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Cost-Benefit Analysis of Conventional and Modern Vegetable Farming in Bhaktapur District

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Abstract

This study aims to evaluate the cost-benefit analysis (CBA) of modern versus conventional vegetable farming in the Bhaktapur District, addressing gaps in existing research that often favor controlled or organic farming without a clear comparison to modern methods. Using a multistage sampling procedure, data were collected from 50 farmers (25 conventional, 25 modern) across Madhyapur Thimi and Suryabinayak municipalities, focusing on three key vegetables: tomato, cauliflower, and radish. Despite higher input costs, modern farming methods have significantly increased crop yields and farmer income. Among the crops studied, cauliflower was the most profitable under both systems, with Benefit-Cost Ratios (BCR) of 3.71 for conventional and 4.12 for modern farming. Tomato also showed strong profitability (BCR: 2.83 conventional, 3.08 modern), while radish, though less profitable, offered quicker harvest cycles and lower risk, making it attractive for small-scale farmers. The findings suggest that prioritizing crops with stable returns, alongside optimized farming techniques, can substantially improve productivity, profitability, and sustainability in Bhaktapur's agricultural sector. To facilitate this transition, the study recommends that federal and provincial governments offer financial incentives such as loans and grants, enabling smallholder farmers to adopt modern practices like tunnel farming and precision agriculture. Such support would enhance long-term agricultural sustainability and strengthen the livelihoods of vegetable farmers in the district.

Keywords: Bhaktapur district, cost-benefit analysis, benefit-cost ratio, conventional farming, modern farming

Introduction

Cost-benefit analysis (CBA) is a vital tool for comparing the economic viability of modern and conventional vegetable farming practices. By evaluating inputs, outputs, and externalities, CBA enables farmers and policymakers to make informed decisions that account for both financial returns and broader environmental and resource implications (Pretty, 2008; Reganold & Wachter, 2016). While modern farming methods, such as precision agriculture, may entail high initial investment, they offer

long-term benefits, including higher yields, resource efficiency, and reduced environmental damage (Zhang et al., 2002). On the other hand, conventional farming methods, while appearing more cost-effective in the short term, often carry hidden costs, such as soil degradation, reduced biodiversity, and pesticide resistance (Tilman et al., 2002). As Tilman et al. (2011) argue, CBA helps align profitability with ecological sustainability, fostering long-term agricultural viability.

Agriculture remains central to Nepal's economy, contributing 24.1% to GDP in 2022, second only to the service sector, and employing 60.4% of the population (MOALD, 2022; World Bank, 2023). Despite its large workforce and natural resource base, the sector continues to face persistent challenges, including low productivity and underemployment (MOALD, 2021). Additionally, Nepal continues to experience food insecurity, as agricultural output falls short of national nutritional needs. This has prompted the widespread adoption of intensive farming practices that rely on synthetic inputs, creating environmental and health concerns (FAO, 2022).

In response to these challenges, sustainable agriculture has gained prominence. The United Nations Development Programme (2021) identifies sustainable agriculture as key to achieving several Sustainable Development Goals. Similarly, Nepal's Ministry of Agriculture and Livestock Development (2022) highlights agroecology as a cornerstone of its national agricultural development strategy. However, the widespread adoption of modern, sustainable practices faces barriers. These include a lack of standardized certification systems, inadequate infrastructure, limited awareness among stakeholders, and weak policy enforcement (IFAD, 2021; MOALD, 2023).

Modern agricultural technologies–such as improved seed varieties, mechanization, and biotechnology–have significantly increased productivity and crop resilience globally. Genetic engineering, for example, enables the development of crops with traits like pest and drought resistance, which enhance yield potential and stability (Brookes & Barfoot, 2023). Mechanization and the electrification of tools further improve labor efficiency and production capacity (World Bank, 2023). Yet, the adoption of these innovations in Nepal is hindered by infrastructure limitations, financial constraints, and gaps in farmer education (MOALD, 2023).

Vegetable farming, in particular, holds substantial economic promise for Nepal's smallholder farmers. Compared to cereal crops, vegetables provide quicker returns and up to three times higher economic value per unit area due to their shorter production cycles, high market demand, and potential for multiple annual harvests (FAO, 2022;

MOALD, 2023). As a result, vegetable cultivation contributes to food security, income generation, and rural employment (UNDP, 2022). Recent studies emphasize the growing importance of this subsector, supported by expanding domestic and regional market opportunities (Poudel et al., 2024).

CBA of Conventional v/s Modern Vegetable Farming: Global Perspectives

A global review of empirical studies reveals that organic and integrated crop management (ICM) systems can be economically viable and, in many cases, more profitable than conventional farming. However, their success often hinges on contextual factors such as market price premiums, input costs, and labor demands. Brumfield et al. (2000) found that while organic systems had higher costs and lower yields, they remained competitive only with price premiums, whereas ICM achieved the best returns for tomatoes and pumpkins. In Iran, Nezhad and Zohoori (2010) reported the economic viability of organic greenhouse farming, highlighting cost sensitivity but no significant performance differences between modern and traditional systems. Similarly, Sgroi et al. (2015) concluded that organic lemon farming in Sicily was more profitable due to higher sale prices, despite lower yields. In Ghana, Kuwornu et al. (2018) demonstrated that ICM yielded higher net returns than conventional systems for vegetable production, supported by robust cost-benefit and sensitivity analyses. Fachrista et al. (2021) showed that organic vegetable farming in Central Java produced greater revenues and was more economically feasible than conventional farming. Tafa et al. (2021) emphasized the long-term financial advantages of conservation agriculture over conventional maize farming in South Africa, despite higher initial costs. Lastly, Dat et al. (2023) found that organic rice production in Vietnam outperformed traditional methods in profitability, with a higher benefit-cost ratio despite increased input expenses.

Evidence from Nepalese Agricultural Systems

A comprehensive review of case studies in Nepal highlights the economic and environmental viability of organic, climate-smart, and mechanized farming systems compared to conventional methods. Raut et al. (2009) found that organic shiitake mushroom, kiwi, and sugar beet farming were commercially viable, with mushrooms offering the highest benefit per rupee invested. Bastakoti et al. (2011) emphasized the sustainability of organic maize and rice farming, noting improved soil organic carbon and climate resilience. Shrestha et al. (2014) revealed higher profitability and lower costs for organic vegetable farming in the Kathmandu Valley, despite reliance on price premiums. Paudel and Adhikari (2018) showed that off-season open-field tomato

farming had the highest benefit-cost (B:C) ratio, indicating strong economic potential. Dhakal et al. (2019) found that rice farming in Nepal's plains was more profitable than in hilly areas due to higher productivity. Acharya et al. (2021) demonstrated that mechanized rice farms had higher yields, lower labor costs, and better returns than traditional systems. K.C. and Paudel (2023) reported that tomato, cauliflower, and radish farming in Bhaktapur was profitable, though middlemen significantly influenced pricing. Finally, Poudel et al. (2024) concluded that climate-smart agriculture (CSA) practices–particularly organic fertilization, improved seeds, and solar water management–offered substantial financial and climate adaptation benefits, making them superior to conventional approaches.

This study aims to fill this gap by providing a clear, localized assessment of modern versus conventional vegetable farming practices in Bhaktapur, thereby offering insights into their economic viability and sustainability in the district. While there is extensive research internationally and nationally on the cost-benefit aspects of vegetable farming, studies that directly compare modern and conventional methods remain limited, particularly in the context of Bhaktapur. The ongoing global debate on farming methods reflects contrasting findings. Some researchers advocate for the superiority of controlled or integrated crop management systems over organic and conventional methods, while others emphasize the commercial and ecological benefits of organic practices, and a few suggest that the method of production has little impact on profitability. These contradictory outcomes often depend on market conditions and consumer preferences.

This study examines the economic outcomes of modern versus conventional vegetable farming in Nepal, with a focus on validating the advantages of modern systems, such as improved produce quality, higher efficiency, and greater market stability, through empirical analysis. Utilizing a cost-benefit framework, the research will evaluate key indicators including production costs, input-output ratios, environmental impact, and net profitability.

Research Methodology

Bhaktapur district, located in Nepal's Bagmati province, serves as an ideal study area for comparing modern and conventional vegetable farming due to its diverse agricultural practices and proximity to Kathmandu's high-demand market. The district spans 119 km² with a temperate climate favorable for vegetable cultivation, and its farming landscape features about 60% conventional farms relying on traditional

methods and 40% modern farms utilizing advanced techniques like greenhouse cultivation and drip irrigation. This study employs a multistage sampling procedure to select two municipalities, Madhyapur Thimi and Suryabinayak, out of the district's four, then randomly chooses three key vegetables (tomato, cauliflower, and radish) from six common crops under the Prime Minister Agriculture Modernization Project (PMAMP). Finally, a sample of 50 farmers (25 practicing conventional and 25 practicing modern farming) was selected using simple random sampling from a list of 105 farmers provided by the PMAMP unit. This approach ensures a representative and manageable sample to conduct a comparative cost-benefit analysis, addressing the economic viability of both farming methods within the district's specific socio-economic and geographic context.

A mixed-methods approach was utilized to ensure reliability and depth. Quantitative data were gathered through structured questionnaires, while qualitative insights were collected via personal interviews and field observations. Information included input costs, labor usage, crop yields, market prices, and farming techniques. Cross-validation was carried out through repeated farm visits and consultations with local agricultural extension officers.

Cost-Benefit Analysis (CBA) was the primary evaluation framework used to measure the economic performance of modern vegetable farming. Two financial indicators were employed: Net Present Value (NPV) and Benefit-Cost Ratio (BCR). Costs were categorized into fixed (e.g., land rent) and variable (e.g., seeds, fertilizers, labor) components, while revenues were calculated by multiplying crop yield per ropani by the prevailing market price.

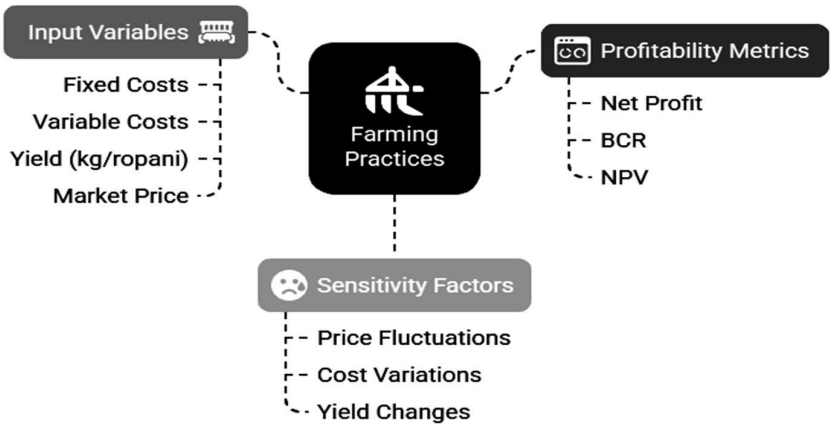
Data analysis was performed using Microsoft Excel, including calculation of NPV and BCR, generation of charts, and sensitivity analyses. A discount rate of 10% was applied to future cash flows, in line with conventional agricultural economic analysis (Pretty, 2008; Reganold & Wachter, 2016).

Several key assumptions guided the financial modeling. Input costs were projected to increase by 5% annually, and land rent was expected to rise by 10% every two years. Revenue was assumed to grow at 10% per year based on historical vegetable price trends. Cropping frequency differed between methods: tomatoes and cauliflower were cultivated in two seasons, conventionally or three under protected structures; radish was grown in three seasons, conventionally or four in modern systems. Sensitivity analysis was conducted to assess economic resilience by simulating ±30%

variations in prices, input costs, and yields. These scenarios helped evaluate the impact of market volatility and input fluctuation on crop profitability.

Conceptual Framework

This study's conceptual framework focuses on comparing modern and traditional vegetable farming by examining both input methods and output marketing factors. It evaluates how farming techniques affect production quantity, quality, and costs, while also considering market-related aspects like packaging, pricing, and sales strategies. Profitability is assessed through cost-benefit analysis (CBA), which compares the financial viability of each method. Ultimately, the framework aims to guide investors in making informed decisions by highlighting the economic advantages and disadvantages of both farming approaches.



Results

Cost of Production in Conventional Farming

The total cost of vegetable production in Bhaktapur's conventional farming system includes fixed costs like land rent and taxes, and variable costs such as labor, land preparation, irrigation, seeds, manure, fertilizers, and plant protection. Data from 25 conventional farmers revealed that tomato cultivation is the most input-intensive, costing NRs 49,500 per ropani, largely due to high hybrid seed (NRs 4,000) and labor (NRs 9,000) expenses, reflecting the crop's intensive resource needs. Cauliflower production costs slightly less at NRs 48,500 per ropani, with the highest labor costs (NRs 10,000) and significant manure use (NRs 7,000), indicating a mix of organic and chemical inputs. Radish is the least costly at NRs 44,000 per ropani, benefiting from low seed and plant protection costs but requiring higher land preparation for root

growth. Fixed land rent costs (NRs 20,000 per ropani) make up 40-45% of total expenses, underscoring land scarcity's economic impact. This cost structure highlights farmers' balancing act between traditional and modern inputs, with manure comprising 17-25% of variable costs, while efficient land use remains key to maximizing profitability.

BCR of Conventional Farming

The benefit-cost ratio of tomato, cauliflower, and radish produced by conventional practice in Bhaktapur district is estimated, whose result, along with averages and per unit cost, is shown in Table 4.2.

Table 1

BCR of Conventional Farming

Vegetables	Total cost of production (NRs./ ropani)	Average production cost (Kg/ ropani)	Per unit production cost (NRs./ Kg)	Average price per Kg (NRs.)	Total income (NRs.)	Net profit per ropani (NRs.)	Benefit cost ratio (BCR)
Tomato	49500	6000	19	35	140000	90500	2.83
Cauliflower	48500	2900	20	32	180000	131500	3.71
Radish	44001	4500	14	25	105000	60999	2.39

Source: Survey Data, 2024

The data reveal that among the three key crops grown in Bhaktapur, cauliflower is the most economically viable with a Benefit-Cost Ratio (BCR) of 3.71, generating a net profit of NRs 131,500 from a total cost of NRs 48,500 per ropani and stable market demand. Tomato follows with a strong BCR of 2.83 and a net profit of NRs 90,500, though its higher production cost (NRs 19/kg) suggests room for input optimization. Radish, while the least profitable with a BCR of 2.39 and net profit of NRs 60,999, offers the advantage of multiple harvests annually and lower risk due to minimal input costs. These findings suggest farmers should prioritize cauliflower for maximum returns, tomatoes for balanced profitability, and radish for steady, low-risk income.

NPV of Conventional Farming

This analysis uses NPV and cash flow comparisons at a 10% discount rate to evaluate the economic viability of tomato, cauliflower, and radish farming. The results, presented in Table 2, inform optimal crop choices and resource allocation for maximizing farmer profits.

Table 2

NPV of Conventional Farming

Vegetable	Initial Cost (NRs.)	Annual Net Profit (NRs.)	NPV (NRs.)
Tomato	49500	90500	175,815
Cauliflower	48500	131500	276,467
Radish	44001	60999	107,761

Source: Survey Data, 2024

Table 2 presents the Net Present Value (NPV) analysis of tomato, cauliflower, and radish cultivation under conventional farming in Bhaktapur, using a 10% discount rate over three years. Initial costs per ropani are NRs. 49,500 for tomato, NRs. 48,500 for cauliflower, and NRs. 44,001 for radish, with annual net profits of NRs. 90,500, NRs. 131,500, and NRs. 60,999 respectively. The NPVs–NRs. 175,815 for tomato, NRs. 276,467 for cauliflower, and NRs. 107,761 for radish–indicate all three crops are economically viable, with cauliflower offering the highest returns over the period, affirming the profitability of conventional vegetable farming in the region.

Sensitivity Analysis of Conventional Farming

Price sensitivity analysis shows how changes in market prices affect the profitability of tomato, cauliflower, and radish. For tomatoes, a 30% price increase from NRs 35 to 45.5/kg raises NPV to NRs 58,940 with a BCR of 3.68, while a 30% price drop to 24.5/kg lowers NPV to NRs 11,900 and BCR to 1.98, still marginally profitable. Cauliflower remains highly resilient, maintaining an NPV of NRs 30,692 and a BCR of 2.59 even with a 30% price fall from NRs 32 to 22.4/kg. Radish is more vulnerable, becoming unprofitable with a 30% price drop to 17.5/kg, resulting in an NPV of -NRs 9,100. Overall, cauliflower is the most price-stable crop (BCR > 2.5), tomato shows moderate resilience, and radish requires favorable prices to remain profitable.

Cost Sensitivity Analysis

Cost sensitivity analysis reveals how fluctuations in production costs impact the profitability of tomato, cauliflower, and radish farming in Bhaktapur. A 30% increase in tomato costs (NRs 49,500 to 64,350) cuts NPV by 75% to NRs 8,180 but keeps it profitable with a BCR of 2.18, while a 30% cost reduction raises NPV to NRs 61,070 (BCR 4.01). Cauliflower shows strong cost resilience; even with a 30% cost rise to NRs 63,075, NPV remains high at NRs 50,925 (BCR 3.09), and with a 30% cost cut, NPV jumps to NRs 106,180 (BCR 5.76). Radish is more sensitive, becoming unprofitable

(NPV -NRs 2,350) at a 30% cost increase, with viability threatened beyond a 20% hike (NRs 52,801). This highlights cauliflower's robustness, the moderate stability of tomato, and the need for careful cost control in radish farming, emphasizing the importance of input efficiency for maximizing profits.

Yield Sensitivity Analysis

Yield sensitivity analysis highlights that profitability in conventional vegetable farming in Bhaktapur is highly influenced by harvest variations. Cauliflower shows the greatest resilience, maintaining strong profitability (BCR > 2.5) even with a 30% yield drop, and offering the highest NPV gains (NRs 124,600) at increased yields. Tomato remains moderately profitable under lower yields (BCR 1.98 at -30%), but yield protection is essential to sustain returns. Radish is the most vulnerable, becoming unprofitable when yields fall by 30%, though it shows strong gains with improved yields (BCR 3.01). Overall, cauliflower is best suited for variable yield conditions, while tomato and radish require stable or enhanced productivity to remain viable.

Cost of Production in Modern Farming

Modern vegetable farming in Bhaktapur reveals notable cost variations across tomato, cauliflower, and radish cultivation. Tomato is the most capital-intensive, costing NRs 123,565 per ropani due to high tunnel infrastructure (NRs 35,000), labor (NRs 18,000), and nutrient inputs like organic fertilizer (NRs 10,500) and micronutrients (NRs 6,000), resulting in variable costs comprising 84% of the total. Cauliflower, with a total cost of NRs 77,750, has a more balanced input structure focused on soil health, avoiding tunnel expenses but still investing in manure (NRs 10,500) and micronutrients. Radish is the least costly at NRs 73,400, with minimal seed and labor costs, no tunnel use, and modest plant protection needs, though it still requires organic inputs. All crops share fixed land rent of NRs 20,000, but the dominance of variable costs–especially in tomatoes–underscores how modern farming reallocates spending toward input-intensive practices for yield maximization. These differences suggest farmers should align input investments with expected returns and market stability, especially when adopting resource-heavy methods.

BCR of Modern Farming

The benefit-cost ratio of tomato, cauliflower, and radish produced by modern practice in Bhaktapur district is estimated, whose result, along with averages and per unit cost, is shown in Table 3.

Table 3

BCR of Modern Farming

	Total cost of production (NRs./ ropani)	Average production cost (Kg/ ropani)	Per unit productio n cost (NRs./ Kg)	Average price per Kg (NRs.)	Total income (NRs.)	Net profit per ropani (NRs.)	Benefit cost ratio (BCR)
Tomato	123565	9500	24	35	380000	256435	3.08
Cauliflower	77750	4500	22	32	320000	242250	4.12
Radish	73400	6000	17	25	200000	126600	2.72

Source: Survey Data, 2024

Modern vegetable farming in Bhaktapur has proven economically viable, with all three studied crops, cauliflower, tomato, and radish showing Benefit-Cost Ratios (BCR) above 1. Cauliflower leads in profitability with a BCR of 4.12, driven by low production costs (NRs. 22/kg) and strong market prices, yielding a net profit of NRs. 242,250 per ropani. Tomato also performs well with a BCR of 3.08, thanks to high yields and market prices, despite higher input costs. Radish, while still profitable (BCR 2.72), offers the lowest return due to its lower selling price. These findings highlight cauliflower and tomato as the most rewarding crops under modern farming, guiding farmers toward more profitable cultivation choices.

NPV of Modern Farming

This analysis evaluates the economic viability of tomato, cauliflower, and radish farming using key financial metrics. By comparing NPV and cash flows, we assess which crops offer the best returns for farmers in modern farming practice. The 10% discount rate accounts for inflation and opportunity costs, ensuring realistic projections.

Table 4

NPV of Modern Farming

Vegetable	Initial Cost (NRs.)	Annual Net Profit (NRs.)	NPV (NRs.)
Tomato	123,565	256,435	518,990
Cauliflower	77,750	242,250	525,940
Radish	73,400	126,600	241,640

Source: Survey Data, 2024

Table 4 highlights that modern vegetable farming in Bhaktapur is economically promising, with all three crops showing positive three-year Net Present Values (NPV) at a 10% discount rate. Cauliflower ranks highest with an NPV of NRs. 525,940, thanks to its balanced input costs and strong returns, making it the most financially rewarding option. Tomato follows closely with an NPV of NRs. 518,990, supported by the highest annual profit despite higher initial costs. Radish, with the lowest NPV of NRs. 241,640, remains viable but less lucrative, suggesting it's better suited for low-risk strategies. Overall, cauliflower and tomato are the top choices for maximizing long-term profits in modern farming.

Price Sensitivity Analysis – Modern Farming

Price sensitivity analysis in Bhaktapur shows that market fluctuations significantly impact vegetable profitability. Tomato remains marginally profitable even with a 30% price drop (BCR 1.88), while a 30% increase greatly enhances returns (BCR 3.5, NPV NRs. 649,543). Cauliflower proves the most resilient, maintaining profitability under all price scenarios, with a peak BCR of 4.82 at a 30% price rise. Radish is more vulnerable–its BCR drops to 1.43 at a 30% price decline, suggesting price volatility poses a risk. Overall, cauliflower is the most stable crop, while tomato and radish require market price awareness.

Cost Sensitivity Analysis

Cost sensitivity analysis shows that tomato and cauliflower remain profitable even with a 30% increase in costs, though profitability improves significantly with cost reduction. Tomato's BCR ranges from 2.37 to 4.39, depending on cost changes. Cauliflower reaches a BCR of 5.88 with a 30% cost cut and remains profitable even at higher costs. Radish, however, becomes marginally profitable (BCR 2.09) at a 30% cost rise, showing higher cost sensitivity. These results stress the importance of efficient input management, especially for radish, while reaffirming tomato and cauliflower's economic resilience.

Yield Sensitivity Analysis

Yield sensitivity analysis reveals that cauliflower remains profitable even with a 30% yield reduction (BCR > 2.5), making it the most yield-resilient crop. Tomato sees strong profitability with increased yields (BCR up to 3.5), but drops to marginal levels when yields fall by 30%. Radish shows high sensitivity–its BCR drops to 1.43 at lower yields but climbs to 2.66 when yields rise by 30%. These findings underscore the need for yield-enhancing practices like improved seeds, pest control, and irrigation,

especially for tomato and radish, while confirming cauliflower's suitability for variable growing conditions.

Comparative Analysis of Conventional and Modern Farming

A comparative analysis of conventional and modern vegetable farming in Bhaktapur district reveals clear economic advantages of adopting modern farming techniques for tomato, cauliflower, and radish. In tomato cultivation, modern farming incurs a higher production cost of NRs. 123,565 per ropani compared to NRs. 49,500 under conventional methods. However, this higher investment results in significantly greater returns, with modern tomato farming generating a total income of NRs. 380,000 and a net profit of NRs. 256,435, compared to NRs. 140,000 income and NRs. 90,500 profit in conventional farming. The benefit-cost ratio (BCR) also improves from 2.83 to 3.08, and the net present value (NPV) over three years rises sharply from NRs. 175,815 to NRs. 518,990. Similarly, cauliflower farming under modern methods sees a production cost of NRs. 77,750 per ropani versus NRs. 48,500 in conventional farming. This investment delivers a total income of NRs. 320,000, a net profit of NRs. 242,250, and a BCR of 4.12, surpassing the conventional BCR of 3.71 and net profit of NRs. 131,500. The NPV in modern cauliflower farming reaches NRs. 525,940 compared to NRs. 276,467 in conventional practices. In the case of radish, modern farming costs NRs. 73,400 per ropani against NRs. 44,001 in conventional farming, but yields a higher income of NRs. 200,000 and a net profit of NRs. 126,600, while conventional farming offers only NRs. 105,000 in income and NRs. 60,999 in profit. The BCR improves from 2.39 to 2.72, and the NPV increases from NRs. 107,761 to NRs. 241,640. Overall, these comparisons demonstrate that modern vegetable farming significantly enhances productivity, profitability, and long-term returns, making it a more economically viable choice for farmers in Bhaktapur.

Discussion of the Result

The findings of this study provide a thorough evaluation of the cost-benefit dynamics between conventional and modern vegetable farming systems in Bhaktapur district, with a focus on tomato, cauliflower, and radish. The comparative analysis highlights significant differences in profitability, input costs, and resilience to economic and agronomic fluctuations. Among the three crops, cauliflower emerges as the most economically viable in both farming systems, with Benefit-Cost Ratios (BCRs) of 3.71 in conventional and 4.12 in modern systems. Its strong financial performance is credited to efficient input usage, stable demand, and lower sensitivity to market and yield

variations. Even under a 30% price drop or cost increase, cauliflower maintains profitability, making it a robust option for farmers facing uncertain conditions (Dat et al., 2023; Fachrista et al., 2021). Tomato, while also profitable (BCR 2.83 in conventional and 3.08 in modern farming), involves higher initial investments, particularly in modern systems, due to tunnel infrastructure and labor costs. However, its high market price and strong yield potential sustain its viability (Brumfield et al., 2000; Kuwornu et al., 2018). Radish, though the least profitable (BCR 2.39 and 2.72), provides quick returns and lower investment risks, making it attractive for risk-averse or resource-constrained farmers. Sensitivity analysis further reveals crop-specific vulnerabilities: tomato is moderately sensitive to yield variation, while radish is highly sensitive to both price and cost fluctuations, sometimes becoming unprofitable under adverse conditions. Cauliflower, by contrast, consistently performs well across scenarios, reinforcing its position as a reliable income source in Bhaktapur's farming system (Sgroi et al., 2015).

Modern vegetable farming offers higher economic returns than conventional methods. For example, modern tomato farming yields NRs. 380,000 per ropani compared to NRs. 140,000 in conventional farming, despite higher costs. Similar trends are seen with cauliflower and radish, where improved productivity, better input management, and market access result in higher incomes and net profits. However, the upfront capital required for modern farming–particularly infrastructure like tunnel farming can limit adoption among smallholders, a finding consistent with studies by Brumfield et al. (2000) and Kuwornu et al. (2018). Furthermore, while Bhaktapur's current systems may not yet fully support strict organic certification, controlled or modern farming emerges as a practical, scalable alternative that combines technical efficiency with profitability. These conclusions align with global and national studies demonstrating the economic superiority of improved farming practices such as those by Dat et al. (2023), Fachrista et al. (2021), and Sgroi et al. (2015) internationally, and Raut et al. (2009) and Acharya et al. (2021) in Nepal. Ultimately, the study confirms that modern farming, particularly for crops like cauliflower and tomato, holds strong potential for improving farmers' livelihoods in Bhaktapur, provided that investments are matched with access to training, finance, and market support.

Conclusion and Implications

The study highlights key insights into the economic viability of conventional and modern vegetable farming systems in Bhaktapur district, focusing on tomato, cauliflower, and radish. Cauliflower emerges as the most profitable crop, with a

Benefit-Cost Ratio (BCR) of 4.12 in modern farming and 3.71 in conventional systems, demonstrating strong resilience even with a 30% price drop, where the BCR remains above 2.5. Tomato shows substantial profitability with a BCR of 3.08 under modern farming, generating a net profit of NRs. 256,435 per ropani despite higher production costs (NRs. 123,565) compared to conventional farming (NRs. 49,500) (Brumfield et al., 2000). Radish, while less lucrative (BCR of 2.72 in modern and 2.39 in conventional farming), offers quicker turnover and lower risks, suitable for small-scale farmers.

The comparison reveals that modern farming, despite its higher costs, significantly increases yields and income. Tomato yields rise from 6,000 kg to 9,500 kg per ropani, boosting total income from NRs. 140,000 to NRs. 380,000. Similarly, cauliflower income increases from NRs. 180,000 to NRs. 320,000, and radish from NRs. 105,000 to NRs. 200,000. However, adoption depends on farmers' access to capital and technical skills. Policymakers should promote affordable modern techniques, especially for high-value crops like cauliflower and tomato, while helping farmers manage market and cost risks. Strategic crop selection based on profitability, resilience, and resource efficiency can enhance Bhaktapur's agricultural sustainability and farmer incomes (Acharya et al., 2021; Poudel et al., 2024; Shrestha et al., 2014).

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