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Resource use and productivity analysis of Rabi potato production in Chhatrapati Sambhajinagar District of Maharashtra

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Abstract

Potato (*Solanum tuberosum* L.) is a major food as well as commercial crop that holds considerable economic importance. The present study was carried out in Chhatrapati Sambhajinagar district of Maharashtra to assess the resource productivity and resource-use efficiency of Rabi potato cultivation. The study encompassed Kannad, Khultabad and Phulambri talukas, with primary data obtained from 90 selected potato growers. The Cobb-Douglas production function was used to analyse the contribution and efficiency of major production resources. At the overall level, the R^2 was 0.982, indicating that 98.20 per cent of the variation in potato production was explained by the selected variables. The F-value was 5.760 and significant at the 1 per cent level, while the return to scale was 0.605, indicating decreasing returns to scale. Area under potato, human labour and irrigation had positive and significant effects on output, whereas bullock labour, phosphorus and plant protection had negative and significant effects. Based on the MVP-to-price ratios, area under potato, human labour, machine labour, tubers, manure, nitrogen, potash and irrigation were underutilized, while bullock labour, phosphorus and plant protection were overutilized. The study highlights the need for efficient allocation of production resources to improve potato productivity and profitability.

Keywords: Potato, resource productivity, resource-use efficiency, Cobb-Douglas production function, rabi Potato, Chhatrapati Sambhajinagar

Introduction

Potato (*Solanum tuberosum* L.) is an important food and commercial crop and holds a prominent place in agricultural production worldwide. It originated in the Andean region of South America and gradually spread to various parts of the world due to its wide adaptability, high yield potential and relatively short growing period. Potato is commonly known as the “poor man’s friend” because it provides an economical source of dietary energy and produces substantial food output per unit of land within a short period. Therefore, it contributes significantly to food and nutritional security, particularly in developing countries (FAO, 2023; Ezekiel *et al.*, 2013) ^[3, 2]. Globally, potato is grown over nearly 17 million hectares, with annual production estimated at about 383–390 million tonnes. The average productivity is approximately 22–23 tonnes per hectare. China is the leading producer, contributing around 25.5 per cent of the total global production, whereas India accounts for nearly 15 per cent. This demonstrates the significant contribution of Asian countries to global potato production. The growth in potato production can be attributed to the use of improved varieties, enhanced production practices, technological development and more efficient management of farm resources

(FAOSTAT, 2023–24) ^[3].

In India, potato is the leading tuber crop and is grown across a wide range of agro-climatic conditions. As per the First Advance Estimates of the Department of Agriculture and Farmers Welfare, potato production during 2024–25 is expected to reach 595.72 lakh tonnes. The average productivity at the national level is estimated to be between 23 and 25 tonnes per hectare. Uttar Pradesh, West Bengal, Bihar, Gujarat, Madhya Pradesh, Punjab and Maharashtra are among the major potato-producing states of the country (DA&FW, 2024; Indian Horticulture Database, 2023) ^[1, 4].

Although potato cultivation in Maharashtra is relatively restricted, it has considerable economic significance in specific regions of the state. During 2024–25, potato cultivation covered approximately 14.445 thousand hectares in Maharashtra. The crop is cultivated mainly in Pune, Ahmednagar, Satara, Nashik, Beed and Chhatrapati Sambhajinagar districts, largely during the Rabi season under irrigated conditions. Variations in soil characteristics, availability of irrigation and crop management practices contribute to differences in potato productivity among different regions.

Chhatrapati Sambhajinagar district is gradually emerging as

an important region for Rabi potato cultivation in the Marathwada region. As reported in the Final Rabi Report (2024), potato cultivation covered 1,037 hectares in the district, generating an estimated production of 24,867 tonnes with an average productivity of 17.2 tonnes per hectare. At the taluka level, Khultabad had the largest area under potato cultivation and the highest production, followed by Phulambri and Kannad. Since the productivity of potato in the district is lower than the national average, there is considerable potential for improving production through efficient utilization of resources, adoption of improved varieties, balanced application of nutrients, timely irrigation and improved crop management practices (District Agriculture Office, Chhatrapati Sambhajnagar).

Efficient utilization of agricultural resources is essential for improving productivity and profitability in potato cultivation, particularly because inputs such as seed, labour, fertilizers, irrigation and plant protection chemicals involve substantial expenditure. Assessment of resource productivity helps to determine the contribution of individual inputs to potato output, while resource-use efficiency indicates whether these inputs are being utilized at economically optimal levels. The Cobb-Douglas production function provides a useful framework for analysing the relationship between input use and output and for estimating the marginal productivity of different resources. By comparing the marginal value product of an input with its marginal factor cost, the extent of underutilization or overutilization of resources can be identified. A recent study on potato cultivation in Haryana demonstrated that seed and manure-fertilizer inputs were underutilized, whereas human labour and irrigation were overutilized, emphasizing the importance of optimal resource allocation for enhancing productivity and profitability (Shivam *et al.*, 2025) ^[5].

Objective of the study

1. To study the resource productivity and resource use efficiency of potato in Chhatrapati Sambhajnagar.

Materials and Methods

Cobb-Douglas Production function

The Cobb-Douglas production function was employed to examine the relationship between potato output and the major production resources used by the selected potato growers. The model was used to estimate the contribution of different inputs and to assess their resource-use efficiency in Rabi potato cultivation.

The functional form of the Cobb-Douglas production function was specified as:

$$Y = aX_1^{b_1} X_2^{b_2} X_3^{b_3} X_4^{b_4} X_5^{b_5} X_6^{b_6} X_7^{b_7} X_8^{b_8} X_9^{b_9} X_{10}^{b_{10}}$$

Where

Y = Estimated yield in quintals

a = Intercept of the production function

b_i = Partial regression coefficients of the respective resource variables ($i = 1, 2, \dots, 10$)

The explanatory variables included in the production function were defined as follows:

X_1 = Area under potato cultivation (hectares)

X_2 = Human labour (man-days)

X_3 = Bullock labour (pair-days)

X_4 = Machine labour (hours)

X_5 = Tubers (quintals)

X_6 = Manure (quintals)

X_7 = Nitrogen (kilograms)

X_8 = Phosphorus (kilograms)

X_9 = Potash (kilograms)

X_{10} = Plant protection chemicals (litres)

Resource-use efficiency was assessed by comparing the Marginal Value Product (MVP) of each input with its Marginal Factor Cost (MFC). An MVP/MFC ratio greater than one indicated underutilization of the resource, suggesting scope for increasing its use. A ratio less than one indicated overutilization, while a ratio equal to one represented optimum economic utilization of the resource.

Results and Discussion

Estimates of Cobb–Douglas Production Function in Potato Production (Small Farm)

Table 1 shows that the per hectare cost and return analysis of Rabi potato cultivation indicates that, at the overall level, Cost A, Cost B and Cost C were ₹49697.71, ₹77787.71 and ₹81753.04, respectively. The corresponding gross income was ₹152660.00, while farm business income, family labour income and net profit were ₹102962.29, ₹74872.29 and ₹70906.96, respectively. The overall input-output ratio was 1:1.87, indicating favourable returns from potato cultivation. On small farms, Cost A, Cost B and Cost C were ₹48824.82, ₹75774.82 and ₹79878.82, respectively. The gross income was ₹150025.00, with farm business income of ₹101200.18, family labour income of ₹74250.18 and net profit of ₹70146.18. The input-output ratio was 1:1.88, indicating profitable cultivation.

For medium farms, the corresponding values of Cost A, Cost B and Cost C were ₹49596.69, ₹76696.69 and ₹80638.69. The gross income amounted to ₹152320.00, while farm business income, family labour income and net profit were ₹102723.31, ₹75623.31 and ₹71681.31, respectively. The input-output ratio was 1:1.89.

In the case of large farms, Cost A, Cost B and Cost C were ₹50671.62, ₹80891.62 and ₹84743.62, respectively. The gross income was ₹155635.00, whereas farm business income was ₹104963.38, family labour income was ₹74743.38, and net profit was ₹17891.38. The input-output ratio was 1:1.84.

Overall, the results indicate that Rabi potato cultivation remained economically viable across all farm-size groups, as reflected by the favourable input-output ratios reported for small, medium and large farms.

Estimates of Cobb–Douglas Production Function in Potato Production (Medium Farm)

Table 2 shows that the estimates of the Cobb–Douglas production function for potato production on medium farms indicate an estimated intercept (log a) of 1.412. The coefficient of multiple determination (R^2) is 0.971, showing that 97.10 per cent of the variation in potato production is

explained by the variables included in the model. The F-value of 6.185 is significant at the 1 per cent level, indicating that the fitted regression model is statistically significant. The estimated return to scale (Σbi) is 0.495, indicating decreasing returns to scale. The geometric mean of potato production is 454.0 quintals per farm, and the price of potato is ₹850 per quintal.

The regression coefficient of area under potato is 0.338, which is positive and significant at the 1 per cent level, indicating that an increase in the area under potato cultivation results in higher potato production. Its MVP to price ratio of 2.149 indicates that the resource is underutilized. The coefficient of human labour is 0.098, which is positive but non-significant, while its MVP to price ratio of 2.091 indicates underutilization of human labour.

The regression coefficients of bullock labour, machine labour and nitrogen are -0.062, -0.205 and -0.058, respectively, indicating negative relationships with potato production. Among these inputs, machine labour is significant at the 5 per cent level, whereas bullock labour and nitrogen are non-significant. The MVP to price ratios indicate that all three resources are overutilized.

The regression coefficients of tubers, manure, phosphorus, potash, plant protection and irrigation are 0.125, 0.020, 0.024, 0.022, 0.018 and 0.175, respectively, showing positive relationships with potato production. Among these variables, irrigation is significant at the 5 per cent level, while tubers, manure, phosphorus, potash and plant protection are non-significant. The MVP to price ratios indicate that these resources are underutilized.

Estimates of Cobb–Douglas Production Function in Potato Production (Large Farm)

The estimates of the Cobb–Douglas production function for potato production on large farms are presented in Table 3. The estimated intercept (log a) is 5.680. The coefficient of multiple determination (R^2) is 0.948, indicating that 94.80 per cent of the variation in potato production is explained by the variables included in the model. The F-value of 3.410 is significant at the 1 per cent level, indicating that the fitted regression model is statistically significant. The estimated return to scale (Σbi) is 0.530, indicating decreasing returns to scale. The geometric mean of potato production is 995.0 quintals per farm, and the price of potato is ₹850 per quintal. The regression coefficient of area under potato is 0.335, which is positive and significant at the 1 per cent level, indicating that an increase in the area under potato cultivation leads to an increase in potato production. Its MVP to price ratio of 1.980 indicates that this resource is underutilized.

The regression coefficients of human labour (0.102), bullock labour (0.026), tubers (0.155), nitrogen (0.007), potash (0.011) and irrigation (0.080) are positive but non-significant. The MVP to price ratios indicate that human labour, bullock labour, tubers, nitrogen, potash and irrigation are underutilized.

The regression coefficients of machine labour (-0.038), phosphorus (-0.052) and plant protection (-0.118) are negative. Among these inputs, phosphorus and plant protection are significant at the 5 per cent level, whereas

machine labour is non-significant. The MVP to price ratios indicate that machine labour and plant protection are overutilized.

The regression coefficient of manure is 0.022, which is positive and significant at the 5 per cent level. Its MVP to price ratio of 1.573 indicates that manure is underutilized.

Estimates of Cobb–Douglas Production Function in Potato Production (Overall)

The estimates of the Cobb–Douglas production function for potato production at the overall level are presented in Table 4. The estimated intercept (log a) is 4.792, while the coefficient of multiple determination (R^2) is 0.982, indicating that 98.20 per cent of the variation in potato production is explained by the variables included in the model. The estimated F-value of 5.760 is significant at the 1 per cent level, confirming the statistical significance of the fitted regression model. The estimated return to scale (Σbi) is 0.605, indicating decreasing returns to scale. The geometric mean of potato production is 435.0 quintals per farm, and the prevailing price of potato is ₹850 per quintal.

The regression coefficient of area under potato is 0.342, which is positive and significant at the 1 per cent level, indicating that an increase in the area devoted to potato cultivation leads to an increase in potato production. The MVP to price ratio of 2.144 indicates that area under potato is underutilized. The coefficient of human labour is 0.078, which is positive and significant at the 5 per cent level, while its MVP to price ratio of 1.544 indicates underutilization of human labour.

The regression coefficient of bullock labour is -0.128, which is negative and significant at the 5 per cent level, indicating that bullock labour is overutilized. In contrast, the coefficient of machine labour is 0.078, which is positive but non-significant. Its MVP to price ratio of 6.831 indicates that machine labour is underutilized. The coefficient of tubers is 0.125 and is positive but non-significant, with an MVP to price ratio of 1.394, indicating underutilization of tubers. Similarly, the coefficient of manure is 0.024, which is positive but non-significant, and its MVP to price ratio of 1.777 indicates that manure is underutilized.

The regression coefficient for nitrogen is 0.068, which is positive but non-significant. Its MVP to price ratio of 14.340 indicates substantial underutilization of nitrogen. The coefficient of phosphorus is -1.035, which is negative and significant at the 5 per cent level, indicating overutilization of phosphorus. The regression coefficient of potash is 0.148, which is positive and significant at the 5 per cent level, while its MVP to price ratio of 17.224 indicates that potash is underutilized.

The regression coefficient of plant protection is -0.120, which is negative and significant at the 5 per cent level, indicating overutilization of plant protection inputs. Finally, the coefficient of irrigation is 0.125, which is positive and significant at the 1 per cent level. Its MVP to price ratio of 2.255 indicates that irrigation is underutilized. Overall, the results indicate that most of the production resources in potato cultivation are underutilized, while bullock labour, phosphorus and plant protection inputs are overutilized.

Table 1: Estimates of Cobb-Douglas production function in potato production (Small farm)

Sr. No.	Independent Variable	Regression coefficient (bi)	Standard error bi (SE)	t' value	Geometric mean of input (xi)	marginal product (q)	Marginal value product (Rs)	Price of input (Rs)	MVP to price ratio	Optimum resources use
1	Area under potato (ha/farm)	0.282	0.110	2.564*	1.020	48.061	40852.12	33500.00	1.219	1.660
2	Human labour (man day/farm)	0.182	0.162	1.23	47.500	0.677	575.45	180.00	3.197	151.857
3	Bullock labour (hours/farm)	0.210	0.190	-1.105	3.100	-11.777	-10010.81	400.00	-25.027	-
4	Machine labour (hours/ farm)	0.260	0.102	2.549*	5.400	8.368	7112.96	300.00	23.710	128.033
5	Tubers (q/farm)	0.440	0.158	2.785**	17.500	4.370	3714.29	800.00	4.643	81.250
6	Manure (q/farm)	0.180	0.198	0.909	19.800	1.581	1343.69	100.00	13.437	266.050
7	Nitrogen (kg/farm)	-0.105	0.132	-0.795	135.000	-0.135	-114.99	13.04	-8.818	-
8	Phosphorus (kg/farm)	0.250	0.174	1.437	105.000	0.414	351.90	49.24	7.147	750.406
9	Potash (kg/farm)	0.110	0.101	1.089	88.000	0.217	184.66	34.20	5.399	475.146
10	Plant protection (lit.)	-0.150	0.058	-2.586*	3.400	-7.669	-6518.75	500.00	-13.038	--
11	Irrigation (m ³ / farm)	-0.420	0.234	-1.795	2050.000	-0.036	-30.39	2.00	-15.195	--

Incept (log a) ----- 5.612 Note: Geometric mean (Y) of potato production

F value ----- 3.882** was 173.8 q/ha per farm and price Rs.850/q.

R² ----- 0.954Return to scale ($\sum bi$) ----- 0.822

(*) Significant at 5 per cent level

(**) Significant at 1 per cent level

Table 2: Estimates of Cobb-Douglas production function in potato production (Medium farm)

Sr. No.	Independent Variable	Regression coefficient (bi)	Standard error bi (SE)	t' value	Geometric mean of input (xi)	marginal product (q)	Marginal value product (Rs)	Price of input (Rs)	MVP to price ratio	Optimum resources use
1	Area under potato (ha/farm)	0.338	0.101	3.347**	2.550	60.165	51140.25	23800.00	2.149	5.479
2	Human labour (man day/farm)	0.098	0.086	1.140	100.500	0.443	376.38	180.00	2.091	210.145
3	Bullock labour (hours/farm)	-0.062	0.052	-1.192	11.200	-2.512	-2135.20	400.00	-5.338	--
4	Machine labour (hours/ farm)	-0.205	0.092	-2.228*	15.200	-6.121	-5202.85	300.00	-17.343	--
5	Tubers (q/farm)	0.125	0.148	0.845	44.333	1.351	1148.35	800.00	1.435	60.288
6	Manure (q/farm)	0.020	0.074	0.270	53.333	0.171	145.35	100.00	1.454	77.037
7	Nitrogen (kg/farm)	-0.058	0.139	-0.417	136.333	-0.194	-164.90	13.04	-12.646	--
8	Phosphorus (kg/farm)	0.024	0.115	0.209	110.333	0.099	84.15	49.24	1.709	187.989
9	Potash (kg/farm)	0.022	0.087	0.253	90.333	0.111	94.35	34.20	2.759	248.293
10	Plant protection (lit.)	0.018	0.178	0.101	8.800	0.929	789.65	500	1.579	13.895
11	Irrigation (m ³ / farm)	0.175	0.073	2.397*	6400.000	0.012	10.20	2.00	5.100	32640.000

Incept (log a) ----- 1.412 Note: Geometric mean (Y) of potato production

F value ----- 6.185** was 454.0 q/ha per farm and price was Rs. 850/q.

R² ----- 0.971Return to scale ($\sum bi$) ----- 0.495

(*) Significant at 5 per cent level

(**) Significant at 1 per cent level

Table 3: Estimates of Cobb-Douglas production function in potato production (Large farm)

Sr. No.	Independent Variable	Regression coefficient (bi)	Standard error bi (SE)	t' value	Geometric mean of input (xi)	marginal product (q)	Marginal value product (Rs)	Price of input (Rs)	MVP to price ratio	Optimum resources use
1	Area under potato (ha/farm)	0.335	0.081	4.136**	5.400	61.731	52471.35	26512.20	1.980	10.690
2	Human labour (man day/farm)	0.102	0.141	0.723	230.00	0.432	367.20	180.00	2.040	479.400
3	Bullock labour (hours/farm)	0.026	0.018	1.444	26.000	0.995	845.75	400.00	2.114	54.964
4	Machine labour (hours/ farm)	-0.038	0.169	-0.225	34.000	-1.112	-945.20	300.00	-3.151	-
5	Tubers (q/farm)	0.155	0.092	1.685	96.000	1.606	1365.10	800.00	1.706	163.776
6	Manure (q/farm)	0.022	0.009	2.444*	118.000	0.185	157.25	100.00	1.573	185.614
7	Nitrogen (kg/farm)	0.007	0.081	0.086	140.00	0.050	42.50	13.04	3.259	466.264
8	Phosphorus (kg/farm)	-0.052	0.022	-2.64*	120.000	-0.431	-366.52	49.24	7.444	-
9	Potash (kg/farm)	0.011	0.183	0.060	95.200	0.115	97.75	34.20	2.858	271.510
10	Plant protection (lit.)	-0.118	0.050	-2.360*	20.000	-5.871	-4990.35	500.00	-9.981	-
11	Irrigation (m ³ / farm)	0.080	0.112	0.714	16500.000	0.0048	4.08	2.00	2.040	33666.000

Incept (log a) ----- 5.680 Note: Geometric mean (Y) of potato production

F value ----- 3.410** was 995.0 q/ha per farm and price was Rs. 850/q.

R² ----- 0.948Return to scale ($\sum bi$) ----- 0.530

(*) Significant at 5 per cent level

(**) Significant at 1 per cent level

Table 4: Estimates of Cobb-Douglas production function in potato production (Overall)

Sr. No.	Independent Variable	Regression coefficient (bi)	Standard error bi (SE)	t' value	Geometric mean of input (xi)	marginal product (q)	Marginal value product (Rs)	Price of input (Rs)	MVP to price ratio	Optimum resources use
1	Area under potato (ha/farm)	0.342	0.093	3.677**	2.400	62.062	52752.70	24600.00	2.144	5.146
2	Human labour (man day/farm)	0.078	0.032	2.438*	104.000	0.327	277.95	180.00	1.544	160.576
3	Bullock labour (hours/farm)	-0.128	0.061	-2.098*	9.700	-5.753	-4890.05	400.00	-12.225	-
4	Machine labour (hours/ farm)	0.078	0.060	1.300	14.100	2.411	2049.35	300.00	6.831	56.319
5	Tubers (q/farm)	0.125	0.064	1.953	41.500	1.312	1115.20	800.00	1.394	57.851
6	Manure (q/farm)	0.024	0.098	0.245	50.000	0.209	177.65	100.00	1.777	88.825
7	Nitrogen (kg/farm)	0.068	0.068	1.000	135.000	0.220	187.00	13.04	14.340	2935.968
8	Phosphorus (kg/farm)	-1.035	0.058	-2.328*	111.000	-0.530	-450.50	49.24	-9.149	-
9	Potash (kg/farm)	0.148	0.058	2.552*	93.000	0.693	589.05	34.20	17.224	1601.801
10	Plant protection (lit.)	-0.120	0.055	-2.182*	8.800	-5.939	-5048.15	500.00	-10.096	-
11	Irrigation (m ³ / farm)	0.125	0.044	2.841**	10200.000	0.0053	4.51	2.00	2.255	22976.250

Incept (log a) ----- 4.792 Note: Geometric mean (Y) of potato production

F value ----- 5.760** was 435.0 q/ha per farm and price was Rs. 850/q.

R² ----- 0.982

Return to scale ($\sum bi$) ----- 0.605

(*) Significant at 5 per cent level

(**) Significant at 1 per cent level

Conclusion

The study concludes that potato (*Solanum tuberosum* L.) cultivation has considerable economic potential in Chhatrapati Sambhajinagar district of Maharashtra. The Cobb-Douglas production function showed that the selected inputs significantly influenced potato production, with an overall R² of 0.982 and decreasing returns to scale (0.605). Area under potato, human labour and irrigation had positive and significant effects on output, whereas bullock labour, phosphorus and plant protection were negatively associated with production. The MVP-to-price ratios indicated that area under potato, human labour, machine labour, tubers, manure, nitrogen, potash and irrigation were underutilized, while bullock labour, phosphorus and plant protection were overutilized. Therefore, efficient allocation and balanced use of production resources are essential for improving potato productivity and profitability. Farmers can benefit by increasing the use of underutilized resources to economically optimum levels and reducing excessive use of overutilized inputs.

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