CHALLENGES AND OPPORTUNITIES FOR THE FRESH FRUIT SUPPLY CHAIN IN DISTRICT CHITRAL

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ABSTRACT

This study investigates the opportunities and challenges in the fresh fruit supply chain of Chitral, focusing on apples, walnuts, and apricots, three economically significant fruits in the region. The research aims to identify key structural, logistical, and institutional bottlenecks; assess post-harvest losses; and explore value addition potential for Chitral. Using a mixed-methods approach, primary data will be collected from fruit growers across major production clusters through structured and unstructured questionnaires, alongside key informant interviews with government officials, other stakeholders, and market actors. Descriptive analysis will analyze factors affecting supply chain efficiency and income generation. Findings will inform targeted policy recommendations and capacity-building strategies to strengthen Chitral's fresh fruit sector and improve the livelihoods of smallholder farmers, contributing to regional economic development and agricultural value chain integration.

PREFACE

This final project report presents the progress of the research project titled "Challenges and Opportunities for the Fresh Fruit Supply Chain in District Chitral." The study focuses on three economically significant fruits of the region—apples, walnuts, and apricots—and seeks to identify structural, logistical, and institutional challenges, assess post-harvest losses, and explore opportunities for value addition. The purpose of this research is to generate evidence-based insights that can strengthen Chitral's fresh fruit sector, improve the livelihoods of smallholder farmers, and contribute to regional agricultural value chain integration and sustainable economic development.

The research design phase has been successfully completed, and the inception and midterm milestones have been achieved within the stipulated timelines. Secondary data collection, literature review, stakeholder consultations, and pretesting of research instruments have laid a strong foundation for the ongoing field research. The next phase will focus on comprehensive fieldwork, advanced analysis, and the formulation of targeted policy recommendations for strengthening the fresh fruit supply chain in Chitral.

The research team gratefully acknowledges the support and valuable contributions of the KPK Agriculture Department, the Aga Khan Rural Support Programme (AKRSP), Sarhad Rural Support Programme (SRSP), Zarai Taraqiati Bank Limited (ZTBL) and other local institutions and market actors, whose insights have been instrumental in refining the research design and tools. Above all, we extend our sincere gratitude to the RASTA – PIDE & Planning Commission Competitive Research Grants Programme (CGP 7.0) and to our esteemed mentors Dr. Shujaat Farooq, Dean (Research) formerly Chief of Research / Director (Research) PIDE, Dr. Ather Maqsood Ahmed, Founder Department of Economics at NUST and RASTA PMU for providing the funding and institutional support that have made this study possible.

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INTRODUCTION

1.1. Background and Context of the Study

Importance of Food: Food is a fundamental human necessity, essential not only for survival but also for health, economic development, and social stability (Wang, M. 2021 & FAO, 2019). Among all food categories, fresh fruits, in particular, play a critical role in nutrition by providing essential vitamins, minerals, and antioxidants that contribute to improved health outcomes (WHO, 2020). Fresh fruit is produced both locally and in distant regions, often thousands of miles from the point of consumption. Therefore, the fresh fruit supply chain (FFSC) functions as a critical linkage between production and consumption sites (Amentae, T. K. 2018), facilitating the movement of highly perishable goods while maintaining quality and minimizing post-harvest losses (Hogsholt, 2024). In mountainous regions like Chitral, fresh fruit production is a vital livelihood activity that contributes to both food security and income generation for rural households (Khan & Schrader, 2024). The unique agro-ecological conditions of Chitral enable the cultivation of high-value fruits such as apples, apricots, and walnuts, which are important for local nutrition and economic development (Kupiec-Teahan et al., 2010). Thus, given the nutritional and economic importance of fresh fruits, understanding the dynamics of their supply chains is crucial for enhancing accessibility and sustainability.

Role of Fresh Fruit Supply Chains (FFSCs): Fresh fruit supply chains encompass the entire process from production, harvesting, handling, storage, transportation, processing, to marketing (Altendorf, 2023; Nguyen et al., 2021). Efficient fresh fruit supply chains (FFSCs) are essential for minimizing post-harvest losses (Anand & Barua, 2022), maintaining fruit quality (Kader & Rolle, 2004), and ensuring timely delivery to markets (FAO, 2019), factors that are particularly critical for perishable commodities like fruits. In mountainous regions, FFSCs are essential for linking smallholder farmers to regional and national markets, thereby supporting rural livelihoods and economic growth (Altendorf, 2023). Additionally, FFSCs can empower marginalized groups by creating opportunities for participation in value addition and market access (Kupiec-Teahan et al., 2010)

Historical Evolution of FSCs in Mountainous Regions: Historically, supply chains in mountainous areas such as Chitral were characterized by informal, localized networks with limited infrastructure and market access (Kupiec-Teahan et al., 2010). Transport often relied on manual labor and animal caravans due to poor road connectivity, restricting the flow of fresh fruits to distant markets (Ali & Qaiser, 2009). Supply chains, initially, acted as a major constraint on human population expansion, remaining largely localized and structurally simple until the Industrial Revolution. The advent of globalization and technological progress in agriculture, transportation, and processing significantly increased their complexity and extended their reach on a global scale (Mohajan, 2019; Wang, 2021). Eventually, infrastructural improvements and policy support facilitated gradual commercialization and integration of these supply chains with broader markets along with technological advances such as cold storage and improved packaging have further extended the shelf life of fresh fruits, enabling access to urban and export markets (Altendorf, 2023). However, this transformation has not been uniformly experienced across all regions. In Chitral, despite the broader advancements in supply chain infrastructure and technology, fresh fruit supply chains continue to face significant challenges. The region's rugged terrain, underdeveloped transportation networks, limited cold storage facilities, and weak market linkages have hindered the efficient movement of produce and restricted farmers' access to profitable markets (Khan & Schrader, 2024).

Fruit Production Hubs: Globally, fruit production hubs thrive where favorable agro-climatic conditions align with strong market access and infrastructure. For instance, Brazil's Belem metropolitan region excels due to its proximity to consumer markets and export facilities (Santos, 2024). Similarly, Southeast Asia, including Thailand, the Philippines, and Vietnam, is a major tropical fruit hub supported by year-round climates and efficient logistics (FAO, 2021).

Further, Pakistan is recognized as one of the leading fruit-producing countries globally, ranking 4th in Mango production with approximately 1.88 million tones, 6th in Guava production at 2.4 million tones, 10th in Apple production at 0.672 million tones and holding significant positions in Dates and Citrus production with 0.72 million tones and 2.1 million tons respectively (Shah et al., 2022; TDAP, 2022). For fiscal year 2021–22, Pakistan exported approximately 0.570 million tons of fruit, reflecting a 1.1% increase compared to the previous year (GOP, 2024).

Within Pakistan, Punjab province is recognized as the central hub for fruit production accounting for nearly 40% of the country's total fruit output approximately with 6.05 million tones, followed by Baluchistan with 1.44 million tones, Sindh with 0.99 million tones, and Khyber Pakhtunkhwa with 0.32 million tones, having diverse fruit crops, lags in total volume (GOP, 2024).

However, the northern and hilly regions, including Chitral, are known for temperate fruits such as apples, pears, apricots, and walnuts, although much of this production is on a smaller, household scale. Among fruits, Apricot ranks as the second most important fruit crop in the district after apple, accounting for approximately 19% of the total fruit production (Hussain et al., 2017). The major fruits cultivated in Chitral include apples, pears, apricots, walnuts, mulberries, pomegranates, and persimmons, primarily grown for self-consumption and local commercial markets.

National Economic Contribution and Export Potential: Globally, fruit production is not only growing at over 2% annually, but also trade is expanding faster at 7%, accounting for 9% of total global fruit output (Gabriel, 2023). In Pakistan, fresh fruit sector plays a vital role in the national economy, with strong export potential and growing domestic demand. In 2025, the market is projected to generate USD 9.97 billion in revenue, with a projected Compound Annual Growth Rate (CAGR) of 6.28% through 2030 (Statista, 2025). Fruit exports are a key component of Pakistan's horticultural trade, with citrus and mangoes contributing over 60% of total export revenues (Shamrooz et al., 2023). In the first half of FY 2024–25, Pakistan exported 105,690 metric tons of citrus, generating $30.9 million, primarily to Afghanistan, the UAE, and Indonesia, being most favorable destination (*Pakistan Today*, 2025). Additionally, The Pakistan Fruits and Vegetables Export Strategy 2023–2027 aims to boost export volumes by improving production quality, promoting value addition, and diversifying markets. Although Pakistan cultivates fruits on over 0.87 million hectares, producing more than 7.2 million tons annually, its fruit exports account for just 0.37% of global exports contributing only 0.1% to national GDP (Shamrooz et al., 2023), the sector still holds considerable untapped growth potential and waits for government policies to be exploited.

Women Empowerment: Women's empowerment within District Chitral's fresh fruit supply chain is essential for advancing socio-economic development and ensuring sustainable livelihoods. Despite a relatively low female labor force participation rate in Chitral compared to the national average of 22.2% (AKRSP, 2014), emerging opportunities in entrepreneurship and fruit marketing are creating space for women's engagement.

Research from Lahore's weekly bazaars reveals that enhanced mobility significantly improves women's empowerment, as seen in increased decision-making authority and property ownership (Salahuddin et al., 2021). In Khyber Pakhtunkhwa generally and Chitral particularly, initiatives such as the Sarhad Rural Support Programme's Women's Economic Empowerment and Market Development project aim to integrate women into value chains, including Mango, Dairy, and Citrus, through social mobilization and market linkages, fostering productivity and long-term inclusion (Department of Foreign Affairs and Trade, Australia, 2022).

Community Based Interventions: Community-based interventions have significantly strengthened the fresh fruit supply chain in District Chitral by addressing key challenges across production and post-harvest stages. The Aga Khan Rural Support Programme (AKRSP) led a six-year initiative (1999–2004) that promoted fruit nurseries, established model orchards, introduced integrated pest management (IPM), and provided new plant varieties and farmer field schools, resulting in notable improvements in orchard productivity and fruit quality (Shamoon Sadiq, 2017). These efforts were supported by infrastructure enhancements, such as micro-hydel power and improved water courses, contributing to agricultural sustainability in remote areas.

In parallel, the Pakistan Horticulture Development and Export Board (PHDEB) has played a key role in coordinating multi-stakeholder task forces comprising local communities, government agencies, and private sector actors. PHDEB's area-specific strategies emphasize strengthening fruit value chains, particularly for apples, pears, and apricots, by linking farmers with exporters, providing training on quality production, timely harvesting, and standardized packaging to meet international export standards (Business Recorder, 2007). Further research on the apricot value chain in Chitral underscores the role of community participation in promoting sustainable land use practices, enhancing livelihoods while conserving the upland ecosystem (Hussain et al., 2017).

However, persistent challenges such as scattered orchards, inadequate road infrastructure, and limited commercial orientation of fruit plantations highlight the continued need for integrated, community-based approaches that combine technical capacity-building, infrastructure development, and improved market access (Bukhari, 2014).

Financial Inclusion: Farm Credit and Support Mechanisms: Financial inclusion through farm credit and support mechanisms is critical for improving agricultural productivity and livelihoods in District Chitral, where subsistence farming dominates and formal credit access remains limited. The findings indicate that interest-free credit provision and higher credit availability at the village level significantly enhance smallholders' current and future participation in agricultural markets (Sher et al., 2024), ensuring financial inclusivity. Also, institutional credit, mainly from organizations such as ZTBL, AKRSP, NRSP positively affects farm productivity and income by enabling timely procurement of agricultural inputs and technologies (Ahmad & Ahmad, 2024).

For the fiscal year 2021-2022, a total disbursement of Agriculture farm credit specifically to Chitral region stood Rs 384.928 million, of which Rs 238.098 million came from ZTBL, HBL contributed Rs 112.1 million, Bank of Khyber contributed Rs 20.730 million, and Microfinance shared Rs 14.00 million of the total disbursement (SBP).

While farmers reported barriers such as high interest rates and complicated loan procedures, indicating a need for more user-friendly and affordable credit services (Shabbir Ahmad, 2018). At the

national level, smallholder farmers face multiple constraints in accessing credit, including low financial literacy, limited collateral, and bureaucratic hurdles. Research in southern Punjab reveals that education, farming experience, and agricultural income significantly enhance credit uptake among smallholders, pointing to the value of targeted capacity-building programs (Javed et al., 2022).

Regulation and Technological Adoption: Regulatory oversight and technological adoption are critical to strengthening the fresh fruit supply chain in District Chitral, yet both remain underdeveloped, limiting the region's competitiveness in domestic and export markets. Currently, there are no formal government regulations or rules guiding the cultivation and harvesting of apricots, Chitral's major fruit crop, resulting in a lack of standardization and quality control (Hussain et al., 2017).

This regulatory vacuum extends to other fruits, compounded by the absence of packaging standards, cold storage, and logistics infrastructure, which collectively undermine supply chain efficiency (Khan & Bae, 2017).

While technological adoption among smallholder farmers remains low due to limited financial resources and awareness. Traditional farming and post-harvest practices dominate, leading to significant losses and compromised product quality. The lack of modern technologies, such as cold chain systems, traceability mechanisms, and standardized packaging, also hampers compliance with national and international Sanitary and Phytosanitary Standards (SPS), restricting export potential (Rizvi et al., 2020).

However, donor and government led interventions have introduced model orchards, integrated pest management, and farmer training to improve productivity (Sadiq, 2017), meaningful progress depends on stronger regulatory frameworks.

These must enforce quality standards, promote market access, and incentivize investment in infrastructure like cold storage and processing units to fully realize Chitral's potential as a high-value fruit-producing region (Shamrooz et al., 2023).

Challenges in Fresh Fruit Supply Chains in Mountainous Regions: Despite progress, FFSCs in mountainous regions face several challenges. Such that a wide range of literatures have focused on challenges in Fresh Fruit Supply Chains including a complex interplay of factors from physical factors such as mechanical damages during harvesting, transportation and storage, often due to poor Infrastructure and Logistics (Agarwal, 2017; Ahmad et al., 2021; Altendorf, 2023; Hayatu, 2000), natural factors such as microbial activity like bacteria and fungi, pests attack and insect infestations (Yahaya, 2005), and technical factors such as lack of cold storage and lack of contemporary knowledge about technology (Kiaya, 2014), to the human and institutional factors such as inadequate time management, lack of farmer training, and general ignorance of post-harvest handling best practices (Bantayehu et al., 2017; FAO, 2024).

These factors encourage the informal intermediaries, which ultimately reduces the bargaining power and limits access to profitable markets (Kupiec-Teahan et al., 2010).

- **Types of Fresh Fruit Supply Chains**
- Fresh fruit supply chains in mountainous regions can be broadly categorized into:

- **Short Local Supply Chains**
- These involve direct sales from farmers to consumers or local markets, often informal and small-scale (Gori & Castellini, 2023; Kupiec-Teahan et al., 2010)
- **Extended Supply Chains**
- These include intermediaries and may involve some processing and storage, enabling access to regional markets (Altendorf, 2023).
- **Modern Integrated Chains**
- Characterized by advanced logistics, cold chains, quality control, and formal contracts, these chains maximize value addition and reduce losses (Altendorf, 2023).
- However, in regions like Chitral, short and extended supply chains predominate, with ongoing efforts to develop more modern, resilient supply chains (Altendorf, 2023; Khan & Schrader, 2024)

Opportunities for Value Addition and Market Linkages: Mountainous regions such as Chitral have potential for value addition through processing such as drying, juicing, and packaging can help reduce post-harvest losses and extend shelf life (Kupiec-Teahan et al., 2010). Additionally, certification schemes such as organic labeling and geographical indications can enhance product differentiation and increase market value and competitiveness in both domestic and export markets (KPRTP, n.d).

Strengthening market linkages by reducing dependence on intermediaries and fostering direct connections between farmers and buyers is essential to improve farmers' bargaining power and increase incomes (Khan & Schrader, 2024; Altendorf, 2023). Innovative transport solutions, such as ropeways or zip lines, have been proposed as effective means to overcome difficult mountainous terrain and improve access to markets in remote areas like Chitral (Hogsholt, 2024; Hussain et al., 2017).

Institutional Support and Policy Framework: Institutional support and policy frameworks are critical to strengthening fresh fruit supply chains (FSCs) in mountainous regions. FAO and its partners have implemented programs focusing on capacity building, infrastructure development, and market facilitation to enhance mountain agriculture and food security (FAO, 2019; Altendorf, 2023). Complementing these efforts, research highlights the importance of legal frameworks, farmer education, and integration of producers with retailers and consumers to improve supply chain sustainability and efficiency (Joshi et al., 2023). Public-private partnerships and certification schemes further enhance product quality and market access, supporting economic viability in fragile mountain contexts (Hogsholt, 2024; Alpine Convention, 2018).

Gender and Labor Dynamics: While specific data on gender dynamics in Chitral's FSCs are limited, FAO emphasizes the importance of inclusive supply chains that empower women and marginalized groups through training, credit access, and participation in value addition activities (Kupiec-Teahan et al., 2010). Studies in Chitral highlight women's significant roles in local food systems and value chains, particularly in processing and marketing activities, despite facing challenges related to land ownership and access to resources (Hussain et al., 2017; Sabbah et al., 2024). Addressing labor

shortages and improving working conditions are also critical for sustaining production and enhancing supply chain efficiency (ADB, 2020).

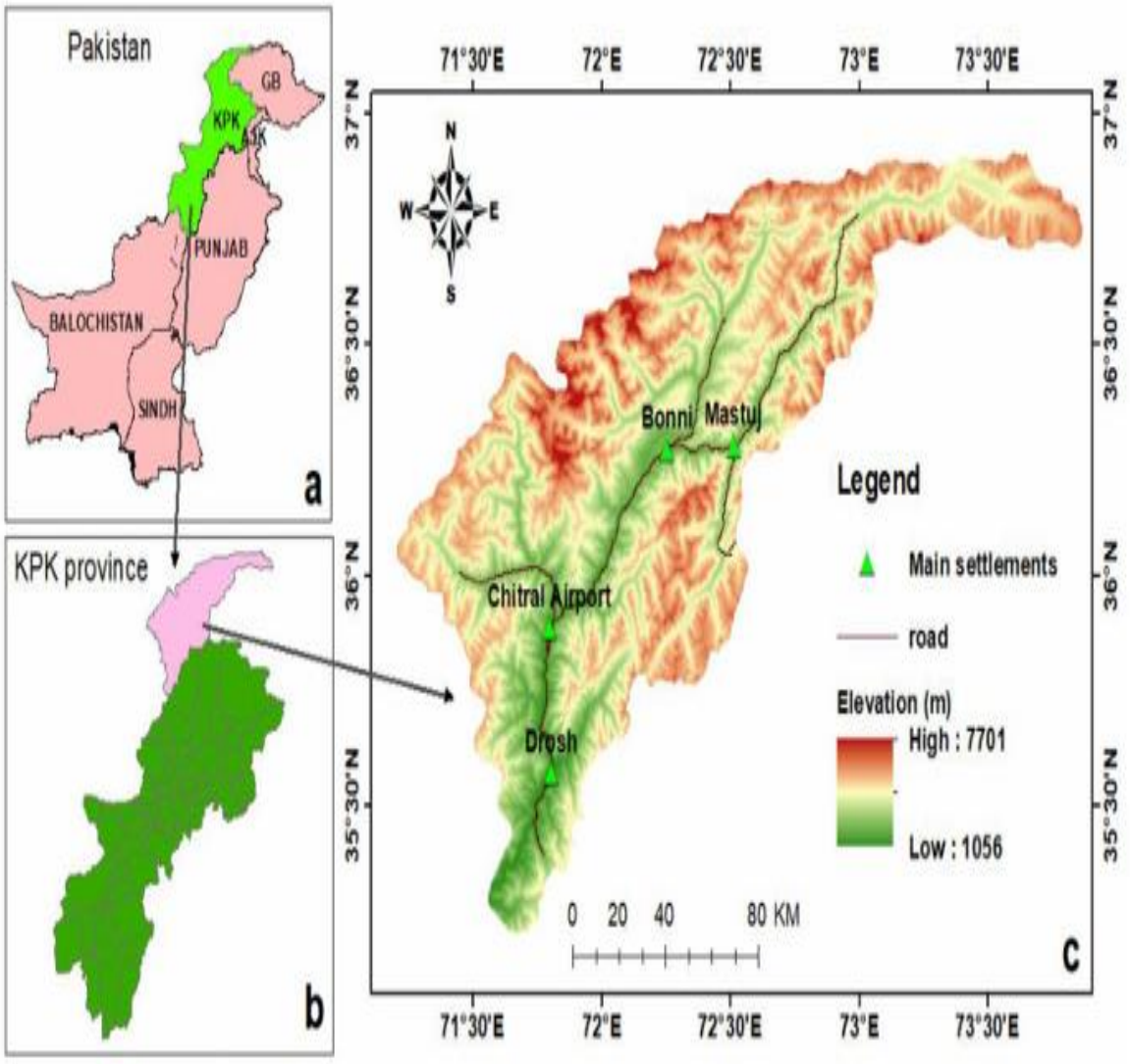
Climate Change and Risk Management: Mountainous agricultural systems, including those in Chitral and the broader Hindu Kush Himalaya region, are highly vulnerable to climate change impacts, with increasing frequency and intensity of extreme weather events disrupting agricultural production and supply chains (Altendorf, 2023; Asad et al., 2023). Studies highlight that rising temperatures, erratic precipitation patterns, and glacial lake outburst floods (GLOFs) have severely damaged fertile lands, crop yields, and fruit orchards, leading to reduced agricultural income and heightened food insecurity (Asad et al., 2023; Khan & Hussain, 2024).

To mitigate these risks, climate-resilient practices such as agroforestry, crop diversification, and improved water management are widely recommended (Kupiec-Teahan et al., 2010; Spies, 2020). Additionally, early warning systems and infrastructure resilience are critical components of risk management strategies to safeguard livelihoods and maintain supply chain continuity (Altendorf, 2023).

However, limited institutional support and lack of resources constrain the adaptive capacity of mountain farming communities, underscoring the urgent need for targeted interventions and strengthened extension services (Asad et al., 2023).

Demographic and Geographic Profile of Chitral: The demographic and geographic profile of Chitral provides an analytical insight revealing a fragmented but potential hub for fresh fruit supply chain development. Geographically, Chitral District covers total area of 14,850 sq. km providing a shelter to 515,933 populations by 15% increase since 2017, as per census 2023. Administratively, it is divided into Lower Chitral and Upper Chitral, covering an area of 6,458 sq. km with population of 320,407 and 8,392 sq. km with population of 195,528 respectively.

Figure 1: Location Map of the Study Area



Notes:
(a) geographical map of Pakistan with provincial boundaries, (b) geographical map of Khyber Pakhtunkhwa (KPK) with district wise boundaries, and (c) Digital Elevation Model (DEM) of Chitral valley where rectangular shows the main settlements of the study area and solid line shows major road network.
Source: (Hussain et al., 2022).

However, the vastness of its geography i.e., ranking Upper Chitral 2nd and lower Chitral 4th district in area wise in KPK and the low population density i.e., 50 persons/km^2 in lower Chitral and 23 persons/km^2 in Upper Chitral respectively, illustrate that inhabitants are widely scattered, which has direct and indirect implications for fruit supply chain logistics such as collection, transportation, and market access. Such that Upper Chitral with low population density poses challenges for timely and effective delivery of fresh fruits due to transportation constraints and connectivity issues while Lower Chitral with high population density provides an opportunity for being distribution hub in fruit marketing relatively having better transportation and connectivity.

Table 1: Area, Population, Density and Growth Rate in Chitral

Location	Area in Sq.Kms	Population in No.		%age change in 2023 over 2017	Population density Per Sq.Km		Total Housing Units (Census 2023)	Average Household Size; Census 2023	Growth rate 2023 (Percent)	Area wise District Position in KPK	Population wise District Position in KPK	Sex Ratio (Males per 100 Females)	
		2017	2023		2017	2023						2017	2023
Chitral Lower	6,458	278,328	320,407	15.12	43	50	46,028	6.90	2.38	4	32	102	104
Chitral Upper	8,392	169,297	195,528	15.49	20	23	26,365	7.40	2.44	2	35		106

Source: Bureau of Statistics Planning & Development Department Government of Khyber Pakhtunkhwa

Further, the gender composition of Chitral showing a sex ratio of 104 for lower Chitral and 106 for Upper Chitral represents an opportunity for inclusive labor participation in fruit farming. Such as a possible gender balance intervention i.e., capacity-building of women in sorting, grading, and local marketing, can possibly enhance efficiency and inclusiveness.

Climatic Conditions of Chitral: Chitral district consisting of Chitral and Drosh meteorological stations, like other regions of Pakistan, has four climatic seasons i.e., Spring, Summer, Autumn and Winter but with a variety of cold winters from December to February, warm to hot summers from May to August and high rainfall. The climatic variability as mentioned in below table indicates the probability of direct impact on fruit supply chain i.e., fruit cultivation cycle, harvesting timing, and post-harvest mechanisms.

Table 2: Monthly Mean Temperature and Rainfall 2024

STATION	Chitral			Drosh		
	Mean Temperature C			Mean Temperature C		
	Max:	Min:	Total Rain fall in mm	Max:	Min:	Total Rain fall in mm
January	15.7	-1.7	12.4	14.7	1.9	10.0
February	12.4	1.2	55.9	11.5	0.4	72.7
March	15.4	4.2	189.7	14.4	3.4	158.4
April	19.7	7.5	284.4	18.9	6.8	300.4
May	29.3	13.4	27.0	29.0	13.9	40.2
June	33.3	16.8	9.6	33.9	18.8	10.6
July	35.8	20.9	20.1	35.8	21.7	24.4
August	34.9	21.0	3.6	35.1	21.3	8.8
September	32.7	15.0	20.4	32.8	17.8	9.8
October	26.6	9.7	23.7	27.0	10.9	27.4
November	20.3	5.6	10.4	20.6	6.3	12.2
December	13.1	-1.9	5.1	12.0	-0.7	16.2
Mean	24.10	9.30	55.19	23.80	10.21	57.59

Source: Bureau of Statistics Planning & Development Department Government of Khyber Pakhtunkhwa

Further, the data shows that the temperature reaches up to 35/36°C in Summer which is recognized an ideal to ripening of fruit i.e., apple and apricot etc. but a disastrous if cold storage is not available leading to spoilage of fruit. In contrast, the temperature drops below 0°C ranging from -1.7°C to -1.9°C in Chitral, suitable for temperate fruit.

Additionally, the rainfall patterns in Chitral district fluctuates with respective to heavy precipitation in Spring from February to April but the month April receives heavy rainfall coinciding with the initial stage of flowering of different fruits which is significant for production output along with the risk of disturbance during pollination and then following by dry Summer from June to July. The month August and September are thought to be best for harvesting receive low rainfall supporting drying procedure, processing and value addition of fruits.

Market Potentials for Fruits in Chitral: Khyber Pakhtunkhwa (KPK), with more than 36,863 hectares dedicated to fruit cultivation, is Pakistan's second-largest fruit-producing province (Hussain et al., 2017). Chitral produces 477 tons of rabi fruits, contributing 0.8% of KP's total production and 81 hectares dedicated to rabi fruit cultivation, which makes up only 1.1% of the province's total fruit area. However, Chitral produces 4,380 tonnes of kharif fruits contributing 1.8% of KPK's total output on 96 hectares of land, which covers up just only 0.3% of KPK's total area.

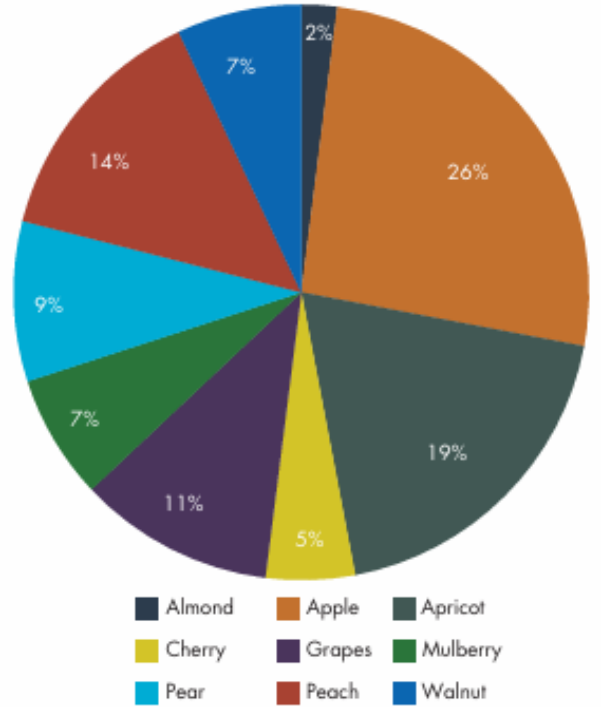
Table 3: Fruits Production in Chitral: 2023-24

Types of Fruits		**Area KPK (Ha)**	**Area Chitral (Ha) / % Share with KPK**	**Production in KPK (Tonnes)**	**Production in Chitral (Tonnes)/ % Share with KPK**	**Yield per Ha (Kg)**
Kharif Fruits	Apple	4694	--	46407	--	--
	Apricot	1569	--	12177	--	--
	Walnut	1721	--	15026	--	--
	Total*	29,211	96 (0.3)	246,104	4,380 (1.8)	7,348
Rabi Fruits*		7,652	81 (1.1)	60,787	477 (0.8)	5,919

*Source: GOP (2024) & *Bureau of Statistics Planning & Development Department Government of Khyber Pakhtunkhwa 2023-24*

However, the fruit production in Chitral, according to Hussain et al., 2017, constitutes the Apple fruit ranking first contributing to 26% of total production, followed by Apricot and Walnut contributing 19% and 7% respectively.

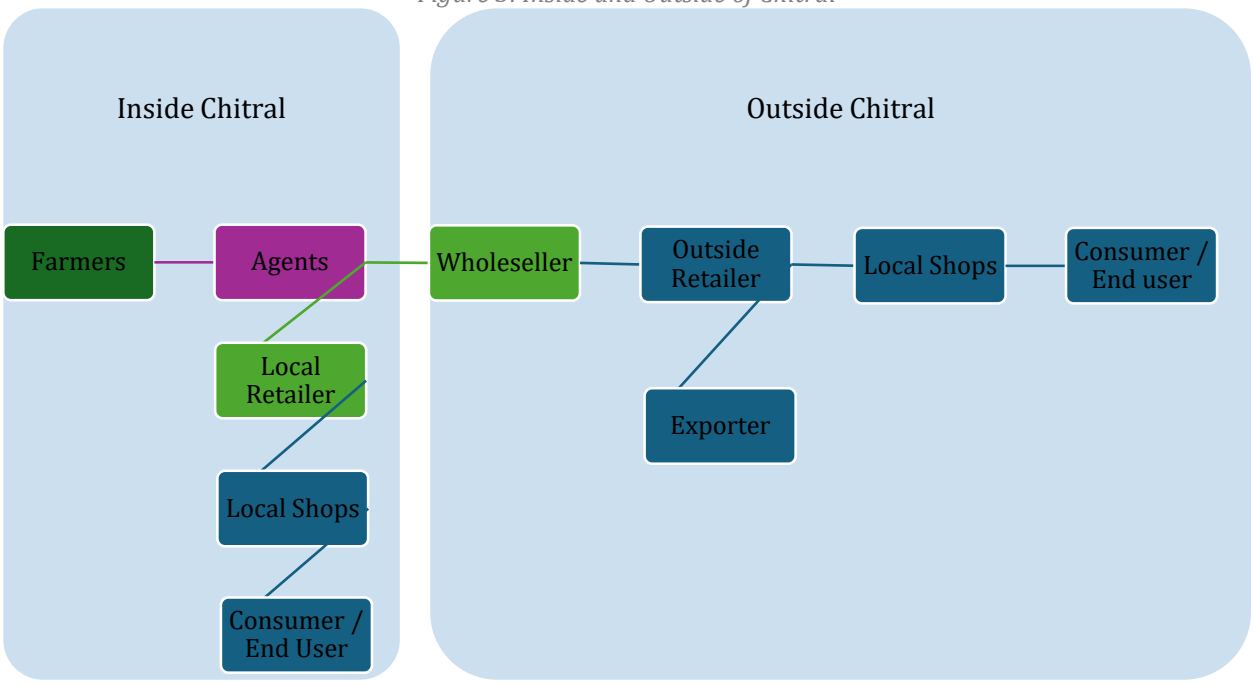
Figure 2: Fruit Production in Chitral



Source: Hussain et al., 2017.

Marketing Channels of Fruits in Chitral: Fruits marketing in Chitral is channelized in two distinct ways, according to Khan & Bae (2017), either by participation of local commission agents, local wholesalers and local retailers to the end consumers from producers, which is highly practiced within district supply chain mechanism, or through the participation of other districts commission agents, wholesalers and retailers to the end consumers from producers, which is hardly practiced with other districts supply chain mechanism. Such that in Lower Chitral, villagers sell their fruits first in nearby markets i.e., Garam Chashma and Drosh. While in Upper Chitral, products are sold in Mastuj and Booni markets. From these local hubs, the fruits are then transported to Chitral town and finally supplied to Peshawar and other parts of the country.

Figure 3: Inside and Outside of Chitral



Source: Authors own illustration.

Road, Irrigation and Storage Infrastructures in Chitral: To make effective and efficient fresh fruit chain, the mechanism depends upon three physical factors including road connectivity required for timely transport of fresh fruits, irrigation infrastructure which is required for production and storage facilities which is required to minimize post-harvest losses. The road network extends by length of only 705 km collectively in lower and upper Chitral for an area of 14,850 sq. km. The data indicates a fragile transport infrastructure in Chitral such that only 13/15% road network are paved while remaining 85/88% are unpaved showing poor road network intensifying the constrain in fruit supply chain. The data also portrays intra district disparity the lower region having better quality network than the high quantity but low-grade road network in upper region.

Table 4: Road Connectivity in Chitral 2023-24

Location	Total (KM)	High Type (KM)	% High Type	Low Type (KM)	% Low Type
Chitral Lower	288	43	15%	245	85%
Chitral Upper	417	51	12%	366	88%

Source: Bureau of Statistics Planning & Development Department Government of Khyber Pakhtunkhwa

Further, the irrigation infrastructure also depicts low level of government participation in irrigation management such that the total area of 20,934 hectares being irrigated, almost 78% irrigates through the community-built irrigation network than 22% through government provided irrigation channels.

Table 5: Irrigation Infrastructure in Chitral 2023-24

Location	Total (Ha)	Govt. canals (Ha)	Private canals (Ha)	% Private Canals
Chitral District	20,934	4,521	16,413	78.4%

Source: Bureau of Statistics Planning & Development Department Government of Khyber Pakhtunkhwa

However, the data shows that the entire Chitral district has only 15 Ggodowns with a total storage capacity of 13,250 tonnes and on average each Godowns serving a capacity for approximately 883 tonnes. The district ranking 2nd in whole KPK by area wise and the region origin for a multiple fruit, this low capacity is insufficient to manage and store the annual fruit production in the district.

Table 6: Storage Facilities in Chitral 2023-24

Location	No. of Godown	Storage Capacity *(Tonnes)*	Average Capacity Per Godown
Chitral District	15	13,250	≈ 883

Source: Bureau of Statistics Planning & Development Department Government of Khyber Pakhtunkhwa

1.2. Purpose and Scope of the Study

1.2.1. Objectives

- To assess the fruit cycle and post-harvest losses and examine existing handling, storage, and transportation practices among smallholder fruit producers.
- To identify and map the key structural, logistical, and market-related bottlenecks in the fresh fruit supply chain in Chitral.
- To explore the feasibility and potential impact of value addition (drying, packaging, branding) and cooperative models on market access and income generation.
- To evaluate the role of institutional support, financial services, and extension programs in enabling supply chain participation and upgrading.
- To analyze the influence of climate variability and gendered labor dynamics on supply chain resilience and productivity.

1.2.2. Research Questions

- What are the key structural, logistical, and institutional challenges affecting the efficiency and profitability of the fresh fruit supply chain in Chitral?
- What policy, infrastructure, and capacity-building interventions can enhance value capture, market integration, resilience and sustainability of the fresh fruit supply chain in Chitral?
- What interventions are available for financial inclusion and climate change mitigation for the fresh fruit sector in Chitral?

1.2.3. Research Problem

Chitral's fresh fruit supply chain is constrained by multiple interrelated challenges that reduce its efficiency, profitability, and impact on local economic development. Despite having favorable agro-climatic conditions for fruit cultivation, the sector remains underdeveloped due to systemic inefficiencies, weak institutional coordination, and poor infrastructure, particularly in post-harvest handling and cold chain logistics. These issues lead to high post-harvest losses, limited market access, and low income for farmers. To address these issues, a systematic evaluation of the fresh fruit supply chain in Chitral is urgently needed. This includes identifying bottlenecks, assessing value addition opportunities, and recommending evidence-based interventions.

LITERATURE REVIEW

Understanding the complexities of fresh fruit supply chains, particularly in regions like Chitral, requires an integrated methodological approach combining quantitative and qualitative tools. Structured surveys aligned with the fruit production cycle are essential for capturing season-specific insights on production practices, post-harvest losses, and marketing inefficiencies. These instruments are most effective when adapted to local contexts and pre-tested with farmers to ensure clarity and cultural relevance (Khan & Bae, 2017). Complementing quantitative data, Key Informant Interviews (KIIs) provide rich contextual insights into institutional dynamics, credit availability, and policy gaps affecting the fruit supply chain. KIIs are recognized as a qualitative research method that targets individuals with specialized knowledge and insider perspectives, allowing for in-depth exploration of institutional support, market linkages, credit access, and policy implementation (GeoPoll, 2024). These interviews provide rich qualitative insights that complement quantitative data by uncovering nuanced barriers and opportunities within the fresh fruit supply chain (UCLA Health Policy, 2023). The purposeful selection of key informants-who possess relevant expertise and experience-ensures that the data collected reflect diverse viewpoints and practical realities on the ground (FAO, 2014).

The insights gained will inform evidence-based policy recommendations aimed at enhancing fruit production, improving market access, and ultimately supporting the livelihoods of commercial fruit growers in the region (Appalachian State University, 2020). Such participatory qualitative methods are particularly valuable in rural and mountainous regions like Chitral, where formal data systems may be weak or outdated. Interviews with officials from the Agriculture Department, credit institutions, and NGOs like the Aga Khan Rural Support Programme (AKRSP) help triangulate survey findings, leading to a more comprehensive analysis of systemic challenges (Bukhari, 2014; Hussain et al., 2017).

Descriptive statistics serve as foundational tools in agricultural value chain studies, enabling researchers to summarize and interpret patterns related to production levels, market participation, and income variability across farming clusters and are well-suited for providing an overview of complex supply chain data (Hassen & Chen, 2020). However, uncovering drivers of supply chain performance requires advanced econometric methods, including logistic regression, probit models, and structural equation modeling, which can isolate the influence of variables such as landholding size, access to extension services, and market information availability on farmers' market engagement-enabling rigorous analysis of relationships and causal effects within the data (Ananthapadmanabhan, 2019; Khan & Bae, 2017). The integration of descriptive and econometric analyses aligns with best practices in agricultural supply chain research, facilitating the generation of practical findings that can inform policy interventions and further academic inquiry (Zhu, 2024).

Empirical research in Pakistan highlights the critical role of transportation, financial services, and advisory support in enabling smallholder farmers to access high-value markets. Growers with reliable access to credit and extension services are significantly more likely to engage in profitable marketing channels, reinforcing the necessity of institutional strengthening and infrastructure development to support fruit growers in remote regions like Chitral (Bukhari, 2014; Rizvi et al., 2020).

Global experiences in fruit supply chain development offer valuable lessons for policymakers in Pakistan. Successful interventions in countries such as Turkey and Tajikistan demonstrate that coordinated efforts-including farm-level training, investment in post-harvest technologies, and market integration strategies-can substantially improve farmer incomes and supply chain resilience. Projects introducing cold storage, quality grading systems, and farmer-business linkages in these regions have resulted in considerable income improvements for smallholder fruit producers (FAO, 2021; Khan, 2024). For Chitral, adopting a similar model tailored to its mountainous terrain and fragmented infrastructure can help mitigate supply-side constraints while enhancing grower participation in regional and national markets. Strategic investment in capacity building, storage facilities, and institutional partnerships will be crucial to realizing the district's horticultural potential (Sadiq, 2017; Hussain et al., 2017).

RESEARCH METHODOLOGY

3.1. Detailed Methodology

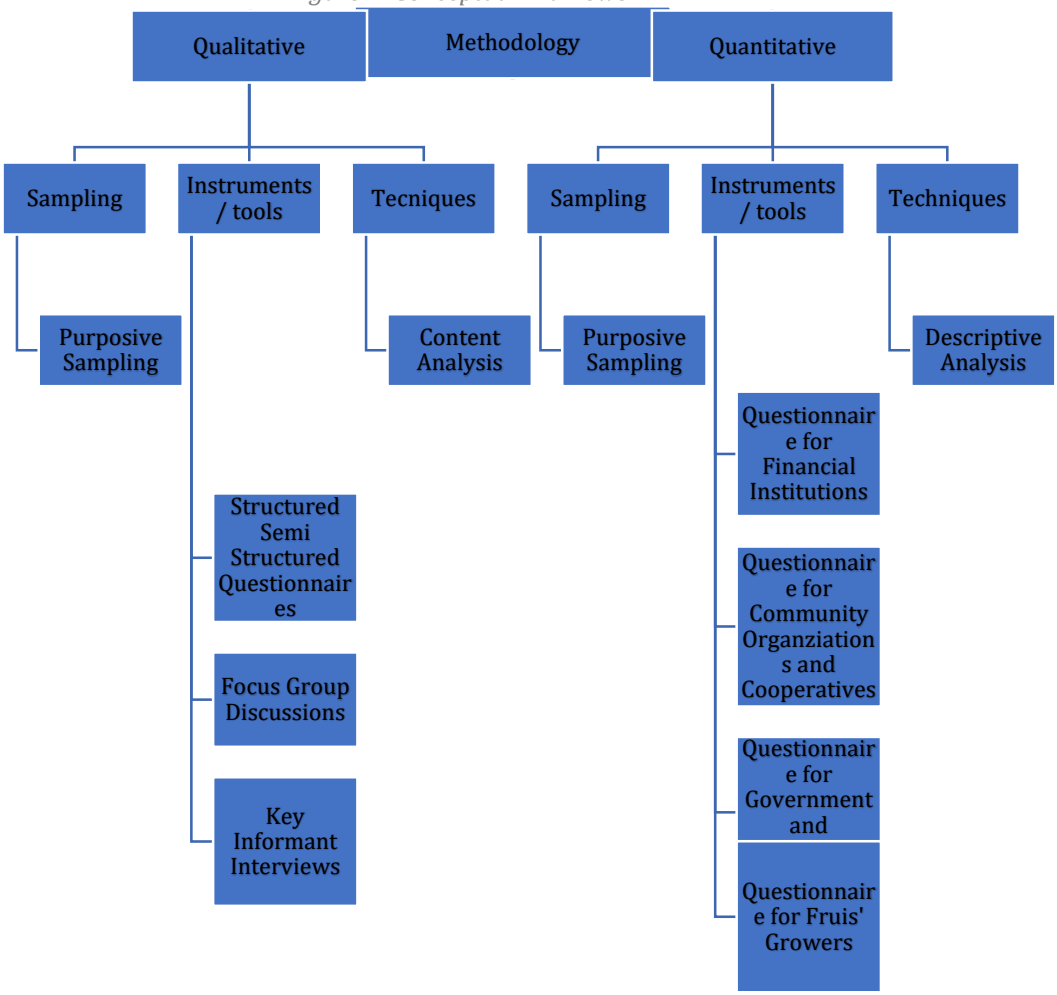
As, the present study focuses on Chitral District, located in the Khyber Pakhtunkhwa, Pakistan. According to the Bureau of Statistics, Khyber Pakhtunkhwa apples, walnuts and apricots are three main fruits of the district. Our target population will be the growers of these fruits in the region. While other fruits are also cultivated in the region, this study is limited to these three due to their economic significance and widespread cultivation.

To achieve the study objectives, combining both quantitative and qualitative data collection techniques to ensure a comprehensive understanding of the subject. Quantitative data will be gathered through a structured survey questionnaire specifically developed for growers of apples, walnuts, and apricots.

This questionnaire will be carefully designed to align with the local fruit production cycles and will draw upon international best practices to ensure accuracy and relevance. It will be reviewed and refined with guidance from agricultural experts who possess in-depth knowledge of the regional context.

To complement and enrich the survey findings, qualitative data will be collected through key informant interviews with relevant stakeholders in the district. These interviews will provide valuable insights into local farming practices, challenges, and opportunities, helping to contextualize and deepen the interpretation of the quantitative results.

Figure 4: Conceptual Framework



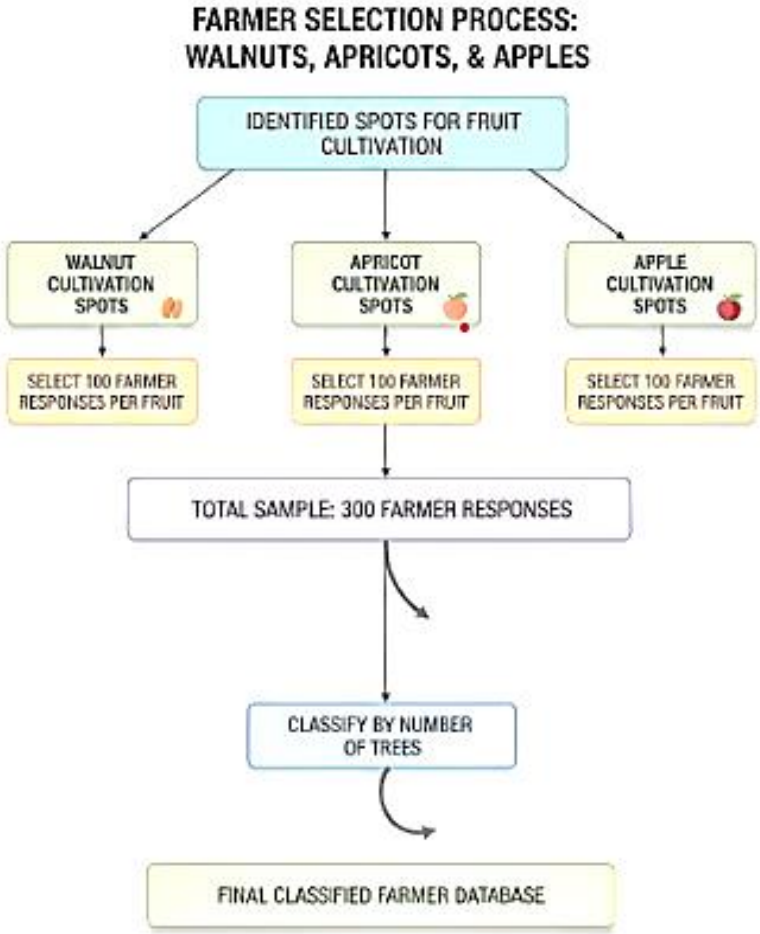
Source: Authors' compilations.

3.2. Sampling Design

The study will incorporate the following sampling technique to ensure adequate representation across the three major fruit cultivation systems, i.e. apple, apricot, and walnut, within Chitral district.

Sampling Strategy: We will employ a purposive sampling technique to select the respondents. The sampling strategy will be implemented through the following steps:

Figure 5: Sampling Strategy Steps



Source: Authors' compilations.

3.2.1. Step 1: Inclusion Criteria

In the first stage, a selection of the farmers involved in fruit cultivation will be made within each category based on following criteria:

- Possession of at least >=10 fruit-bearing trees of the respective fruit type. The threshold of fruit bearing of tree will be decided in consultation with agriculture department.
- Continuous involvement in fruit production for a minimum of three years.
- Representation from multiple villages within each cultivation cluster to capture spatial diversity.

3.2.2. Step 2: Identification of Cluster

In the second stage, clusters will be delineated using secondary data from:

- Department of Agriculture (GoKP),
- AKRSP orchard mapping (2024),

- ZTBL agricultural credit disbursement data. local community-based organizations for Walnuts, Apricots and Apples.

Such that, major production regions based on fruit category i.e. apple, apricot and walnut and the existing financial institutions are demarcated to employ strategic survey plan accordingly as:

Table 7: Apple, Walnut and Apricot Hubs

Apple Hub	Walnut Hub	Apricot Hub
Brep *(Upper Chitral)*	Gram Chachma *(Lower Chitral)*	Owir region *(Lower Chitral)*
Mastuj *(Upper Chitral)*	Bumburait *(Lower Chitral)*	Booni *(Upper Chitral)*
Booni *(Upper Chitral*	Madaklasht *(Lower Chitral)*	
Gram Chachma *(Lower Chitral)*	Torkhow *(Lower Chitral)*	Riri *(Lower Chitral)*
	(Upper Chitral)	
Xhupu *(Upper Chitral)*	*(Upper Chitral)*	Chapari *(Upper Chitral)*
	(Upper Chitral)	
Power *(Upper Chitral)*	*(Upper Chitral)*	Masttuj *(Upper Chitral)*
Murkhow *(Upper Chitral)*	*(Upper Chitral)*	Chuij *(Upper Chitral)*
Chuij (Upper Chitral)	*(Upper Chitral)*	Gram chashma *(Lower Chitral*
Bumburait *(Lower Chitral)*	*(Upper Chitral)*	

Source: *Deputy Director Plant Protection, Agri Extension KPK*

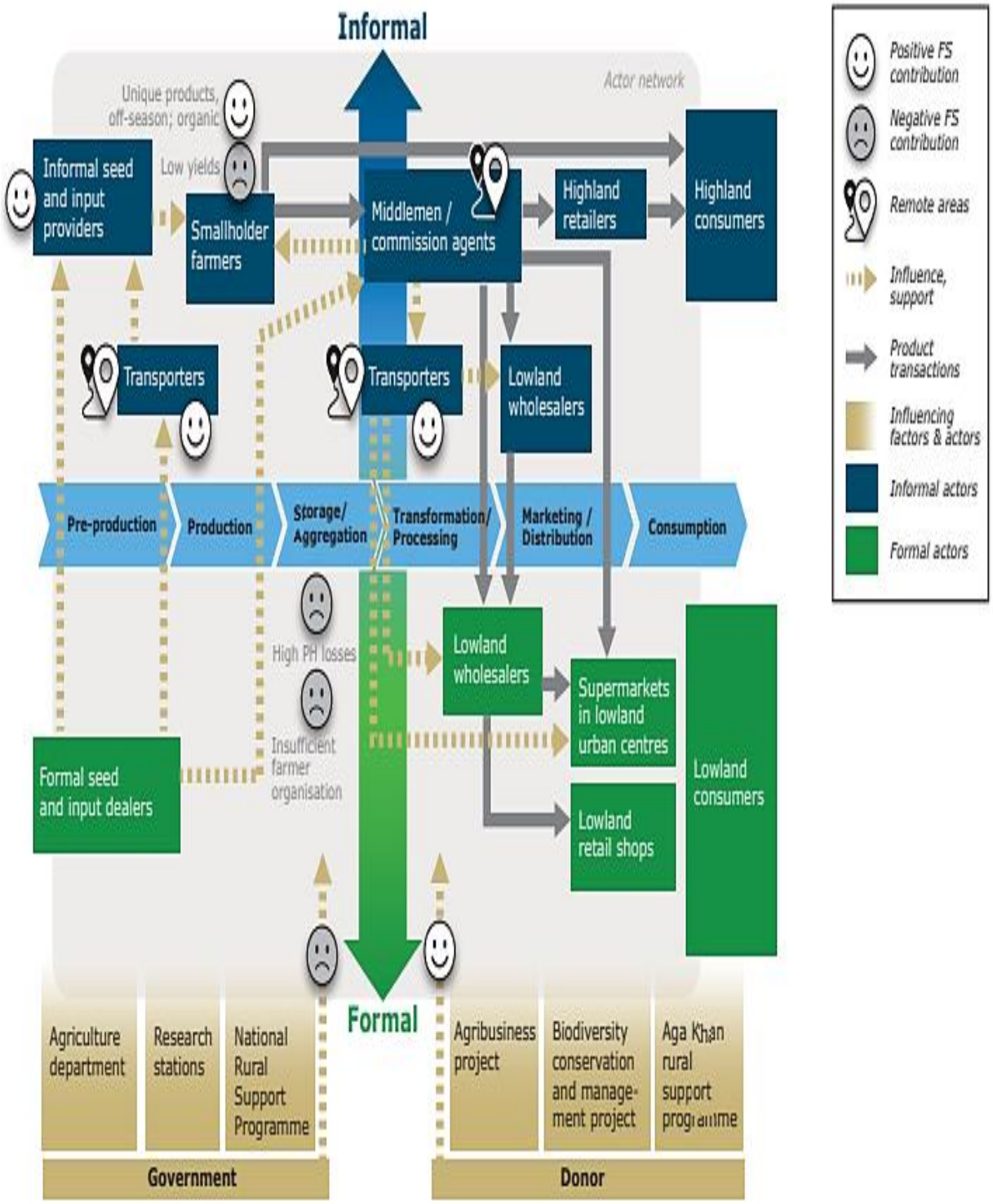
Table 8: Financial Institutions (Lenders)

Bank/Institutions	Branch Location	Agriculture Loans/credits
ZTBL (Zarai Taraqiati Bank Limited)	Booni, Upper Chitral, Main Bazar	Production Loan Schemes Financing Product for Fruits & Vegetable Saver. Kissan Khushhal Scheme (KKS)
	Chitral town branch, By Pass Road, Chitral City	
	Main Bazar, Darosh	
	Main road, Warijoon	
HBL Microfinance Bank Ltd.	Main Bazar, Booni, Chitral	Roshan Zameen Scheme
Bank Al Habib	Ataleeq Bazar, Near Ataleeq Bus Stand, Bypass Road, Chitral.	AL Habib Kissan Revolving Credit Scheme AL Habib Farm Production Financing Scheme
NRSP Microfinance Bank Ltd.	By Pass Road, Tehsil & District Chitral	Kissan Zarri Taraqiati Loan (KZTL)
U Microfinance Bank Ltd.	Village Bypass Road, Post office Chitral, Attaliq Bazar, Tehsil Chitral	Agri Pass Book Loan

Source: ?

Market: According to Khan & Schrader (2024), the fruit and vegetable supply chain in Chitral is dominated by informal private actors. Further, these actors bridge the gap between highland producers and lowland consumers. Smallholder farmers lack direct market access, selling over 95% of their produce through middlemen and commission agents. These intermediaries manage logistics but offer low prices to farmers while facing high transport costs and risks. Transporters are crucial in moving goods across long distances and also act as informal agro-dealers supplying inputs, though often of poor quality. Retail in highlands occurs in small local markets, while lowland supermarkets purchase high-value produce due to off-season advantages. Government support remains minimal, with donor-funded projects playing a more effective role in improving agribusiness and biodiversity.

Figure 6:



Source: Khan & Schrader (2024).

3.2.3. Step 3: Stratification

The identified cultivation spots will be treated as distinct strata for each fruit. Using spatial data of the Agriculture Department, a subsample from each stratum will be selected through a proportionate stratified sampling approach. This method minimizes selection bias and enhances the representativeness of the findings across the three fruit categories.

Within each cluster, fruit farmers will be stratified by:

- **Primary fruit type** (apple, apricot, walnut),
- **Landholding size** (small: <2 acres, medium: 2–5 acres, large: >5 acres),
- **Market participation level** (subsistence, semi-commercial, commercial).

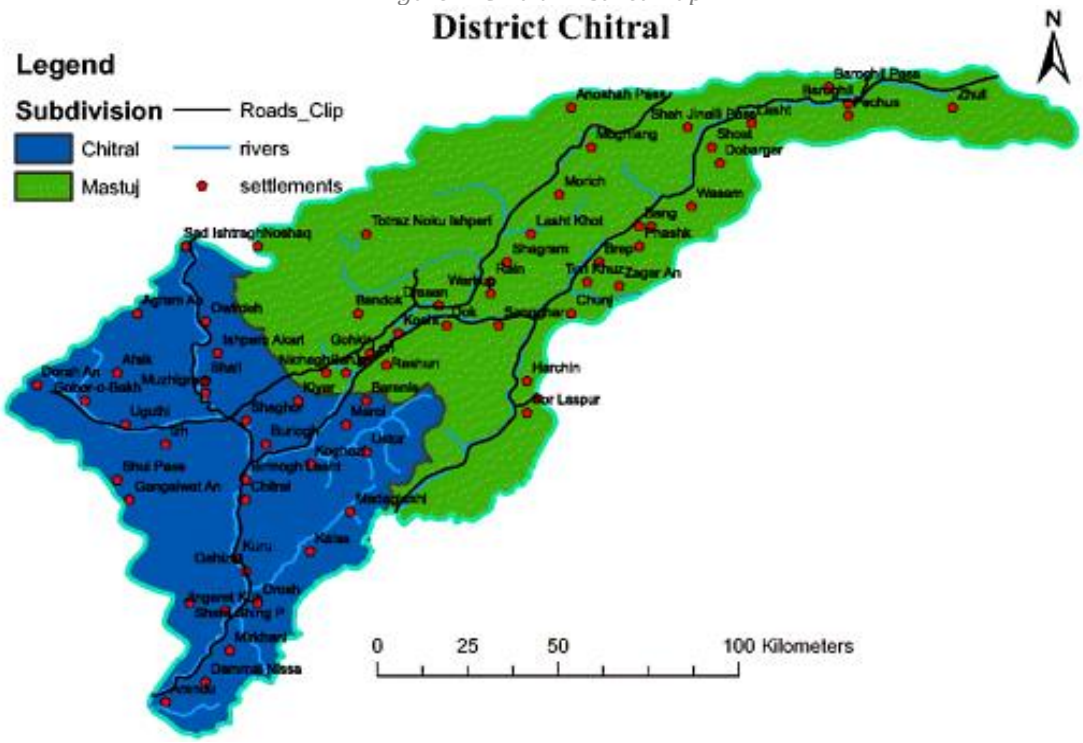
3.2.4. Step 4: Classification by Number of Trees

In the fourth stage, respondents will be classified by the number of trees into small-scale, medium-scale, and large-scale growers. This classification will enable comparative analysis of production capacities, post-harvest management practices, and marketing behaviors among different scales of operation.

3.2.5. Step 5: Final Classified Farmer Database

Finally, classified dataset of 100 farmers of each fruit will provide the empirical database for subsequent statistical and qualitative analyses. This database served as the foundation for examining the challenges and opportunities of the fresh fruit supply chain in Chitral district.

Figure 7: Chitral District Map



Source: Khan & Schrader (2024).

3.4. Determination of Sample Size

When the total population size is unknown, the sample size is determined by following formula:

Cochran's formula $\boldsymbol{n} = \left[\frac{\boldsymbol{z^2 p(1-p)}}{\boldsymbol{e^2}}\right]$

z = z -value corresponding to the desired confidence level,

p = assumed proportion (probability) of selecting a farmer, and

e = margin of error.

At a 95% confidence level ($z = 1.96$), a 10% margin of error ($e = 0.10$), and an assumed probability of selection ($p = 0.50$), the estimated sample size is approximately 97. For convenience, the sample size is rounded to 100 farmers for each fruit category. For qualitative insights, **25–30 Key Informant Interviews (KIIs) and 6–8 Focus Group Discussions (FGDs)** will be conducted with:

- Agriculture officers,
- Extension workers,
- Local traders/exporters, commission agents
- Credit officers (ZTBL, AKRSP, NRSP),
- Women producers and cooperative members.

3.5. Data Collection Methods

3.5.1. Qualitative Data

A **structured questionnaire** will be administered to fruit growers to capture:

- Production cycle and yield variability,
- Post-harvest handling, transport, and storage practices,
- Market access, credit availability, and extension services,
- Climate risk exposure and adaptation behaviors,
- Gender and labor participation patterns.

3.5.2. Quantitative Data

Key Informant Interviews (KIIs): Conducted using semi-structured guides to explore institutional frameworks, policy gaps, and market dynamics.

Focus Group Discussions (FGDs): Conducted separately for men and women farmers to identify perceptions, constraints, and empowerment opportunities.

EVALUATION FRAMEWORK

Figure 8: Evaluation Framework of the Study

Objectives				
Assess fruit cycle & post-harvest losses (handling, storage, transportation)	What are the key structural, logistical, and institutional challenges affecting the efficiency and profitability of the fresh fruit supply chain in Chitral?	Descriptive Statistics/ Regression Analysis	% of farmers using canal/pump/rain as a source for irrigation	OC7
			% of Planting material getting from Govt. Nursery/Private Nursery/NGO/Self	OC5
			% of farmers getting assistance from NGO/Govt/commission agent in selecting in type of fruit plantation	OC12
			%of farmers using Manual / mechanical / both as Harvesting method	PH1
			%of farmers using, with branches/without branches/both/fruit cut with scissor/plucked with hand as plucking method	PH3 PH3a
			%of farmers using Newspaper garbage/bhosa/other filling material during packing as packaging techniques	PH6
			%of farmers using vehicle/animal/Manual/other as mode of transportation	PH12
			Average post-harvest loss per fruit type (%)	PH10a
			%of farmers with access to cold storage	PH16
			Average distance to market (km)	PH13
			Average transport cost per crate/kg	PH15
			Yield per acre vs. district average	PP5
			% Trained on post-harvest management.	CM1 CR1
			Average transport cost from nursery to the orchard	PH15
			Average profit per acre	PH4a PH15 PH17a
			Average distance of fruits firms from Metalled Road/Local market /Fertilizer shop/	OC9
			Pesticide shop/Extension office/Wholesale fruit markets/ Cold Storage Facility	
Identify structural, logistical & market-related bottlenecks	What are the key structural, logistical, and institutional challenges affecting the efficiency and profitability of the fresh fruit supply chain in Chitral?	Descriptive and logistic Regression	Average transport time (hrs/days) from harvest to market.	PH14
			% Using intermediaries vs direct selling.	MS1
			% Citing poor road access.	OC9
			% of cooperatives lacking storage or transport.	CM6
			% govt officers citing coordination/infrastructure gaps.	PR2
			% of farmers lacking storage or transport i.e. Metalled Road , Local market, Wholesale market , Extension Office, Fertilizer Shop, Pesticide Shop and Cold Storage Facility	OC9
			% of farmers using different irrigation sources i.e. Canal, Pump, Raid fed and Merzhoi water management system etc Solar powered lift irrigation system	OC7
		Distance And Cost Modelling	Storage & transport cost per trip	PH15 PH17a
			Avg. cost of transport (% of revenue).	PH15

Explore feasibility & impact of value addition (drying, packaging, branding, cooperatives)	What policy, infrastructure, and capacity-building interventions can enhance value capture, market integration, resilience and sustainability of the fresh fruit supply chain in Chitral?	Cost–Benefit Analysis	% of Profit by selling products	PP5 PP4 PP3
			% of loss by selling products	PP5 PP4 PP3
			% Cooperatives engaged in value addition (drying, packaging, branding).	CM1
			Cost–benefit ratio of value-added processes.	PP5 PP4 PP3
			% of trained farmers in quality/branding.	VA2
			% of cooperatives forming new market linkages.	CM5
		Regression Analysis	Average income difference between value-added vs non-value-added farmers.	
		Economic Analysis	Share of processed output in total marketed volume.	PP5
			% of farmers perform grading	PH8
Evaluate role of institutional support, financial services, and extension programs	What interventions are available for financial inclusion and climate change mitigation for the fresh fruit sector in Chitral?	Descriptive Analysis/Multinomial Probit / Logit Models	% Farmers with access to formal credit.	VA13
			Average horticulture loan size and term.	LC2 LC4
			% Farmers insured against climate shocks.	VA-13a
			% Financial institutions offering crop-specific loans at different rate.	IR2
			% Farmers reached by extension programs.	CR4
			% Institutions citing inadequate funds/staff.	CR5
			% Farmers aware of government schemes.	VA2a
			% of farmers realise pest and disease/improper pruning and thinning as main reason of low grading fruits	PH-9
Analyze influence of climate variability & gendered labor dynamics	What interventions are available for financial inclusion and climate change mitigation for the fresh fruit sector in Chitral?	Descriptive analysis/Climate-Shock Impact Modeling	% Farmers reporting major climate events (flood, drought, GLOF).	CC1
			Avg. yield loss due to climate incidents (%).	CC2
			% of adopting protective physical barriers, canopy and Spray as risk management strategy	CC3
			% of farmers receiving Government and	CC4
			NGO supports in climate mitigation and adaptation	
			% Of female labor in orchard Management/Harvesting/Packaging/Marketing	GR1
			Avg. working hours women vs men.	GR2a
			% of wage gap between men and women working in field	GR3a
			% of women face hurdles working in the field due to Sociocultural barriers, limited land and asset ownership, and lack of education	GR5b
			% of respondents practise farming as their primary occupation	RP8
			% of farmers getting plants Government Nursery	OC5
			% of respondents avail plants because free provision/ distribution by NGO/govt	OC7
			% of farmers incorporating solar powered lift irrigation system	OC7
			% of farmers realise Weather and climate as main reason of low grading fruits	PH-9
		Gender Participation Index Construction	Gender Participation Index (GPI) score.	OC14 GR3a GR5b

Note: codes are based on module i.e. Farmers questionnaires, Financial institutions questionnaires, Community organizations & Cooperatives questionnaires and Govt. & Extension Agents.

Source: ?

FINDINGS AND DISCUSSION

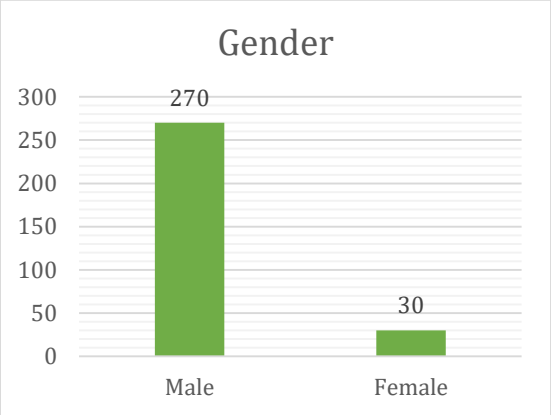
5.1. Results

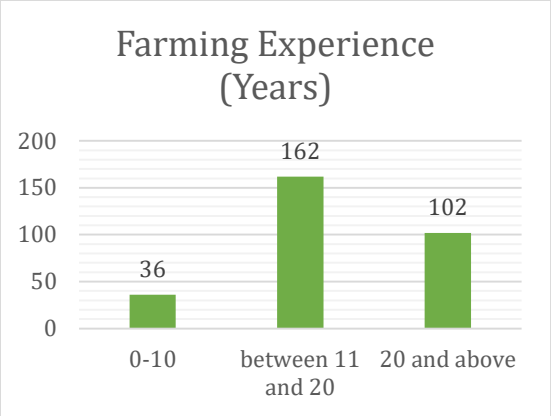
Socioeconomic Profile of Growers

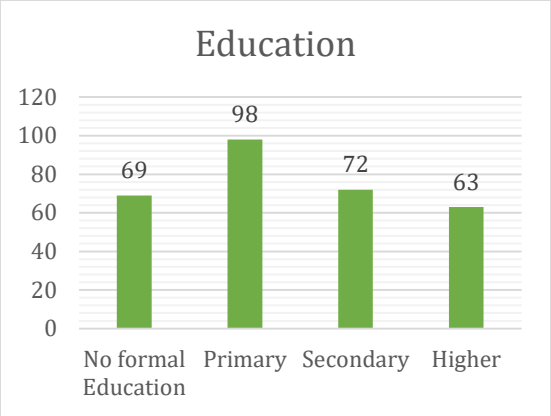
The socioeconomic profile of Chitral's fruit growers reveals a sector characterized by deep experiential knowledge, significant structural vulnerabilities, and emerging opportunities that, if strategically targeted, could transform supply chain performance. 4.1 reveals severe age concentration of the farmers: 58% of respondents are older than 45 years, while only 8% are under 30 years of age. About 58% of the respondents have more than 20 years of farming experience. The predominance of experienced farmers represents an invaluable repository of traditional orchard management knowledge that underpins the quality of Chitral's premium fruit output. However, the near absence of youth participation signals a looming succession crisis: if current trends continue, the district risks losing both its skilled farming workforce and the institutional knowledge embedded in it within 10–15 years.

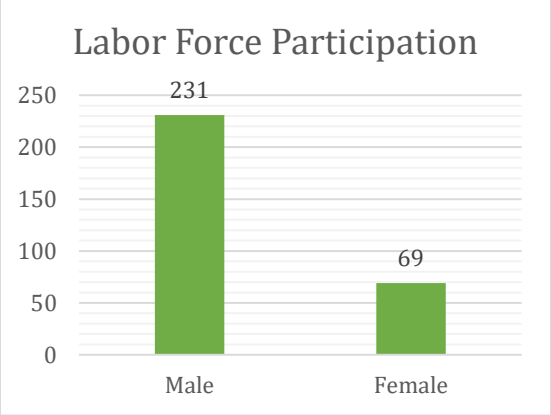
Gender participation reveals a striking and economically costly imbalance. 90% of surveyed growers are male, with women constituting only 10% of formal respondents. Female labor participation (23%) is very low in the region. This gender gap is not simply a social equity concern, it represents a measurable supply chain efficiency loss. Evidence from comparable horticulture value chain interventions in Pakistan and the Hindu Kush Himalayan region demonstrates that expanding women's participation in post-harvest handling, quality grading, processing, and cooperative marketing activities can increase household incomes by 25–40% while simultaneously improving the consistency and quality of produce entering the supply chain (FAO 2021; AKRSP, 2014).

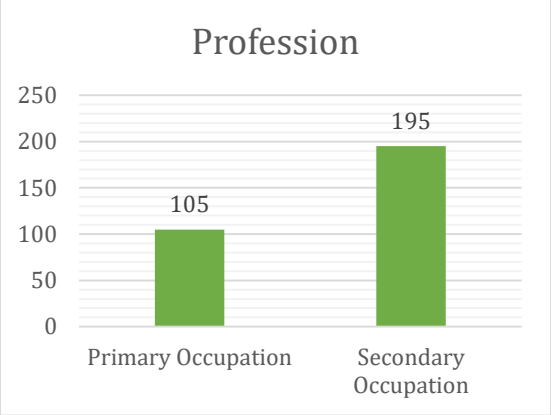
Figure 9: The Socioeconomic Profile of Chitral's Fruit Growers











Source: Author's compilations.

Demographics of the Growers

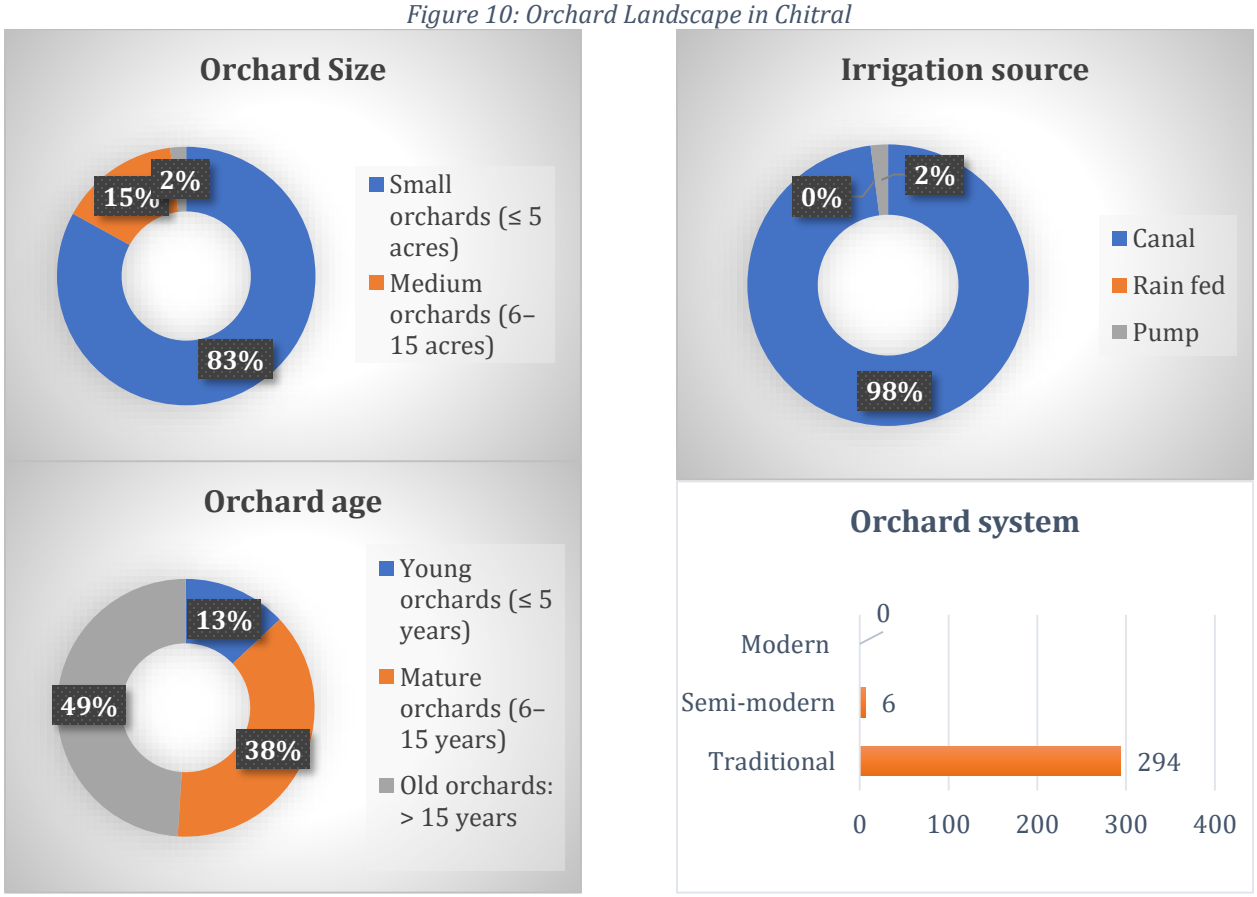
Nearly a quarter of respondents (23%) report no formal education, while 32% and 24% have completed primary and secondary schooling respectively, leaving only 21% with higher education qualifications. The supply chain consequences are multi-layered: growers with limited literacy face significant disadvantages in accessing market price information, understanding formal contract terms, applying for institutional credit, and engaging with extension programs

A further structural insight is that 65% of respondents treat fruit farming as a secondary occupation, supplementing primary incomes from other sources. While this diversification provides a degree of household income resilience, it profoundly limits investment in orchard improvement, post-harvest infrastructure, and market development. Farmers whose primary income derives from other activities have neither the time nor the financial motivation to adopt modern orchard management practices, negotiate better market contracts, or invest in post-harvest technologies resulting in chronically under-capitalized orchards and reactive rather than strategic marketing behavior. Reversing this pattern requires a fundamental shift in the profitability and predictability of fruit farming income, achievable through a combination of assured market linkages, price stabilization mechanisms, and direct input subsidies that make horticulture a more attractive primary livelihood than competing income sources.

Orchard Characteristics

Figure depicts that orchard landscape in Chitral is characterized by smallholder fragmentation and concerning physical deterioration. A 83% of orchards are classified as small (under 5 acres), with only 15% in the medium category and just 2% large commercial orchards present. This fragmentation carries direct economic consequences: small orchard holders face unit production costs approximately 30–45% higher than in consolidated operations, cannot access mechanized harvesting or sorting equipment, and have insufficient volumes to negotiate meaningful supply agreements with urban buyers or processors. Nearly half of orchards are well into the declining productivity phase as they are more than 15 years old. About 38% are in the mature 6–15 year bracket, and only 13% are young orchards. It is well documented in the literature that fruit trees 15–20 years of age without replanting produce yields 40–60% lower than orchards in their prime productive years, with inferior fruit size, color, and sugar content that reduces marketability.

Figure 10: Orchard Landscape in Chitral

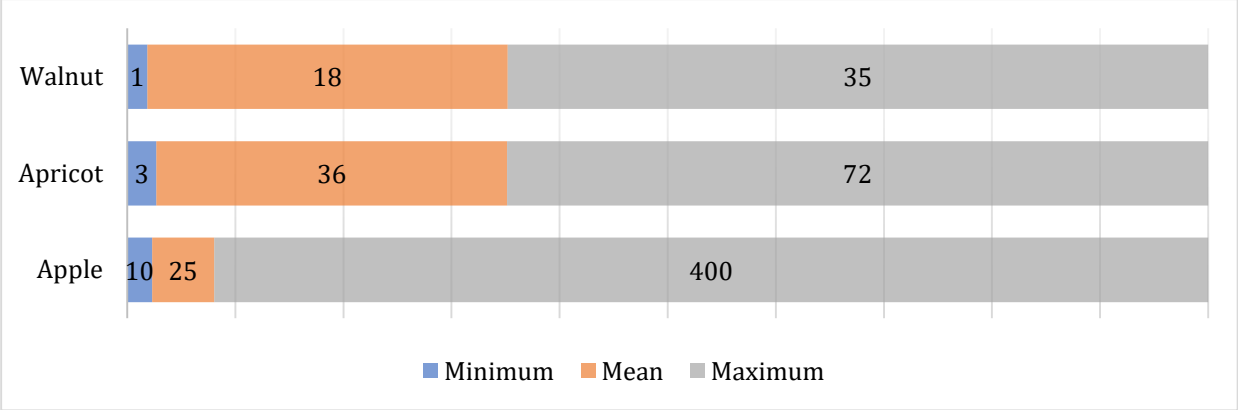


Source: Author's compilations.

Regarding orchard management, 98% of respondents rely entirely on traditional management systems, with only 2% using semi-modern approaches and none operating fully modern orchards. Modern high-density apple orchard systems can achieve yields of 40,000–60,000 kg per hectare compared to the 8,000–15,000 kg per hectare typical of traditional systems a productivity gain of 3–5 times. The near-absence of modern management practices reflects a systematic failure of extension service delivery, lack of access to certified planting material, and the absence of demonstrable models that show farmers the financial returns from modernization. Targeted demonstration orchards managed jointly with progressive farmers would provide the most credible pathway to technology

adoption at scale. However, canal irrigation is quite important in irrigation practices with 98% of orchards being dependent on canals, no rain fed irrigation system, and only 2 percent utilize pumps in irrigation. Such dependency causes orchard productivity to be very dependent on water availability, seasonal fluctuation, and climate-related interruption in glacial melting and stream flows. Any disruption of canal systems would therefore affect yield and quality of fruits immediately. The survey shows (4.1) that the orchard lands are mainly held by Apples which have an average of 250 trees per farm whereas the apricot and Walnut trees are also very few.

Figure 11: Number of Trees by Fruit Type

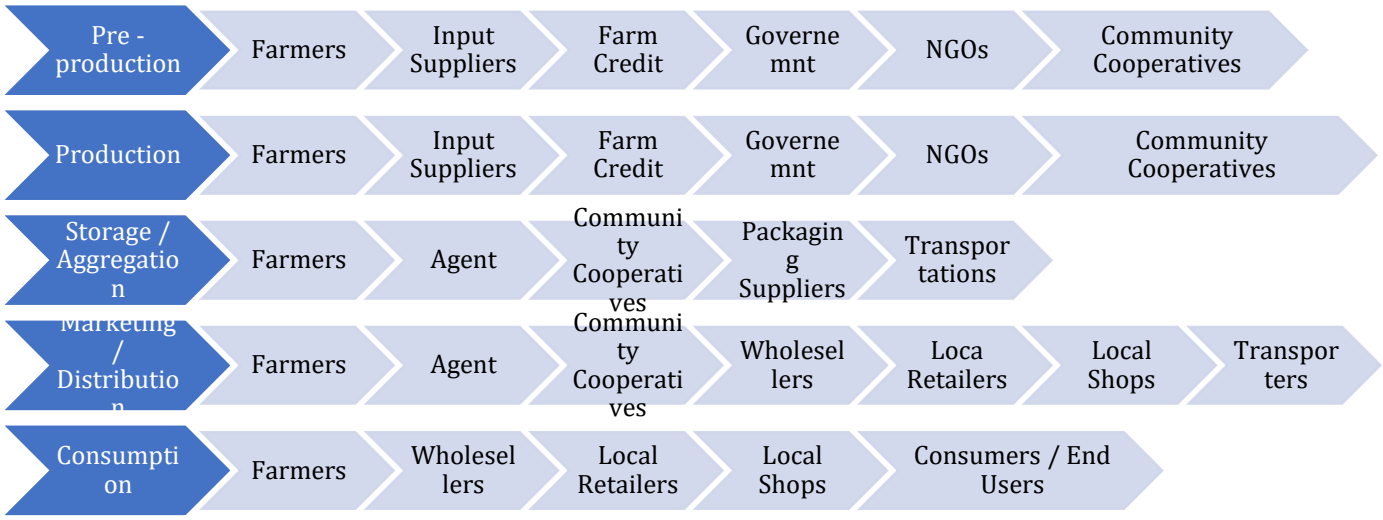


Source: Author's calculation based on survey.

Input Use Pattern and Production

Input utilization and production patterns in Chitral reveal a sector operating significantly below its agronomic potential.4.3 depicts that most growers (75%) use mixed fertilizer. Al-though this reflects the adaptive practice and partiality in the management of soil fertility, as reported only 15 percent and 10 percent of the growers engage in the use of only organic inputs and conventional fertilizers respectively. Considering the fact that there is limited access to quality inputs and there are no standardized guidelines on how best to manage nutrients, the dominance of mixed-use results in variable yields and quality.

Figure 12: Input Use Pattern and Production

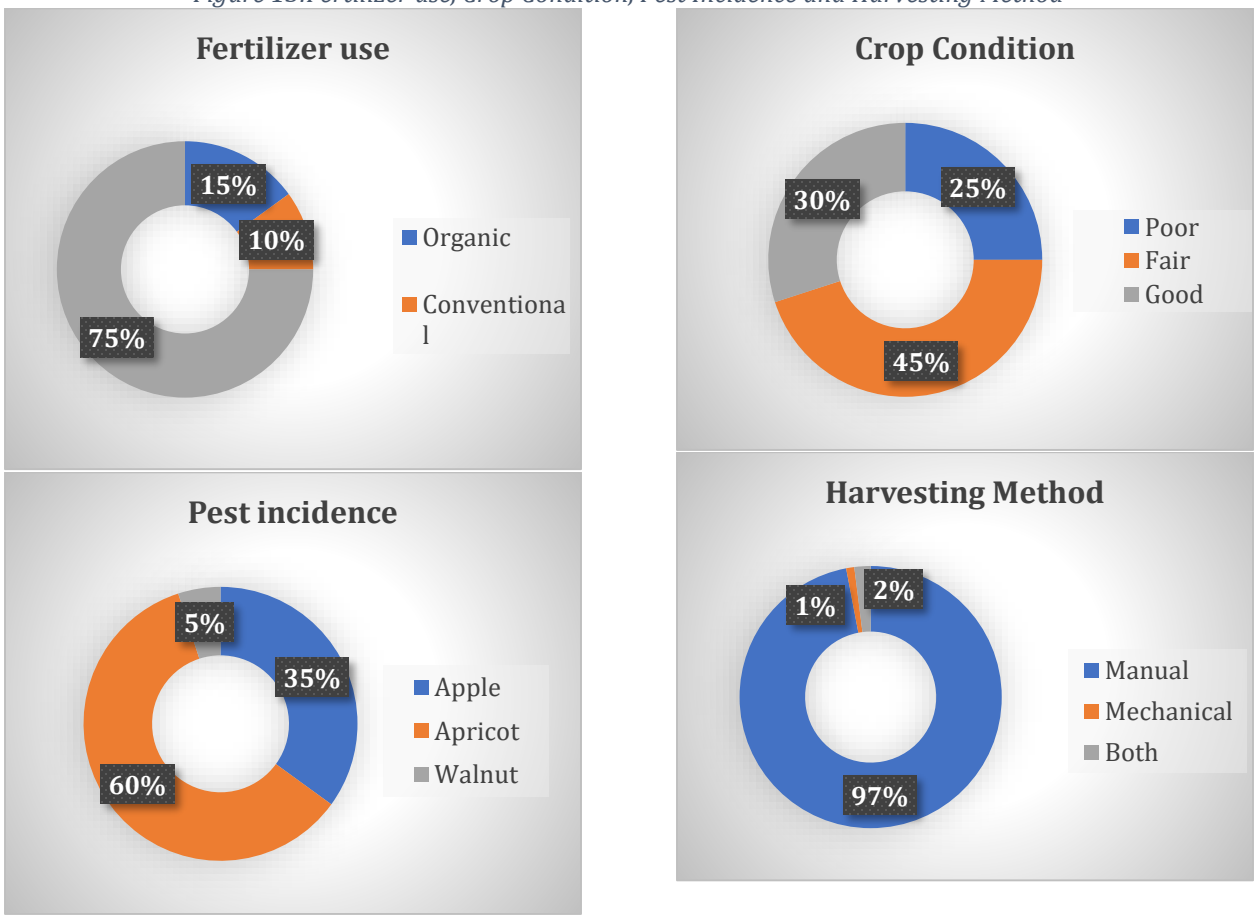


Source: Author's calculation based on survey.

The survey also reveals that the significant issue with production is pest incidence, especially among apricot orchards where 60 percent of the respondents had pest problems with apples coming second at 35 percent. The walnut orchards are relatively less affected with only 5 percent incidence of the pests. Therefore, high pest pressure, particularly during apricot production raises the production cost and post-harvest losses besides influencing the quality and marketability of fruits. The challenges are further worsened by limited use of integrated pest management practices.

Additionally, assessment of crop conditions shows that there are only 33 percent of orchards which can be regarded as being in good condition with 50 percent being rated as fair and 17 percent as poor. The abundance of favorable and poor crop conditions implies inferior orchard management, old trees and lack of sufficient input use. The conditions also create imbalanced supply volumes and quality, which makes it challenging to the traders and processors who need consistency of fresh fruits supply. The survey also reveals that harvesting is dominantly done manually, and all respondents have mentioned that they harvest using purely manual techniques and have often used mechanical or hybrid techniques. Although harvesting manually decreases the first capital expenditure and less damage is caused when done in a careful manner, it is labor-intensive and reduces the capability to harvest in the best seasons, which in most cases causes delays and loss of quality.

Figure 13:Fertilizer use, Crop Condition, Pest Incidence and Harvesting Method

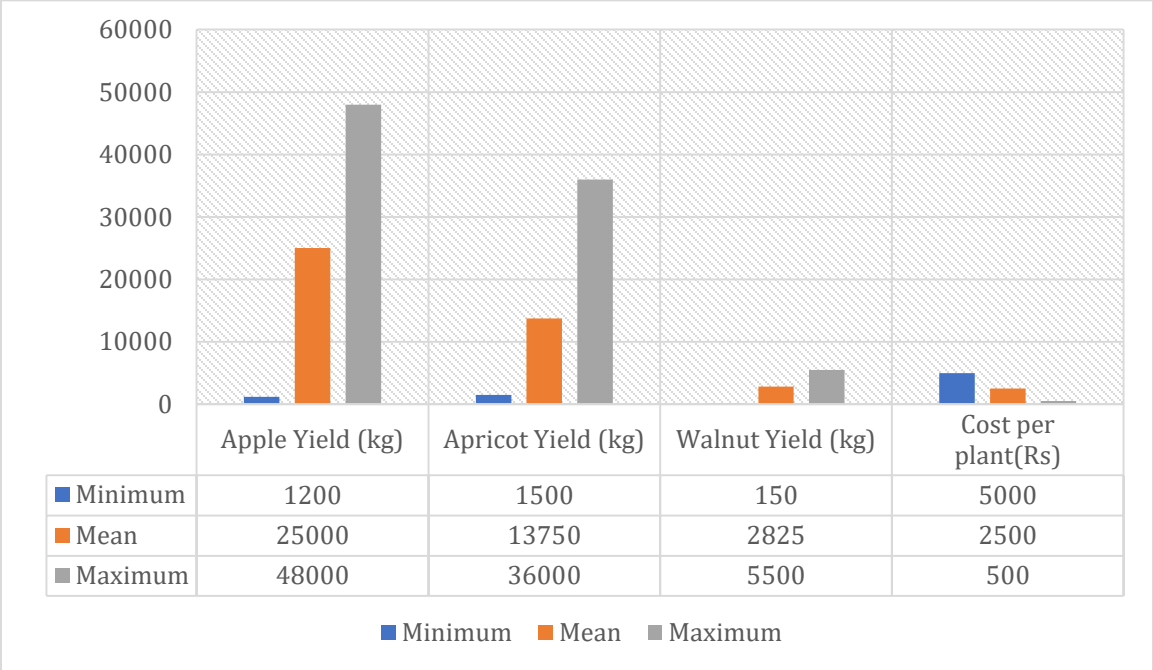


Source: Author's calculation based on survey.

Inputs and Harvesting

From 4.2 Apple production leads in volume, with maximum recorded farm outputs of 48,000 kg per annum and average yields of 25,000 kg, followed by apricots at an average of 13,750 kg and walnuts at 2,825 kg. Internationally, well-managed apple orchards in comparable mountain climates achieve average yields of 35,000–50,000 kg per hectare, suggesting that current Chitral output represents only 50–70% of achievable potential. With input costs of approximately Rs. 5,000 per apple plant, Rs. 2,500 per apricot plant, and Rs. 500 per walnut plant, farmers operating without assured market access face a net return squeeze that is unsustainable particularly where post-harvest losses eliminate 38–54% of production value before any income is realized. The seasonality concentration of apple and apricot harvests in July–October further amplifies price risk: seasonal gluts depress farm-gate prices by 30–50% below mid-season levels when all produce arrives at market simultaneously without storage options.

Figure 14: Yield and Cost of Production



	Apple Yield (kg)	Apricot Yield (kg)	Walnut Yield (kg)	Cost per plant(Rs)
Minimum	1200	1500	150	5000
Mean	25000	13750	2825	2500
Maximum	48000	36000	5500	500

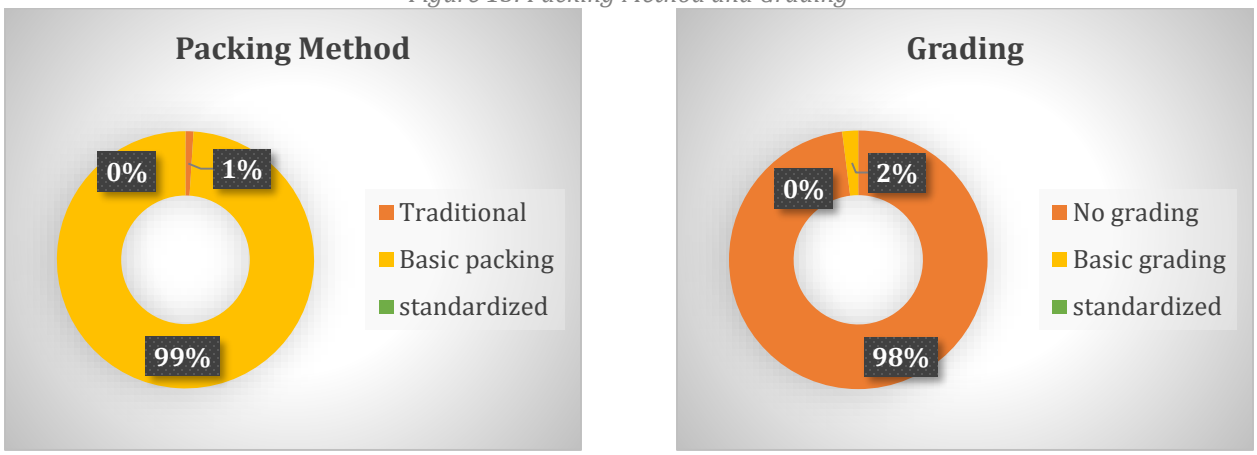
Source: Author's calculation based on survey.

Post-harvest Handling

Post-harvest management represents the most immediate and correctable source of value destruction in Chitral's fresh fruit supply chain (4.4). Current practices are almost uniformly sub-standard: packing is entirely informal, with every surveyed grower using improvised materials (newspapers, crop residue) and none employing standardized packaging the single most basic requirement for entering formal retail markets. Standardized corrugated fiberboard boxes with graded tissue wrapping estimated to cost an additional Rs. 15–25 per crate could reduce mechanical damage by 40–60% and enable Chitral fruit to compete in premium urban supermarket channels where packaging quality is a prerequisite for listing (Kader & Rolle, 2004; Anand & Barua, 2022).

Grading is virtually absent: 98% of growers do not grade at all, with only 2% performing basic grading. The absence of grading means there is no quality differentiation, no price premium for superior fruit, and no incentive for farmers to improve orchard or post-harvest practices. Farmers are forced to sell fruits at undifferentiated low prices regardless of quality, suppressing both income and the motivation for quality improvement.

Figure 15: Packing Method and Grading



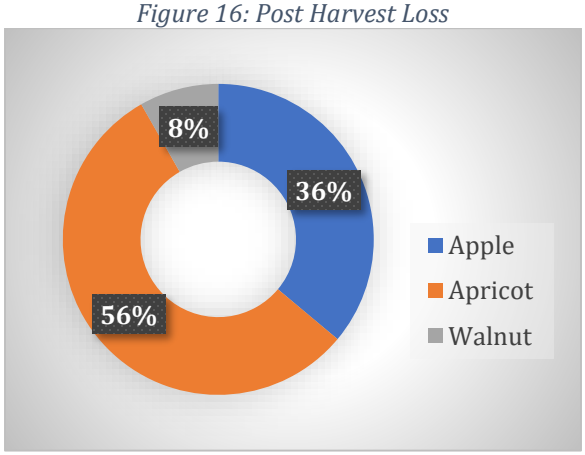
Source: Author's calculation based on survey.

Post-Harvest Handling and Losses

In packing, the survey shows that newspapers and Bhosa are used as filling and cushioning material everywhere, which implies low awareness and the lack of access to the relevant packaging materials. Newspaper and Bhosa, although cheap and easy to get, does not offer sufficient cover against bruising, moisture and temperature change and is another cause of post harvests loss.

The post-harvest loss figures documented in this study are among the most compelling evidence for urgent supply chain investment in Chitral. Apricots sustain average post-harvest losses of 54% — meaning that more than half of all apricots harvested never reach a paying customer. Apple losses of 38% and walnut losses of 8% represent further significant value destruction. Translating these percentages into economic terms: based on district production data and prevailing market prices, the monetary value of post-harvest losses in Chitral is conservatively estimated at PKR 150–220 million annually. International experience consistently shows that targeted investments in cold chain infrastructure, packaging, and grading systems can reduce fresh fruit post-harvest losses by 50–70% within 3–5 years — potentially recovering PKR 75–150 million in currently wasted annual value for Chitral's farming households (Altendorf, 2023; Hussain et al. 2017).

Figure 16: Post Harvest Loss



Source: Author's calculation based on survey.

Transportation and Storage Characteristics

Transportation and storage data reveal a logistics system that is both economically prohibitive and physically punishing for perishable produce. From 4.3, the average distance farm to wholesale the market is 65 km extending to 125 km in remote upper valleys. This translates into journey times averaging 4 hours and reaching up to 8 hours on unpaved mountain roads. For soft fruits such as apricots harvested in peak summer temperatures, an 8-hour unrefrigerated journey is sufficient to initiate spoilage and fermentation that renders produce unsaleable at premium price points. At an average transport cost of Rs. 5,750 per trip (range: Rs. 3,500–8,000), transport expenses consume an estimated 8% to 15% of farm-gate revenue for small volume producers, directly compressing already thin margins. For many farmers in remote upper-valley clusters, the arithmetic of transport costs relative to achievable farm-gate prices makes marketing beyond the farm gate economically irrational, leading to distress sales to local commission agents at prices 40–60% below urban wholesale levels.

Table 9: Transportation Distance, Time and Cost

Variable	Minimum	Mean	Maximum
Local Market Distance (km)	5	17	30
Wholesale Market Distance (km)	5	65	125
Extension Office (km)	5	65	125
Fertilizer Shop (km)	5	17	30
Pesticide Shop (km)	5	17	30
Transport Time (hours)	0.5	4	8
Transport Cost (Rs/trip)	3,500	5,750	8,000

Source: Author's calculation based on survey.

Further, the entire respondents depend on vehicles as the only means of transport with a little or neither use of animal based nor manual transport (4.5). Although transport usage allows reaching the remote markets, it is also evidence of absolute reliance on road accessibility and petrol supplies. Thus, any inconvenience caused by the weather, landslides, or damage to the infrastructure may have a serious impact on the movement of the fruits, causing delays and losses.

Marketing and Sales

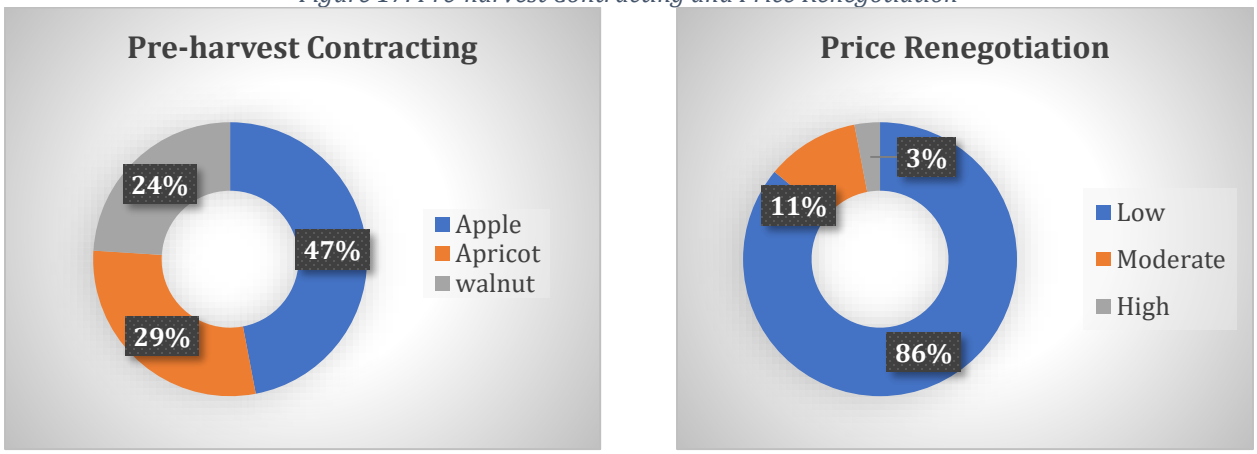
The marketing and sales profile of Chitral's fruit growers reveals a supply chain characterized by near total farmer dependence on intermediaries and a deeply inequitable value chain. 4.6 shows that 98% of growers sell through intermediaries, with only 2% achieving any form of direct selling. The value chain margin analysis is sobering: Chitral apples that leave the farm gate at Rs. 25–45 per kg is sold in Peshawar wholesale markets at Rs. 55–80 per kg and reach Lahore consumers at Rs. 90–140 per kg — meaning farmers capture as little as 18–32% of the final consumer price, while intermediary layers absorb 68–82% of the value.

Pre-harvest contracting is widespread across all three major fruit types: apples (37%), apricots (34%), and walnuts (29%). These contracts operate almost exclusively in favor of buyers: 86% of farmers report zero scope for price renegotiation once contracts are signed, even when crop quality, yields, or market prices develop more favorably than anticipated. This contractual rigidity functions as a risk transfer mechanism from buyers to producers' buyers are protected from market downside while farmers are excluded from market upside. The perverse incentive consequence is equally

damaging: since contract prices are fixed regardless of quality, farmers have no financial motivation to invest in post-harvest handling, grading, or packaging improvements.

Moreover, the likelihood of price renegotiation following contracting is not very high and 86% of the respondents indicated that there was low scope of renegotiation meaning that growers possess low bargaining power. The renegotiation is very high only in 3 percent implying that most contracts are in the favor of buyers as opposed to producers. On the same note, contractor default is reported to be low among 96 percent of growers, which implies stability in contractual terms, but this stability is usually achieved to the disadvantage of lower prices and limited market access by farmers.

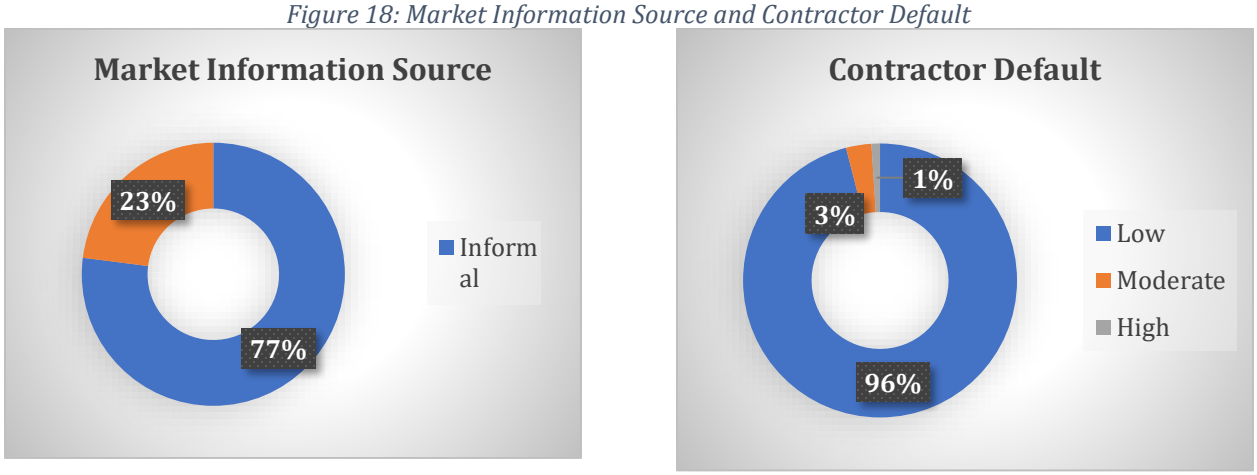
Figure 17: Pre-harvest Contracting and Price Renegotiation



Source: Author's calculation based on survey.

Additionally, market information (4.7)is mainly obtained from informal sources with 77 percent of the growers making use of traders, fellow farmers or personal contacts. While formal sources of market information are only available to 33 percent, the survey reported. Thus, the lack of access to quality and timely price information further undermines the quality decision-making ability of farmers and continues creating information asymmetry in the supply chain.

Figure 18: Market Information Source and Contractor Default



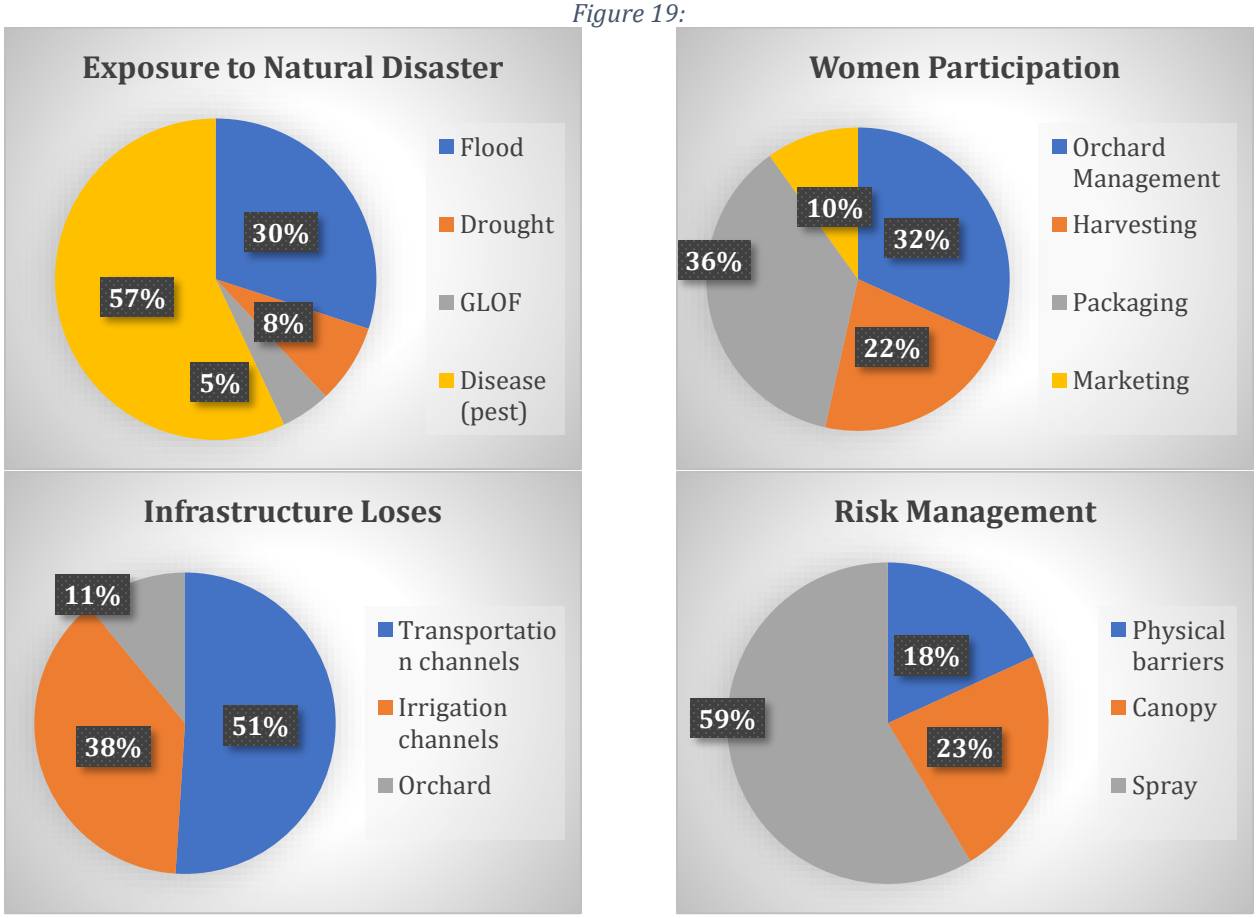
Source: Author's calculation based on survey.

Climate Risk and Gender Dynamics

Climate risk and gender dynamics are interdependent dimensions of supply chain resilience in Chitral. Climate shocks disproportionately affect those with least adaptive capacity, and women

farmers already marginalized from formal institutions face the highest exposure with the fewest risk management resources available to them. The climate risk profile documented in this survey (4.8) is severe: 62% of growers report regular pest and disease outbreaks (exacerbated by warming temperatures), 33% experience periodic flood damage to orchards and transport routes, and 5% are directly threatened by Glacial Lake Outburst Floods (GLOFs). Critically, Chitral's agricultural system is 98% dependent on glacial melt and canal irrigation, making it exquisitely sensitive to changes in glacial retreat patterns — a risk that will intensify significantly through 2050 as climate change accelerates glacial mass loss in the Hindu Kush Himalayan region.

Figure 19:



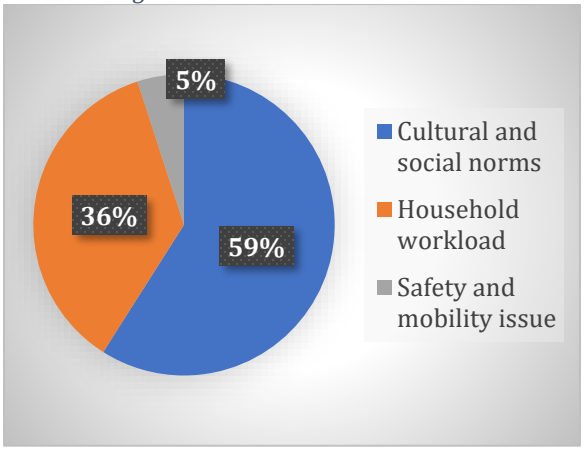
Source: Author's calculation based on survey.

The most frequently reported climate impact is damage to transportation channels (45% of respondents), followed by irrigation channel damage (38%) and orchard damage (17%). Road and bridge disruption seriously affects timely market access, raising transport costs and post-harvest losses, while irrigation damage impairs orchard productivity and fruit quality. Risk management strategies remain predominantly reactive: chemical sprays (59%), canopy management (23%), and physical barriers (18%) provide some short-term protection but are inadequate for managing rising climate variability and extreme events, underscoring the importance of more holistic, climate-resilient adaptation measures.

Further, the participation of women in the whole fruit supply chain is still disproportionate and is mostly focused on activities that do not pay high returns. The survey shows that the most responses

are in packaging (45%), then orchard management (22%), and harvesting (18%) and marketing-related activities (15%). This trend indicates that although women do play important role, the role they play is usually informal, unnoticed and restricted when it comes to making decisions. The fact that women are only involved lowly in production intensive activities is an indicator of both the cultural barriers and the lack of accessibility to resources and training.

Figure 20: Women Field Hurdles



Source: Author's calculation based on survey.

Furthermore, a number of structural obstacles limit optimal participation of women in fruit farming in chitral. The 4.9 reveals that the most common limitation is the cultural and social norms, with 59 percent of respondents reporting, then the large household workloads (36%) and safety and mobility concerns (5%). These impediments prevent women to take part in field operations, markets, and enjoy training and extension provisions, hence lowering the supply chain as a whole efficiency and inclusive provision. Generally, the overall findings demonstrate that the fresh fruit supply chain in Chitral is extremely exposed to risks posed by climate, especially, pests, floods, and damage to infrastructure, and that gender inequalities further limit adaptive capacity.

To counter these problems, all-inclusive interventions involving climate-resilient infrastructure, better management of pests and diseases, and gender-sensitive policies to minimize social obstacles, improve the capabilities of women, and enable their active role in all supply chain phases are needed to address these issues.

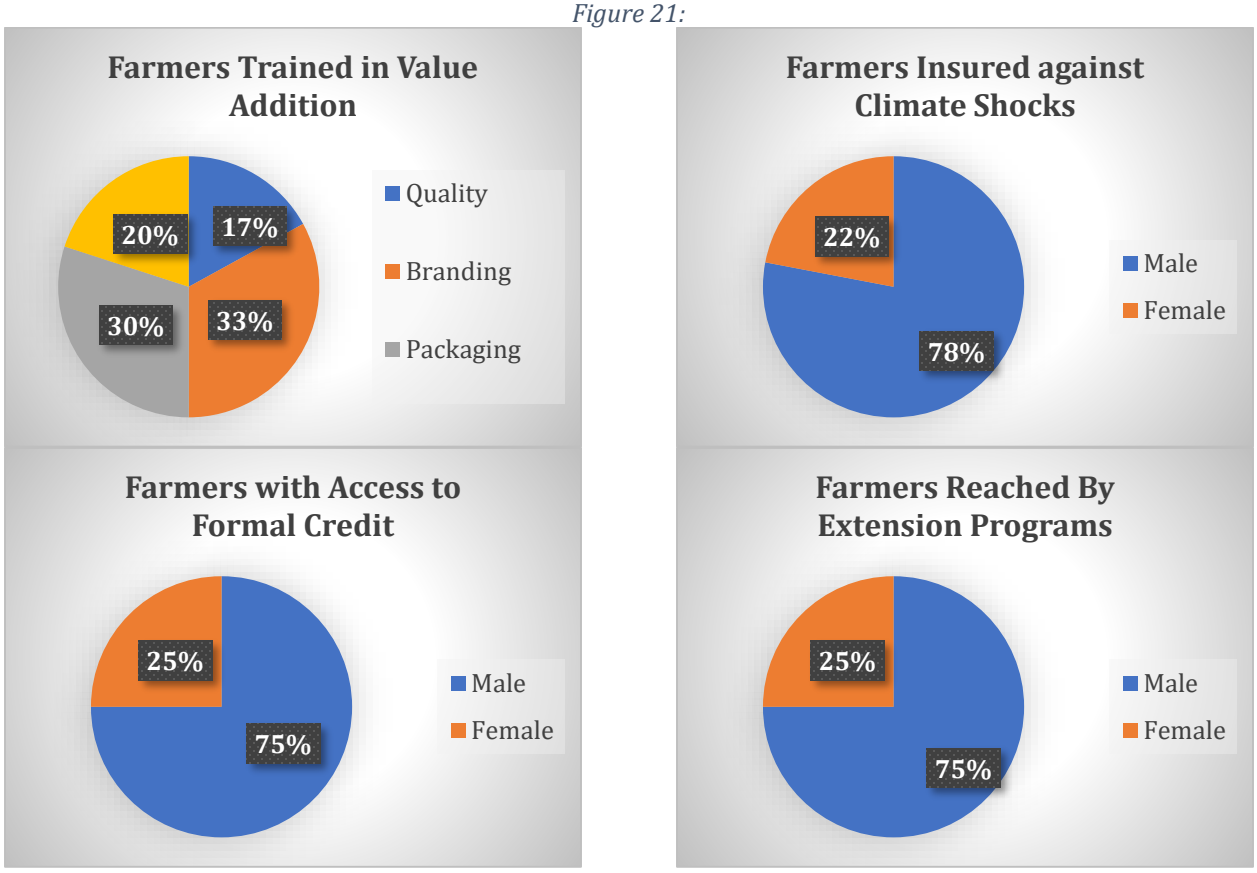
Role of Formal and Informal Institutions

The institutional environment serving Chitral's fruit growers is characterized by a significant mismatch between the scale of support needed and the depth actually delivered a gap most acute in the domains of value addition and financial inclusion, and most severe for women farmers. Training coverage (4.10) in value-addition skills is strikingly low: only 13% of farmers have received quality improvement training, 16% packaging training, 23% branding training, and a mere 10% post-harvest management training.

These are precisely the competencies that determine whether Chitral's fruit can compete in premium market segments. A comprehensive, market-linked capacity-building program targeting the 77–90% of farmers currently without value-addition skills could, based on regional experience, increase

average farm-gate price realizations by 25–40% within two years of implementation (FAO, 2021; AKRSP, 2014).

Figure 21:

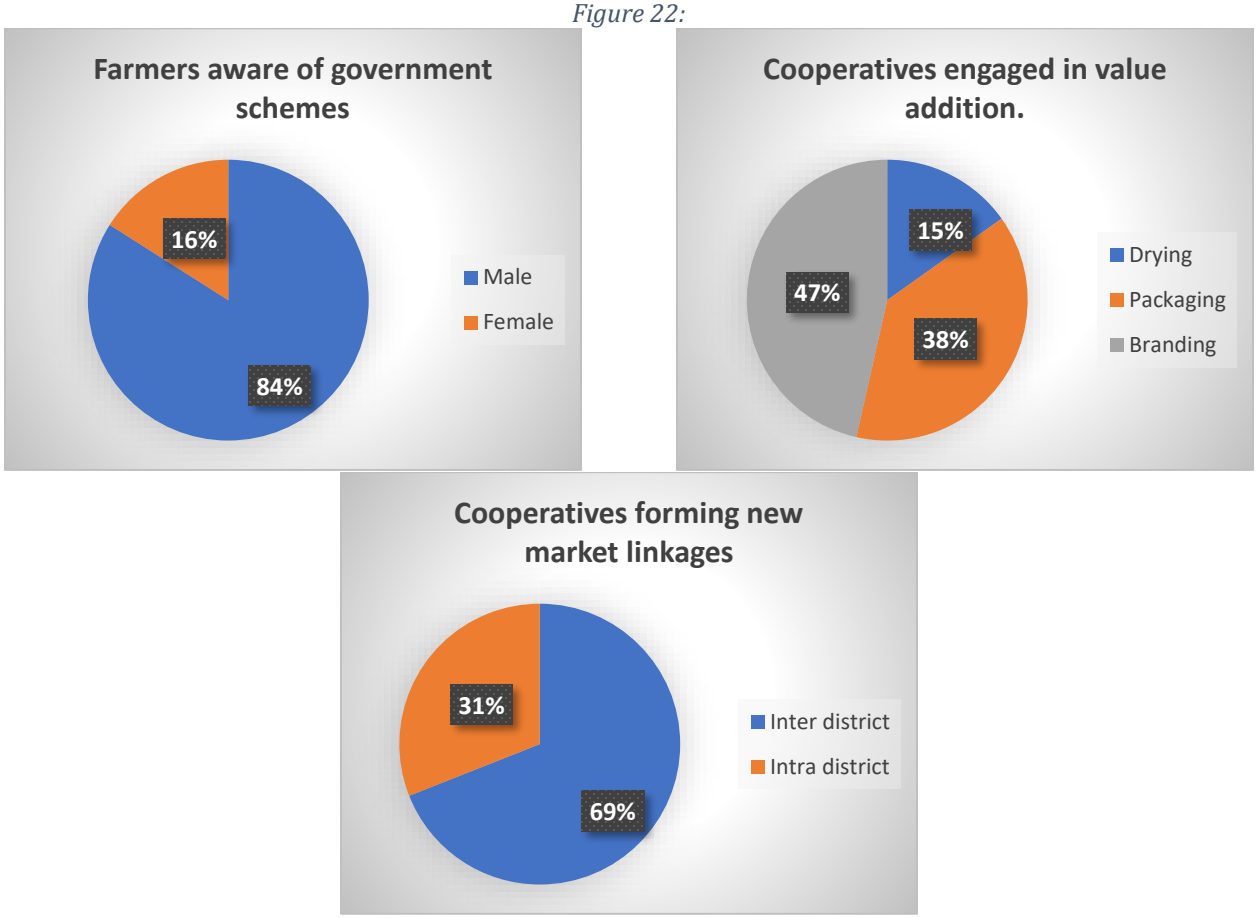


Source: Author's calculation based on survey.

Gender disparity in institutional access is substantial: 72% of male farmers have access to formal credit, compared with only 28% of female farmers. Insurance coverage similarly skews toward men (71% vs. 29% for women). Extension program coverage is more balanced (53% male vs. 47% female), but remains insufficient in depth and quality.

The cooperative sector shows genuine promise (4.11): cooperatives are active in value addition (drying, packaging, branding) and establishing inter-district market linkages (69%), indicating that collective action institutions could be a powerful lever for supply chain improvement if properly supported and scaled.

Figure 22:



Source: Author's calculation based on survey.

Summary

The results reveal that the fruit supply chain in Chitral is characterized by strong traditional knowledge alongside significant structural inefficiencies that constrain productivity and profitability. The socioeconomic profile shows a highly experienced but aging farming population, with limited youth participation, indicating a potential future labor and knowledge gap. Gender disparities are pronounced, with women's participation largely informal and underutilized, despite evidence that their inclusion could substantially enhance household incomes and supply chain efficiency. Educational limitations and the predominance of farming as a secondary occupation further restrict adoption of modern practices and investment in orchard development.

Orchard characteristics highlight smallholder fragmentation, aging tree stock, and near-total reliance on traditional management practices, all contributing to low productivity relative to global benchmarks. Input use remains suboptimal, with inconsistent fertilizer practices, high pest incidence—particularly in apricot production—and generally poor crop conditions. Production levels, especially for apples, fall short of achievable potential, while high input costs combined with significant post-harvest losses reduce net returns.

Post-harvest handling emerges as a critical bottleneck, with the absence of grading, standardized packaging, and storage infrastructure leading to substantial value losses, particularly for apricots and apples. Weak transportation and storage systems further exacerbate these losses due to long distances, high costs, and lack of cold chain facilities. Marketing structures are heavily intermediary-driven, limiting farmers' share in final prices and reinforcing low bargaining power, while dependence on informal market information perpetuates inefficiencies.

Climate risks, including pests, floods, and infrastructure damage, significantly threaten production and supply chain stability, with limited adoption of effective mitigation strategies. These challenges are compounded by gender inequalities, which restrict women's adaptive capacity. Finally, institutional support remains inadequate, with low access to training, credit, and insurance—particularly for women although cooperatives present a promising avenue for improving value addition and market access. Overall, the findings underscore the need for integrated interventions focusing on modernization, infrastructure development, institutional strengthening, and inclusive participation to enhance the efficiency and resilience of Chitral's fruit supply chain.

5.2. Supply Chain in Chitral

5.2.1. Existing Supply Chain in Chitral

To identify and map fresh fruit supply chains in Chitral, a qualitative fieldwork was conducted including Focus Group Discussions (FGDs) with farmers and Key Informant Interviews (KIIs) with traders, transporters and Agriculture Department Khyber Pakhtunkhwa (KP) officials. The aim was to understand how the fruits flow between farms and markets and from firms to folks and how the structural and institutional factors influence these movements. The research used the Supply Chain Management viewpoint (citation of the study we were discussing about), and applied a value chain mapping method, which follows how products, information, and value are moved through system actors. The fieldwork revealed that the existing marketing channels lack a standardized supply chain.

Instead, there are different commodity specific channels of apples, walnuts and apricots which are mainly influenced by nature, shelf life as well as market demand trends. While apples tend to move quickly through trader-led networks due to their perishable nature, walnuts have relatively longer storage potential, and apricots follow both fresh and processed (dried) marketing channels. Despite these comparative variations, one structural element that is shared by all fruits is the use of intermediaries who link farmers to wholesale markets.

During FGDs with apple growers, farmers described how traders usually visit villages during harvest seasons and purchase produce directly from orchards. One participant explained that farmers rarely transport apples themselves to markets outside the district because of logistical and financial barriers. According to him, "most of us cannot carry apples ourselves to the markets since it involves cash, contacts and experience to get transport and sell in the markets.''

Another farmer expounded on the information asymmetry that influences marketing decision making, saying that the producers do not know much about the price fluctuations in the largest marketing centers like Peshawar and Lahore. He added that, "since apples are not long-lasting and cannot be stored and so we usually accept the price that the traders offer as we are not aware of the price we are going to receive in the down cities.'' A very good example of such an account emerged when a farmer told of his personal experience in trying to get around middlemen and sell directly in a wholesale market. As he recounted, "once I attempted to go to the wholesale market with my apples myself believing I will get a better price. However, upon arrival there, I found out that no one in the market takes you seriously without having contacts. Eventually I was forced to sell my apples below the expected price and upon the transport expenses I even suffered a loss.'' His experience of how informal networks and relationships are relevant in wholesale markets that frequently dictate access and bargaining power.

5.2.2. Existing Supply Chain Model

In the same discussion, another farmer stressed that there are financial constraints that do not allow many producers to get directly involved in the activities of the market. Investment, according to him, is the primary reason why farmers cannot market their produce on their own. He emphasized that, "Money is needed to accommodate transport, packaging, and other market costs and the majority of the farmers in this area are poor people and cannot afford to take on such risks.'' This assertion underscores the effects of liquidity and credit constraints that limit the farmers in contributing to better value chains in the supply chain.

The geographic conditions also proved to be one of critical factors that have influenced the supply chain structure. During a KII, an agriculture extension officer reflected on the difficulty of interpreting distance in the mountainous terrain of Chitral. He stated that, "distance, here in Chitral, is not to be conceived in the same sense as in the plains. Even twenty kilometers distance can mean two hours of traveling here.''

Figure 23:

Source: Author's calculation based on survey.

This observation highlights how the rugged nature of the terrain and poor road network in the region contribute towards the high time and cost of transporting agricultural products. Due to such logistical limitations, the apples are usually sold to middlemen or traders who pool the output of several farms. These middlemen then secure transportation to the urban center wholesale markets. One of the transporters interviewed in KII said that traders usually mix apples of various villages and then ship them to either Peshawar or Islamabad markets. He, however, indicated that due to the lack of grading and sorting practices at the farm level, this creates inconsistencies in quality. According to him, "when apples reach the wholesale markets they are often mixed in quality because farmers do not grade them beforehand, and this reduces their overall value." However, the supply chain dynamics for walnuts are slightly different since the product is less perishable and can be stored longer. In discussion with walnut growers, farmers said that this gives them some freedom in terms of the time to sell. One of participants clarified that, "Walnut can be stored for months which is why sometimes we wait till the price is better and sell them.''

Unfortunately, the lack of local processing facilities restrains this advantage. Another farmer said, "majority of the producers sell walnuts in the shell since they do not have machinery to shell and package them.'' This observation was affirmed in a KII with a trader in Chitral town who clarified that most of the value addition is done outside the district. He explained that the walnuts are usually carried to bigger markets where they are graded, peeled, and packaged before being marketed to the retailers. In his words, "the actual profit is made after the walnuts have left Chitral since the processing and packaging are done there.''

Apricot marketing channels showed even more complicated structure of supply chains because of the existence of both fresh and dried product paths. In FGDs, farmers described those fresh apricots are highly delicate and have to sell right after the harvest. One farmer stated, "when there is mismatch between traders' arrival time and the harvest season, much of the harvest could go waste.'' In order to minimize these losses, the households normally dry apricots under the sun through the traditional methods of drying. Another farmer mentioned, "nearly all households dry apricots, although the quality of the product depends on weather conditions and is not always similar,'' One of the development practitioners who was interviewed in KII pointed out the untapped potential of enhanced processing technologies. He reiterated, "with improved solar drying apparatus, standardized packaging, the dried apricots of Chitral would be able to enter into the high-value markets.''

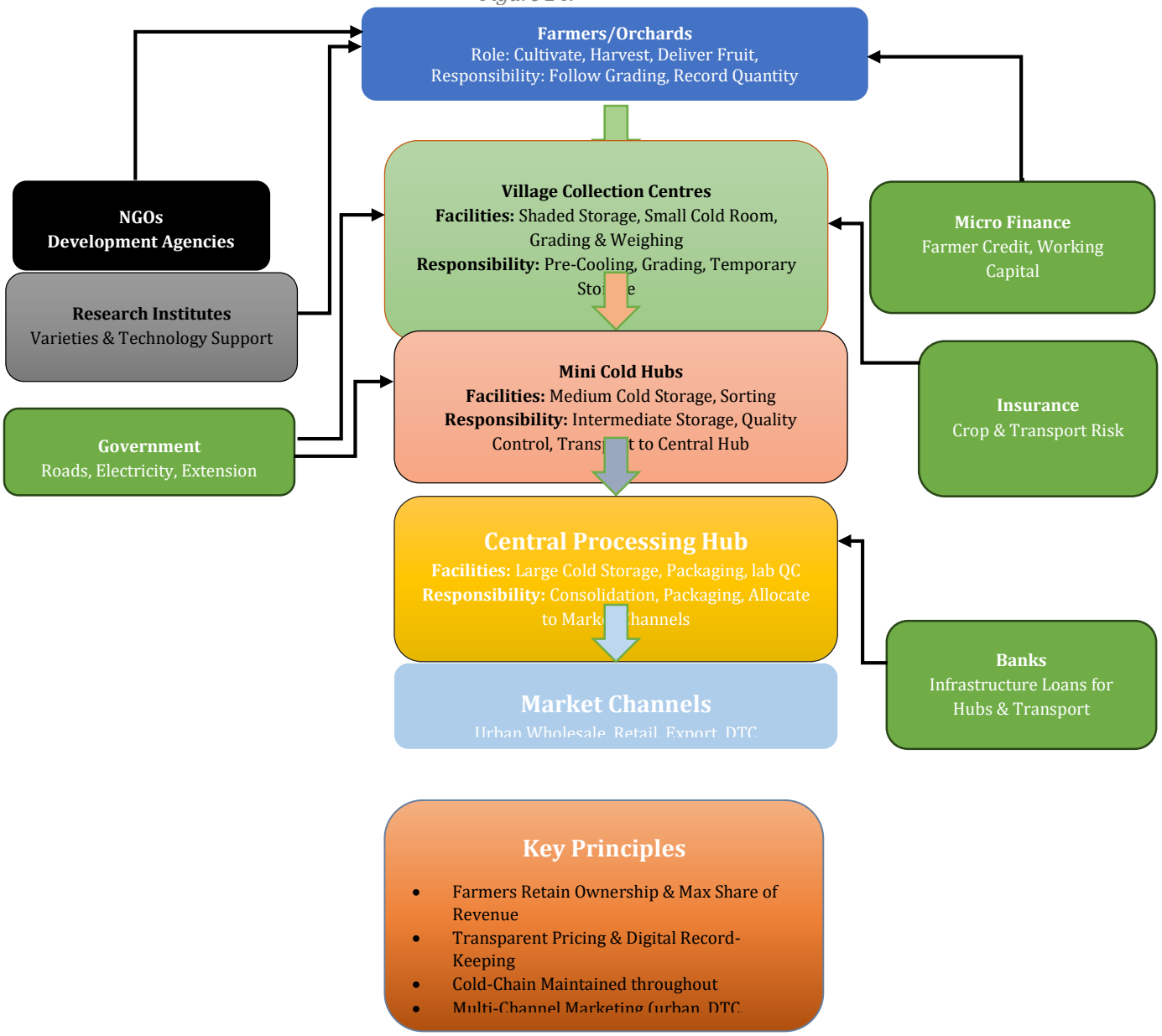
In all the FGDs and KIIs, several structural issues were pointed out. Firstly, the farmers have small orchards and typically sell their goods individually and this undermines their bargaining power.

Secondly, the middlemen are superior in the process of marketing because they control the transportation, market networks, and market information. Thirdly, the area is also characterized by lack of post-harvest infrastructure i.e. cold storage units, grading centres and processing units. Finally, geographic isolation and mountainous landscapes are also a source of these limitations, as they raise transportation rates and the time of travel. Based on these findings, it is clear that the traditional supply chain model in Chitral is still fragmented and mostly intermediary-based. such that Farmers make the major production but only get a small portion of the end market value. A farmer encapsulated this scenario in a nutshell when he was having a discussion and he said, "We cultivate the fruit, others decide the price and get more profit than we do.''

5.2.3. Proposed supply chain for Chitral region

After receiving feedback form all the stakeholders and reviewing international best practices in the supply chain of fresh fruits for mountainous regions. This study proposes a new supply chain model for the Chitral region for apple, apricot and walnuts. It is well documented in the literature that in mountainous regions, fruit loss ranges between 30% and 40%. Our data indicates that majority of the producers operate on small and fragmented landholdings. These growers have limited access to the resources as well as to the wholesale market. Due to poor infrastructure in the region, limited access to credit and information asymmetry about the price they are exploit by the fruit agents and sell their output at lower prices. The proposed supply chain model is presented below. The main objective of the proposed model is to reduce the fruit losses, increase the farmer income, increase their bargaining power and strengthen their market access. At the production level, growers or orchard owners are the primary actors in the supply chain model. They manage orchards, grow fruits and harvesting produce. Majority of the producers operate on small and fragmented landholdings. They rely on fruit agents who directly purchase fruit from them due to limited access to resources, technology and market. They compel to sell their product to fruit agents at lower price. In the proposed model framers are encouraged to adopt modern method of cultivation, harvesting, grading and packaging.

Figure 24:


Farmers/Orchards
Role: Cultivate, Harvest, Deliver Fruit,
Responsibility: Follow Grading, Record Quantity
NGOs
Development Agencies
Research Institutes
Varieties & Technology Support
Government
Roads, Electricity, Extension
Village Collection Centres
Facilities: Shaded Storage, Small Cold Room, Grading & Weighing
Responsibility: Pre-Cooling, Grading, Temporary Sto e
Micro Finance
Farmer Credit, Working Capital
Mini Cold Hubs
Facilities: Medium Cold Storage, Sorting
Responsibility: Intermediate Storage, Quality Control, Trans t to Central Hub
Insurance
Crop & Transport Risk
Central Processing Hub
Facilities: Large Cold Storage, Packaging, lab QC
Responsibility: Consolidation, Packaging, Allocate to Mark hannels
Banks
Infrastructure Loans for Hubs & Transport
Market Channels
Urban Wholesale, Retail, Export, DTC
Key Principles
Farmers Retain Ownership & Max Share of Revenue
Transparent Pricing & Digital Record-Keeping
Cold-Chain Maintained throughout
Multi-Channel Marketing (urban, DTC

Source: Author's calculation based on survey.

5.2.4. Village Collection Centres

First stage of the proposed supply chain model is aggregation of fruit at village level called village collection centres. These collection centres must locate in accessible distance from the village production places. These collection centres must be equipped with some basic facilities like shaded storage areas, weighing scales, grading tables, and small pre-colling units. The fruit produced by different growers are aggregated, weighed and recorded for transparency in procurement. Basic grading and sorting will be conducted to remove the damage and low-quality fruit. Pre-colling is done to preserve the fruit quality and early ripening. This will give more bargaining power to the grower with agents and also minimize the fruit loss as well.

5.2.5. Mini-cold Hubs

In proposed model, this stage is very crucial as in mountainous regions, villages are scattered in clusters. It not feasible for each village to transport their production to the main city hub. Fruits are aggregated at village level then transported to mini-cold hubs. These mini hubs will serve two major functions. First, they maintain the cold chain to extend the shelf life of fruits and second aggregation of produce of serval village collection centres to enable economy of scales in transportation and storage. These hubs are equipped with medium sized cold storage along with quality management facilities. At these hubs, medium size storage facility, further sorting and grading equipment, and packaging facilities will be available.

5.2.6. Central Processing Hub

This will serve as the main hub of the fruit supply chain equipped with large storage facilities. The central hub must be equipped with modern grading and sorting equipment, labelling and packing, and quality testing. At this hub, fruit will be process according to requirement of different markets (local and foreign). This will also manage the logistics and distribution of fruit across different markets. This will help to enhance the regional identity such as Chitral apple and apricot.

5.3. Proposed Supply Chain Model

The effectiveness of the proposed supply chain model heavily relies upon the role/involvement of various stakeholders. Their role and responsibilities are as follows.

Government Institutions: Government institution's paly pivotal role in the enabling environment of the proposed supply chain model. In the mountainous region like Chitral, for smooth and efficient fruit supply chain require a sufficient public investment in form of physical infrastructure and institution support mechanism. Government is responsible for providing and maintaining transport infrastructure that includes construction of road for the connectivity between remote villages, mini cold hub and main processing hubs and markets. Improved connectivity reduces the transportation time, physical damages of fruits. In mountainous uninterpreted supply of electricity is challenge for the government. Reliable supply of electricity which is essential for the cold storage and fruit process operation. Without reliable power supply it is very difficult to maintain cold storage which will lead to high post-harvest loss.

Non-governmental Organizations/Development Agencies: In the proposed model, the main role of NGO's and development agencies is to educate and train growers about latest methods used by the growers at the different stages of the fruit and the time of harvesting. This will lead to increased production and quality of the fruit.

Research Institutions: Main role of these institutions is to provide technical support to the growers. Their contribution includes the development of improved fruit verities, pest and disease management strategies and innovation in post-harvest technologies. Their support will help to improve the quality and quality of fruit.

Financial Institutions: Financial institutions (microfinance banks, commercial banks and insurance companies) are another key stakeholder in the ecosystem of the proposed supply chain model. Majority of the growers operates as small-scale farmers and they have very limited access to the farm credit. The microfinance may provide running capital to the growers and producing organizations for the purchase of inputs, harvesting instruments and packing materials. Commercial bank can provide the short term, medium term and long-term credits to the village collection centres, small cold hubs and central processing hub for the establishment cold storage, processing facilities and refrigerating transport system. The insurance companies can mitigate the risk of crop failure, transportation losses and climate shocks. This (FAO, 2021) will enhance the resilience of supply chain.

Implementation of Proposed Supply Chain Model: The following table provides the implementation plan of the proposed supply chain model along with responsibilities and expected outcomes.

Table 10: The Implementation Plan of the Proposed Supply Chain Model

Time Horizon	Plans	Responsibilities	Expected Outcomes
Short Term (0–2 Years)	Establish Village Collection Centres (VCCs) Provide grading, weighing, storage, pre-cooling Train farmers on post-harvest practices Form farmer groups/cooperatives Improve local transport coordination	Government: Extension services, infrastructure NGOs: Training & capacity building Farmers: Adopt improved practices Microfinance: Working capital support	Reduced post-harvest losses Improved product quality Increased bargaining power Reduced reliance on intermediaries
Medium Term (3–5 Years)	Develop Mini Cold Hubs Introduce cold chain logistics Sorting, grading, packaging at hubs Strengthen urban market linkages Expand access to credit	Government: Roads, electricity, subsidies Private Sector: Storage & logistics investment Banks: Medium-term financing Farmer Groups: Collective marketing Transporters: Efficient logistics	Extended shelf life Reduced transport losses Better price realization Improved market integration
Long Term (5–10 Years)	Establish Central Processing Hub Develop value-added products Integrate into export markets Introduce digital systems Branding ("Chitral Fruits")	Government: Policy & export facilitation Private Sector: Processing & branding Research Institutes: Innovation Exporters: Market expansion Insurance: Risk mitigation	Value addition Higher farmer income share Export growth Sustainable supply chain

Source: Authors' compilations.

CONCLUSION

The District Chitral's fresh fruit sector presents a paradox of high productive potential and systemic underperformance. Post-harvest losses of 38–54% destroy an estimated PKR 150–220 million annually in production value. Farmers receive a meagre 15–32% of final consumer prices. Infrastructure deficits consist of 88% unpaved roads in Upper Chitral, only 15 cold storage facilities for the entire district, near-zero grading and processing capacity leading to even high-quality produce arrives at market damaged, undifferentiated, and undervalued. Demonstrated by the minor sized and aging orchards, severe gender inequities, limited human capital investment, and a near-total absence of modern management technologies is the supply chain. These factors mutually reinforce low farm-gate prices, reduce reinvestment capacity, which perpetuates low yields and poor quality, which reinforces low prices.

Institutional failures have a multiplying effect on the physical infrastructure deficits, creating a second tier of supply chain constraints that will persist even if roads and cold storage are improved causing the entire system to be stuck in a failing state of limbo. The dominance of informal intermediaries handling 98% of all fruit sales, pre-harvest contracts with zero renegotiation rights for 86% of farmers, training coverage of only 10–23% across all value-addition skills, and gender disparities in credit and insurance access, male largely dominating the sector (72% male vs. 28% female) collectively constitute formidable institutional barriers. Climate-related hazards are affecting 62% of farmers through pest outbreaks, 33% through floods, and an escalating proportion through glacial melt disruption add a compounding layer of risk that the current institutional framework is wholly unprepared to absorb.

Chitral's supply chain crisis requires an integrated and sequenced investment program that deals with physical infrastructure, institutional capacity, and market systems all at the same time. The business case for investment is compelling: studies from comparable mountain horticulture interventions consistently generate benefit-cost ratios of 3:1 to 6:1 within five years (FAO, 2021; Hussain, et al. 2017). For Chitral, a phased investment program of approximately PKR 2.0–3.5 billion over five years encompassing rural road upgrading, 8–10 district cold storage hubs totaling 25,000 tons of capacity, 15–20 community-level fruit collection and grading centers, and intensive training programs for 15,000–20,000 farming households could realistically and statistically reduce post-harvest losses from 38–54% to only 15–20% and increase average farm-gate price realizations by 35–50%. In summary, this report states that Chitral's fresh fruit supply chain stands at an inflection point. The convergence of growing domestic and regional demand for premium mountain produce, increasing government and donor interest in KPK horticultural development, and the expanding evidence base on effective supply chain intervention provides a unique policy window to transform Chitral's fruit sector from a subsistence-oriented, loss-prone system into a commercially integrated, climate-resilient economic driver. If the investments and institutional frameworks are correctly balanced, Chitral's fresh fruits that are already prized for their quality have the potential to become a regional brand, generating sustainable rural livelihoods and contributing meaningfully to KPK's horticultural export ambitions.

RECOMMENDATION / POLICY IMPLICATIONS

The empirical evidence collected and analyzed in this report makes a powerful case for transformative, integrated policy action in Chitral's fresh fruit supply chain. The constraints are formidable but well-understood, the opportunities are real and quantifiable, and the investment case is strong. The following recommendations are directed at the Government of KPK, federal agricultural development agencies, multilateral development partners, and private sector actors including processors, retailers, and financial institutions with an interest in the growing market for premium Pakistani mountain produce.

Youth Engagement and Human Capital Development: The imminent succession crisis states that with 58% of farmers over 45 and only 8% under 30 makes youth re-engagement an urgent priority rather than a long-term aspiration. A dedicated Chitral Horticultural Youth Program should offer three-year, market-linked agri-preneurship pathways that combine technical training in modern orchard management, post-harvest handling, and digital market tools with start-up financing packages which grant a covering of30–40% of initial investment, concessional loans for the remainder) and guaranteeing market linkage. Side by side, the program should formally recruit experienced older farmers as paid master farmer trainers, creating a structured knowledge transfer mechanism that preserves traditional wisdom while enabling modernization. Digital recruitment and awareness campaigns should position horticulture as a high-potential agribusiness sector: a well-managed 3–5-acre orchard in Chitral can generate annual net incomes of PKR 400,000–700,000 comparable to government employment salaries within 5–7 years of investment.

Gender-Sensitive Supply Chain Interventions: There is significant evidence that states that women's expanded participation in post-harvest handling and marketing improves both household income and overall supply chain quality, women centric supply chain design is a high-return investment. This requires establishing a community-based Fruit Processing and Packaging Units located within or adjacent to villages, designed and managed predominantly by women, providing safe workspaces for sorting, grading, packaging, drying, and branding activities; designing credit products through NRSP and HBL Microfinance that reach women directly, targeting the 72% gender credit gap identified in this study; ensuring that at least 40% of all cooperative memberships, training program seats, and extension visits are allocated to women farmers with gender-sensitive delivery mechanisms; and integrating women's economic empowerment indicators into the performance metrics of all government and donor horticultural programs. Experience from AKRSP demonstrates that focused interventions of this type can increase women's contribution to household income by 30–45% within three years (AKRSP, 2014).

Orchard Rehabilitation and Diversification: Almost half (49%) of orchards are over 15 years old, whereas 93% are under fragmented smallholder management, an immediate and sustained orchard rehabilitation program is the single highest-impact productivity intervention available to Chitral's fruit sector. The program should provide subsidized legitimate planting material with a minimum 50% subsidy on improved disease-resistant, climate-adaptive varieties in order to incentivize replanting of 20–30% of the district's aging orchard area within five years while delivering hands-on training in high-density planting systems (target density 800–1,200 trees per hectare vs. current

average of 150–200) that have demonstrated 3–5x yield improvements in comparable mountain environments; that will promote systematic diversification beyond apple monocultures into high-value apricot varieties suitable for both fresh export and dried fruit processing, and grafted walnut varieties with improved kernel quality; and establish 5–8 permanent demonstration orchards across key production clusters jointly managed with progressive farmer partners.

Climate-Smart Practices: The mixed-input system currently used by 75% of Chitral's farmers provides a productive starting point for scaling evidence-based, climate-smart production practices. Priority actions should be including the following; such as establishing a district-level mobile soil testing service that enables site-specific nutrient recommendations, reducing input over-application costs while improving yield consistency; increasing Integrated Pest Management (IPM) programs that address the huge 60% apricot and 35% apple pest incidence rates, with emphasis on pheromone traps, biological controls, and calendar-based spray programs that reduce pesticide costs by 30–50% while improving produce safety and market eligibility; introducing drip irrigation adoption modules (reducing water use by 30–50% that is critical given Chitral's glacial water insecurity); and supporting a Chitral Agri-Met Network of 10–15 local weather stations with farmer-accessible SMS-based weather and pest-risk alerts for data-driven farm management.

Post-Harvest Control and Value Addition: Reducing Chitral's 38–54% post-harvest losses require simultaneous investment across three mutually reinforcing components. First and foremost, a network of 8–10 Solar-Powered Cold Storage Hubs strategically located at key production cluster nodes across both Upper and Lower Chitral, each with 1,500–2,500 tonnes capacity, providing 24–48-hour storage at harvest point to break the currently absolute link between harvest and immediate distress sale. Solar power is essential given Chitral's grid reliability constraints; capital cost estimated at PKR 800M–1.2B across the network, recoverable within 6–8 years through storage fees and improved produce premiums. Second, 15–20 Community Fruit Collection and Grading Centers equipped with sorting tables, standardized packaging materials, weighing equipment, and basic quality testing tools that enables consistent Grade A/B classification that is a prerequisite for formal retail market access. Third, a Chitral Premium Fruit Brand developed jointly by government, cooperatives, and private sector partners, targeting a 20–30% price premium in urban retail channels and an initial 10–15% share in Gulf export markets.

Market Access and Strengthening of the Institution: Transforming the market architecture requires a coordinated institutional and digital market development strategy. Three priority interventions are required. First, a Chitral Fruit Growers Cooperative Federation that would a second-tier cooperative body aggregating output from village-level primary cooperatives — should be legally registered, technically supported, and provided with working capital financing to enable bulk marketing directly to urban wholesalers and supermarket chains, targeting a 35–45% farmer price-share within three years of operation. Second, a Mobile Market Information System should be setup, providing daily SMS/WhatsApp-based wholesale price dissemination for Peshawar, Rawalpindi, and Lahore markets and hence enabling all farmers to access price information currently available to only 23% of growers through formal channels. Third, a standardized Contract Farming Framework mandating minimum price floors indexed to seasonal averages, quality-linked premium

provisions, and enforceable renegotiation triggers addressing the contractual inequity that currently locks 86% of pre-harvest contracted farmers into below-market prices with no recourse.

Infrastructure and Risk Management: Infrastructure investment and climate risk management should all be treated as the enabling foundation upon which all other supply chain investments depend. Priority interventions comprise of upgrading 200–250 km of the highest-priority rural roads connecting major production clusters to district collection centers using climate-resilient engineering standards (flood-resistant bridges, reinforced embankments, sealed surfaces) that will upkeep the functionality of logistics during the July–October harvest season; rehabilitating and extending the 78% community-managed irrigation network with concrete-lining of priority canals and installation of glacier-melt monitoring equipment; introducing an Area-Based Crop Insurance Scheme with subsidized premiums (at least 50% government subsidy) and simplified claim procedures, targeting 60% farmer coverage within three years; and establishing a Chitral Agricultural Climate Risk Fund that would be a dedicated contingency financing mechanism jointly capitalized by the government and development partners enabling a rapid post-disaster rehabilitation following GLOF or flood events, preventing the multi-year income losses that currently push farming households into debt and orchard abandonment.

Supply Chain: The proposed supply chain model for Chitral restructures the existing fragmented system into an integrated framework based on village collection centres, mini cold hubs, and a central processing facility. This strategy also seeks to minimize post-harvesting losses, enhance the quality of products, and increase the share of farmers in the value chain. By strengthening the market linkages and limiting the excessive use of intermediaries, the model will increase the efficiency and bargaining power of the farmers. It is recommended that policymakers adopt a phased implementation strategy, focusing on pilot projects, infrastructure development, and capacity building to ensure sustainable and scalable improvements in the region's fruit supply chain.

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