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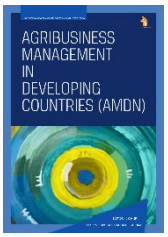

RESEARCH ARTICLE

ECONOMIC ANALYSIS OF APPLE (*Malus domestica*) PRODUCTION BEFORE AND AFTER COVID-19 IN GHARAPJHONG RURAL MUNICIPALITY OF MUSTANG DISTRICT, NEPAL

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ABSTRACT

This study, conducted in 2024, assesses the economic impact of the COVID-19 pandemic on apple production in Gharapjhong Rural Municipality, Mustang District, Nepal. Data were collected from 70 apple producers through interviews, direct observations, and five focus group discussions, using a pre-tested semi-structured questionnaire. The analysis employed descriptive statistics, independent sample t-tests, and weighted linear regression using Microsoft Excel, SPSS, and STATA 14.2. The findings reveal no statistically significant change in apple production after COVID-19. However, the total average cost of production increased from Rs 72, 21,570 before to Rs 1, 19, 32,450 after the pandemic. While fixed costs remained constant, variable costs increased notably. The farm gate price rose from Rs 60 to Rs 80 per kilogram, with the producer's share improving from 50% to 57%, and the marketing margin remaining unchanged at Rs 60. Despite these shifts, the average benefit-cost ratio (BCR) declined from 1.8 to 0.9, indicating reduced profitability. Major challenges included disease outbreaks, flower and fruit drop, and a lack of technical knowledge. Mustang's favorable agro-climatic conditions make it suitable for apple farming, yet persistent issues such as poor infrastructure, market access limitations, and climate vulnerability hinder productivity. The study suggests strategic interventions including infrastructure development, improved farming practices, market expansion, climate resilience measures, and stronger collaboration between the government and private sector to boost the sector's potential. Apple farming in Mustang remains a vital yet vulnerable agricultural enterprise with opportunities for significant economic contributions if systemic issues are addressed.

KEYWORDS

COVID-19, Mustang, apple production, challenges, weighted regression

1. INTRODUCTION

Agriculture is a vital sector for many developing countries, playing a crucial role in food security, employment, and economic development. In Nepal, agriculture remains the cornerstone of the national economy, providing livelihoods for approximately 66% of the population and contributing significantly to the country's Gross Domestic Product (GDP) (Thapa et al., 2024). The sector encompasses diverse agro-ecological zones, allowing the cultivation of a wide range of crops, including cereals, fruits, and vegetables. Horticultural crops hold a significant place in Nepal's agricultural sector. Among these, the apple (*Malus domestica*) stands out as both essential and irreplaceable, recognized globally as the fourth most widely cultivated fruit, apples serve not only as a key nutritional resource but also as a driver of rural economic growth (Musacchi and Serra, 2018). In Nepal, apple farming alone has contributed about 0.3470% to the national agricultural GDP (MoALD, 2023). Research has also emphasized the exceptional antioxidant content of apples, underlining their importance in supporting human health (Groth et al., 2020). Apart from this, cultivating niche-specific fruits, including apples, presents an opportunity to meet the huge demand in nearby markets such as India and China. Jumla, Mugu, Mustang, Dolpa, Solukhumbu, Rukum, and Rolpa are among the leading apple-growing regions (Devkota et al., 2017)

Apple is a high-value temperate fruit crop, plays a crucial role in Nepal's rural economy, particularly in the mountainous regions where favorable agro-climatic conditions support its cultivation. The total area dedicated to apple cultivation in Nepal is approximately 11,932 hectares, with a total production of 102,548 metric tons, resulting in an average yield of 7.24 metric tons per hectare (MoALD, 2023). Mustang is located in the Dhaulagiri zone of Gandaki Province, being particularly renowned for its apple cultivation due to its high altitude, dry climate, and suitable terrain. Mustang yields apples from semi-commercia to commercial grade, of which Red Delicious, Royal Delicious, and Golden Delicious account for approximately 80% of total apple production with other varieties such as Jonathan, Chocolate, and Macintosh (Pandey et al., 2023).

Despite these advantageous conditions, apple productivity in Mustang remains suboptimal, with an average yield of 12.80 metric tons per hectare, which is significantly lower than the global average of 17.56 metric tons per hectare (Gayak et al., 2020). This yield gap can be attributed to several factors, including poor orchard management practices, limited access to improved apple varieties, inadequate post-harvest handling techniques, and climatic constraints. These challenges underscore the need for targeted interventions, such as the introduction of high-yielding varieties, enhanced orchard management practices, and improved post-harvest technologies, to increase productivity and strengthen the economic potential of apple cultivation in the region (Khanal, 2014).

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Apple farming in Nepal faces several challenges that hinder its full potential, including inadequate transportation infrastructure, limited market access, unpredictable weather conditions, pest infestations, and a lack of technical knowledge among farmers (Amgai et al., 2015). These constraints have impeded the ability of Nepalese apple growers to fully exploit the region's favorable agro-climatic conditions. Furthermore, the impact of climate change, characterized by irregular rainfall patterns and an increase in pest and disease outbreaks, has exacerbated productivity issues. These environmental stressors not only affect apple yields but also compromise fruit quality and marketability, further constraining the economic viability of apple farming (Devkota et al., 2017).

The COVID-19 pandemic further exacerbated the challenges faced by apple farming in Nepal, disrupting supply chains, limiting access to agricultural inputs, and causing fluctuations in demand and supply. These disruptions led to a reduction in apple production and significant financial losses for farmers (Shah et al., 2020). Before the onset of the COVID-19 pandemic, Nepal's agricultural sector experienced a consistent decline in its contribution to the national GDP, decreasing from 29.15% in 2016 to 22.33% in 2018. This downward trend continued during the pandemic in 2019, with the sector's contribution further reducing to 21.58%. In the post-pandemic period, the contribution stabilized at approximately 22%, underscoring the persistent challenges faced by Nepalese agriculture in sustaining economic growth amid external shocks and disruptions (O'Neill, 2024). Additionally, traders faced challenges related to transportation, limited market information, and a lack of adequate storage and processing facilities, all of which hindered the commercialization of apple farming (Amgai et al., 2016). Despite these setbacks, the government has designated Mustang as an Apple Zone under the Prime Minister Agriculture Modernization Project (PMAMP), offering a potential opportunity to enhance apple productivity and increase income for local farmers.

However, the sector's full potential remains unrealized due to issues such as fragmented landholdings, insufficient extension services, and poor post-harvest handling practices (Chapai et al., 2024). The Mustang district of Nepal, known for its unique agro-climatic conditions, has become a key center for apple cultivation, offering significant potential to boost the region's economic development. This study aims to evaluate the current status, challenges, and opportunities in apple production before and after COVID-19 in Mustang, Nepal, with a focus on identifying key barriers and exploring potential solutions. The research will contribute to the development of sustainable apple farming practices, ultimately enhancing productivity and profitability in the region.

2. Materials and Methods

2.1 Research Methodology

This study was conducted in the Mustang district of Gandaki Province, Nepal, specifically in five rural municipalities: Thasang, Gharapjhong, Bara Muktikshtri, Lo-gyakar, and Lo-manthang. These areas were selected due to their high apple production potential, with Gharapjhong being a key region within the PMAMP Apple Zone and the One District, One Project (ODOP) initiative. Mustang, located in northern Nepal, is a remote and sparsely populated district, known for its diverse altitude range, from 1,372 to 8,167 meters. The district covers 3,573 square kilometers and has a population of 14,452 (2021).

The research focused on evaluating apple production within the district, with particular emphasis on agricultural practices, productivity, and challenges faced by farmers. Mustang's agricultural and animal husbandry sectors are vital to its economy, and the district's location within the Annapurna Conservation Area, managed by the NTNC, further influences local development programs. The study also considered the socio-economic aspects of the district, including its relatively high GDP per capita of US$2,466 (WIKIPEDIA, 2020).

Table 1: Area covered by Mustang district in different field.

Description	Area covered (km²)	% of area
Total area of the district	3639.6	100
Total forest area	123.2	3.38
Total cultivable land	40.3	1.10
Irrigated cultivable land	32.5	0.89
Rain-fed cultivable land	7.83	0.21
Pasture land	1476.8	40.57
River, stream, cliff, mountain, stone etc.	1505.7	41.36
Area covered by residence and buildings	3.20	0.08
Area covered by snow	305.9	8.40
Area covered by lakes	0.92	0.02
Other	183.5	5.04

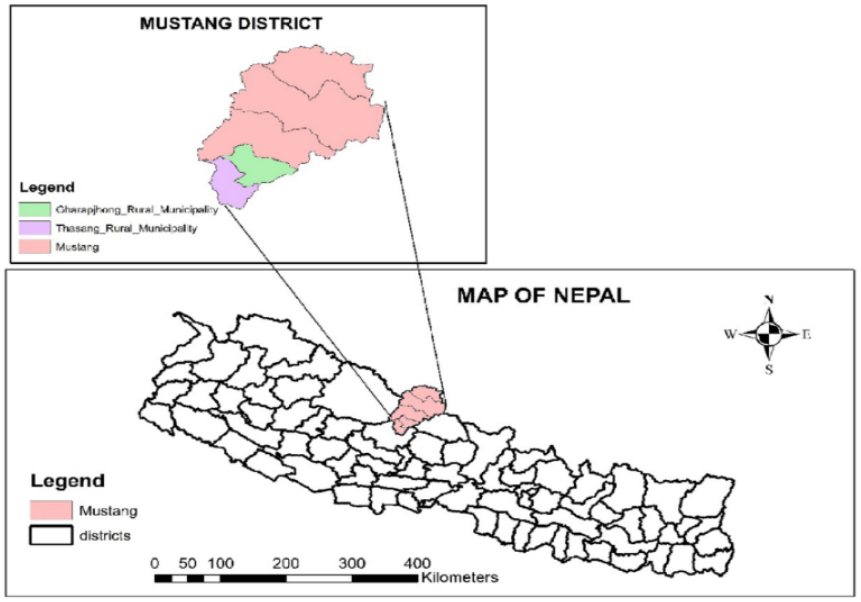

Figure 1: A map of Nepal showing Mustang district **(**Source: Research Gate, 2023)

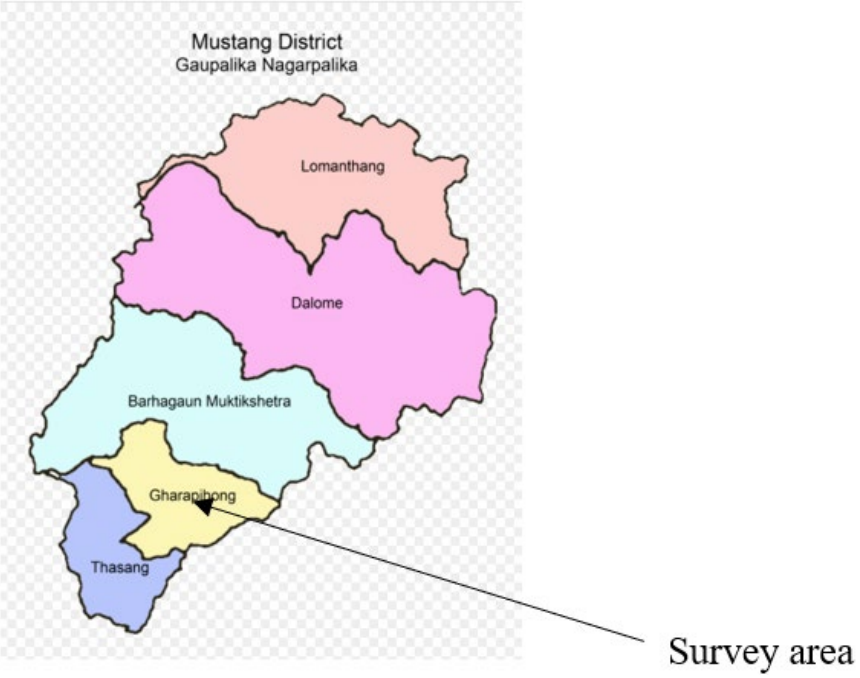

Figure 2: Map showing Gharapjhong rural municipality

2.2 Sample size and sampling procedure

Mustang district was the large-scale producer of apples. From the total apple-growing farmers, 70 farms were selected by using the random sampling method in order to collect information on the apple production before and after COVID-19. Data was collected in April-May 2024 using both primary and secondary sources.

Mathematically, $n = N / 1+ N + (e)^2$

Where,

n= the sample size

N= the population size

e= the acceptable sampling error

95% confidence level and p=0.05 are assumed

2.2.1 Primary Data

Primary data was gathered from local apple farmers through household surveys, focus group discussions (FGD), and key informant interviews (KII). The survey focused on production costs, marketing channels, and the impact of COVID-19 on farming activities and income.

2.2.2 Secondary Data

Secondary data for the study was gathered from reputable sources such as the Ministry of Agriculture and Livestock Development (MOALD), the Organization for Economic Cooperation and Development (OECD), the Central Bureau of Statistics (CBS), and the Food and Agriculture Organization (FAO), along with published books, journals, research papers, and online resources.

2.3 Survey Design and Data Collection

2.3.1 Household Survey

A personal interview schedule (PSI) was used for the household survey, gathering information on family size, education level, major income sources, apple production costs, pricing, and production and marketing challenges. Farmers were also asked about the support received from government and non-government sectors.

2.3.2 Focus Group Discussion (FGD)

FGDs were conducted with groups of apple farmers to gather insights on their perceptions, opinions, and experiences regarding apple production. Topics included production challenges, disease outbreaks during the pandemic, marketing issues, and the farmers' adaptive strategies.

2.3.3 Key Informant Interviews (KII)

In-depth interviews were held with key informants, such as experts and community leaders, to gain expert perspectives on the apple sector. A notable interview was conducted with Mrs. Karma Gurung, a large-scale apple producer, who highlighted issues related to transportation and marketing challenges that impacted apple production and sales during the COVID-19 pandemic.

2.4 Techniques of Data Analysis

The primary and secondary data collected from household surveys, focus group discussions, and key informant interviews were entered into Microsoft Excel, cleaned, coded, and organized. The data were then analyzed using SPSS, STATA 14.2, and Excel. Economic analyses, including benefit-cost ratio (BCR), gross margin, and marketing margin analyses, were conducted. Independent sample t-tests and weighted linear regression were used to assess relationships between variables.

2.4.1 Socio-Demographic and Economic Characteristics

Descriptive analysis was used to assess socio-economic and farm characteristics, including family size, age, income, gender, occupation, and the distribution of economically active populations. Simple statistical tools such as frequency counts, percentages, means, and standard deviations were applied.

2.4.2 Cost of Production and Losses

The costs of apple farming, including both fixed and variable costs, were analyzed. Variable costs included manure, fertilizers, labor, and irrigation, while fixed costs encompassed land. The total loss due to production disruptions before and after COVID-19 was calculated.

2.4.3 Benefit-Cost Ratio (BCR)

The BCR was calculated to assess the profitability of apple farming:

BCR = Total Benefit / Total Cost

A BCR greater than 1 indicates profitability, while a BCR less than 1 suggests a loss.

2.4.4 Marketing Margin and Producer's Share

The marketing margin, which represents the difference between the price paid by consumers and the price received by producers, was calculated to assess the distribution of value along the supply chain. The marketing margin was determined using the following formula:

Market Margin = Retail Price - Farm Gate Price

2.4.5 Weighted Linear Regression before and after COVID-19

A weighted linear regression model was employed to examine the relationships between various independent variables and the dependent variable. The model is expressed as

$Y = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \beta_7 x_7 + e_i$

Where,

Y = the response variable (dependent variables)

α = Constant

x_1 = Production (ton)

x_2 = Price per kg (Rs)

x_3 = Apple plant number (No)

x_4 = Income (Lakh)

x_5 = Benefit cost ratio (Proportion)

x_6 = Apple cultivated area (Ropani)

x_7 = Total cost (thousand

β_1 = Regression coefficient of production (ton)

β_2= Regression coefficient of price per kg (Rs)

β_3= Regression coefficient of apple plant number (No)

β_4 = Regression coefficient of income (lakh)

β_5 = Regression coefficient of benefit cost ratio (BCR)

β_6= Regression coefficient of apple cultivated area (Ropani)

β_7 = Regression coefficient of total cost (thousand)

e_i = Error term or disturbance term

2.4.6 Problem Ranking

Apple production and marketing issues were ranked based on their severity. Using a four-point scaling technique, farmer's ranked problems as severe, moderate, slight, or no problem. The ranking was quantified using the Spearman's Rank Correlation Coefficient formula to determine the importance of each issue.

Mathematically,

According to "Spearman's Rank Correlation Coefficient"

$Iimp = \sum (Si\ Fi / Shi * N)$

Where,

Iimp= Important of index value

Si= Scale of i^{th} problem

Fi= Frequency of i^{th} problem

Shi= highest index value

N= Total number of respondents

3. Results and Discussions

3.1 Socio-demographic characteristics of the respondents

The table provides a detailed demographic and agricultural profile of 70 farmers, offering insights into gender distribution, ethnicity, occupation, education, land ownership, farm registration, and cultivation practices. The majority of the respondents are male (62.86%), suggesting a male-dominated farming sector, while female participation remains relatively lower at 37.14%. Ethnically, the Thakali community is the most involved in farming (65.71%), followed by Indigenous groups (18.75%), Dalits (12.86%), and a small proportion from other communities (2.86%). The dominance of the Thakali ethnic group in farming could be attributed to their historical and cultural association with apple cultivation in regions like Mustang. Agriculture is the primary occupation for 71.43% of respondents, indicating strong engagement in farming as a livelihood source. However, 28.57% are involved in other occupations, suggesting a level of economic diversification. Education levels among farmers are significantly high, with 88.57% being literate and only 11.43% being illiterate. This suggests that modern farming practices and agricultural innovations have the potential for adoption, given the high literacy rate. A group researchers observed that factors such as education, ethnicity, the number of economically active household members, and farm experience positively contribute to increased apple production (Gayak et al., 2020).

Land ownership patterns reveal that 80% of farmers own their land, ensuring stability in agricultural activities. However, 5.71% rely solely on leased land, while 14.29% operate on both owned and leased land, highlighting the varying degrees of access to land resources. In other study, researcher reported that 93.6% of farmers owned land, while 28.2% cultivated on leasehold land, and 19.9% engaged in sharecropping (Khatri et al., 2024). Notably, farm registration is evenly split, with 50% of farms registered and 50% non-registered. This balance suggests potential barriers to farm formalization, which could impact farmers' access to government subsidies, financial support, and agricultural extension services. Regarding cultivation practices, extensive farming is the predominant method (67.14%), indicating reliance on traditional, low-input farming systems. Meanwhile, 32.86% practice semi-intensive farming, which suggests some level of modernization and improved management techniques. The dominance of extensive farming underscores the need for interventions to enhance productivity through improved agronomic practices, mechanization, and sustainable input use. Overall, the findings highlight the socio-economic structure of the farming community and suggest opportunities for policy interventions. The high literacy rate presents an opportunity to introduce advanced agricultural technologies and training programs. Additionally, the equal distribution of registered and non-registered farms indicates the need to encourage formal registration to improve farmers' access to institutional support. Furthermore, promoting semi-intensive and intensive farming practices could enhance productivity and economic returns in the region.

Table 2: Socio-demographic characteristics of the respondents of Gharapjhong rural municipality of Mustang

Indicators	Variables	N	Percentage (%)
Gender	Male	43	62.86
	Female	27	37.14
Ethnicity	Thakali	46	65.71
	Indigenious	13	18.75
	Dalits	8	12.86
	Others	3	2.86
Occupation	Agriculture	50	71.43
	others	20	28.57
Education	Literate	67	88.57
	Illiterate	13	11.43
Land	Owned	56	80
	Lease	14	5.71
	Both	10	14.29
Farm registration	Registered	35	50
	Non-registered	35	50
Type of cultivation	Extensive	47	67.14
	Semi-intensive	23	32.86
Total		70	100

3.2 Apple cultivation information

3.2.1 Apple varieties cultivated in Gharapjhong rural municipality

Major five varieties of apples were cultivated in mustang. The Red Delicious variety accounts for the largest share (40%), indicating its widespread cultivation and popularity. This preference could be attributed to its high market demand, favorable taste, longer shelf life, or adaptability to local climatic conditions. Following this, the Jonathan variety constitutes 21.43% of the total, showing that it is also a significant choice among farmers. Its proportion suggests that while it is not as widely grown as Red Delicious, it still holds considerable importance, likely due to its unique flavor, disease resistance, or productivity. The Royal Delicious variety represents 17.14%, indicating moderate cultivation. Its presence suggests that it is a preferred alternative to Red Delicious but with possibly different agronomic or economic advantages. The Golden Delicious variety accounts for 7.14%, showing a comparatively lower adoption rate. This could be due to market preferences, its susceptibility to pests and diseases, or specific environmental requirements. The Red Spur variety has the smallest share at 4.29%, suggesting limited cultivation. Its lower proportion may result from lower consumer demand, challenges in production, or lesser yield potential compared to other varieties.

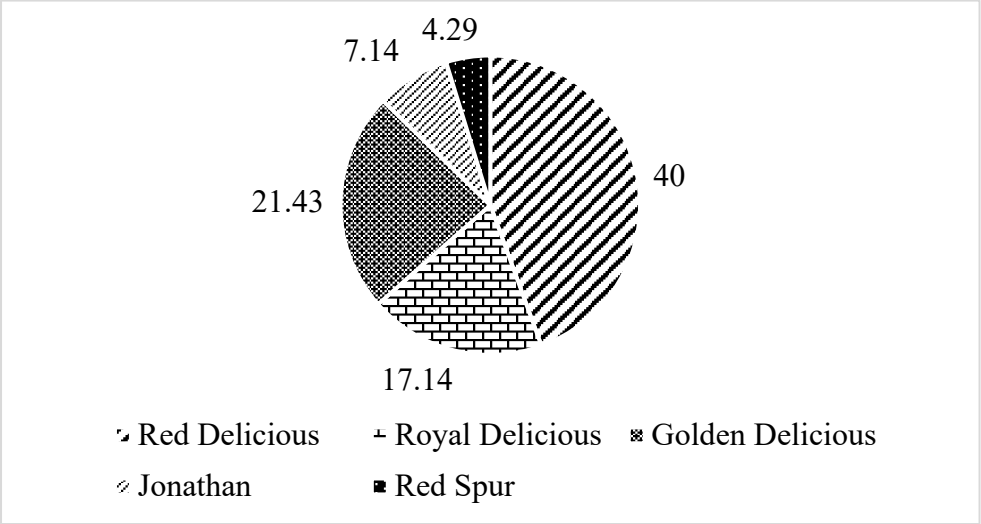

Figure 3: Cultivated varieties of apple in orchard at of Gharapjhong rural municipality of Mustang

3.3 Apple Pricing and Farmer Satisfaction in Gharapjhong Rural Municipality of Mustang

3.3.1 Maximum Unit Price of Apples

In Gharapjhong Rural Municipality, apple growers received varying prices for their produce, with the highest unit price recorded at Rs. 160 per kilogram. However, this price was limited to apples that were handpicked directly by consumers, accounting for only 14.29% of the total apple sales. The most commonly received price was Rs. 130 per kilogram, comprising 32.86% of the total sales. Additionally, 28.57% of the apples were sold at Rs. 140 per kilogram, followed by 22.86% at Rs. 150 per kilogram, and a small portion (1.43%) at Rs. 120 per kilogram. These figures indicate that while premium prices are attainable under specific conditions (such as consumer picking), the majority of the apples were sold within the Rs. 130–150 range. This pricing structure suggests a relatively stable mid-tier market with limited opportunities for farmers to earn higher premiums unless additional value (e.g., self-picking) is integrated into the consumer experience. The prevalence of Rs. 130 per kilogram as the most frequent price point reflects both market demand and existing supply chain mechanisms in the region.

3.3.2 Minimum Unit Price of Apples

The minimum prices received for apples in the region further reflect disparities in market access and quality perception. Apples were sold at minimum prices ranging from Rs. 70 to Rs. 100 per kilogram. Among these, Rs. 80 per kilogram was the most common, representing 41.43% of the total, followed by Rs. 90 (30%), Rs. 100 (18.57%), and Rs. 70 (10%). The significant proportion of apples sold at or below Rs. 80 per kilogram highlights the challenges faced by producers in securing better returns, possibly due to overproduction, quality issues, or limited market linkages. This calls for improved post-harvest handling, grading, and market integration to help farmers move their produce into higher price brackets.

3.3.3 Farmer Satisfaction with Apple Production

Regarding farmer satisfaction with apple production, the majority of respondents reported moderate satisfaction (38.57%), while 28.57% indicated high satisfaction, and 22.86% expressed very high satisfaction. Only 10% of the farmers reported a low level of satisfaction.

The moderate satisfaction levels among most growers suggest a cautious optimism. While the potential for high-income generation exists, it is tempered by several challenges. Farmers specifically cited emerging diseases, pest infestations, and unpredictable weather conditions as significant threats to apple cultivation. These factors have likely contributed to uncertainties in yield and quality, thereby affecting both income and satisfaction.

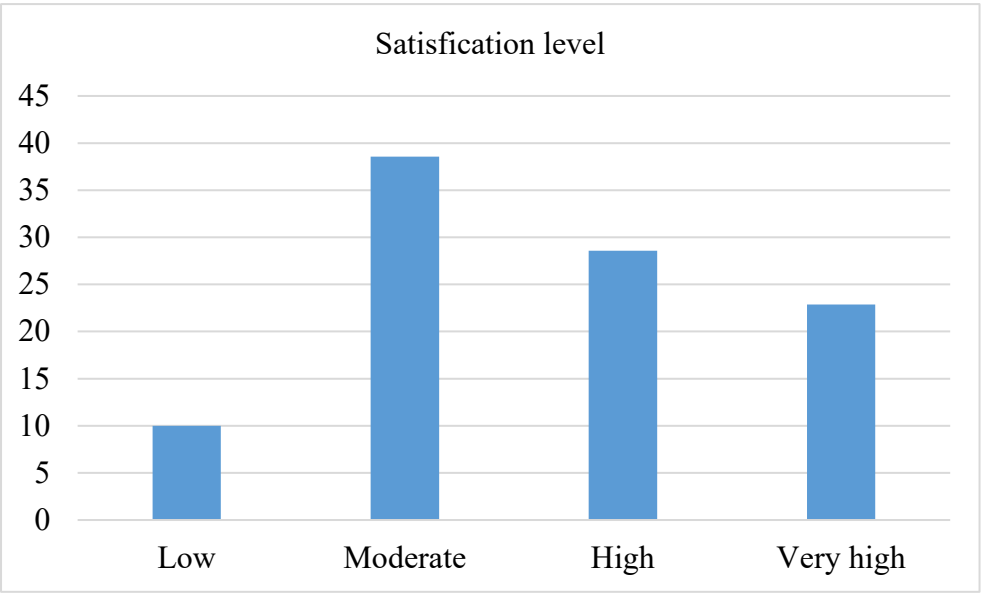

Figure 4: Satisfaction level of producer of Gharapjhong rural municipality of Mustang

3.4 Economic Analysis of Apple Production

3.4.1 Benefit Cost Ratio (BCR)

The economic viability of apple production in Mustang was assessed using the Benefit-Cost Ratio (BCR), alongside an evaluation of farm gate and retail prices, marketing margins, and producer shares before and after the COVID-19 pandemic. The BCR, which is the ratio of total benefits to total costs, was found to be 1.8 prior to the pandemic, indicating a profitable enterprise. However, post-COVID-19, the BCR dropped to 0.9, suggesting that apple production had become economically unviable. This decline may be attributed to multiple factors, including poor orchard management, increased pest infestations, and adverse climatic conditions such as excessive rainfall. Additionally, the Mustang region has been experiencing rising temperatures, which may have altered the ecological

suitability for apple cultivation, particularly by shifting the lower elevation limit upwards.

Despite numerous constraints, apple cultivation has proven to be a beneficial and economically viable farming system in the Himalayan region of Nepal. A long-term economic analysis conducted reported a Benefit-Cost (BC) ratio of 1.90 over a 20-year period, with an internal rate of return (IRR) of 33.3% and a payback period of approximately 7.3 years (Chapai et al., 2024). These indicators suggest that, despite production challenges, apple farming remains a profitable enterprise. In Mustang district, efforts to address key limitations—such as insect pest infestations, inadequate technical support, ineffective marketing systems, and post-harvest losses have shown promising economic outcomes. A group researchers observed that overcoming these constraints led to a BC ratio of 1.84, reaffirming the profitability of apple farming in the region (Gayak et al., 2020). Similarly, a study reported that the BC ratio among apple farmers in Mustang varied widely, ranging from 1.19 to 2.68, depending on factors such as orchard management practices and market access (Bhandari and Aryal, 2016). Khadka, further reinforced the economic potential of apple cultivation by noting BC ratios of 1.98 in Mustang and 2.44 in Jumla, suggesting that apple farming can yield substantial returns under favorable conditions (Khadka, 2018). In Darchula, the economic efficiency of apple production was also confirmed, with a BC ratio of 1.88, an IRR of 22.03%, and a payback period of 8 years and 8 months (Pandey et al., 2023).

3.4.2 Farm Gate and Retail Prices

Despite the reduction in profitability, there were notable changes in both farm gate and retail prices. The average farm gate price of apples increased from NRs. 60 per kg before COVID-19 to NRs. 80 per kg after the pandemic. Similarly, the retail price rose from NRs. 120 to NRs. 140 per kg. This parallel increase in prices suggests that, although overall profitability declined, farmers were able to capture a greater portion of the consumer price. The marketing margin, defined as the difference between the retail and farm gate prices, remained constant at NRs. 60 per kg in both periods. However, the producer share calculated as the percentage of the retail price received by the farmer increased from 50% before COVID-19 to 57% after. This indicates a slight improvement in the position of farmers in the value chain post-COVID-19, potentially due to better market linkages, reduced intermediary roles, or improved bargaining power of producers.

Table 3: Farm gate and retail price

Apple	Farm gate price (NRs. / kg)	Retail price (NRs / kg)
Before COVID-19	Rs.60	Rs.120
After COVID-19	Rs.80	Rs.140

3.4.3 Market Margin and Producer Share

The marketing margin and producer share are important indicators of the distribution of value within the apple supply chain. The marketing margin refers to the difference between the retail price paid by consumers and the farm gate price received by producers. Prior to the COVID-19 pandemic, the average farm gate price for apples in Mustang was NRs. 60 per kilogram, while the average retail price was NRs. 120 per kilogram. This resulted in a marketing margin of NRs. 60 per kilogram. The producer share, defined as the proportion of the retail price received by the farmer, was calculated using the formula:

Producer Share (%) = (Farm Gate Price / Retail Price) × 100

Using this formula, the producer share before COVID-19 was found to be 50%, indicating that farmers received half of the final consumer price.

Following the COVID-19 pandemic, both farm gate and retail prices increased. The average farm gate price rose to NRs. 80 per kilogram, while the retail price increased to NRs. 140 per kilogram. Despite the changes in absolute prices, the marketing margin remained constant at NRs. 60 per kilogram. However, the producer share increased to 57%, suggesting a relative improvement in the farmers' position within the marketing chain. This shift implies that although intermediary margins remained the same in monetary terms, producers were able to capture a larger percentage of the retail price after the pandemic. The increase in producer share may reflect changes in market dynamics, such as improved market access, reduced dependency on intermediaries, or enhanced bargaining power of farmers. Overall, while the marketing margin did not change, the increased producer share post-COVID-19 represents a positive development for apple growers in Mustang, highlighting the potential for greater equity in the agricultural marketing system.

3.4.4 Cost of Apple Production

The comparative analysis of apple production costs before and after COVID-19 reveals a significant increase in total production expenses, primarily driven by a sharp rise in variable costs. While fixed costs, such as land rent, remained constant at NRs. 731,000 with an average fixed cost of NRs. 10,443, variable costs surged from NRs. 13,712,140 to NRs. 23,133,900. This escalation was most notable in sapling cost (from NRs. 351,440 to NRs. 3,125,650), manure cost (from NRs. 2,494,050 to NRs. 4,352,850), fertilizer cost (from NRs. 2,694,250 to NRs. 5,475,500), and irrigation cost (from NRs. 47,600 to NRs. 645,000), along with an extraordinary rise in miscellaneous costs (from NRs. 3,122,000 to NRs. 36,644,000), possibly due to market disruptions and inflation in input prices after the pandemic. As a result, the total cost increased from NRs. 14,443,140 to NRs. 23,864,900, and the average total cost rose from NRs. 7,221,570 to NRs. 11,932,450. These findings indicate a substantial financial burden on farmers in the post-pandemic period, emphasizing the need for policy support, cost-effective input supply, and improved resource management strategies to maintain the profitability and sustainability of apple farming in the region.

Table 4: Cost of Production of apple at Gharapjhong rural municipality of Mustang

	Before COVID-19	After COVID-19
Fixed cost (FC)	Total Amount	Total Amount
Land rent	731000	731000
Variable Cost (VC)		
Sapling cost	3,51,440	31,25,650
Manure cost	24,94,050	43,52,850
Fertilizer cost	26,94,250	54,75,500
Labor cost	17,50,800	23,13,400
T. Pruning cost	14,52,000	17,51,000
Irrigation cost	47,600	6,45,000
P. Protection cost	14,39,000	14,39,000
Harvesting cost	3,61,000	3,67,500
Miscellaneous cost	31,22,000	3,66,44,000
Total Fixed Cost	7,31,000	7,31,000
Total average fixed cost	10,443	10,443
Total Variable Cost	1,37,12,140	2,31,33,900
Total average variable cost	1,95,888	3,30,484
Total Cost	1,44,43,140	2,38,64,900
Total average Cost	72,21,570	1,19,32,450

3.4.5 Price of apple product before and after COVID-19

The price comparison of apple and apple-based products before and after COVID-19 indicates a noticeable increase across all categories. The price of fresh apples rose from NRs. 60 per kg to NRs. 80 per kg, reflecting a 33% increase, which may be attributed to higher production costs and reduced supply during the pandemic. Similarly, the price of dry apples increased from NRs. 1200 per kg to NRs. 1500 per kg, showing a 25% rise. This could be due to increased demand for preserved food products during the pandemic period, as well as higher processing and packaging costs. The price of apple-based beverages also experienced a substantial increase, rising from NRs. 750 to NRs. 900 per bottle, indicating a 20% hike. These trends suggest that while the pandemic negatively affected production and supply chains, it also led to higher consumer prices for both fresh and processed apple products, which may have impacted affordability and market accessibility for consumers, while offering potential for increased value addition and income for producers and processors.

Table 5: Price of apple product before and after COVID-19.

	Before COVID-19	After COVID-19
	Per kg / bottle	Per kg / bottle
Apple	Rs.60 /kg	Rs.80 / kg
Dry apple	Rs.1200 / kg	Rs.1500 / kg
Beverage	Rs.750 / bottle	Rs.900 / bottle

3.4.6 Economics Analysis of Apple Production

The comparative analysis of key economic indicators before and after COVID-19 reveals significant changes in the apple production value chain.

The Benefit-Cost Ratio (BCR), a measure of profitability, declined from 1.8 to 0.9, indicating a shift from a profitable enterprise to a loss-making one after the pandemic. Interestingly, the farm gate price of apples increased from NRs. 60/kg to NRs. 80/kg, and the retail price rose from NRs. 120/kg to NRs. 140/kg. Despite this price increase, the marketing margin remained constant at NRs. 60/kg, suggesting that the gap between producer and consumer prices did not change. However, the producer share the percentage of the retail price received by farmers improved from 50% before COVID-19 to 57% after, indicating that farmers captured a slightly larger portion of the final price. This could reflect stronger bargaining power, reduced middlemen, or improved direct marketing practices post-pandemic. Nonetheless, the overall decline in BCR highlights that the increased production costs likely outweighed the gains in price and producer share.

Table 6: Economics analysis of apple production before and after COVID-19

		Amount	
Indicators	**Unit**	**Before COVID-19**	**After COVID-19**
BCR	Proportion	1.8	0.9
Farm gate price	NRs. / kg	60	80
Retail price	NRs. / kg	120	140
Marketing margin	NRs. / kg	60	60
Producer share	%	50	57

3.5 Descriptive Statistics

The descriptive statistics presented in Table 7 summarize the socio-economic and demographic characteristics of the 70 respondents involved in apple farming. The gender variable, coded as 0 for female and 1 for male, has a mean value of 0.63 with a standard deviation of 0.487, indicating a male-dominated sample. The average age of respondents is 52.23 years, ranging from 30 to 80 years, suggesting the involvement of middle-aged to elderly individuals in apple farming. For family type (1 = nuclear, 2 = joint), the mean is 1.74, indicating a higher representation of joint families. The average landholding size is 9.24 ropani, with a wide range from 1 to 39 ropani and a standard deviation of 8.01, reflecting significant variation in land ownership. The main occupation variable (0 = other, 1 = agriculture) has a mean of 0.84, showing that most respondents are primarily engaged in agriculture. Regarding education (1 = illiterate, 2 = literate), the mean of 1.89 suggests that the majority of respondents are literate. These statistics provide a foundational understanding of the respondent profile in the study area.

Table 7: Descriptive statistics of socio-economic and demographic characteristics of respondents Gharapjhong rural municipality of Mustang.

Descriptive Statistics					
	N	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Gender	70	0	1	0.63	0.487
Age	70	30	80	52.23	13.189
Family type	70	1	2	1.74	0.440
Total land (Ropani)	70	1.0	39.0	9.236	8.0067
Main Occupation	70	0	1	0.84	0.367
Education	70	1	2	1.89	0.320

Table 8 presents a comparative analysis of key variables related to apple farming before and after the COVID-19 pandemic. The average apple cultivated area increased from 7.01 ± 4.90 ropani before the pandemic to 8.26 ± 5.13 ropani after, indicating a slight expansion in land allocation for apple production. Similarly, average production rose from 8.09 ± 6.91 tons to 9.26 ± 8.14 tons, reflecting a positive trend in output. The average price per kilogram of apples also showed a marginal increase from Rs. 6.83 ± 6.67 to Rs. 7.00 ± 7.06. Farmers' average income improved from Rs. 82.29 ± 21.75 lakh to Rs. 93.29 ± 26.36 lakh, suggesting enhanced profitability despite the pandemic. The number of major buyers increased from a mean of 4.20 ± 2.48 to 5.50 ± 5.91, indicating better market access or diversification in sales channels post-COVID. However, the average government subsidy received by farmers declined from 1.81 ± 0.47 to 1.46 ± 0.50, suggesting reduced institutional support in the post-pandemic period. These findings highlight both opportunities and challenges faced by apple farmers during the recovery phase following the pandemic.

Table 8: Comparative analysis of key apple farming variables before and after covid-19 of respondents Gharapjhong rural municipality of Mustang.

Before COVID-19			**After COVID-19**
Variables	N	Mean ± S.D	Mean ± S.D
Apple cultivated area (Ropani)	70	7.01 ± 4.90	8.26 ± 5.13
Production (ton)	70	8.09 ± 6.907	9.26 ± 8.136
Price per kg (Rs)	70	6.83 ± 6.670	7.00 ± 7.055
Income (Rs/ lakh)	70	82.29 ± 21.748	93.29 ± 26.360
Major buyer	70	4.20 ± 2.482	5.50 ± 5.912
Government subsidy	70	1.81 ± 0.472	1.46 ± 0.502

3.6 Mean comparison of variables before and after COVID-19

3.6.1 Independent sample t-test.

The table 9 presents the results of an independent sample t-test conducted to compare the means of key variables related to apple farming before and after the COVID-19 pandemic. The results indicate that total cost showed a statistically significant increase after COVID-19, rising from a mean of Rs. 202,919.90 to Rs. 337,037.10 (t = 2.55, p = 0.0119), significant at the 5% level (**). Similarly, the price per kilogram of apples significantly increased from Rs. 84.71 to Rs. 98.29 (t = 4.11, p = 0.0001), which is highly significant at the 1% level (***). In contrast, variables such as apple cultivated area, production, income, and benefit from raw or by-products did not exhibit statistically significant changes, as their p-values were greater than 0.05, indicating that the differences observed in their means could be due to chance. Interestingly, labor requirement showed a marginally significant increase post-COVID-19 (t = 1.74, p = 0.0847), significant at the 10% level (*), suggesting a higher demand for labor in apple farming after the pandemic, possibly due to changes in operational needs or labor availability. Overall, the analysis reveals that while some economic indicators like total cost and product price significantly changed after the pandemic, other production-related variables remained relatively stable.

Table 9: Independent sample t-Test for Key Variables before and after COVID-19

Variables	**Before COVID-19**		**After COVID-19**		**Independent Sample Test**	
	Mean	**SD**	**Mean**	**SD**	**t-test value**	**Sig. (P)**
Total cost	202919.9	147076.2	337037.1	414746	2.55	0.0119**
Price per kg (Rs)	84.71	16.48	98.29	22.19	4.11	0.0001***
Apple cultivated area (Ropani)	8.13	86.86	9.23	8.13	0.89	0.3766
Production (Ton)	7	6.57	7.36	7.15	0.31	0.7587
Income (lakh)	4.24	2.42	4.86	2.42	1.5	0.1353
Benefit from raw or by product	1.56	0.715	1.61	0.67	0.48	0.6254
Labor requirement (individual)	14.24	12.34	18.54	16.64	1.74	0.0847*

**** p<.01, ** p<.05, * p<.1*

3.6.2 Weighted linear regression before and after COVID-19

This weighted linear regression model Table 10 examines the key factors influencing apple production (in tons) before and after the COVID-19 pandemic. The model shows a strong overall fit, with an R-squared value of 0.960, indicating that approximately 96% of the variation in production is explained by the independent variables included in the model. The F-test value of 252.129 with a p-value of 0.000 suggests that the overall model is statistically significant. Among the independent variables, several factors showed significant associations with apple production. The number of apple plants had a highly significant positive effect on production (Coef. = 0.035, $p < 0.01$), suggesting that an increase in plant numbers substantially contributes to greater output. Similarly, income (Coef. = 0.948, $p < 0.01$) and BCR ratio (Coef. = 0.815, $p < 0.01$) were both strongly and positively associated with production, indicating that higher returns and profitability are linked with increased production levels.

Apple cultivated area also had a significant positive impact (Coef. = 0.257, $p < 0.01$), meaning that expanding the area under cultivation is directly associated with higher yields. The price per kilogram of apples had a marginally significant effect (Coef. = 0.023, $p = 0.06$), implying that price fluctuations might modestly influence production decisions. In contrast, total cost was not statistically significant (Coef. = 0.000037, $p = 0.145$), suggesting that variations in total costs did not have a direct impact on production in this model. The constant term was also not significant, indicating that production levels cannot be adequately predicted without considering the other variables. In summary, the regression results highlight that production is significantly influenced by factors such as plant number, income, profitability (BCR), cultivated area, and to a lesser extent, price per kg, while total cost did not show a direct effect. These findings underscore the importance of financial and agronomic factors in determining apple production outcomes before and after the pandemic.

Table 10: Weighted linear regression model of production determinants before and after COVID-19

Production (ton)	Coef.	St. Err.	t-value	p-value	[95% Conf	Interval]	Sig
Price per kg (Rs)	0.023	0.012	1.92	0.06	0.048	0.001	*
Apple plant number	0.035	0.003	10.49	0.00	0.028	0.042	***
Income (Rs/lakh)	0.948	0.162	5.85	0.00	0.624	1.272	***
BCR ratio	0.815	0.133	6.15	0.00	0.55	1.08	***
Apple cultivated area~i	0.257	0.055	4.63	0.00	0.368	0.146	***
Total cost	0.000037	0.000025	1.47	0.145	0.000013	0.000088	
Constant	-.807	.923	-0.87	.385	-2.651	1.037	
Mean dependent var	7.000		SD dependent var	6.565			
R-squared	0.960		Number of obs	70			
F-test	252.129		Prob > F	0.000			
Akaike crit. (AIC)	249.737		Bayesian crit. (BIC)	265.477			

*** p<.01, ** p<.05, * p<.1

3.7 Problems associated during production and marketing of apple

3.7.1 Production related problems in apple farming

Based on this research, he most significant issue identified was disease infestation, with the lowest index value of 0.44, indicating its high frequency and impact, and ranking it as the first major constraint. Flower and fruit drop and lack of technical knowledge were both ranked second, sharing an index of 0.45, suggesting that both physiological and knowledge-related issues significantly hamper production. Lack of government subsidy and insect problems followed closely, ranked third and fourth with index values of 0.48 and 0.49, respectively. These results reflect both financial and pest management challenges faced by farmers. Interestingly, unavailability of quality inputs like fertilizer and sapling appeared twice in the table with different index values (0.69 and 0.76), indicating either a data entry duplication or differing perceptions based on context or timing. These were ranked fifth. Likewise, lack of irrigation was identified as the sixth major issue, with the highest index of 0.80, highlighting its relative importance compared to other problems but potentially perceived as slightly less immediate than disease and pest-related concerns.

Farmers in apple-growing regions of Nepal face numerous challenges that hinder productivity and profitability. According to a study, the major issues include poor soil fertility, unfavorable climatic conditions, and the prevalence of pests and diseases (Ghimire and Kafle, 2014). These factors significantly affect apple yield and fruit quality. In the Far Western region of Nepal, the situation is further complicated by the lack of agricultural inputs and inadequate transportation infrastructure, as highlighted by (Bajgain et al., 2024). Without timely access to essential inputs such as fertilizers, quality saplings, and plant protection materials, apple cultivation becomes increasingly difficult. Furthermore, poor road connectivity limits farmers' access to markets, reducing their ability to sell produce at competitive prices.

Similarly, in the Dolpa district, farmers grapple with a combination of problems including insufficient irrigation facilities, pest infestations, substandard storage conditions, and underdeveloped marketing systems (Ojha et al., 2021). The lack of road infrastructure exacerbates the problem by isolating apple-producing areas from potential buyers, traders, and support services. Farmers lack sufficient knowledge regarding the best practices for irrigating, fertilizing, and pruning their apple trees effectively (Subedi et al., 2016). In addition to these region-specific challenges, the overall apple supply chain in Nepal suffers from inefficiencies. Farmers often lack access to technical training and modern cultivation practices, which could otherwise help mitigate some of the problems mentioned above. Climate change is also emerging as a growing concern, bringing unpredictable weather patterns that further threaten apple productivity (Poudel et al., 2024).

Table 11: Ranking of major production problems faced by apple growers of respondents Gharapjhong rural municipality of Mustang.

Production problems	Index	Rank
Disease	0.44	1st
Flower/ fruit drop	0.45	2nd
Lack of technical knowledge	0.45	2nd
Lack of government subsidy	0.48	3th
Insect problem	0.49	4th
Unavailability of agriculture inputs	0.69	5th
Lack of irrigation	0.8	6th

3.7.2 Marketing related problems in apple farming

The most critical issue identified is the lengthy marketing channel, with the lowest index value of 0.48, earning it the first rank. This suggests that the involvement of multiple intermediaries between producers and consumers reduces efficiency and likely cuts into the farmers' profit margins. The problems of difficulties in transportation and distance to market are both ranked second, with an equal index value of 0.51. a group researcher also identified key marketing challenges in apple farming within the Mustang district, including inadequate transportation, limited market awareness, insufficient processing facilities, and the absence of proper storage infrastructure (Amgai et al., 2015). These issues highlight significant logistical barriers that hinder timely and cost-effective delivery of produce, especially from rural or remote production areas to urban market centers. Similarly, the inefficiency of market and price information systems is ranked third, with a higher index value of 0.68, pointing to a lack of timely and accurate information dissemination about market prices and demand. This hampers farmers' ability to make informed decisions and negotiate better prices. A group researchers conducted a study in Jumla, highlighting that apple farming is a profitable venture in Nepal's hilly regions (Sapkota et al., 2022). However, the expansion of apple production could be achieved through the establishment of government-

operated farms, the development of efficient marketing channels via cooperatives, the provision of subsidies and credit facilities for farmers, and the implementation of research-based farming and post-harvest practices.

Table 12: Ranking of the marketing problems faced by apple growers of respondents Gharapjhong rural municipality of Mustang.

Marketing problems	Index	Rank
Lengthy marketing channel	0.48	1st
Difficult in transportation	0.51	2nd
Distant to market	0.51	2nd
Inefficient market / price information system	0.68	3rd

4. Conclusion

Almost all households were unaware of COVID-19's impact on the apple production sector and struggled to manage the sudden changes brought by the pandemic. Despite shortages of pesticides, manure, and fertilizer during this period, production levels remained consistent with pre-pandemic levels. However, demand decreased, resulting in financial losses for farmers. While it was evident that COVID-19 led to losses in the apple sector, there was no clear strategy to support affected producers. Before COVID-19, the benefit-cost ratio (BCR) was 1.8, indicating profitability. After COVID-19, the BCR dropped to 0.9, showing a negative impact on apple enterprises. The farm gate and retail prices of apples increased slightly by only NRs. 20 after COVID-19. Challenges in managing diseases like apple scab and woolly apple aphid contributed to higher production costs. Coordination among producers was adequate, as evidenced by the consistent marketing margin. However, fewer than half of the farmers were satisfied with the prices they received. There was no formal marketing channel for apple businesses in Nepal, leading to intermediaries profiting more than the producers themselves. The COVID-19 pandemic caused significant disruptions in apple production, but government support, such as subsidies on various agricultural commodities, helped farmers mitigate the adverse effects.

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Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest. All contributors have reviewed and approved the final version of the manuscript.

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