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Profitability and resource-use efficiency of tomato production in Lalitpur District, Nepal

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ABSTRACT
Tomato (*Solanum lycopersicum L.)* is one of the most commercially important and widely cultivated vegetable crops in the mid-hills of Nepal. Protected cultivation methods like polyhouses and rain shelters offer promising opportunities for improving yield and income, particularly during the off-season. However, limited empirical evidence exists on the economic viability and resource use efficiency of such practices at the local level. The study was conducted in the Lalitpur area to evaluate the profitability and resource use efficiency of tomato production. Primary data were gathered from 68 tomato producers using a pre-tested semi-structured questionnaire. The benefit-cost ratio was 1.15, indicating that tomato cultivation in the study area is profitable, with farmers earning an additional 15 paisa for every rupee invested. The analysis revealed that plant protection, fixed cost, and micro-nutrient had a positive and significant effect on gross returns from tomato cultivation, while other expenses (machinery operation, maintenance & irrigation) had a negative and significant effect. The return to scale was 1.23, indicating increasing returns to scale. Additionally, resources such as seed, plant protection, and micro-nutrients were found to be underutilized, while fertilizers, labor, fixed variables, and other inputs such as irrigation and machinery costs were overutilized. Therefore, improving profitability in tomato cultivation can be achieved by reducing expenditure on overutilized resources and increasing investment in underutilized resources. The findings have important implications for farmers, extension workers, policymakers, and future researchers.
Keywords: efficiency, profitability, regression, tomato production

1. Introduction

Tomato (Solanum lycopersicum L.) is a member of the Solanaceae family and is closely related to potatoes, peppers, and eggplants [1], [2]. It is a globally significant vegetable crop, ranking third in importance after potatoes and onions [3], [4]. Tomatoes are nutritionally rich vegetables that offer numerous health benefits. They contain essential nutrients, including vitamins, minerals, proteins, amino acids, and fatty acids [5], [6] and are particularly notable for their high content of bioactive compounds such as carotenoids, especially lycopene, and phenolic compounds [3], [7].

The Lalitpur district is located in the central mid-hill region of Nepal in the Bagmati province. Low productivity has been identified as a major problem, followed by high post-harvest losses (30%) and weak R&D on variety development for tomato cultivation in this district [8]. Tomato is one of the most important vegetables in terms of acreage, production, productivity, commercial use, and consumption, especially in the mid-hills of Nepal. The area under cultivation for tomatoes is 21,747 hectares, with an annual production and productivity of 413,761 metric tons and 19.03 metric tons per hectare, respectively [9]. Challenges in tomato cultivation include labor shortages and high input costs [10] pest and disease problems [10], [11] market-related constraints such as price fluctuations, high transportation costs, inadequate post-harvest infrastructure, limited access to quality inputs such as certified seeds, fertilizers, and pesticides, climate factors, and the need for microclimate control in off-season production [12].

Tomato cultivation in protected structures like polyhouses and rainshelters offers higher yields compared to open field conditions [13]. Although polyhouse cultivation incurs higher costs, it can lead to increased net returns and yield [14]. Rainshelter cultivation has demonstrated a higher benefit-cost ratio compared to polyhouse cultivation [13]. Off-season tomato production can be profitable, with small farmers achieving higher benefit-cost ratios. Factors such as age, experience, education, irrigation, and extension contact positively influence revenue in off-season tomato production However, challenges like price fluctuations, disease attacks, and high initial investments persist in protected and off-season tomato cultivation [15].

Polyhouse cultivation has shown promising results, with improved cultivars demonstrating superior performance in terms of early flowering, fruit setting, and yield [16]. Supplementary light and CO2 enrichment can significantly enhance growth, photosynthesis, yield, and fruit quality in autumn through spring greenhouse production, with the combination of both treatments yielding the best results [17]. Off-season vegetable cultivation, including tomatoes, helps address supply shortages, control price fluctuations, and provide economic returns to farmers [18]. Various methods are employed for off-season cultivation, such as leveraging agro-climatic diversity, using different varieties, and protected cultivation. However, the successful adoption of these practices requires consistent technical support, training, and reliable input supply [19]. Plastic houses offer better control over microclimatic parameters, maintaining lower soil temperatures and higher relative humidity compared to open fields. The use of appropriate mulching materials, such as black or silver-black mulch, can further enhance growing conditions and yield in both plastic houses and open fields [20].

Despite the growing importance of off-season tomato cultivation in Nepal, especially under protected structures, there is limited empirical evidence on the economic viability and input use efficiency at the farmer level in the mid-hills. This lack of localized economic analysis creates a critical knowledge gap for policymakers and stakeholders aiming to promote sustainable tomato production. This study aims to assess the current state of tomato cultivation in polyhouses and to understand the socio-economic conditions of tomato growers in the study area. It examines the economics of tomato production, focusing on production volume, costs, and profitability, as well as the resource use efficiency of major inputs utilized by tomato farmers in the Lalitpur district. Consequently, this study will assist relevant tomato stakeholders in evaluating the financial sustainability and potential profitability of tomato cultivation.

2. Methods

2.1. Study site

The study is conducted in Lalitpur district, one of Nepal's most promising regions for tomato production. Located at 27°32'31.0812"N latitude and 85°20'3.4692"E longitude, Lalitpur covers an area of 385 square kilometres. Within this area, 184 hectares are dedicated to tomato cultivation, with farmers engaged in both on-season and off-season tomato farming. The study focuses on two municipalities in Lalitpur: Godawari Municipality and Mahalaxmi Municipality. These areas have the largest cultivation areas and significant potential for year-round tomato production using plastic tunnels. Both municipalities were intentionally selected for the study due to their substantial share in both the area and production of tomatoes.

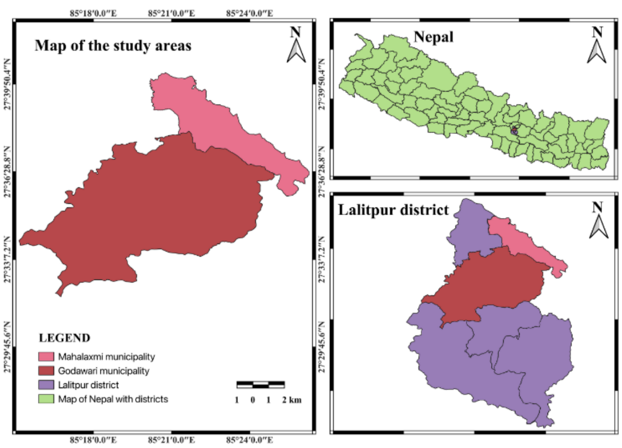

Figure 1. Map of study site

2.2. Sampling and data collection procedure

A total of 68 tomato producers were selected from the study area using the sampling formula. The sample size was determined using equation (1) given by Yamane [21].

$$n=N/(1+N(e)^2) \quad (1)$$

where: n = sample size; N = population size (sampling frame); and e = level of precision considered as 10%.

The sampling frame of 215 was based on the list of tomato producers obtained from the Agriculture and Knowledge Center, Lalitpur. From the list of tomato farmers using plastic tunnels, those cultivating tomatoes on more than two ropani of land were selected to form the sampling population. Samples were then chosen using a simple random sampling technique.

For this study, primary data were collected through household surveys using a pre-tested semi-structured questionnaire. Secondary information was obtained from websites, publications from the Ministry of Agriculture and Livestock Development (MoALD) in Nepal, as well as published and unpublished articles, research papers, and annual and progress reports from governmental and non-governmental organizations such as the District Agriculture Development Office (DADO), Agriculture Knowledge Center (AKC), and Agriculture Information and Training Center (AITC).

2.3. Variable selection and data analysis

The total cost (TC) refers to the sum of all costs incurred in the production of goods or services. It is composed of two main components: i) Total fixed cost ii) Total variable cost. Total fixed cost: The fixed costs included taxes paid by producers on land and water, the rental value of the land used, depreciation on farm equipment, and insurance costs incurred as in (2). The rental value was determined based on information provided by the tomato producers. Depreciation costs were calculated using the "Straight line" method at a rate of 15%.

$$\text{Fixed cost} = \text{Taxation (Land \& Water)} + \text{Depreciation cost} + \text{RentalValue} + \text{Insurance cost} \quad (2)$$

Total variable cost: Variable cost included the cost incurred on seed, organic fertilizers (FYM, oil cakes, compost), chemical fertilizers (Urea, DAP, MOP), micro-nutrients, plant protection, other costs (machine operational, maintenance cost, and irrigation cost), and labor cost as shown in (3).

$$\text{Variable cost} = \text{land preparation cost} + \text{seed cost} + \text{labor cost} + \text{fertilizer cost} + \text{micro-nutrient cost} + \text{Plant protection cost} + \text{other cost} \quad (3)$$

Gross revenue was calculated as the total production of tomatoes multiplied by the gate price as in (4).

$$\text{Gross revenue} = \text{Total product*Farm gate price} \quad (4)$$

Gross profit was calculated by subtracting the gross revenue from the total cost of production (total fixed cost + total variable cost).

The gross revenue was divided by the total cost of production to calculate this parameter, as shown in equation (5).

$$\text{B/C ratio} = \text{(Gross revenue)/(Total cost of production)} \quad (5)$$

2.4. Cobb-Douglas production function

The Cobb-Douglas production function, a widely used economic model, is employed in this study to analyze the relationship between inputs and output in tomato cultivation. The function used in this study is represented by (6).

$$Y = \alpha X_1^{\beta 1} X_2^{\beta 2} X_3^{\beta 3} X_4^{\beta 4} X_5^{\beta 5} X_6^{\beta 6} X_7^{\beta 7} \quad (6)$$

Where: Y is the gross revenue from tomato production; X1 is the seed cost; X2 is the manure and chemical fertilizer cost; X3 is the plant protection cost; X4 is the labor cost; X5 is the fixed cost; X6 is the micro-nutrient cost; and X7 is the other expenses, including machine operation, maintenance, and irrigation cost, while ß1………ß7 are the coefficient to be estimated. This exponential form can be changed into a log-linear form to estimate these parameters, represented by (7).

$$\log(Y) = \log(\alpha) + \beta_1\log(X_1) + \beta_2\log(X_2) + \beta_3\log(X_3) + \beta_4\log(X_4) + \beta_5\log(X_5) + \beta_6\log(X_6) + \beta_7\log(X_7) \quad (7)$$

where: ßi is the regression coefficient of the input variable in the Cobb-Douglas equation.

Decision rule for determining the nature of the scale: RTS < 1 : Decreasing return to scale; RTS = 1 : Constant return to scale; RTS > 1 : Increasing return to scale.

Resource use efficiency (RUE) in economics refers to the optimal use of inputs to produce the maximum possible output with the least amount of waste. It was calculated by using the (9) adopted by [22], [23].

$$\text{RUE} = (\text{Marginal product value (MVP)})/(\text{Marginal factor cost (MFC)}) \quad (9)$$

The marginal product value is calculated by using the coefficient of each input by using (10):

$$\text{MVP} = (\text{Geometric mean of gross revenue (Y)})/(\text{Geometric mean of input}(X_i))^*\beta_i \quad (10)$$

Decision rule for Resource Use Efficiency (RUE): r > 1 : underutilization of resources; r = 1 : efficient utilization of resources; r < 1 : overutilization of resources.

3. Results and Discussion

3.1. Socio-economics and demographic characteristics

The socio-economic and demographic characteristics of the respondents are presented in Table 1. The average age of respondents was 41.30 years, with a standard deviation of 8.29 years. They had an average of 10.25 years of education, and the standard deviation was 3.82 years. The mean family size was 5 members, with a standard deviation of 1.50 members. On average, there were three economically active members per family, with a standard deviation of 0.79. Respondents had an average of 6.40 years of experience, with a standard deviation of 2.65 years. The average total land holdings were 12.85 ropanis, with a standard deviation of 7.08 ropanis. On average, 9.38 ropanis were used for tomato farming, with a standard deviation of 5.43 ropanis.

Table 1. Socio-economics and demographic characteristics of the study area

Variables	Mean	Standard Deviation	Beta Coefficient
Age	41.30	8.29	-0.19
Education level	10.25	3.82	-0.06
Total family size	5	1.50	-0.07
Economically active member	3	0.79	0.15
Experience	6.40	2.65	0.28
Total land holdings	12.85	7.08	-1.02*
Land under tomato farming	9.38	5.43	1.19*

Note: *indicates significance at the 10% level of significance

The beta coefficients indicate the relationship between these variables and the outcome. Age had a beta coefficient of -0.19, suggesting a negative impact on the outcome. It implied that older farmers may be less adaptive to modern technologies or intensive farming practices, which could reduce efficiency. Education level had a beta coefficient of -0.06, indicating a minimal negative effect. It suggested that general formal education might not directly translate into better farm management unless it is agriculture-specific or supported by practical training. Total family size had a beta coefficient of -0.07, also reflecting a slight negative influence, possibly due to higher dependency ratios or inefficient labor use within the household. In contrast, the number of economically active family members had a beta coefficient of 0.15, indicating that the availability of working hands contributes positively to farm productivity. Experience had a beta coefficient of 0.28, highlighting that seasoned farmers are likely to make better decisions and manage resources more efficiently. Total land holdings had a beta coefficient of -1.02, indicating a significant negative relationship, which could be due to divided attention or inefficient allocation of inputs across various crops or land parcels. In contrast, land under tomato farming had a beta coefficient of 1.19, suggesting that specialization and increased focus on tomato farming improved returns.

3.2. Cost return and profitability analysis

The breakdown of variable costs per hectare in the study area highlights the distribution of expenses associated with tomato production (Table 2). Labor expense incurred per hectare over the entire tomato production period represents the most significant expenditure, accounting for 29.374% of the total costs, at NRs. 60651.1 per hectare. Fixed costs follow, comprising 20.948% of the total, amounting to NRs. 43252 per hectare.

Table 2. Cost analysis of resources used for tomato production (NRs. /ha)

Particulars	Mean	% of the total cost
Seed cost	7864	3.809
Fertilizer cost	28507	13.807
Plant protection cost	19217.65	9.308
Labor cost	60651.1	29.374
Fixed cost	43252	20.948
Micro nutrient cost	8158.9	3.952
Other expenses	39320	19.044
Total Cost of Production	206970.7	100

This category includes various miscellaneous expenses such as machine operation, maintenance, and irrigation. Fertilizer costs make up 13.807% of the expenses, totaling NRs. 28507 per hectare. This highlights the importance of fertilizers in tomato cultivation. Plant protection costs are 9.308% of the expenses, amounting to NRs. 19217.65 per hectare. This includes costs for pesticides and other measures to safeguard the plants from pests and diseases. Micro nutrient costs constitute 3.952% of the total costs, equating to NRs. 8158.9 per hectare. These nutrients are essential for plant growth and development. Seed costs and plant protection costs are relatively minor, with seed costs constituting 3.809% of the total costs, amounting to NRs. 7864 per hectare.

The study also provided data on productivity, income, profit, and the benefit-cost (BC) ratio (Table 3). The average productivity was 65.68 tonnes per hectare. Similarly, the total profit was NRs. 30718.7 per hectare. The average income per hectare was NRs. 237689.4 (around 1,736.81$). The BC ratio had a mean of 1.15, indicating that tomato production is a profitable enterprise.

Table 3. Cost return, productivity, and BC analysis of tomato production

Particulars	Mean
Productivity (kg/ha)	65683.77
Profit (NRs. /ha)	30718.7
Income (NRs. /ha)	237689.4
BC ratio	1.15

3.3. Cobb-Douglas production function and returns to scale

In the Cobb-Douglas production function, the gross revenue from tomato cultivation was regressed against multiple independent cost variables (Table 4). The adjusted R-square value was 0.6981, indicating that 69.81% of the variation in gross revenue from tomato cultivation was explained by the independent input costs included in the model. The cost of micronutrients was significant at the 1% level, while plant protection and fixed costs were significant at the 5% level.

Table 4. Production function analysis of tomato cultivation

Explanatory variable	Coefficient	Standard error	t-value	P value
Log(seed)	0.29	0.33	0.874	0.386
Log(fertilizer cost)	-0.14	0.27	-0.505	0.615
Log(plant protection cost)	0.32**	0.13	2.579	0.012
Log(labor cost)	0.12	0.35	0.361	0.719
Log (fixed cost)	0.27**	0.11	2.480	0.015
Log(micronutrient cost)	0.52***	0.15	3.358	0.001
Log(other expenses)	-0.15*	0.08	-1.795	0.077
Constant	2.584	4.39	0.587	0.559
R-square	0.7125			
Adjusted R-square	0.6981			
F-value	39.75			
Return to scale	1.23			

Note: ***, **, and * indicate significant at 1%, 5%, and 10% probability levels, respectively

Chalagai et al. [12] observed that 1% increase in plant protection would significantly increase the gross revenue of tomato by 0.93%. Kunwar et al. [24] also reported that 1% increase in plant protection cost would increase the revenue by 0.436%, which was, however, non-significant. Additionally, other expenses (such as machine operation, maintenance, and irrigation) were significant at the 10% level. The sum of the estimated coefficients for all variables was 1.23, indicating increasing returns to scale; this implies that a 100% increase in all factors of production included in the model would result in a 123% increase in gross revenue from tomato cultivation. Subedi et al. [4] also found increasing returns to scale in tomato production (1.02) under open field conditions in Kapilvastu, Nepal.

The Variance Inflation Factor (VIF) is used to detect the presence and severity of multicollinearity in multiple regression analysis. Multicollinearity occurs when two or more predictor variables in a regression model are highly correlated, leading to unreliable and unstable estimates of regression coefficients. Table 5 shows the tolerance and VIF for the explanatory variables used in the model. A VIF value greater than 10 indicates a problem with multicollinearity. In this case, the VIF values for all variables were less than 10, indicating no serious multicollinearity issues in the regression model.

Table 5. Collinearity statistics of the variables used in regression analysis

Explanatory variables	Collinearity Statistics	
	Tolerance	*VIF*
Log(seed)	0.792	1.264
Log(fertilizer cost)	0.804	1.246
Log(plant protection cost)	0.583	1.719
Log(labor cost)	0.816	1.227
Log (fixed cost)	0.47	2.13
Log(micronutrient cost)	0.759	1.319
Log(other expenses)	0.811	1.234

3.4. Resource use efficiency (RUE/r)

Table 6 represents the resource use efficiency of the variables included in the production function of tomato. Resources in the production function are said to be effectively utilized when the Marginal Value Product (MVP) equals the Marginal Factor Cost (MFC). The MVP measures the additional revenue generated from using one more unit of a particular input while keeping all other inputs constant. The MVP for each variable was calculated from the estimated coefficients of the Cobb-Douglas production function analysis. The value of MFC was 1 for all the variables. Resource use efficiency (RUE or r) is calculated by dividing MVP by MFC.

Table 6. Resource use efficiency of the inputs used in tomato production

Variables	Coefficient	GM	MVP	r	Efficiency
Log(seed)	0.29	6.13	1.13	1.13	Underutilized
Log(fertilizer cost)	-0.14	8.76	-0.38	-0.38	Overutilized
Log(plant protection cost)	0.32**	7.60	1.01	1.01	Underutilized
Log(labor cost)	0.12	8.33	0.35	0.35	Overutilized
Log (fixed cost)	0.27**	9.22	0.70	0.70	Overutilized
Log(micronutrient cost)	0.52***	7.15	1.75	1.75	Underutilized
Log(other expenses)	-0.15*	7.53	-0.48	-0.48	Overutilized

Note: ***, **, and * indicate significance at 1%, 5%, and 10% probability levels, respectively; MVP: Marginal Value Product; MFC : Marginal Factor Cost; GM : Geometric mean.

The value of r was greater than one for seed (1.135), plant protection (1.011), and micronutrient (1.746), indicating that these inputs are underutilized. Each additional rupee spent on seeds, plant protection, and micronutrients would yield a return of 1.135, 1.011, and 1.746 rupees, respectively. The underutilization of these inputs in Lalitpur can be attributed to several factors, including limited technical knowledge among farmers, poor access to quality inputs, and weak extension services. Conversely, the value of r for fertilizers (-0.384), labor (0.346), fixed costs (0.703), and other expenses (machine operation, maintenance, and irrigation) (-0.479) was less than one, indicating that these resources were overutilized. The negative values for fertilizers and other expenses suggest that each additional rupee spent on these inputs would decrease the gross revenue by 0.384 and 0.479 rupees, respectively. Similarly, each additional rupee spent on labor and fixed costs would result in gross revenues of 0.346 and 0.703 rupees, respectively. These inputs were used in excess of what is economically optimal, resulting in diminishing returns or even losses. This imbalance in input use underscores the need for better resource management strategies, targeted farmer training, and support systems to ensure efficient input utilization. Kumar et al. [25] reported that resources such as seed and labor were underutilized and overutilized in Panjab tomato production. Fertilizer and plant protection were observed to be overutilized and underutilized by [26] in tomato production.

4. Conclusion

This study provides a comprehensive analysis of the economic viability and resource utilization efficiency in tomato cultivation within the study area. The benefit-cost ratio (1.15) demonstrates that tomato cultivation is a profitable agricultural enterprise, although the current profitability is suboptimal, indicating considerable potential for improvement in the study area. Additionally, the production function analysis identified plant protection costs, fixed costs, micro-nutrient costs, and other expenses (including machine operation, maintenance, and irrigation) as significant predictors of the total income from tomato cultivation. Collinearity diagnostics confirmed the absence of multicollinearity in the regression analysis, validating the use of the production function results without any adjustments. The return to scale was found to be greater than one (1.23), indicating increasing returns to scale. There is an imbalance in the resource use efficiency of the inputs in tomato cultivation. Inputs such as seeds, plant protection chemicals, and micronutrients were underutilized, whereas other inputs like fertilizers, labor, and fixed variables were overutilized. Therefore, increasing investment in underutilized inputs and reducing expenditure on overutilized inputs would lead to higher overall returns. Future research could apply this framework to other regions or crops, integrate climate variability into economic models, and guide policy formulation regarding input subsidies and training programs to promote efficient and sustainable tomato production in Nepal.

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