6 = Irrigation cost (Rs/ha), 'a' is the constant term and bi's are the regression coefficients to be estimated.

In this analysis, all input and output variables were expressed in monetary terms to facilitate the estimation of marginal value productivities and efficiency ratios.

Marginal Value of Productivity (MVP) denotes the Marginal Value Productivity, which reflects the additional monetary return generated from the use of one more unit of a particular input. The marginal value productivity (MVP) of input Xi (i=1,2…,6) for Cobb-Douglas functions are as follows:

$$MVP_i = bi\ \frac{\bar{Y}}{\bar{\bar{X}}}$$

Where, $\overline{Y}$= Geometric mean of output, $\overline{X}$ = Geometric mean of input, bi = the regression coefficients associated with 'Xi' input.

Resource use efficiency represents the effectiveness with which inputs are employed to produce output in the production process. It is assessed by comparing the Marginal Value Product (MVP) of an input to its corresponding Marginal Factor Cost (MFC). In this study, the efficiency of each input was evaluated using the following formula:

$$r = \frac{MVP_i}{MFC_i}$$

Where, r represents the efficiency ratio, MVP denotes the Marginal Value Product, which reflects the additional monetary return generated from the use of one more unit of a particular input, MFC stands for the Marginal Factor Cost, which is considered as 1 because both the dependent and independent variables have been expressed in monetary terms. MFC represents the increase in input cost incurred from employing one additional unit of the input. An efficiency ratio equal to 1 implies optimal use of the input. Ratios greater than 1 indicate underutilization, while ratios less than 1 suggest overutilization of the resource.

RESULTS

Resource use efficiency

This section presents the estimated results related to input productivity and resource use efficiency for key inputs employed in potato cultivation across the selected districts. A summary of the findings is presented in Table 1. The R^2 values, ranging from 63.70 per cent to 71.05 per cent, suggest that the model demonstrates a good fit across all three districts. This indicates that the combined use of key agricultural inputs–human labour, machine labour, seed, manure and fertilizers, plant protection chemicals, and irrigation–explained a significant proportion of the variation in potato output.

Table 1. Regression coefficient and standard error of potato production in Selected Districts

Variables	Coefficients		
	Sonipat	Karnal	Kurukshetra
Constant	7.25	7.02	7.71
Human labour	-0.061*	-0.024NS	-0.057NS
	(0.04)	(0.12)	(0.07)
Machine labour	0.012NS	0.018NS	0.195***
	(0.07)	(0.11)	(0.04)
Seed	0.235*	0.622***	0.177NS
	(0.15)	(0.25)	(0.16)
Manure and Fertilizers	0.308***	0.209***	0.175**
	(0.05)	(0.07)	(0.07)
Plant Protection	-0.032NS	0.069NS	0.026NS
	(0.04)	(0.05)	(0.06)
Irrigation	0.051NS	-0.014NS	-0.045NS
	(0.05)	(0.07)	(0.07)
Return to scale	0.443	0.884	0.471
R^2(%)	71.05	63.70	67.18

Figures in parentheses indicates standard error
***Indicates significance at 1% level, ** 5% level, * 10% level and NS- Non-Significant

In Sonipat district, the coefficients for seed and manure & fertilizers were found to be positive and statistically significant at the 10 per cent and 1 per cent levels, respectively, indicating their strong influence on yield. In contrast, the coefficient for human labour was negative and significant at the 5% level, suggesting an inefficient or excessive use of manual labour. The remaining variables in the model did not exhibit statistical significance.

In Karnal district, seed input emerged as a critical factor, showing a highly significant positive coefficient of 0.622 at the 1% level. Additionally, manure and fertilizers had a significant positive effect (coefficient = 0.209) at the 1% level. However, other inputs such as human labour and machine labour were found to be statistically insignificant in explaining yield variation. In Kurukshetra district, the coefficient for machine labour was positive and highly significant at the 1% level, underlining the important role of mechanization in boosting productivity. Manure and fertilizers also exhibited a positive and significant effect at the 5% level. However, other inputs including seed, human labour, and irrigation, did not show statistically significant relationships with output. The sum of the regression coefficients in all three districts was less than one– ranging from 0.443 in Sonipat to 0.884 in Karnal–indicating decreasing returns to scale. This suggests that a 1 per cent simultaneous increase in all inputs would lead to less than a 1 per cent increase in output, reflecting either input overutilization or diminishing marginal returns under current production practices.

Marginal value productivities of inputs used in potato production

In this section, Marginal Value Productivities (MVPs) of key inputs used in potato cultivation were estimated to evaluate the efficiency of resource use across selected districts. The MVPs were derived from the regression coefficients of the Cobb-Douglas production function and reflect the additional monetary return from one additional unit of expenditure on a particular input. For the purpose of this analysis, the Marginal Factor Cost (MFC) of all inputs was assumed to be unity (MFC = 1), which is a standard practice when all variables are expressed in monetary terms (Sapkota & Bajracharya, 2018). This allows for direct comparison between MVP and MFC to assess the efficiency ratio (r = MVP / MFC). The MVPs, efficiency ratios, t-values, and resulting interpretation of input use are discussed below district-wise and presented in Table 2.

Table 2. Marginal value productivities of inputs used in potato production in Selected Districts

Input	Human Labour	Machine labour	Seed	Manure & Fertilizers	Plant Protection	Irrigation
Sonipat						
B	-0.06	0.01	0.23	0.31	-0.03	0.05
MVP	-1.01	1.50	2.15	2.71	-1.29	2.72
MFC	1	1	1	1	1	1
R	-1.01	1.50	2.15	2.71	-1.29	2.72
t- value	-1.45	0.16	1.55	5.81	-0.92	0.98
Level of resource use	Over Utilized	Under Utilized	Under Utilized	Under Utilized	Over Utilized	Under Utilized
Karnal						
B	-0.02	0.02	0.62	0.21	0.07	-0.01
MVP	-0.38	3.27	6.51	2.28	2.95	-0.62
MFC	1	1	1	1	1	1
R	-0.38	3.27	6.51	2.28	2.95	-0.62
t- value	-0.13	0.02	2.51	3.18	1.27	-0.21
Level of resource use	Over Utilized	Under Utilized	Under Utilized	Under Utilized	Under Utilized	Over Utilized
Kurukshetra						
B	-0.05	0.21	0.18	0.18	0.03	-0.05
MVP	-0.91	2.49	1.92	1.63	1.19	-3.23
MFC	1	1	1	1	1	1
R	-0.91	2.49	1.92	1.63	1.19	-3.23
t- value	-0.76	4.51	1.06	2.21	0.51	-0.65
Level of resource use	Over Utilized	Under Utilized	Under Utilized	Under Utilized	Under Utilized	Over Utilized

In Sonipat, machine labour (MVP = 1.50), seed (2.15), manure & fertilizers (2.71), and irrigation (2.72) were found to be underutilized, indicating that their increased use could yield higher returns. Particularly, irrigation and fertilizer application had the highest MVPs, suggesting strong potential for enhancing productivity through more optimal water and nutrient management. On the other hand, human labour (MVP = -1.01) and plant protection chemicals (MVP = -1.29) showed negative MVPs, indicating overutilization, potentially leading to reduced economic returns. The negative MVP of plant protection may reflect either excessive chemical use or ineffective pest/disease control measures. The t-values were generally low, indicating that statistical significance of individual coefficients should be interpreted with caution.

In Karnal, seed (MVP = 6.51) exhibited the highest value, followed by machine labour (3.27), plant protection (2.95), and manure & fertilizers (2.28), all of which were underutilized. This points to substantial scope for increasing potato yields by enhancing investment in quality seed, mechanization, plant health management, and fertilizer application. Human labour (MVP = -0.38) and irrigation (MVP = -0.62) were overutilized, possibly reflecting inefficient labour deployment and suboptimal water management practices. Notably, seed and fertilizer use were statistically significant and economically justified inputs. In Kurukshetra, the MVPs of machine labour (2.49), seed (1.92), fertilizers (1.63), and plant protection (1.19) indicated that these inputs were underutilized and could improve productivity if applied more effectively. However, irrigation (MVP = -3.23) and human labour (MVP = -0.91) were overutilized, particularly irrigation, which showed the most negative value across all districts, suggesting either overwatering or inefficient scheduling. The t-values reinforced the significance of machine labour and fertilizers, emphasizing mechanization and nutrient application as key factors for yield improvement.

DISCUSSION

The calculated coefficients of multiple determination (R^2) reveal that the chosen inputs–namely human labour, machine labour, seed, manure and fertilizers, plant protection chemicals, and irrigation–account for a significant share of the variability in potato output. Specifically, R^2 values of 71.05 per cent, 63.70 per cent, and 67.18 per cent were observed for Sonipat, Karnal, and Kurukshetra respectively. These findings indicate that the Cobb-Douglas production function is well-suited to the data across all three districts.

In Sonipat, seed and manure & fertilizers emerge as significant contributors to output, while machine labour, although not statistically significant, shows a positive relationship with productivity. The negative coefficient for human labour indicates overutilization, a finding also observed in the MVP results. Karnal shows a similar pattern, where seed plays a dominant role in yield improvement, followed by fertilizers and machine labour. Non-significant but negative coefficients for human labour and irrigation reflect inefficient resource deployment. In Kurukshetra, mechanization is found to be particularly crucial, while overuse of irrigation and human labour remains a concern. Similar studies on the economic aspects of potato cultivation, such as the one conducted in Agra district by Singh et al., (2019), have also emphasized the significance of efficient input management in enhancing profitability.

The Marginal Value Productivities (MVPs) corroborate these observations. Machine labour, seed, and fertilizers consistently show MVP/MFC ratios greater than one, pointing to underutilization and the potential for enhancing productivity through greater investment in these inputs. Conversely, human labour and irrigation reflect negative MVPs across all districts, underlining their inefficient or excessive application. In Kurukshetra, the notably negative MVP of irrigation (-3.23) highlights a critical issue in water resource management.

These findings underline the need for more balanced and optimized input use strategies. Overuse of labour and water not only inflates production costs but also reduces technical efficiency. Meanwhile, better seed quality, mechanization, and fertilizer use present opportunities to enhance output. These results align with earlier findings by Sujan et al., (2017); Kumar et al., (2021) & Kumar et al., (2023), who emphasized the importance of efficient input allocation in increasing agricultural productivity. Studies across different crop systems have also shown that economic performance and input efficiency vary significantly depending on farm practices and scale, underscoring the need for localized analysis (Chiphang et al., 2021).

Overall, the study underscores the value of adopting region-specific input strategies that focus on maximizing returns from underutilized resources while curbing the wasteful application of overused inputs. Improved access to credit, training on input management, and promotion of farm mechanization may further support the efficient use of resources in potato cultivation across Haryana.

CONCLUSION

The study evaluates the efficiency of resource use in potato cultivation using the Cobb-Douglas production function. The analysis shows that fertilizers and seed are significantly underutilized in all districts, indicating potential for increasing yield through improved nutrient management and seed quality. In Sonipat, a strong input-output relationship is observed, with a coefficient of determination (R^2) of 71.05 per cent. Human labour is overutilized, which contributes to inefficiency and higher production costs. Similar inefficiencies are evident in Karnal and Kurukshetra. In Karnal, seed shows the highest marginal return, suggesting it remains a critical area for investment. Irrigation exhibits negative returns, reflecting poor water use efficiency. In Kurukshetra, underutilization of machine labour highlights the importance of mechanization. These findings suggest the need for input optimization strategies to improve productivity and profitability in potato farming across Haryana.

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