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AN ECONOMICS OF POTATO PRODUCTION IN KANGRA DISTRICT OF HIMACHAL PRADESH

A Raina[1], P Sharma[1], Garima Gupta[2*] and S Kumari[2]

ABSTRACT: In Kangra district of Himachal Pradesh is renowned for its disease-free quality seed potato production, an economic study of 200 growers grouped into small (105) and large (95) farms revealed an overall cost of cultivation at Rs. 94,667 per farm and Rs. 3,08,051 per ha in 2022-23. Among all inputs, potato seed accounted for 29% per hectare, while human labor constituted 27% of costs. The total variable cost was 89%, with fixed costs at 11% per ha. Gross income averaged Rs. 4,67,705 per ha. Efficiency analysis across farm categories showed the cost of potato production at Rs. 250 per quintal (q). Large farms exhibited a slightly higher output-input ratio (1.52) compared to small farms. Production costs ranged from Rs. 1,195 to Rs. 1,270 per q for large and small farms, respectively, with variable costs higher on small farms (Rs. 1,117) than on large ones (Rs. 1,074) per q. The reported benefit-cost ratio stood at 1.88, indicating favorable returns. Potato prices ranged from Rs. 1,860 to Rs. 1,880 per q, with larger farms realizing higher prices. Break-even analysis suggested the need for small, large, and overall farm categories to achieve at least 50.72, 38.02, and 44.14 q of potatoes, respectively, to maintain a no-profit, no-loss condition. The analysis underscores potential profit increase by optimizing human labor, manure, and fertilizer use.

KEYWORDS: CACP cost concepts, Cost-benefit analysis, economic analysis, net returns.

INTRODUCTION

The potato (*Solanum tuberosum*), grown for its starchy tubers, belongs to the nightshade family (Solanaceae) and is cultivated worldwide, originating in the Peruvian and Bolivian Andes (Singh *et al.*, 2020). China and India lead global potato production, contributing about one-third of the total crop (FAOSTAT, 2023). In 2022-23, global production reached 376 million tonnes (mt), with China producing 94 mt and India 54 mt. In Himachal Pradesh, agriculture comprises 14% of the state's Gross State Domestic Product (GSDP) (Economic Survey of Himachal Pradesh, 2022-23), with potatoes being a significant crop, yielding 1,94,500 metric tonnes on 15,100 ha (Statistical Yearbook of Himachal Pradesh, 2022-23). Kangra district alone produces 16,030 tonnes on over 1,250 ha, representing nearly 11% of the state's vegetable production (Statistical Yearbook of Himachal Pradesh, 2022-23). Sharma *et al.* (2017) highlight Kangra's potatoes for their high dry matter content (20%), ideal for chip manufacturing. Harvested typically in May, but usable till July, Kangra's potatoes are in demand by food processing industries, particularly in Palampur and NagrotaBagwan. However, geographical and topographical constraints limit agricultural land availability (Sharma *et al.*, 2017). To address the profitability and efficiency of potato cultivation, including cultivation costs, marketing, technical efficiency, and climate change impacts, an economic analysis of Himachal Pradesh's potato output is vital. Insights from this research can guide policymakers and farmers in improving the financial performance of the potato farming industry in the region.

MATERIALS AND METHODS

The study was carried out during 2022-23 for Kangra district employing a

[1]University School of Business, Chandigarh University, Gharuan (Mohali), Punjab- 140413, India
[2]University Institute of Agricultural Sciences, Chandigarh University, Gharuan (Mohali), Punjab- 140413, India
*Corresponding author; email: garima.e8884@cumail.in / hod.agri@cumail.in

systematic sampling approach. Initially, a list of potato-growing blocks was compiled based on cultivation area, with the first two blocks selected purposively. Then, a two-stage stratified random sampling method was utilized to select farmers and villages. Working closely with revenue and agriculture department representatives, a comprehensive list of potato-growing communities within each selected block was created. Subsequently, five villages were randomly chosen in each block, resulting in a total of ten sample villages. With the help of revenue officials, a list of potato-cultivating farmers in each sample village was generated. Employing the proportionate allocation technique, 200 farmers were sampled from these villages, considering time and resource constraints. Using the square root cumulative frequency approach by (Sharma *et al.*, 2017; Kumari *et al.*, 2020); and the farmers were categorized into two groups: 95 large farmers and 105 small farmers. Data collection involved structured interviews with growers following carefully planned schedules. Production function analysis and tabular techniques were applied to analyze the collected data. Cost and return calculations for potato cultivation were conducted using established methodologies.

Cost concepts

The tabular technique and production function analysis were used to analyse the gathered data. The following ideas were applied for calculating the costs and returns of potatoes.

– Cost A consists of the material cost, bullock/tractor fees, and working capital interest.

– Cost B is equal to Cost A plus interest on fixed capital and the land's rental value.

– Cost B + estimated value of family labour equals Cost C.

– Cost D is equal to Cost C plus 10% of Cost C.

The interest rate on working capital was calculated based on the current lending rates for 2022–2023 and was set at 10% for half of the crop period and 8% for fixed capital. The typical average land rental value was employed, based on the sample survey. Same approach was employed by and (Sapkota *et al.*, 2019; Dahal *et al.*, 2023).

Benefit-cost ratio

Cost/benefit analysis: A benefit/cost analysis was also conducted to determine the financial viability of potato farming. Any company's economic strengths can be identified using the benefit-to-cost ratio (Shively, 2013). It was computed as follows: Revenue total divided by manufacturing costs equals BCR. Same approach was employed by Sapkota *et al.* (2019) and Dahal *et al.* (2023).

Farm efficiency measures

To assess farm revenue and profit efficiency, the following metrics were utilized, following the approach of Sinha and Singh (2023):

1. Gross farm income (GFI): Represents the gross value of output, adjusted for by-products, and valued at farm harvest rates.
2. Net farm income (NFI): Calculated by subtracting farm expenses from gross farm income, reflecting compensation for farmers' management. NFI = GFI – Cost C.
3. Farm family labour income (FLI): Indicates returns to family labor, derived from gross farm income less Cost B. FLI = GFI – Cost B.
4. Farm business income (FBI): Determined by deducting Cost A from Gross Farm Income, FBI reflects returns to labor, owned land, owned fixed capital, and management. FBI = GFI – Cost A.

5. Farm investment income: Represents the sum of land rental value, interest on owned fixed capital, and net agricultural revenue.

These metrics provide a comprehensive understanding of farm revenue and profit efficiency, facilitating an assessment of different aspects of farm management and resource allocation

Production function analysis

Using input-output data from individual farmers, production functions were approximated to investigate the degree to which different resources were used in potato production. Various log-linear functions were employed, chosen based on R2 values and regression coefficient significance. This methodology propounded by Mahaboob*et al.* (2019), Sharma *et al.*(2017), and Sapkota *et al.*(2019). It aims to assess resource contributions, informing efficient resource allocation strategies.

The following form of production function was employed:

$$Y = b_0\ X_1 b_1\ X_2 b_2\ X_3\ b_3\ X_4 b_4\ X_5 b_5 e_U$$

The function's logarithm is:

$$\text{Log } Y = \text{Log} b_0 + b_1 \text{Log} X_1 + b_2 \text{ Log } X_2 + b_3 \text{ Log } X_3 + b_4 \text{ Log} X_4 + b_5 \text{ Log} X_5 + U$$

Where,

Y= Output of potato (q/ha), X_1 = Seed rate (kg/ha), X_2 = Farmyard manure (q/ha), X_3 = Fertilizers (kg/ha), X_4 = Human labour (Man days/ha), X_5 = Operational holding (ha), b_0 = Constant term, $b_{i's}$ = Regression coefficients, i= 1, 2,..,5

U = Random term

Statistical tools

T-statistics were used to examine the regression coefficient of production elasticity for statistical significance.

Return to scale

Return to scale in the Cobb-Douglas production function was calculated by adding the elasticity coefficients of the independent variables, or (Σin=1bi). Same approach was also employed by Sharma *et al.*(2017) and Sapkota *et al.*(2019).

If Σbi=1, implies constant return to scale.

If Σbi>1, implies increasing return to scale.

If Σbi<1, implies decreasing return to scale.

RESULTS AND DISCUSSION

Because of the state's inherent advantages in the production of seed potato, this crop plays a significant role in the economy of Himachal Pradesh. The perfect environment for growing disease-free potatoes in the state includes mild, temperate climate with high wind speeds, moderate humidity in the higher hills, and negligible to low aphid populations. Potatoes took up 15,100 ha of land in Himachal Pradesh, yielding 1.94 lakh tones.

Labour utilization pattern

Human labor is pivotal for profitable farming, especially for labor-intensive crops like potato. Field preparation, planting, inter-cultivation, and harvesting require a significant labor. Labor needs vary based on farm mechanization levels. The study assessed labor requirements by converting time spent on farm tasks into man-days, with one man-day equating to eight hours. Table 1 details labor distribution for potato cultivation. On average, 208 man-days per hectare were required, ranging from 214 on small farms to 205 on large ones. Family labor contributed 35% overall, with hired labor constituting the remaining 65%. Harvesting/digging (17%), cleaning and transporting (17%), field preparation (18.75%), andweeding/ inter-cultivation/planting (14%) were the most labor-intensive tasks. These primary operations comprised 63.46% of total labor. Srinivas and Ramanathan (2007) have also reported similar findings.

Table 1. Operation-labour utilization for potato cultivation on sample farms.

(Mandays)

S. No.	Particulars	Small		Large		Overall	
		Per farm	Per ha	Per farm	Per ha	Per farm	Per ha
1	Field preparation	5 (16.67)	36 (16.82)	18 (18.37)	38 (18.54)	12 (18.46)	39 (18.75)
2	Seed preparation & treatment	3 (10.00)	21 (9.81)	9 (9.18)	19 (9.27)	6 (9.23)	19 (9.13)
3	Sowing/ planting of tubers	4 (13.33)	29 (13.55)	13 (13.27)	27 (13.17)	9 (13.85)	29 (13.94)
4	Weeding/ interculture	4 (13.33)	29 (13.55)	14 (14.29)	29 (14.15)	9 (13.85)	29 (13.94)
5	Manuring & fertilizer application	3 (10.00)	21 (9.81)	9 (9.18)	19 (9.27)	6 (9.23)	19 (9.13)
6	Plant Protection measures/ sprays	3 (10.00)	21 (9.81)	9 (9.18)	19 (9.27)	6 (9.23)	19 (9.13)
7	Irrigation	3 (10.00)	21 (9.81)	9 (9.18)	19 (9.27)	6 (9.23)	19 (9.13)
8	Harvesting/ digging of tubers	5 (16.67)	36 (16.82)	17 (17.35)	35 (17.07)	11 (16.92)	35 (16.83)
9	Total Labour	30 (100.00)	214 (100.00)	98 (100.00)	205 (100.00)	65 (100.00)	208 (100.00)
i	Family labour	11 (36.67)	79 (36.92)	34 (34.69)	71 (34.63)	23 (35.38)	73 (35.10)
ii	Hired Labour	19 (63.33)	135 (63.08)	64 (65.31)	134 (65.37)	42 (64.62)	135 (64.90)

Note: Figures in the parentheses indicate percentages to the total in each category.

Input use pattern

Table 2 illustrates input usage for potato cultivation, offering insights into farm technology levels crucial for crop yield. Seeds are a key input, constituting a significant portion of the cost, averaging 22.58 q/ha, slightly below the recommended rate of 25 q/ha. Farmyard manure (FYM) averaged 195.16 q/ha, falling short of the recommended 250 q, with no notable difference between farm sizes. Farmers predominantly utilized IFFCO mixture (12:32:16) and urea, applying an average of 177.42 kg/ha and 216.13 kg/ ha, respectively. Larger farms tended to use more of these inputs per hectare. Pesticide and chemical usage for disease and insect control incurred costs of Rs 2,143 and Rs 1,250 per hafor small and large farms, respectively. Tractor services averaged 29.9 hours per ha, with no significant difference between farm sizes. Bullocks, tractors, and power tillers were crucial for field ploughing, with a preference for tractors and power tillers. Bullock labor averaged at 4.84 bullock pairs per farm, with

Table 2. Input use pattern for potato crop on sample farms.

S. No.	Particular	Small		Large		Overall	
		Per farm	Per ha	Per farm	Per ha	Per farm	Per ha
1	Seed(q)	3	21.43	11	22.92	7	22.58
2	FYM(q)	27	192.86	94	195.83	60.5	195.16
3	Fertilizers						
i	Urea(kg)	29	207.14	105	218.75	67	216.13
ii	IFFCO mixture(kg)	20	142.86	90	187.5	55	177.42
	Total	79	350	300	625	122	393.55
4	Pesticides/ chemicals(Rs)	300	2143	600	1250	400	1290
5	BPD	2	14.29	1	2.08	1.5	4.84
6	Tractor/power tiller hours	4.04	28.86	14.5	30.21	9.27	29.9

Note: BPD: Bullock Pair Days, FYM: Farm Yard Manure small farms utilizing more per ha. Human labor requirement averaged 208 man-days per ha, slightly more for small farms (214 man-days). This data informs agricultural optimization, enhancing productivity and overall farm efficiency.

Variable cost structure for potato cultivation on sample farms

The variable cost structure for potato production, comprising inputs like seed, fertilizer, pesticides, and hired labor depicted in Table 3. Seed costs were paramount, constituting 60.38% of the material cost and 32.38% of the total variable cost. Farmyard manure (FYM) costs followed closely, representing about 23.81% of the material cost and approximately 13% of the variable cost. Fertilizer and insecticide costs accounted for 14.65% and 1.15% of the material cost, respectively. Interestingly, fertilizer expenses were higher on large farms compared to small ones, while pesticide expenses per ha were higher on small farms. Hired labor constituted about 19.65% of the total variable cost, with charges for tractor/power tiller/bullock accounting for approximately 10%. Additional variable costs included miscellaneous charges like irrigation channels and tool repairs. Family labor contributed around 11% of the total variable cost. Lal and Sharma (2006) echoed these findings, emphasizing the capital and labor intensity of potato cultivation due to significant costs associated with seed, fertilizer, and human labor.

Costs and returns for potato cultivation on sample farms

A breakdown of per-ha costs and returns, incorporating fixed expenses like interest on fixed capital, depreciation, and rental value of owned land is presented in table 4. Total annual interest and depreciation on fixed capital were proportionally allocated across all crops, with small farms bearing 17.48% and large farms 9.75%. Net returns over variable costs surpassed net returns over total costs by 19.6%, indicating efficient management

Table 3. Variable cost structure for potato cultivation on sample farms.

(Rs)

S. No.	Particulars	Small		Large		Overall	
		Per farm	Per ha	Per farm	Per ha	Per farm	Per ha
1	Material cost						
i	Seed	12000	85714 (31.14)	44000	91667 (33.64)	28000	88691 (32.38)
ii	FYM	4860	34714 (12.61)	16920	35250 (12.93)	10890	34982 (12.77)
iii	Fertilisers	2860	20429 (7.42)	10860	22625 (8.30)	6860	21527 (7.86)
iv	Pesticides	300	2143 (0.78)	600	1250 (0.46)	450	1697 (0.62)
	Sub total	20020	143000 (51.95)	72380	150792 (55.33)	46200	146897 (53.63)
2	Family labour	4400	31429 (11.42)	13600	28333 (10.40)	9000	29881 (10.91)
3	Hired labour	7600	54286 (19.72)	25600	53333 (19.57)	16600	53810 (19.65)
4	Bullock labour/tractor/power tiller charges	4032	28800 (10.46)	12000	25000 (9.17)	8016	26900 (9.82)
5	Miscellaneous Charges (Rs)	550	3929 (1.43)	600	1250 (0.46)	575	2590 (0.95)
6	Working Capital (1+3+4+5)	32202	230014 (83.57)	110580	230375 (84.53)	71391	230195 (84.05)
7	Interest on working capital (@6%p.a)	1932	13800 (5.01)	6635	13823 (5.07)	4284	13812 (5.04)
8	Cash variables expenses	34134	243814 (88.58)	117215	244198 (89.60)	75675	244006 (89.09)
9	Total variable Cost (2+6+7)	38534	275243 (100.00)	130815	272531 (100)	84675	273888 (100)

Note: Figures in the parentheses indicate percentages to the total in each category

Table 4. Costs and returns for potato cultivation on sample farms.

(Rs)

S. No.	Particulars	Small		Large		Overall	
		Per farm	Per ha	Per farm	Per ha	Per farm	Per ha
1	Total variable cost	38534	275243	130815	272531	84675	273887
2	Total fixed cost	5276	37686	14708	30642	9992	34164
a)	Interest on fixed capital	886	6329	1710	3563	1298	4946
b)	Depreciation on fixed capital	890	6357	998	2079	944	4218
c)	Rental value of own land	3500	25000	12000	25000	7750	25000
d)	Imputed management cost	2155	15393	8700	18125	5428	16759
3	Total cost (1+2)	43810	312929	145523	303173	94667	308051
4	Quantity of output (q)	34.5	246.43	121.8	253.75	78	250
5	Price per quintal (Rs)	1860	1860	1880	1880	1870	1870
6	Value of output/Gross returns	64170	458360	228984	477050	146577	467705
7	Net returns over total cost	20360	145431	83461	173877	51911	159654
8	Net returns over variable cost	25636	183117	98169	204519	61903	193818
9	Net returns over cash variable expenses (excluding family labour)	30036	214546	111769	232852	70903	223699
10	Total cost of production (Rs./q)	1270	1270	1195	1195	1233	1233
11	Variable cost of production (Rs./q)	1117	1117	1074	1074	1096	1096
12	Output-input Ratio	1.46	1.46	1.57	1.57	1.52	1.52

of variable inputs. However, lower net returns over total costs imply significant fixed expenses that could impact overall profitability. Total fixed costs per hectare totaled Rs. 37,686, and total variable costs were Rs. 2,75,243, with small farms facing higher fixed costs. Effective cost management strategies are imperative in light of these findings.

Moving from small to large farms, there is an evident decreases in the total cost of cultivation, from Rs. 3,12,929 to Rs. 3,03,173, indicating that larger farms have the capacity to invest more in modern agricultural inputs. This encompasses high-quality seeds, hired labor, manure, fertilizers, plant protection, and machine labor costs, aligning with findings reported by Pandey *et al.* (2004). Raghuvanshi *et al.* (2018) similarly observed a rise in cultivation costs from marginal to large farmers. Gross returns per hectare were notably higher on large farms (Rs. 4,77,050) compared to small farms (Rs. 4,58,360), possibly due to economies of scale. Larger farms can leverage scale efficiencies, achieving higher production and potentially reducing per-unit production costs. The total cost of production (Rs./q) ranged from 1,195 for large farms to 1,270 for small farms, with small farms incurring higher variable production costs (Rs. 1,117) compared to large farms (Rs. 1,074). This disparity in production costs suggests efficiency and cost structure discrepancies, with small farms possibly encountering challenges in achieving cost-effective production. The output-input ratio slightly favored large farms (1.57) over small farms (1.46), with an overall ratio of 1.52, indicating that for every Rs. 1 invested in potato cultivation, Rs. 1.52 was gained. This suggests efficiency potentially stemming from superior management practices and economies of scale. The reported average potato yield of approximately 250 q/ha is pivotal for assessing productivity, emphasizing the importance of consistent and high yields to sustain profitability and agricultural sustainability. The reported benefit-cost ratio of 1.88 as noted by Mohammadi *et al.*(2018), further bolsters the profitability standpoint, indicating that, on average, returns from potato cultivation are 1.88 times the costs incurred, a generally favorable outcome.

Different costs and returns for potato cultivation on sample farms according to CACP cost concepts

The economic evaluation of costs and returns in potato cultivation, as depicted in table 5, serves as a vital instrument for grasping the financial dynamics of farming operations. The computation of operational costs (Cost A) per ha, totaling Rs. 1,87,608 across all farms, and its subsequent augmentation with interest on fixed capital and rental value of owned land to form Cost B at Rs. 2,17,554 per ha, offers invaluable insights. The comparison of these costs across various farm categories unveils nuances in operational efficiency and resource allocation. Further examination of Cost C and Cost B per ha, averaging Rs. 2,34,313 and Rs. 2,17,554, respectively, provides a comprehensive perspective of the overall financial landscape. Remarkably, these costs demonstrate a slightly higher trend on large farms, consistent with the findings of Singh et al. (2020). The analysis of gross returns per ha, totaling Rs. 4,67,705, showcases a marginal increase of about 4% on large farms compared to small farms. This disparity underscores the influence of scale and resource utilization on overall returns.

After looking into total cost (Cost D) per ha, which was estimated to be Rs. 2,57,745 for all farms, it was discovered that large farms had a greater value (Rs. 2,59,933) than small farms (Rs. 2,55,557), which indicates potential and challenges for cost control. The variation in profitability across different farm sizes is reflected in the nuanced analysis of net returns per hectare above operational costs (Cost A) from large (Rs. 2,87,435) to small farms (Rs. 2,72,760), with an average of Rs. 2,80,098. In addition, the analysis of net returns per acre over Costs C and B,

Table 5. Different costs and returns for potato cultivation on sample farms according to CACP cost concepts.

(Rs)

S. No.	Particulars	Small		Large		Overall	
		Per farm	Per ha	Per farm	Per ha	Per farm	Per ha
1	Cost A	25984	185600	91015	189615	58500	187608
2	Cost B	30370	216929	104725	218178	67548	217554
3	Cost C	32525	232322	113425	236303	72975	234313
4	Cost D	35778	255557	124768	259933	80273	257745
5	Gross Farm Income	64170	458360	228984	477050	146577	467705
6	Net returns over						
i	Cost A	38186	272760	137969	287435	88078	280098
ii	Cost B	33800	241431	124259	258872	79030	250152
iii	Cost C	31645	226038	115559	240747	73602	233393
iv	Cost D	28392	202803	104216	217117	66304	209960
7	Output-input ratio	1.46	1.46	1.57	1.57	1.52	1.52

which come to Rs. 2,33,393 and Rs. 2,50,152, respectively, further demonstrates the impact of variables and family work on financial results.

The observed differences in these indicators between large and small farms emphasize the necessity for customized manpower management and cost containment strategies. To sum up, it is critical that scholars, politicians, and farmers carefully examine these past costs and returns. It helps in making well-informed judgements, creating efficient agricultural policies, and pinpointing areas where the farming industry needs to improve. This analysis reveals a dynamic interaction of financial forces that directs the development of profitable and sustainable farming practices.

Farm efficiency

A key component of comprehending the economic dynamics and productivity of potato production across various farm categories was the analysis of various farm efficiency indices. A thorough analysis of important metrics, including net farm income, gross farm revenue, labour income from farm families, income from farm businesses, and income from farm investments, has been given in Table 6. Beginning with gross farm income, the data presented showed that Rs. 4,67,705 was the total amount per hectare. Farmers and other stakeholders were able to assess the total revenue derived from farming operations thanks to this complete metric. Large farms' gross farm revenue (Rs. 4,77,050) was notably higher than small farms' (Rs. 4,58,360), suggesting possible differences in productivity and scale efficiency. Next, we looked at net farm income, which was the total value per hectare after all costs were subtracted. It was Rs. 2,33,393. This important measure shed light on how profitable potato production is when both variable and fixed costs are taken into account. Notably, net farm income provided a complete picture of financial performance by matching net returns over Cost C.

The function and contribution of family labour in farming operations were clarified by examining farm family labour income, which is equal to net returns over Cost B. The revenue from family work on small farms (Rs. 2,41,431) was surpassed by the amount reported by large farms, which was Rs. 2,50,152. This discrepancy suggested differences in how family labour resources were used, with larger farms showing a more active involvement of family members in farming. The differences in efficiency between small and large farms were further highlighted by the trends in farm business income and farm investment income that were seen. These metrics offered a comprehensive picture of the financial gains made from both the main farming operation and the associated investments. In conclusion, academic and farmers benefited much from the examination

Table 6. Measures of farm business returns for potato on sample farms.

(Rs)

Sr. No.	Particulars	Small		Large		Overall	
		Per farm	Per ha	Per farm	Per ha	Per farm	Per ha
1	Gross farm income	64170	458360	228984	477050	146577	467705
2	Net farm income	31645	226038	115559	240747	73602	233393
3	Farm family labour income	33800	241431	124259	258872	79030	250152
4	Farm business income	38186	272760	137969	287435	88078	280098
5	Farm investment income	36031	257367	129269	269310	82650	263339

of these efficiency metrics. It supported well-informed decision-making, the creation of successful agricultural policies, and the identification of areas where the farming industry needed to improve.

Break-even analysis

A crucial component of farm management is determining the break-even output, which is the production level at which no profit or loss is realized. The break-even analysis for potato crop in terms of both money and physical factors is shown in Table 7 for different farm categories. The total fixed cost per hectare for small, large, and overall farm categories was clearly Rs. 37,686, Rs. 30,642, and Rs. 34,164, according to the table. The total variable cost per hectare varied from Rs. 2,72,531 to Rs. 2,75,243 in large and small farms respectively. Potato prices realized per quintal varied between 1,860 and 1,880 rupees, with larger farms realizing higher prices. Large to small category farms have production costs per quintal ranging from Rs. 1,195 to Rs. 1,270. The break-even study indicates that in order to maintain a no-profit, no-loss condition, the small, big, and overall farm categories must produce at least 50.72 quintals, 38.02 quintals, and 44.14 quintals of potatoes, respectively. Small farms had a greater break-even output (Rs. 94,339) in terms of money than large farms (Rs. 71,478). For small farms, the break-even output as a percentage of total output followed a similar pattern, with 20.58% for small farms and 14.98% for large farms.

Table 7. Break-even output of potato on sample farms.

Sr. No.	Particulars	Small	Large	Overall
1	Total fixed cost (Rs./ha)	37686	30642	34164
2	Total variable cost (Rs./ha)	275243	272531	273887
3	Total Cost (Rs./ha)	312929	303173	308051
4	Price per quintal (Rs)	1860	1880	1870
5	Output per ha (q)	246.43	253.75	250
6	Cost of Production (Rs./q)	1270	1195	1233
7	Average Variable Cost (Rs./q)	1117	1074	1096
8	Break-even output (q)	50.72	38.02	44.14
9	Break-even output in monetary terms (Rs.)	94339	71478	82542
10	Break-even output as percent to total output	20.58	14.98	17.66

A thorough grasp of the output levels necessary to cover costs and prevent losses is provided by break-even analysis. It helps farmers with financial planning, pricing tactics, and realistic output targets. Through the assessment of break-even outputs at several farm sizes, producers can customize their approaches to maximize both sustainability and profitability when growing potatoes. Making wise decisions requires these insights, particularly in the competitive and dynamic agricultural environment. Finally, farmers can use the break-even analysis as a useful tool to help them navigate the intricacies of cost and production dynamics.

Production function analysis

Both linear and Cobb-Douglas production functions were used in the regression analysis to look at the input-output relationship in the potato crop under various farmer groups. Based on economic and statistical criteria, the Cobb-Douglas form of the production function was found to be the best match. It was then used to investigate how various factors affected output, production elasticities, and resource usage efficiency. Table 8 provides the regression coefficients, standard errors, and adjusted coefficients of multiple determinations () for potato production. Roughly 72% of the difference in potato production across the farm was explained by the production function. Potato production on an overall farm was significantly and favourably impacted by

Table 8. Estimated regression coefficients of different factors influencing potato production.

S. No.	Particulars	Regression coefficient	Small	Large	Overall
1	Constant	b0	0.890 (0.310)	-3.940 (1.840)	-0.370 (0.341)
2	Seed (X_1)	b1	0.411** (0.112)	1.910* (0.830)	0.270** (0.100)
3	FYM (X_2)	b2	0.013 (0.081)	0.510 (0.272)	0.261** (0.062)
4	Fertilizer (X_3)	b3	-0.330** (0.080)	0.142 (0.341)	0.051 (0.05)
5	Human labour (X_4)	b4	0.952** (0.210)	0.501** (0.180)	0.982** (0.110)
6	Operational holding (X_5)	b5	0.710** (0.120)	1.211** (0.291)	0.361** (0.081)
7	Adjusted coefficient of multiple determination		0.71	0.78	0.72
8	Return to scale	Σb_i	1.1251	1.0149	1.0568

Note: Figures in parentheses indicate standard errors; ** Significant at 1% level of significance; *Significant at 5% level of significance

the value of seed (X_1), labour (X_4), farm yard manure (X_2), and the area of the land holding beneath potatoes (X_5). This suggested that a 1% increase in potato seed quantity and labour cost translated into an approximately 0.27 and 0.98 percent increase in output, respectively. This implies that there was room to increase both profit and potato production. (Lal and Sharma, 2006; Sharma *et al.*, 2017) also reported similar results. On an average farm, the yield of potatoes was positively and significantly impacted by the area under potato crop (X_5) and FYM (X_2). This suggests that increasing the amount of land planted to potatoes could boost production. The chart also demonstrates that, in the case of small farms, the fertiliser (X_3) showed a statistically significant negative impact on productivity. Production decreased by around 0.33 percent for every 1% increase in fertiliser use. Potato crop acreage (X_5), human labour (X_4), and seed (X_1) all significantly increased potato productivity on small farms. More specifically, on large farms, human labour (X_4) and area under potato crop (X_5) showed the most positive significant effect on potato production. A one percent increase in seed quantity and area under potato production was expected to result in 0.41 and 0.71 percent increase in total production.

Resource use efficiency

By contrasting the marginal value product with the factor cost, the resource usage efficiency in the potato production process was examined. If the ratio of factor cost to marginal value production is equal to one, then the resources were employed efficiently. A value of marginal value product (MVP) greater than or equal to one indicates inefficient utilization of the resources. If the MVP was less than one, resources were used excessively. Table 9 displays the calculated level of marginal value productivities for the factors that affected production in a statistically significant way. The table made it clear that for nearly all of the significant factors, the ratio of marginal value productivity to factor cost was found to be more than one for farms of average size. The data further indicates that, across all farms, the MVP for human labour (X_4) was 8.41,

Table 9. Ratio of marginal value productivity to factor cost.

S. No.	Particulars	Small	Large	Overall
1	Seed (X_1)	1.41538	8.51370	1.07070
2	FYM (X_2)	-	-	0.45729
3	Fertilizer (X_3)	-0.08860	-	-
4	Human Labour (X_4)	6.58569	4.43557	8.41321
5	Area under potato crop (X_5)	1.91982	3.86798	1.05597

while the MVP for seed (X_1), FYM, and area under potato crop were 1.07, 0.45, and 1.05 respectively. This suggests that there was a somewhat inefficient use of these resources and more effort from humans must be used in the potato industry. More benefits from potato production would also come from an expansion in the area planted to potatoes. In the case of small farms, the ratio of the MVPs to factor cost for fertilizers (X_3) was found to be negative, indicating that a one-unit increase in fertilizer use would result in a fall in marginal value output. This further suggests that there is room to enhance the efficiency of resource use on small farms and raise production levels by rationalizing this input. Since the marginal value productivity to factor cost ratio for seed on large farms was greater than one (8.51), there was potential for increased use of this input, which would raise potato production. Small farms have a higher MVP (6.58) for human labour (X_4) than large farms (4.43). Additionally, it was discovered that the marginal value productivity for the area planted to potatoes (X_5) was greater than one (3.86). This indicates that by planting more of this crop, there was still room to increase potato production. With a total elasticity of 1.0568, which deviated significantly from unity, increasing returns to scales were discovered. This shows the potential for increasing production while using more seed (X_1), fertiliser (X_2), and operational storage space (X_5). It also illustrates the economics of scale. Similar results were also reported by Sharma *et al.* (2017)

CONCLUSIONS

It was observed that 208 mandays of labour were needed overall per hectare to complete different farm operations in potato. This number fluctuated between 214 mandays on small farms and 205 mandays on large farms. The completion of the field preparation, tuber harvesting and digging, and weeding/interculture required the greatest number of work man-days. On an average farm, these field tasks made for 65% of the entire amount of hired labour needed. The seed was the most important and vital input, accounting for the majority of the cost with the farmers using a seed rate of 22.58 q/ha. Fertiliser and FYM use showed the greatest technological disparity amongst the inputs. Farmers were employing more man-days of labour than advised on an average farm. The cost per hectare for potato growing was Rs 3,08,051. Human effort accounted for a significant portion of the cultivation costs, contributing almost 26% of the entire expenditure. The next largest expense component after labour was seed, making up roughly 23% of the entire cultivation cost. Eleven percent of the entire cost was attributed to fixed costs, with the total variable cost amounting to Rs 2,73,888 per ha. The output-input ratio for all farms was 1.52, meaning that every rupee invested in potato farming would yield a return of that much. According to the break-even analysis, farmers in the small, big, and overall categories would experience no profit, no loss scenario if they produced at least 50.72, 38.02, and 44.14 quintals of potatoes. The results of a production function analysis showed that the main variables influencing potato production were seed, fertilizer, and operational holding size. The efficiency of resource usage shows where there is room to improve productivity while using more seed, fertilizer, and operational holding area. Since the cost of potato seed made up one-fourth of the entire cost, giving farmers access to affordable, high-quality seed will enable them to increase output levels while lowering production costs. It was discovered that far less seed, fertilizer, farm yard manure, and insecticide were used than advised. Therefore, in order to increase potato profitability, farmers must be trained to use these inputs in accordance with a package of techniques.

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AUTHORS CONTRIBUTIONS

Aditi Raina: Data collection, draft manuscript preparation, Pushpak Sharma: Study conception and design, reviewing, Garima Gupta: Data analysis and reviewing, Interpretation of results and reviewing. Sangya Kumari: Data analysis and reviewing.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest

ETHICAL STATEMENT

This article does not contain any studies with human participants or animals performed by any of the authors

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