Impact of Climate Change on Fruit Production in District Ghizer of Gilgit-Baltistan



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CERTIFICATE

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Author's Declaration

I, the undersigned Raja Abdullah Khan, hereby declare that I am the sole author of this thesis. To the best of my knowledge, this thesis contains no material previously published by any other person except where due acknowledgement has been made. This thesis contains no material that has been accepted as part of the requirements of any other academic degree or non-degree program, in English or in any other language. This is a true copy of the thesis, including final revisions.

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Signature of Student

Raja Abdullah Khan

Dedication

This thesis is lovingly dedicated to the cherished memory of my beloved late father, **Raja Sher Babar Khan**.

By the grace of Allah, I successfully defended this thesis on **13 July 2026**. Just four days later, on **17 July 2026**, my beloved father departed from this world. Although he is no longer with us, I am deeply grateful that he witnessed this important milestone in my academic journey before his passing. His unwavering prayers, sacrifices, guidance, and belief in my potential were the foundation of every achievement I have attained.

I also dedicate this work to my beloved mother, whose endless prayers, strength, and unconditional love continue to inspire me every day, and to my brothers and sisters, whose constant encouragement and support have been a source of strength throughout this journey.

This thesis is not only an academic achievement but also a tribute to my father's legacy, values, and dreams for my future. May Allah (SWT) grant him the highest place in **Jannat-ul-Firdous,** forgive his shortcomings, and bless him with eternal peace. **Ameen.**

This milestone will forever be dedicated to him, and I will carry his memory with me in every success that lies ahead.

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Abstract

Gilgit-Baltistan, located within the Himalayan, Karakoram, and Hindu Kush Mountain ranges of northern Pakistan, is highly vulnerable to climate change due to its fragile ecosystems and dependence on glacier-fed water resources. Agriculture directly or indirectly supports nearly 90% of the region's population, with high-value fruits such as cherries and apricots serving as important sources of household income and local economic development. Previous studies have focused predominantly on staple crops, while limited empirical evidence exists on the impacts of climate change on high-value fruit production, farmers' adaptation strategies, and policy responses. This study therefore examines the impacts of climate change on cherry and apricot production in District Ghizer, evaluates the resulting disruptions to market supply, reviews the existing agriculture and climate policy framework, and assesses farmers' adaptation strategies and the constraints they come across.

A mixed-methods research design was adopted. Primary data were collected through a structured questionnaire administered to 119 fruit-growing households selected using stratified random sampling across the valleys of Yasin, Gupis, Phander, Ishkoman, and Punial in District Ghizer. In addition, thirteen key informant interviews were conducted with agricultural officers, climate experts, and community representatives using purposive sampling. Secondary climatic data covering the period 1994–2024 were obtained from the Pakistan Meteorological Department to examine long-term changes in temperature, precipitation, and other climatic variables. Quantitative data were analyzed using descriptive statistics, while qualitative data were examined through thematic analysis to understand farmers' experiences, adaptation practices, and institutional challenges.

A major bottleneck in climate action was observed at policy level, as not a single policy has been developed either for agriculture or for climate change. At farmers' level, findings indicate that climate change has significantly altered the phonological cycles of cherries and apricots through rising temperatures, changing rainfall and snowfall patterns, declining winter chilling hours, and increasing uncertainty in glacier-fed water availability. These climatic changes have contributed to early flowering, irregular fruit set, declining yields, reduced fruit quality, increased fruit cracking, and shorter shelf life. Heavy rainfall during flowering and harvesting seasons, together with inadequate cold storage facilities, poor road infrastructure, and limited market access, were identified as major factors contributing to less production and post-harvest losses. While cherry production has shown improvement in recent years, largely attributed by respondents to improved varieties and increasing market demand mainly driven by more area under cultivation, apricot production has experienced a decline associated with heat stress and insufficient winter chilling. Farmers have adopted various adaptation measures; however, limited access to climate information, weak agricultural extension services, financial constraints, and the lack of climate-resilient fruit varieties continue to restrict their adaptive capacity.

The study concludes that climate change poses a multidimensional threat to fruit production, market stability, and rural livelihoods in District Ghizer. Strengthening climate-responsive agricultural governance, expanding localized climate information and extension services,

promoting climate-smart orchard management, investing in post-harvest infrastructure, improving access to climate-resilient fruit varieties, and enhancing financial support for farmers are essential to increasing the resilience and long-term sustainability of the fruit sector in Gilgit-Baltistan.
Keywords: Climate Change; Fruit Production; Cherries; Apricots; Adaptation; Gilgit-Baltistan; District Ghizer.

Table of Content

Contents

Abstract iv
Table of Content vi
List of figures viii
List of Tables ix
Chapter 1 1
INTRODUCTION 1
1.1 Background: 1
1.2 Problem Statement: 4
1.3 Research Questions: 4
1.4 Objectives: 5
1.5 Significance of the study: 5
CHAPTER 2 6
LITERATURE REVIEW 6
CHAPTER 3 11
METHODOLOGY 11
3.1 Description of Study Site: 11
3.1.1 Map of the study Area: 12
3.2 Data types and Sources: 12
3.3 Unit of data collection (UDC): 13
UDC-1: Climate Data: 13
UDC-2: Local Farmers: 13
UDC- 3: Agricultural and Climate Experts: 13
3.4 Data Sampling: 13
i. Population: 13
ii. Sampling Technique: 13
iii. Sample size: 14
3.5 Data Analysis: 14
3.5.1 Qualitative Data: 15

a. Thematic Analysis:..... 15
3.5.2 Quantitative Data:..... 16
a) DESCRIPTIVE STATISTICS:..... 16
3.6 Conceptual framework:..... 17
Chapter 4..... 18
Results and Discussion:..... 18
4.1 Thematic Analysis:..... 18
4.2 Thematic Analysis of Themes:..... 20
4.2.1 Theme 1: Unpredictable Climatic Patterns:..... 20
a. Sub-theme: Rising Temperature:..... 21
b. Sub-theme: Irregular Rainfall and Snowfall:..... 22
4.2.2 Theme 2: Impact of Climate Change on Fruit Phenology and Productivity:..... 24
a) Sub Theme: Early Flowering and Ripening:..... 24
b) Sub-theme: Disturbed Chilling Requirements:..... 25
c) Sub Theme: Decline in Fruit Yield, Quality, and Shelf Life:..... 26
d) Sub Theme: Increased Pest and Disease Incidence:..... 28
4.2.3 Theme 3: Impact of Climate Change on Water Resources and Glaciers:..... 29
4.2.4 Theme 4: Supply Chain Disruptions and Economic Impacts on Farmers:..... 30
I. Sub Theme: Supply Chain Disruptions:..... 30
II. Sub Theme: Market Instability and Income Loss:..... 31
4.2.5 Theme 5: Low Level of Farmer Adaptation:..... 32
4.2.6 Theme 6: Institutional and Policy Gaps:..... 34
4.2.7 Theme 7: Future Strategies and Recommendations:..... 35
4.3 Analysis of Descriptive Statistics:..... 36
4.3.1 Demographic Analysis of the Respondents:..... 37
Chapter 5..... 86
Conclusion and Policy Recommendations..... 86
References..... 92
Appendix..... 98

List of figures

Figure 1: Map of the Study Area 12
Figure 2: Conceptual framework 17
Figure 3: Themes and Sub-Themes of Thematic Analysis 20
Figure 4: Distribution of Respondents by Tehsils 37
Figure 5: Distribution of Respondents by Occupation 39
Figure 6: Consistent Land Cultivation by Year 40
Figure 7: Family Member Involved in Land Preparation Figure 8: Hired Labor involved in Land Preparation 41
Figure 9: Family Member Involved in Field Management Figure 10: Hired labour involved in field Management 41
Figure 11: Family Member Involved in Harvesting Figure 12: Hired Labor Involved in Harvesting 42
Figure 13: Climatic Factors that Affect the Quantity of Cherries Per Kanal 50
Figure 14: Climatic Factor that Affects the Value of Cherries (In PKR) 51
Figure 15: Climatic Factors that Affect the Quantity of Apricots Per Kanal 52
Figure 16: Climatic Factor that Affects the Value of Apricots (Per Kanal) 53
Figure 17: Adaptation Measures Adopted by Farmers 54
Figure 18: Climate-Related Constraints to Adaptation Strategies 54
Figure 19: Number of Days of Harvest Delay Attributed to Climate Events 56
Figure 20: Selling Channel, Distance to Main Market, and Transport Method 56
Figure 21: Major Supply Chain Challenges 58
Figure 22: Major Supply Chain Challenges, Price Set, and Payment Terms 59
Figure 23: Mean Monthly Temperature (°C) by Month 61
Figure 24: Mean Annual Temperature (°C) 63
Figure 25: Mean Monthly Maximum Temperature (°C) by Month 65
Figure 26: Mean Maximum Annual Temperature (°C) 68
Figure 27: Mean Monthly Minimum Temperature (°C) by Month 70
Figure 28: Mean Annual Minimum Temperature (°C) 73
Figure 29: Monthly Amount of Precipitation by Month 75
Figure 30: Mean Amount of Precipitation (mm) 77
Figure 31: Monthly Heaviest Rainfall by Month 79
Figure 32: Monthly Amount of Snowfall (INCHES) by Month 83

List of Tables

Table 1: Distribution of Key Informant Interviews 19
Table 2: Socioeconomic Profile of Respondent 37
Table 3: Distribution of Respondents by Educational level 38
Table 4:Farming by Land Size in District Ghizer (n=119) 39
Table 5: Area Under Cultivation by Cherries and Apricot 43
Table 6: The Fruit Calendar of Cherries in District Ghizer 44
Table 7: The Fruit Calendar of Apricot in District Ghizer 44
Table 8: Production of Fruits (Previous Year, 2024) 45
Table 9: Production of Fruits (Current Year, 2025) 46
Table 10: Average Prices (PKR) of Cherries and Apricot (Per KG) 47
Table 11: Climate Variables Impact on Cherries and Apricots 47
Table 12: Transport Cost to Main Market (In PKR) 57
Table 13: Rate of Change by Month in Monthly Mean Temperature (°C) 64
Table 14: Rate of Change by Month in Monthly Mean Maximum Temperature (°C) 69
Table 15: Rate of Change by Month in Mean Minimum Temperature (°C) 73
Table 16: Rate of Change by Month in Amount of Precipitation (MM) 78
Table 17: Rate of Change by Month of Precipitation (MM) 82
Table 18: Rate of Change by Month of Snowfall (inches) 84

List of Abbreviations

Abbreviation	Full Form
ADB	Asian Development Bank
°C	Degrees Celsius
CSA	Climate-Smart Agriculture
FOA	Food and Agriculture Organization of the United Nations
GB	Gilgit Baltistan
GDP	Gross Domestic Product
GLOF	Glacier Lake Outburst Flood
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
KII	Key Informant Interviews
KIU	Karakoram International University
KPK	Khyber Pakhtunkhwa
LDCs	Least Developed Countries
MoPD	Ministry of Planning and Development
NGO	Non-Governmental Organization
PMD	Pakistan Meteorological Department
PKR	Pakistani Rupees
UDC	Unit of Data Collection
UNFCCC	United Nations Framework Convention on Climate Change
UNDP	United Nations Development Program
UN	United Nation
WB	World Bank

Chapter 1

INTRODUCTION

1.1 Background:

Climate change has become a reality of the 21st century, significantly affecting ecosystem economies and food security. Persistent floods, GLOFs, droughts, and other extreme weather events are disrupting food production patterns, as observed in various studies, resulting in lower yields. Every single degree Celsius rise in Temperature reduces the global food production capacity by 4.4% of the current daily consumption globally (Hultgren, et al., 2025).

Pakistan, although contributing less than 1% of global greenhouse gas (GHG) emissions, ranks among the top 10 countries most significantly affected by climate change (Food and Agriculture Organization of the United Nations (FAO), 2024). These changing patterns have exacerbated the lives of people living in mountainous regions. They are directly affected by the changing ecosystem, especially in Gilgit-Baltistan (GB), where ecosystems and agriculture-dependent communities face increasing risks. GB contributes only about 0.3% to Pakistan's total GHG emissions (Shigri & Hussain, 2017). Yet its climate is significantly affected by transboundary emissions from neighboring high-emitting countries, i.e., China (30.1% of global GHG emissions) and India (7.8%) (Crippa et al., 2024). These negative spillovers severely affect temperature, black carbon deposition, and disrupted precipitation patterns, thereby affecting regional ecosystems and weather patterns. Consequently, the yields of cherries and apricots are vulnerable to shifting flowering times, pest outbreaks, irregular rainfall, and glacier-melt-driven water stress, which exacerbate farmers' lack of local control.

According to the PMD Gilgit Baltistan, the annual mean Temperature of Gilgit has increased by 0.7 °C from 1994 to 2024. That has a significant impact on the cherries and Apricots in the region, as they are so sensitive that they are affected by changes in the Temperature.

Glaciers dominate the Darkut Valley in District Ghizer, so it is very sensitive to changes in temperature. In 2025, the Provincial Emergency Operation Center in Gilgit-Baltistan reported a temperature of 35 °C in the valley, an unprecedented anomaly in a Glacierized area. These high

temperatures significantly increase glacier melting rates, thereby increasing the risk of glacier hazards, especially flash floods and GLOFs. Raza and Hassain (2015) identify the climate trends in Gilgit Baltistan in their study, which shows a noticeable phenomenon over the past 7 decades. From 1955 to 2000, an average temp rise of 0.33 ° was observed. And from 2001 to 2010, a significant rise of 0.76 °C was observed (Raza & Hussain, 2015). Winter has become hotter. However, other times of the year, especially spring and autumn, have shown mixed patterns: long-term warming, certain years have experienced brief cooling phases, likely associated with inter-annual climatic fluctuations such as changes in snow cover and regional circulation patterns (Ali , Shah , Alotaibi, & Amjad Ali, 2024) (Bashir & Hanif, 2018). This kind of seasonal change, driven by temperature fluctuations, has a wide impact on farming, as in the Gilgit Baltistan region, spring and summer are the two key periods for flowering and fruit setting. The unpredictable rain pattern also significantly impacts food crops. Overall, rainfall has increased, but in the key seasons of spring and autumn, rainfall has decreased, impacting fruit yields (Raza & Hussain, 2015).

Although there was an overall decline, some years saw high short-term increases, indicating the high uncertainty of Rainfall. But even these intermittent rises were not enough to counter the general tendency of decrease. Results show that the rainfall in the district Ghizer has turned into an unpredictable in nature, featuring the long-term decline in annual precipitation, potentially having profound impacts on water sources and agriculture.

The Yasin valley of district Ghizer are noticing the change in climatic pattern. And they drying early in the year, even in the snow in winter and rains. This early drying is compelling farmers in the region to plant summer crops sooner than before. Temperature records from weather stations in the area confirm that March and April are getting warmer, with recent years being the hottest in a decade (Baigal, 2022).

These climate-driven changes severely affect yields each year. Further, it reduces the trees' ability to absorb water from the soil, contributing to soaring temperatures. If a climate-friendly environment (soil, water, and temperature) is not provided at the right time, it will increase the risk by endangering the trees' production capacity and the local economy.

According to the agriculture department of GB, fruit production is a major component of GB's regional economy. About 90% of the population is directly or indirectly linked to agriculture in GB, contributing not only in the form of capital but also labor. Apricots are one of the major crops

and a major source of household income. The average apricot yield in Gilgit Baltistan is about 9.82 tons/ha. Apricots from Gilgit Baltistan contribute to 41% of Pakistan's overall apricot output. Gilgit Baltistan produces apricots worth approximately PKR 5 billion, which could increase to PKR 8 billion with the right measures. Currently, about 35% of production is lost to waste (Akhter & Abbas, 2025). Talking about cherries, the Chinese demand was 0.35 million tons of cherries from Pakistan, worth 3 billion dollars, offering a potentially significant area for development. This development is set to revolutionize the cherry-growing landscape in Gilgit-Baltistan (times, 2024). According to Pamir Times, Gilgit-Baltistan has a capacity of 5000 tons of cherries per season. (times, 2024). The apricots and cherries are highly dependent on seasonal trends, the number of required chill hours, and water supply, all of which are disrupted by climate change.

Major fruits such as cherries and apricots have a seasonal cycle in which they flower and mature. The Agriculture Department of Yasin reports that these plants will start flowering in April, and furthermore, the spring temperatures will be warmer. Once pollinated successfully, the fruits begin to grow in May as the flowers' ovaries swell and develop into young fruits. Cherries are the earliest to bear, and the fruits are ready towards the end of June, being deep red and sweet. Apricots are next, ready in July, with soft, aromatic, golden fruit. This developmental order in fruits indicates altitude, temperature, and developmental conditions in the region, with every stage of flowering, fruit set, development, and ripening closely associated with the climate of the Gilgit region.

Climate change, through shifts in precipitation patterns, directly affects the fruit supply chain in Ghizer. Monsoon is the season of harvesting the main fruits of the area, and it usually starts at the beginning of July. Cherries have been picked and are being shipped to markets, where apricots are fully mature and are ready to be picked. Nonetheless, during this short harvest season, significant logistical issues arise in the event of heavy rainfall. Traditional harvesting methods are slow and labor-intensive; there is no official, structured system, and local farmers use only these methods. This leads to unpredictable weather conditions that damage roads, bridges, and other transport systems, such as landslides and flash floods. These disruptions delay or halt the supply of crops, such as cherries and apricots, from the fields to local markets or to markets beyond their reach. Any kind of delay in transportation reduces the market value of these fruits and leads to post-harvest loss due to the fact that these fruits are highly perishable. In addition to destroying valuable highways, these landslides and flash floods also disrupt harvesting operations. Since both cherries

and apricots are perishable, any delay in harvesting and transport may result in significant post-harvest losses. Therefore, the infrastructure, the lack of systematic harvesting methods, and climate-driven changes in precipitation pose a serious threat to the fruit supply chain in District Ghizer, which is already vulnerable due to poor infrastructure.

This research aims to evaluate the effects of climate change on fruit production, particularly cherries and apricots. The study also examined how farmers can withstand the non-traditional effects of climate change. The study also aims to assess the impact of climate change on their exposure to fruits, given their vulnerability.

In addition, specific recommendations to enhance farmers' resilience and enable them to withstand climate change-related events shall be proposed during the research. The study will also examine the GB government's climate change policies in Gilgit Baltistan and how it responds to farmers' problems.

1.2 Problem Statement:

District Ghizer is also characterized by the production of high-value fruit, such as cherries and apricots, which are of great economic value to the area. Nevertheless, the region has become more susceptible to the effects of Climate change in recent years, including rising temperatures, changing precipitation patterns, and increased frequency of extreme weather events. These climate changes have raised great concerns about their impact on fruit production and quality, as well as on market supply. Yet, few empirical studies have been undertaken to evaluate the effects of climate change on specific fruit crops in the region and the existing policy structures for climate change problems. Further, while local farmers are implementing various adaptation measures to mitigate the stress from climate change, there is a lack of detailed understanding of the effectiveness, sustainability and associated challenges of these measures. This study addresses this gap by examining the effects of climate change on cherry and apricot production in GZR and assessing local adaptation to these changes, their limitations, and the policy context.

1.3 Research Questions:

- How has climate change affected the yield and quality of cherries and apricots in the district Ghizer?

- What are the adaptive measures and challenges of local farmers in response to climate change?

1.4 Objectives:

1. To review the Agriculture and Climate Change policy of Gilgit Baltistan
2. To assess historical trends in climate variables and their impact on the productivity of cherries and apricots.
3. To analyze how climate-related disruptions affect the timely market supply.
4. To analyze farmers' adaptation strategies regarding climate-induced changes in fruit production and the challenges they face.

1.5 Significance of the study:

The research will help enhance agricultural governance in District Ghizer to be more climate-resilient by identifying the major climatic, institutional, and infrastructural issues affecting cherry and apricot farmers under changing climatic conditions. The study can provide evidence, in the form of an explanation, of how increasing temperatures, irregular precipitation, pest outbreaks, and water variability affect fruit production and supply chains, supporting improved planning and decision-making in the agricultural and climate-related departments of Gilgit-Baltistan.

Second, the study results can support reducing production and post-harvest losses by encouraging the adoption of climate-sensitive farming techniques, improved irrigation control, and better supply chain infrastructure, including cold storage and transportation systems. The study outlines farmers' current coping mechanisms and the constraints they face, underscoring the need to implement targeted interventions and technical assistance in areas where farmers are most in need.

The research can also be helpful to policymakers and development organizations, as it may serve as a baseline for understanding how climate change affects high-value fruit crops in District Ghizer. It can assist in developing and implementing localized climate and agricultural policies tailored to mountainous areas. Moreover, the study can inform extension services, scholars, and development organizations in developing farmer training schemes and adaptation options to improve productivity, income security, and the long-term sustainability of fruit production in Gilgit-Baltistan.

CHAPTER 2

LITERATURE REVIEW

Climate change has become one of the most severe issues worldwide, with a significant impact on agricultural systems, food security, and rural livelihoods. Agriculture is climate-sensitive because it is directly affected by temperature, rainfall, and seasonal changes. Over the past decades, climate patterns worldwide have been significantly altered, leading to warmer temperatures, more variable precipitation, and an increased frequency of extreme weather events. The world has been affected by these changes, which have derailed the productivity and sustainability of agriculture (IPCC, 2022).

Climate change is especially dangerous to developing countries, as they have limited adaptive capacity and depend on agriculture that is highly susceptible to it. Climate variability has had the greatest impact on Pakistan, particularly in areas where farming relies on the natural environment rather than sophisticated irrigation systems. Gilgit-Baltistan is a very vulnerable area in the northern mountainous part of Pakistan because of its weak ecosystem, rugged terrain, and reliance on water sources through glaciers (Raza & Hussain , 2015)

One of the most powerful factors of agricultural change is well known to be temperature increase. Increased temperatures influence plant growth cycles, evapotranspiration, and soil moisture availability. Research shows that even a modest temperature rise can drastically reduce crop production and alter production patterns (Lobell & Burke, 2010) . Heat stress reduces the time of crop growth and has adverse impacts on reproductive processes, which eventually leads to low productivity (S. Asseng, et al., 2024) . Temperature is even more important in fruit crops, as they require specific thermal conditions to flower, set fruit, and ripen.

Another important variable that influences agricultural systems is precipitation variability. Alterations in rainfall patterns, such as droughts and excessive rainfall, disrupt soil moisture and water availability. Agriculture in mountainous areas, including Gilgit-Baltistan, is heavily reliant on snowmelt and glacier water and thus extremely vulnerable to precipitation variability. Because of greater precipitation fluctuations, there is uncertainty in agricultural activities, and farmers are unable to predict their crop cycles (Wheeler & Braun, 2013).

Growing crops such as fruits are especially susceptible to climate change because they are perennial and slow to grow. Fruit trees, which are not yearly crops, cannot be easily replaced or modified in a short span. Climate change influences fruit production by altering physiological, morphological, and biochemical processes in plants. Changes in temperature and moisture affect photosynthesis, respiration, hormone regulation, and nutrient uptake, all of which are vital to plant growth and development (Taiz, Zeiger, Møller, & Murphy, 2015). This has led to an increase in produce, with fruit crops becoming smaller, having lower sugar content, not ripening evenly, and being prone to cracks and sunburn, which adversely impact fruit yield and fruit quality (Ameen, Mahmood, Ahmad, & Javaid, 2023) .

The sensitivity of fruit crops to climate change is further reflected in their phenological responses. Phenology refers to the timing of biological events such as flowering, fruit setting, and ripening. These processes are highly temperature-dependent and can be significantly altered by climatic changes. Rising temperatures reduce winter chilling hours, which are essential for proper dormancy and flowering in temperate fruit crops such as cherries and apricots. Insufficient chilling leads to irregular flowering, poor pollination, and reduced fruit yield (Luedeling, Zhang , & Girvetz, 2009).

In addition, early flowering induced by warmer temperatures exposes fruit crops to late frost events, which can severely damage flowers and reduce production. Rainfall during flowering periods can interfere with pollination, while excessive heat during fruit development can reduce fruit quality and increase physiological disorders such as sunburn and cracking (Guo, Dai, Ranjitkar, & Yu, 2014) These findings highlight the complex interactions between climate variables and fruit production systems.

Recent studies have also emphasized that climate change impacts on fruit production are not uniform and vary across crops and regions. A study of Pakistan's fruit sector indicates that climatic variables, such as temperature, precipitation, and carbon emissions, have both positive and negative effects, depending on the type of fruit and location. However, overall evidence suggests that climate change poses a significant threat to fruit productivity, particularly in vulnerable regions (Chandio, Gokmenoglu, Joyo, & Jiang, 2023)

In the context of Gilgit-Baltistan, climate change impacts are more pronounced due to geographical and environmental constraints. Farmers in the region have reported rising

temperatures, reduced snowfall, and changing precipitation patterns. These changes affect the availability of irrigation water and disrupt traditional agricultural practices (Baigal, 2022). Since fruit crops such as cherries and apricots are highly dependent on climatic stability, these changes significantly influence their growth cycles and productivity.

The importance of fruit production in mountainous regions extends beyond food security to livelihoods and economic development. In northern Pakistan, fruits such as apricots and cherries play a vital role in household incomes and regional trade. Studies indicate that apricot production forms a key component of rural livelihoods in the Himalayan region, contributing to both subsistence and commercial agriculture (Kousar, Makhdum, Abbas , Naseer, & Nasir, 2019) . However, climate change threatens this economic stability by reducing production and increasing vulnerability.

International literature provides further insights into the impacts of climate change on fruit production. A systematic review of temperate fruit and nut production highlights that climate change affects yield, quality, and geographic distribution of fruit crops. It also emphasizes that increasing temperatures and water stress significantly reduce productivity and alter growing conditions (Juliana , Fernandez , Ribera-Fonseca , & Vieli, 2024) . These findings are particularly relevant for high-altitude regions such as Gilgit-Baltistan, where climatic conditions are already marginal for agricultural production.

Similarly, studies conducted in Nepal show that climate change has led to shifts in agroclimatic zones, altering crop suitability and production patterns. Farmers have reported delayed maturity, poor fruit quality, sunburn damage, and reduced pollination efficiency due to climatic variability (Subedi, 2019). These findings closely resemble the conditions observed in Gilgit-Baltistan, suggesting that mountain regions across South Asia face similar challenges.

In addition to biophysical impacts, climate change also has significant socio-economic implications for farmers. Research from Tunisia and Chile indicates that climate change contributes to production losses, increased costs, and financial instability for fruit farmers. Water scarcity, extreme weather events, and changing climatic conditions increase production risks and reduce profitability. However, farmers' ability to cope with these challenges varies depending on access to resources, institutional support, and technological adoption.

Adaptation to climate change has become a key area of focus in agricultural research. Farmers adopt various strategies to cope with changing climatic conditions, including adjusting planting dates, using improved crop varieties, adopting efficient irrigation systems, and implementing pest management techniques (Deressa & Hassan, 2009) . However, the effectiveness of these strategies depends on multiple factors, including access to information, financial resources, and institutional support.

In Pakistan, farmers are generally aware of climate change and its impacts, but their capacity to adapt remains limited. Studies indicate that lack of access to extension services, financial constraints, and weak policy support hinder the adoption of effective adaptation strategies (Abid, Schilling, & Zulfiqar, 2016) . These challenges are particularly severe in remote areas such as District Ghizer, where infrastructure and institutional support are limited.

Another important aspect of climate change is its impact on pest and disease dynamics. Rising temperatures and changes in humidity create favorable conditions for the spread of pests and diseases, leading to increased crop losses. Studies show that climate warming enhances pest survival and reproduction rates, thereby increasing their impact on agricultural productivity (Deutsch , et al., 2018). For fruit crops, this results in significant losses in both yield and quality.

Climate change also affects post-harvest processes and supply chains. Fruits such as cherries and apricots are highly perishable and require efficient storage and transportation systems. Extreme weather events such as floods and landslides disrupt transportation networks, delay market access, and increase post-harvest losses (Lobell & Burke, 2010). In mountainous regions like Gilgit-Baltistan, where infrastructure is already weak, these challenges are even more pronounced.

Despite the growing body of literature, several research gaps remain. Most studies in Pakistan focus on staple crops such as wheat and rice, while high-value fruits such as cherries and apricots receive limited attention. There is also a lack of region-specific research that integrates climatic trends with fruit production outcomes in mountainous regions. Furthermore, limited research has examined the challenges farmers face in adapting to climate change in these areas.

In addition, existing studies often focus on either biophysical impacts or socio-economic aspects, but rarely integrate both dimensions. A comprehensive understanding of climate change impacts requires linking climatic variables with production patterns and farmer responses. Such an

approach is particularly important in regions like District Ghizer, where agriculture is closely tied to environmental conditions and livelihood systems.

Therefore, there is a need for more localized, integrated research examining how climate change affects fruit production and how farmers respond to these changes. Understanding these dynamics is essential for developing effective policies and strategies to support climate-resilient agriculture. This study contributes to the existing literature by focusing on cherries and apricots in District Ghizer and comprehensively examining both production impacts and adaptation challenges.

CHAPTER 3

METHODOLOGY

In methodology, we will discuss the description of the study site, Data types and Sources, Unit of data collection (UDC), Sampling, and the data analysis, which are explained below:

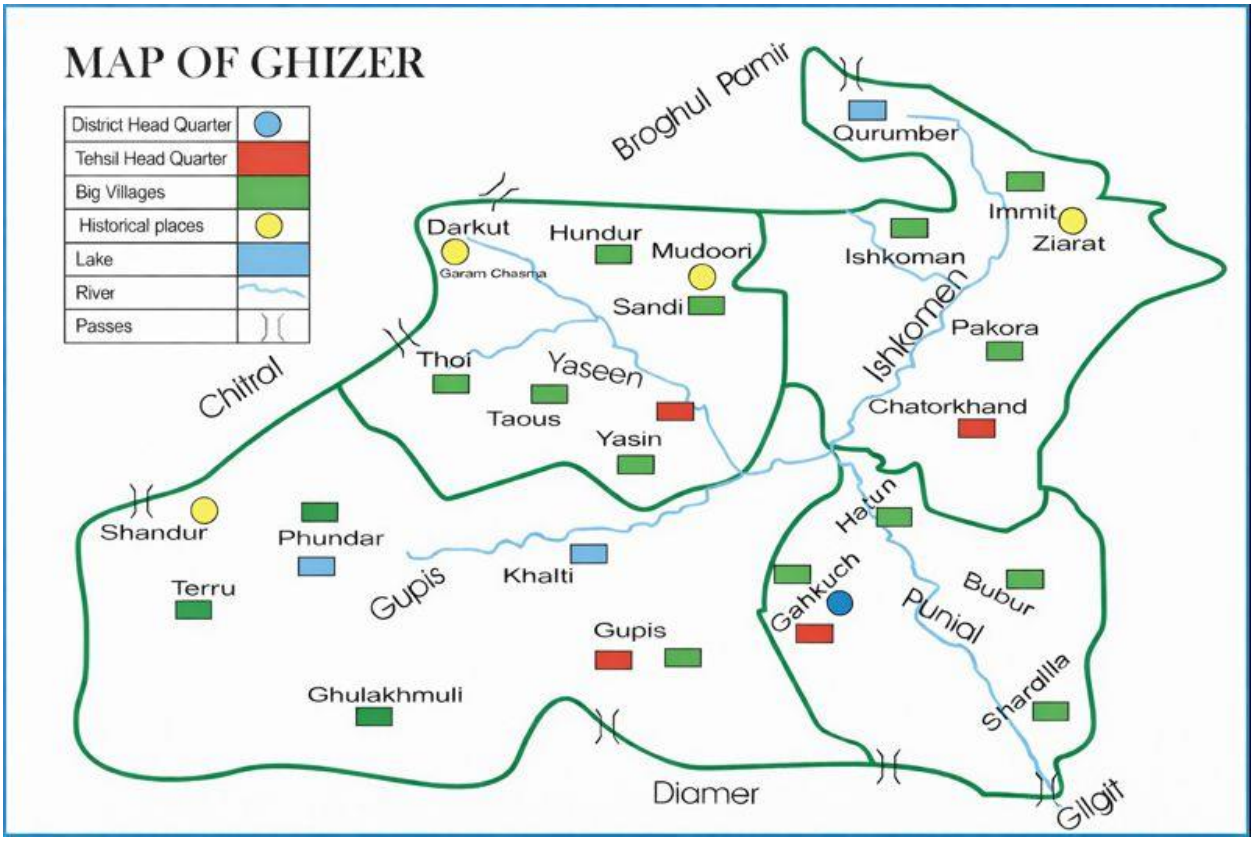
3.1 Description of Study Site:

District Ghizer is one of the ten districts of GB, located in the northern part of Pakistan, with a total area of 12,381 square kilometers. The district is located in western Gilgit-Baltistan. District Ghizer shares borders with Chitral in Khyber Pakhtunkhwa via the highest peak in Ghizer, Koyo Zom (6,871 m), a part of the Hindu Kush Range that serves as a boundary between Ghizer and Chitral; the Wakhan Corridor in Afghanistan; and other districts of Gilgit-Baltistan. The Shandur Pass, the Qurumbar Pass, the Hayal Pass, the Bichhar Pass, the Thoi Pass, and the Darkot Pass are some of the prominent mountain passes in this district. Some of the most historically important valleys in the district include Koh-i-Ghizer, Golaghmuli, Ishkoman, and Yasin Valley. It is marked by rugged mountain ranges, deep gullies, many rivers and streams, and an average elevation of 13,287 feet above sea level. The area is characterized by mountains and peaks. and has a unique geography, a variety of climatic conditions, and agricultural importance. The common languages in the district of Ghizer are Shina, Khowar, Burushaski, and Wakhi, and Urdu is also popular. The climate in the area is predominantly cold in winter, with a few months spilling over into spring and summer. The soil is also fertile due to its favorable temperature variation, which is favorable to the production of some fruits, such as cherries and apricots.

In Ghizer, the effects of climate change on the large fruits**,** including cherries and apricots**,** have been common. The economic value of the fruits has also guided this research, as Gilgit Baltistan's fruits are highly valuable, benefiting the entire country and the locals who rely on their revenue for their livelihoods.

3.1.1 Map of the study Area:

Figure 1: Map of the Study Area



Source: Online website

3.2 Data types and Sources:

We have employed both primary and secondary data in the research. The secondary data concerning the production of fruits and climate indicators during the last two decades, and the primary data obtained by conducting a structured questionnaire among farmers, are gathered.

The policy of the Provincial Agriculture Sector of Gilgit-Baltistan was examined, and the issues with its implementation were investigated through semi-structured interviews with key stakeholders, including representatives of the government of agriculture and climate specialists.

A survey has also been conducted on the effects of climate change on major fruits, in addition to the interview.

3.3 Unit of data collection (UDC):

The primary data for this study are individual fruit farmers in District Ghizer, Gilgit-Baltistan. These farmers are personally experienced in cultivating significant fruits such as cherries and apricots, and they are also well-informed about the impact of changing climate trends on fruit production.

UDC-1: Climate Data:

The first data collection involves secondary data on climatic information in the last 20 years (2004-2024). The important variables to observe in the area include the mean, maximum, and minimum temperatures, precipitation, and other factors. This information has been collected in Pakistan Meteorological Department (PMD).

UDC-2: Local Farmers:

The second unit of data collection involves primary data gathered from local farmers through structured questionnaires and interviews. A sample of around 119 farmers is selected/surveyed from different tehsils of District Ghizer, including Yasin, Ishkoman, Phander Gupis, and Punial, to ensure geographical representation.

UDC- 3: Agricultural and Climate Experts:

The fourth data collection unit comprises qualitative data from agricultural and climatic experts, collected through Key Informant Interviews (KIIs). Some 13 professionals, including agricultural researchers, agriculture department officers, climate experts, local journalists, and a senior community member, have been interviewed.

3.4 Data Sampling:

i. **Population:** The participants for the research are Farmers, Climate experts, and the officials of the agriculture department of District Ghizer.

ii. **Sampling Technique:**

The thesis uses probability and purposive sampling methods to ensure representativeness and expertise.

Purposive Sampling:

Purposive sampling is followed when hiring agricultural and climate experts and Agriculture Department employees. These respondents have been purposively selected due to their knowledge, experience, and involvement in agricultural and climate-related program planning and implementation in the Gilgit-Baltistan region. The semi-structured Key Informant Interviews (KIIs) are used to interview approximately 13 experts.

Probability Sampling (Stratified Random Sampling:

A stratified random sampling technique is employed in the farmers' survey. The area of study (District Ghizer) will be divided into 5 generalized strata, namely, big valleys of fruits (Yasin, Gupis, Phander, Ishkoman, and Punial). Random sampling of farmers (c. 120 people) is done in each valley. In doing this, all important areas that bear fruit are well represented, and so sample bias is minimized.

iii. Sample size:

For this thesis, the estimated sample covers all three identified UDCs. The farmer's survey is conducted through questionnaires with a sample of 119 farmers spread across different valleys of District Ghizer (Yasin, Phander, Ishkoman, and Punial) to cover geographical variability and to identify differences in perceptions and practices. In the country of Gilgit-Baltistan (GB), most of the areas are located at high altitudes, and geographical access is difficult. The UDC-3 used in this study consists of the farmers involved in fruit production in District Ghizer, thus data on the effects of climate change on fruit production and supply chain disruptions will be gathered by probability sampling, which means all the farmers in the target population have a non-zero and known chance of being interviewed.

3.5 Data Analysis:

As the study's first objective is to review the existing climate change and agricultural policies in Gilgit-Baltistan, we have to review the Provincial Agriculture Sector Policy and the climate change policy of Gilgit-Baltistan, but the gap is that the policy didn’t exist in the official documents from the agriculture and meteorological departments, claiming that they are working on the draft. And for analyzing climate-related disruptions that affect the timely market supply and for analyzing

farmers' adaptation strategies regarding climate-induced changes in fruit production and the challenges they face for this purpose, thematic analysis and descriptive statistics is used.

3.5.1 Qualitative Data:

For this thesis, for the qualitative data, we use thematic analysis, which is explained below

a. Thematic Analysis:

In qualitative research, thematic analysis and content analysis are the common methods of data analysis that use non-numeric data to achieve meaningful results (Neuendorf, 2018). Vaismoradi et al . (2016) highlighted the difference between content analysis and thematic analysis. According to them, both methods involve identifying themes, but in content analysis, themes and categories are predefined, whereas in thematic analysis, themes emerge from the data. Bryman (2016) defines thematic analysis as the discovery of key themes and concepts. This method is not limited to data summarization but also includes meaningful analysis and interpretation of qualitative data. During thematic analysis, after the collection of qualitative data, the review of transcripts helps develop a set of themes and sub-themes, based on which the data will be analyzed, interpreted, and organized (Khan, 2022). Virginia Braun and Victoria Clarke (2006) developed six steps of the framework of thematic analysis

1. Review of collected data (Familiarizing) familiarizing with data
2. Generating initial codes
3. Searching for themes
4. Reviewing themes
5. Defining and naming themes
6. producing the report

A structured step-by-step process was used in this study to undertake the thematic analysis procedure. Interviews were held with officials from the Agriculture Department, Meteorological Department, farmers, and senior community members, as well as local journalists in District Ghizer. Collected data was then transcribed and re-read to become familiar with the content and get a deep understanding of participants' point of view. Initial codes were created through a systematic process of finding meaningful statements and patterns about the impacts of climate change, fruit production and adaptation. The codes were analyzed to identify themes by combining

similar codes. The identified themes were subjected to a round of reviewing and refining to make them coherent, consistent and aligned to the coded data. Fifth, the themes were well stated and suitable; they were accurate representations of the concepts. Lastly, the analysis was consolidated within the structure of a narrative and the final report was written which documents the results in line with the research questions.

3.5.2 Quantitative Data:

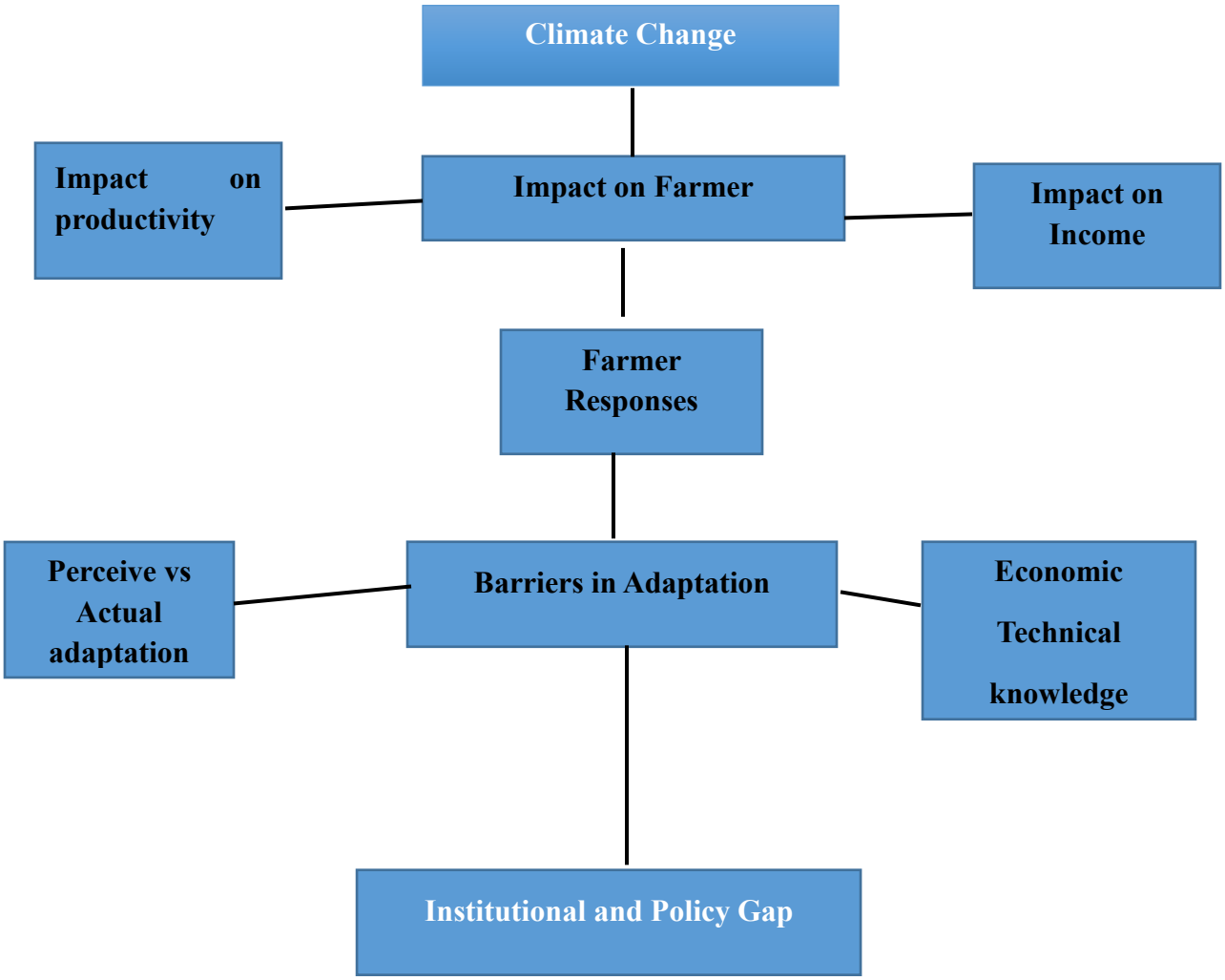
In this thesis descriptive statistics is used for the quantitative data which is explained below model, which are explained below

a) DESCRIPTIVE STATISTICS:

The study uses descriptive analysis to analyze the survey (UDC-1 farmer). The frequency, percentages, mean, and standard deviation have been used to summarize farmers' responses. This approach enables us to understand how farmers perceive climate change in the area, how it affects fruit production, how they adapt to it, the supply chain, and how institutions would support them. The findings are also explained using tables and other visual materials, such as pie charts, which help provide a clear picture of the data's general trends and patterns.

3.6 Conceptual framework:

Figure 2: Conceptual framework



Chapter 4

Results and Discussion:

In this chapter, we explained the content analysis of the policies, the thematic analysis of the interviews, and the descriptive analysis of the survey results.

Among the objectives, the first is to review the agriculture and climate change policy; but unfortunately, in interviews with officials, it was disclosed that Gilgit-Baltistan does not currently have a finalized, fully accepted climate change policy. Department representatives claimed that the climate change policy framework is still in development and has not yet been approved or implemented. Consequently, there is no well-organized regional structure to address climate adaptation and mitigation in vulnerable areas.

Likewise, according to interviews with officials from the Agriculture Department, an agricultural policy is also in the early stages. The consultations and drafting processes are underway, but there is no comprehensive, officially announced agricultural policy in Gilgit-Baltistan at the moment. This situation limits the provision of synergistic technical advice, strong farming suggestions, and future strategic direction for fruit growers.

It is clear that there is a gap in the region's policies, with none having been created in the climate or agriculture sectors. This policy gap hinders the planning, institutional support and implementation of feasible adaptation measures for cherry and apricot production, which is increasingly affected by climatic stress. Consequently, the farmers of District Ghizer are more vulnerable to climate hazards**,** and there is no structured support to help them cope with the ongoing environmental change.

4.1 Thematic Analysis:

Key Informant Interviews (KIIs) were conducted with the government agencies, academia, climate journalists and senior locals to assess the challenges and changes in the production, supply chain, and adaptation measures of the fruit sector to climate change. The government agencies include the Agriculture Department, Gilgit Baltistan; the District Agriculture Extension, Gilgit Baltistan;

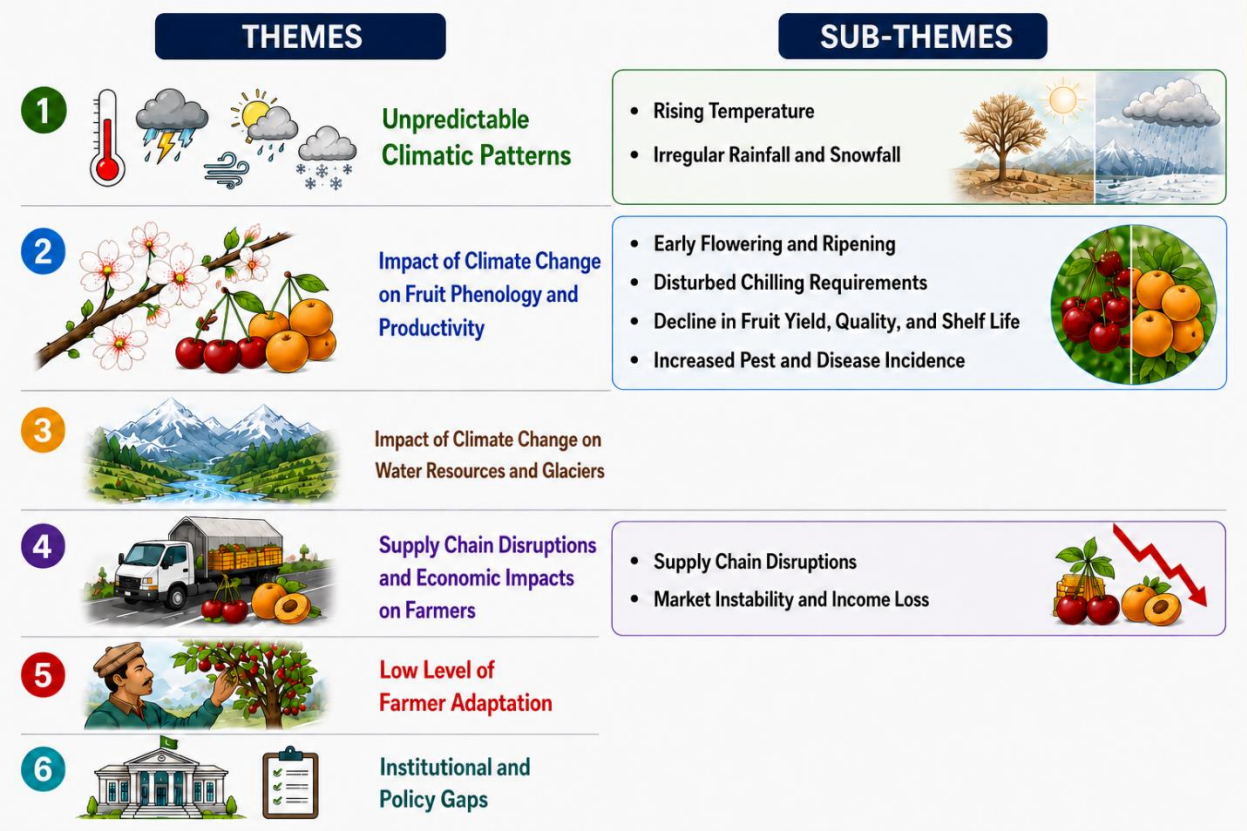
the Pakistan Meteorological Department, Gilgit Baltistan; and the Head of the Department of Forestry, Range and Wildlife Management from the Karakoram International University, Gilgit Baltistan, who were selected to represent academia. Along with government agencies, the climate journalists from District Ghizer are also included in the interview to share their experiences with climate change in the district. And the senior local, who has great experience with climate change and is also a farmer, interviewed him for his perspective. The descriptions of the respondents are;

Table 1: Distribution of Key Informant Interviews

Organization	Organization form	Number of Respondents
Agriculture Department Gilgit	Government	6
District Ghizer Agriculture Extension Department	Government	2
Pakistan Meteorological Department, Gilgit Baltistan	Government	1
Karakoram university	Academia	1
Local Journalist	Private	2
Senior local	Local	1

In thematic analysis, after the interview and data collection, the familiarizing process is applied to review the data. After multiple reviews of data, different themes emerged. When themes emerged, they were classified by theme number as described in the figure. In this study, after multiple reviews of collected data, nine themes were identified. The nine themes identified after thematic analysis are Perceived Climate Change and Changing Climatic Patterns, Impact of Climate Change on Fruit Phenology, Decline in Fruit Yield, Quality, and Shelf Life, Increased Pest and Disease Incidence, Supply Chain Disruptions, Market Instability and Income Loss, Low Level of Farmer Adaptation, and Institutional and Policy Gaps.

Figure 3: Themes and Sub-Themes of Thematic Analysis



4.2 Thematic Analysis of Themes:

Detailed discussion about the themes of thematic analysis is as follows,

4.2.1 Theme 1: Unpredictable Climatic Patterns:

Climate change has long been recognized as a global environmental problem, with its effects more pronounced in developing nations. Despite Pakistan's contribution to global greenhouse gas (GHG) emissions being less than 1 percent, it is one of the nation's facing the greatest consequences of climate change. Gilgit-Baltistan, being a mountainous area, is highly fragile, with its ecosystem, water resources, and livelihoods dependent on glaciers and climate. The Ghizer District is an agrarian area with high-altitude terrain and is increasingly exposed to climatic variability. The theme examines respondents' perceptions and lived experiences of the district's changing climatic patterns.

In all the interviews, climate change proved to be a glaring and undeniable fact in District Ghizer. The people who work in agriculture departments, research institutions, meteorological services, journalism, and local communities all agreed unanimously that the region had undergone significant climatic changes over the last two to three decades. Climate change was not understood as a short-term or periodic phenomenon but rather as a long-term change in environmental stability and the predictability of seasons.

The respondents emphasized the lack of applicability of set climatic norms. Both institutional and community respondents described climate change as a disturbance of the natural balance, in which past experience and knowledge do not necessarily explain the current behavior of the climate. While there were differences in the specific jargon and professions used, there was high agreement that climate change is a constant and fast-changing process. The injustice of climate change was also mentioned by respondents. While Pakistan's contribution to climate change emissions reduction is very small, a lot of people were concerned about the disproportionate burden of climate change risks in areas like District Ghizer. It was particularly noticed by the community respondents, who saw climate change as leading to greater uncertainty and insecurity over their livelihoods. Overall, climate change was seen as a systemic problem with environmental, social and economic impacts, requiring long-term and local adaptation solutions. There is significant awareness of the district community to climate change and its increasing threat in District Ghizer in the theme on changing climatic patterns. The results are credible because the perceptions of the respondent groups are similar. Climate change is not just an abstract, but something lived as a fact, changing the stability of the environment, making it more vulnerable and thus, more urgent, the realization of adaptation and resilience-building plans.

a. Sub-theme: Rising Temperature:

The scientific evidence shows that global temperatures are steadily increasing, and since the middle of the 19th century, the average global surface temperature has increased by about 0.11 degrees Fahrenheit (0.06 degrees Celsius) per 10 years(Lindsey & Dahlman, 2025)**.** Research has indicated that average annual temperatures in 2001-2010 were about 0.33 °C higher than it was in 1955-2000 in Gilgit-Baltistan (Raza & Hussain). These trends imply that the high-altitude areas are warming faster than the rest of the globe.

The rising temperature emerged as one of the most powerful and frequently used subthemes in interviews. Respondents reported a universal rise in summer temperatures across District Ghizer. Regions that had hitherto been characterized by moderate weather conditions, such as Yasin, Darkut, and Phandar, were reported to be extremely hot, especially during the summer months, when temperatures reached 30-35 degrees Celsius.

"*..the Metrologic department notifies that the temperature in Darkut has reached 35 degrees centigrade*." (respondent 11)

One respondent claims that the mean temperature of the Gilgit region increases by 0.7 **°C**

"*… mean temperature of the Gilgit Region has increased by 0.7* ***°C..."*** **(respondent 13)**

Older respondents related today to their childhoods, when they used to need a blanket at night during summer, whereas today they need a fan and cooling systems.

"*…in the early days we used blankets at night in the summer, but now we need fans day and night*."(respondent 12)

Respondents also indicated that changes in seasonal patterns have been caused by rising temperatures. Summer was reported to be longer and harsher, while winter has been shortened and milder. Also, the spring and autumn seasons were seen to be diminishing. Scientists, government officials, and experienced farmers agreed that these observations were generally consistent with scientific data and lived experience.

The sub-theme of rising temperatures shows a clear pattern of increasing warmth across District Ghizer. The respondents across all generations and groups reported similar evidence. This suggests that rising temperatures are indicative of long-term climatic shifts, rather than temporary fluctuations. This warming has disturbed the seasonal equilibrium, and has impacted agriculture, water availability, and human comfort.

b. Sub-theme: Irregular Rainfall and Snowfall:

Precipitation patterns are very important for maintaining agriculture, replenishing glaciers, and supplying water in high-altitude areas. In District Ghizer, snowfall has been known to play a long-term role in storing water, whereas rainfall was known to support crop growth. Climatic change

has been driving increases in the timing, intensity, and predictability of precipitation, exposing people to climatic hazards.

Irregular rainfall and snowfall patterns were also widely reported. Respondents noted that snowfall is decreasing and that the snowfall pattern has shifted, previously occurring consistently in the winter months, towards late winter or early spring. In some years, snowfall is minimal, while in others it occurs unexpectedly during flowering periods, causing severe damage to fruit crops.

"*.. we noticed that that snowfall pattern is shifted toward spring. When the blossom season started, suddenly there was snowfall*." (respondent 7)

Snowfall has decreased over the past decades. Respondents say that in the winter months, the Ghizer valleys experience the highest snowfall. But this year, in December 2025, there has been no snowfall, which is a major concern because the district depends on glacier water for drinking and agricultural use.

"*..in my school days, heavy snowfall used to occur at the end of October, covering the mountains entirely in white. We used to make our own paths to school, and there would be no one else around. The snow would be at least four feet deep. And now you see, today is mid-December, and there is no snowfall*…"(respondent 12)

The respondent states that Rainfall has become increasingly erratic and intense, with downpours becoming sudden and heavy rather than the light, predictable rains of the past. Most respondents highlighted that rainfall during flowering causes flower dropping, fruit cracking, fungal attacks, and ultimately low yields. The changes have disrupted the normal agricultural calendar, leaving farmers uncertain and more at risk.

"… *When flowering starts on trees, sudden and unpredictable rainfall occurs, which causes the flowers to fall off. As a result, fruit production decreases*…" (respondents 1 & 4)

The respondents attributed that when the rain falls at the right time and evenly, as is necessary in the flowering and fruit setting, it is slowly becoming less. Meanwhile, rainfall is becoming increasingly unpredictable, coming quite unexpectedly and at inappropriate times.

The sub-theme of abnormal rainfall and snowfall highlights the growing climatic uncertainty in District Ghizer. Reduced and relocated snowfall poses a long-term threat to water security, and

unpredictable rainfall increases the risk to agriculture. These shifts indicate larger-scale climatic instability and the need for better water management, climate-resistant agricultural practices, and early warning systems.

4.2.2 Theme 2: Impact of Climate Change on Fruit Phenology and Productivity:

The timing of biological processes, including flowering and the setting and ripening of fruits, is highly dependent on climatic conditions, particularly temperature and winter chilling. At high altitudes and in regions with temperatures below 30 degrees Fahrenheit, gradual climatic changes can affect the development of plants. Major crops in District Ghizer, such as cherries and apricots, need specific temperatures and chilling hours to ensure proper behavioral cycles. This has gotten worse due to climate change, including the decrease of winter cold and increased temperatures.

All the interviewees named climate change as an important agent of disruption in the natural biological timings of the fruit crops of District Ghizer. Fluctuations in flowering, fruit setting and ripening were recorded by officials and researchers alike. Farmers too noted these changes. These disruptions are not what can be considered minor differences in timings between flowering and setting; rather, they are big changes that have a direct effect on the quality, quantity, and marketability of the crops. It was noted by many that disrupted biological timings of the crops are a direct, observable, and notable result of climate change. Of those interviewed, just about all agreed that traditional agricultural calendars are no longer valid as the timings of the stages of fruit development occur earlier and are unpredictable. This has increased both the climatic and economic uncertainties for farmers. The widespread observations of disrupted biological timings of crops, both by farmers and those in the agricultural value chain, of course explains the validity of the results. This disruption of biological timings is not either sporadic or occasional.

a) Sub Theme: Early Flowering and Ripening:

One of the most recurring sub-themes in the interviews was the changes in the flowering and ripening of cherries and apricots. Respondents indicated that flowering has occurred 10 to 15 days earlier than before. In extreme cases, they were observed to flower out of the normal season.

Early ripening has resulted in fruits entering the market before buyers arrive from down-country areas, leading to economic losses for farmers.

The issue of early flowering and ripening became serious. According to the respondents, the cherry and apricot are now flowering 10-15 days earlier than they used to. A number of respondents mentioned that the flowering time of cherries and apricots is shifting earlier from 15 April to the first of April. Which significantly impacts quality and reduces production.

"*.. the flowering of cherries and apricot shifts to the first of April, which has an impact on the quality of the fruits*…" (respondent 9&8)

A number of interviewees mentioned unusual events, e.g., cherry blossoming in November, which was described as totally unnatural.

"…*Sometimes the Flower of the fruits are ripening even in November due to the increasing temperature* ..." (respondent 7)

Due to early flowering, the maturity time has also shifted to early. Early maturing has disrupted market timing because, in most cases, fruits are ready before traders arrive in lower regions. Consequently, it either saturates the market at once or becomes spoiled by the absence of immediate customers, resulting in huge financial losses for farmers.

The sub-theme of early flowering and ripening shows a clear change in the phenological time of cherries and apricots in District Ghizer. The recurrent nature of previous and abnormal flowering instances points to the close connection between rising temperatures and distortions in biological cycles. Besides diminishing the quality and yield of the fruit, these alterations also delay the time to market, which ends up costing the farmer a lot of money.

b) Sub-theme: Disturbed Chilling Requirements:

High-temperature fruit trees require a certain number of winter chilling hours to break dormancy and ensure normal flower and fruit development. Synchronized bud break, successful pollination, and fruit set require sufficient chilling. Due to warmer winters in many high-altitude areas caused by climate change, chilling accumulation is decreasing, which threatens fruit yields.

Several of the respondents elaborated that chilling of a fruit tree has been adversely affected by a lower degree of winter chilling. Poor chilling results in abnormal flowering, poor pollination, and weakly set fruits. It was reported that apples, cherries, and apricots were especially prone to these changes, leading to uneven fruit development and low yields. The phenological changes represent

a direct biological response to increased temperature and are commonly the first consequence of climate change in the field.

The disturbed chilling need sub-theme indicates a highly important physiological effect of climate change to fruit crops in District Ghizer. Less chilling of fruits and reduced or absent normal flowering and fruit setting have affected yields, resulting in fewer and less predictable yields. The results highlighted that climate change is transforming fruit production at the biological level, further supporting the use of adaptive horticultural and climate-adaptive crop management practices.

c) Sub Theme: Decline in Fruit Yield, Quality, and Shelf Life:

The main source of livelihood in District Ghizer is fruit production, with cherries and apricots accounting for a major share of household income and local markets. Climatic factors such as temperature, rainfall, humidity, and water availability strongly influence fruit yield, quality, and shelf life. The frequency of heat stress, unpredictable rainfall, and water scarcity resulting from climate change directly impacts crop productivity and post-harvest performance. This theme reflects the views of farmers and experts on the declining productivity, poor quality, and shortening shelf life of fruits under changing climatic conditions.

This theme reflects the findings of farmers and experts on the decline in fruit productivity and quality in the market.

The fruit production is also determined by flowering, pollination, fruit set, as well as whether water is sufficient and provided enough to grow the fruits. These stages may be drastically derailed by climatic extremes, including heat waves, rainfall during flowering, and prolonged dry spells. The disturbances may cause partial or total crop failure in climate-sensitive areas such as District Ghizer.

The results of almost all respondents indicated a reduction in total fruit yield. The main climate-related effects identified were heat waves, rainfall during flowering, and water scarcity. In certain years, crops fail entirely due to sudden climatic shocks.

The low yield reflects climate change as the key driver of decreased fruit productivity in District Ghizer. Rising climatic insecurity and extreme events have disrupted natural production processes,

resulting in reduced, less predictable yields. This would constitute a significant drain on the household and sustainable agricultural production on the land in the long term.

Fruit quality- Size, Color, taste of fruits, sweetness, and appearance are all important factors that determine the value of the fruits. It requires good climatic conditions that allow for the gradual, natural maturation of fruits. Nevertheless, when it is too hot, humid, or rainy during ripening, physiological development may be disrupted, leading to low-quality fruit.

The deterioration in quality became one of the central issues for the respondents. There were also major alterations in fruit quality, including smaller size, poor color formation, reduced sweetness, and altered taste, as observed by farmers and experts. Respondents pointed out that nowadays fruits ripen too quickly and fail to mature naturally, which negatively affects taste and texture. The ripening period was also reported to make the fruit less appealing and less valuable due to humidity and rainfall. Another quality issue often reported was increased fruit cracking, especially in cherries. These flaws cause fruits not to meet the high-end market standards, leaving farmers to sell them at lower prices or dump them altogether.

The quality deterioration sub-theme shows that climate change is not limited to the quantity of fruit in District Ghizer but also affects its marketability. Loss of size and color, loss of sweetness, and increased cracking significantly reduce fruit value. The resulting quality losses increase farmers' economic vulnerability, even in seasons with seemingly healthy yields.

An important post-harvest trait that affects storage, transportation, and market access is shelf life. Fruits like cherries and fresh apricots are naturally perishable, and when the temperature is high, the fruits breathe and decay very quickly. Cold storage and post-harvest facilities are lacking, so climate change further reduces shelf life.

According to the respondents, the shelf life of cherries and fresh apricots is currently reduced to 4-5 days due to the weather conditions. The first factor found to increase fruit respiration and spoilage rates was high temperature. The farmers have no access to cold storage facilities and must sell their produce as quickly as possible at an unfavorable price. The short shelf life prevents farmers from transporting fruits to distant markets and incurring losses after harvest. Respondents noted that the decline in quality and the short shelf life are two phenomena that go hand in hand,

as the accelerated ripening and spoilage processes decrease market value and consumer acceptability.

The short shelf-life subtheme highlights the critical post-harvest effects of climate change on fruit production in District Ghizer. High temperatures and insufficient storage facilities have greatly shortened fruit shelf life, thereby increasing spoilage and financial losses. Shelf-life issues need to be addressed through climate-adaptive responses and enhanced post-harvest management. systems.

This Theme shows that climate change has significantly affected fruit yields, quality, and shelf life in District Ghizer. Low productivity, poor quality, and high perishability have impaired farmers' incomes and their market competitiveness. Similar to these results, there is a need to develop integrated adaptation strategies that minimize on-farm production risk and post-harvest vulnerability to enhance resilience in the fruit industry.

d) Sub Theme: Increased Pest and Disease Incidence:

The well-being of crops relies on certain weather conditions. Without a stable climate, crop growing seasons and insect populations will change and adapt. Higher temperatures and humidity create environments that help the spread of diseases, such as plant infections and fungal infections. This can be devastating to fruit-producing regions, like District Ghizer, which produces cherries and apricots. The region can be impacted by all forms of pest and disease stress and biotic stress, which can lead to pest pressure.

The respondents noted a rise in pest problems and plant diseases. There is an increase in reported infections and pest strikes of particular concern. Reported new pest infections risk posed by changes in temperature and humidity. Increased plant diseases and pest problems have led to the spread of new infections.

"…*after rainfall suddenly increases in temperature, that environment is favorable for the pests which attack the fruits*…"

In the time of flowers, the rainfall is linked to fungal diseases and fruit damage, further reducing productivity.

"*…we see an absorption of fungal attack on fruits after rainfall during the flower stages and ripening stage…*"

The results demonstrate a significant association between climate change and pest and disease pressure in District Ghizer. Farmers particularly face new biotic stressors as newer pests and fungal diseases continue to be a growing concern. Potential solutions for these challenges might include management of early warning systems and climate-related pest control and biotic stress adaptive agronomic practices to reduce losses to yields and keep agriculture productive amidst the challenges of climate change

4.2.3 Theme 3: Impact of Climate Change on Water Resources and Glaciers:

Although glacier melt increases the volume of water available, most respondents stated that the availability of water has become very erratic. Several interviewees also stated that from April to February, a critical time for the flowering and setting of fruit for cherries and apricots, has experienced serious water shortages. Erratic water availability coupled with the timing of shortages to the critical crop stages was frequently stated to be the most damaging impact of climate change to fruit production.

Water shortage also had multiple meanings, including changes in the timing and amount of water supply. Respondents stated that winter season snowfall was low, which resulted in a shortage of early season meltwater, but late season glacier melt was excessive and caused a large water surplus for which there were no storage facilities, and which could not be used for irrigation. As a result, farmers faced significant water shortages during critical crop growth and development periods and, after the crops matured, had an excessive surplus of water.

In addition to seasonal shortages, respondents indicated that severe rainfall and floods caused by glacial melt tend to destroy traditional irrigation systems (Kuhls). Such floods normally erode waterways and obstruct water-supply inlets with debris, altering the normal water supply to the orchards. This damage compels farmers to establish temporary or even ineffective water facilities, which reduce irrigation uniformity at times when it is most needed.

Some respondents were also concerned about water shortages during the summer in certain localities, especially in low-altitude villages and at the tail-end of irrigation systems. Although there is more glacial melt in the summer, water distribution remains uneven, leading to

undersupply in some orchards. Farmers have raised concerns about the sustainability of long-term water sources, fearing that with a rapid increase in glacial melt, the total amount of water would eventually run out.

The water was presented as a more restrictive factor in fruit production in District Ghizer, due to unpredictable snowmelt, decreased snowfall, recurrent flood damage, and inadequate irrigation systems. The respondents highlighted that unless water storage, irrigation maintenance, and climate-resilient water management are improved, the sustainability of cherry and apricot production will remain under serious threat.

This Theme will highlight water availability as a serious, increasingly problematic factor affecting fruit production in the District of Ghizer. Climate change has disrupted the natural hydrologic balance, leading to water shortages during major phenological periods and surpluses during low-demand periods. These difficulties are further exacerbated by the destruction of traditional irrigation systems and the unequal distribution of water.

4.2.4 Theme 4: Supply Chain Disruptions and Economic Impacts on Farmers:

Climate change affects not only fruit production but also the movement of produce from farms to markets, creating significant economic challenges for farmers in District Ghizer. The findings reveal that climate-induced hazards such as floods, landslides, and extreme weather events disrupt transportation networks, delay market access, and increase post-harvest losses. At the same time, inadequate cold-chain infrastructure, limited storage facilities, and weak market support systems reduce farmers' ability to maintain fruit quality and secure profitable prices

I. Sub Theme: Supply Chain Disruptions:

Water is very important for agriculture in high-altitude regions such as District Ghizer, where irrigation is dependent on water from snow, glaciers, and seasonal run-off. In cherry and apricot cultivation, water must be supplied adequately and on time during critical crop periods such as flowering and fruit setting. With climate change, the distribution of water from snowfall and the rate of glacier melting in the region has changed, thereby disrupting the predictable water supply in the region. This variability poses challenges to the management and sustainability of water in glacier-dependent agriculture.

Respondents unanimously pointed out obstruction from landslides and floods as the main disruptions in the fruit supply chain. Such obstructions result in the late arrival of cherries and apricots in many urban markets. Respondents explained that if an obstruction lasts more than 5 days in the summer, when cherries and apricots are exposed to heat, they lead to enormous spoilage of fruits and cause a loss of income to the farmers. Under severe weather conditions, the impacts of the disruptions are tightly coupled to the production and transport of fruits.

Outside of disruptions in transportation, the supply chain's most notable weaknesses include the lack of cold chain systems, lack of cold storage, processing facilities, and grading units. This shortage of infrastructure and facilities limits farmers' ability to keep fruits fresh and extend their shelf life after harvest. Though some respondents reported the use of air-conditioned trucks, these efforts are insufficient and unreachable for the majority of small-scale farmers. Without cold-chain services, farmers are forced to quickly sell products at a loss in order to avoid total product loss.

The supply chain disruptions result in economic losses directly attributed to the effects of climate change, even in productive years. The combination of poor transport systems and insufficient post-harvest systems reduces the ability of farmers to benefit from production under varied climate conditions.

II. Sub Theme: Market Instability and Income Loss:

Areas of District Ghizer respond to environmental and infrastructural factors differently depending on their altitude. In those areas, highly sensitive supply chains deal with the high demands of processing cherries and apricots. This requires harvesting the fruits at the correct time and transporting them in the best condition. Supply chains with good road access, and cold storage, grading, and processing facilities can be effective. However, weak infrastructure, coupled with climate change, has resulted in the increasing disruption of these systems. Consequently, farmers are unable to deliver adequately quality produce, resulting in a loss of potential earnings..

The focus group reported that landslides, flooding, and extreme weather events related to climate change are top contributors to supply chain disruptions. Flood damage and heavy vehicle congestion related to flooding delays the transport of cherries and apricots. The focus group indicated that blockages lasting more than five days will cause irreparable loss to the fruit, which becomes highly perishable during the peak summer, and delays will even facilitate blockages that

will cause spoilage before the fruit reaches its market destination. The interviewee also said that blockages during summer will dry cherries and apricots on the road and result in huge financial losses. Due to supply chain disruptions that climate variability brings, especially during a peak season where fruit production is in abundance, the economy suffers the most. Respondents also listed underdeveloped cold chain infrastructure, besides transport-related problems, as a critical concern. Farmers have scant access to cold storage, grading units, and processing facilities that are essential to maintaining the quality and marketability of fruits. Some measures have been taken, including providing air-conditioned trucks, but the services are still beyond the reach of small-scale farmers. Farmers will also incur post-harvest losses and supply chain contract failures due to climate variability, which will further increase their economic vulnerability. Respondents said that the lack of adequate cold chains increases the risk of selling off fruits at a loss and affects transport and post-harvest infrastructure. The respondents indicate that poor transport networks, inadequate post-harvest infrastructure, and the absence of market support all diminish farmers' resilience to climate shocks, making fruit farming less secure and profitable.

The theme shows that climate change not only alters production levels but also increases supply chain vulnerabilities for fruit in District Ghizer. Due to a lack of cold chain and post-harvest infrastructure, coupled with poor and inadequate transport infrastructure, farmers are unable to deliver fresh fruits promptly. These situations exacerbate the negative impacts of climate change on the economy and create an urgent need to adapt the supply chain to climate change. This can be done by investing in the construction of roads, cold storage facilities, and post-harvest infrastructure to make access to the market for fruit production and supply chain sustainable.

4.2.5 Theme 5: Low Level of Farmer Adaptation:

Climate change adaptation plays a vital role in supporting agricultural output and livelihoods, particularly in climate-prone areas such as District Ghizer, where altitudes are high. Climate-smart farming practices, such as improved irrigation, resistant crop varieties, and defensive infrastructure, can help mitigate the negative impacts of rising temperatures, unreliable rainfall, and severe weather. Nonetheless, farmers' ability to adopt these practices depends on knowledge, access to technology, financial resources, and auxiliary services. This theme examines how much farmers in District Ghizer have adjusted to the new climatic conditions and the major obstacles to successful adaptation.

The majority of respondents emphasized that farmers still depend heavily on traditional farming methods and have not sufficiently embraced climate change adaptation strategies. One contributing factor to this poor adaptation is the lack of training and awareness about climate-smart farming practices. Most farmers lack knowledge of new practices, better crop varieties, or technologies that could help them cope with new climatic conditions.

The second major constraint is that modern agricultural technologies, efficient irrigation systems, climate-resistant seeds, and defensive infrastructure are very expensive. Small farmers cannot invest in such technologies due to a lack of financial means and the inability to access credit. In addition, poor agricultural extension services also reduce farmers' ability to adapt. Lack of support in the field, inadequate technical advice, and infrequent contact with extension officers diminish the effectiveness of broadcasting information on climate and solutions.

Even though farmers are trying to make some changes, such as shifting irrigation patterns or planting times, these are usually responsive and temporary. By themselves, they cannot adequately help address the growing risks posed by climate variability and extreme weather. Farmers are also highly exposed to the long-term effects of climate change without any systematic support, training, or affordable technologies.

The main barriers include:

- Lack of awareness and training
- High cost of modern technology
- Weak extension services

The theme shows that farmers in District Ghizer have yet to adopt climate change adaptation proactively, and their adaptation is largely reactive. Poor extension services, knowledge gaps, and financial constraints are key challenges to implementing climate-smart agricultural practices. Training programs need to be strengthened, opportunities to access affordable technology need to be provided, and extension assistance needs to be renewed to ensure farmers can survive the persistent climatic issues and sustain long-term fruit production.

4.2.6 Theme 6: Institutional and Policy Gaps:

To ensure an effective response to climate change in the agricultural sector, strong institutional backing, robust policy frameworks, research facilities, and advisory services are essential. Institutions play a critical role in advising farmers, providing access to climate-appropriate technologies, and issuing early warnings of weather hazards. In high-altitude areas such as District Ghizer, where climatic variability is high and agriculture is weak, robust governance and policy backing are needed to maintain productivity and subsistence. This theme also addresses respondents' impressions of institutional and policy-level factors that hinder climate change adaptation in the agricultural sector.

Respondents were unanimous in their view that weaknesses in institutional and policy frameworks pose a major challenge to effective climate change adaptation in the agricultural sector. A lack of an apparent, integrated climate change and agriculture policy was also a key area of concern. In the absence of a clear policy framework, efforts to address climate-related risks in agriculture have been fragmented and poorly aligned, undermining long-term planning and sustainable interventions.

Moreover, the absence of institutional training was identified as a fundamental gap. Other institutions and affected departments are typically understaffed with skilled personnel knowledgeable in climate-smart agriculture, risk control, and adaptation planning. This limits their capacity to assist farmers with new knowledge, technical advice, and practical solutions.

Respondents in remote and mountainous regions also raised concerns about limitations in research infrastructure. The absence of research centers and funding, and poor data-collection systems, restricts the development of place-based solutions, such as climate-resilient crop varieties and locally relevant adaptation strategies.

In addition, the agrometeorological advisory service was described as weak or ineffective. Farmers lack access to reliable weather forecasts, early warnings, and climate advisories that can help them determine when to plant, irrigate, and harvest. The absence of such services exposes farmers to climatic shocks and limits their ability to adapt to varying climatic conditions.

Respondents widely agreed that:

- No climate change and agriculture policy
- Lack of institutional trainings
- Research infrastructure is limited
- Agro-meteorological advisory services are weak or absent

This Theme highlights the most significant institutional and policy barriers to climate change adaptation in the agricultural sector of District Ghizer. Poor governance, a lack of clear policy frameworks, weak research facilities, inadequate training, and poor advisory services all reduce farmers' ability to adopt climate-smart practices and adapt to climate risks. To facilitate sustainable agriculture and increase resilience to climate change, it will be necessary to strengthen institutions, ensure policy coherence, invest in research, and improve advisory services.

4.2.7 Theme 7: Future Strategies and Recommendations:

High-altitude areas, such as the District of Ghizer, engaged in fruit production, require proactive planning and the adoption of climate-resilient practices to ensure sustainable production. Fruit farmers have been facing increasing threats from climate variability, extreme weather, and post-harvest losses, which are undermining productivity and livelihoods. Future strategies must address both production and post-harvest issues by incorporating technological, institutional, and human capacity interventions. This topic centers on respondents' recommendations for countering the negative effects of climate change and building long-term resilience in the fruit industry.

The last theme identified through the interviews focuses on a future approach and suggestions to reduce the effects of climate change on fruit production. Respondents highlighted the urgency of adopting climate-resilient practices, such as fruit varieties that withstand unpredictable temperatures, frost, and variable rainfall, to ensure more stable yields. They also emphasized the need to invest in cold storage, processing, and value-addition units to minimize post-harvest losses, particularly rainfall losses during harvesting, and to increase farmers' incomes and market access.

Also, participants stressed the importance of intensifying agro-meteorological services to access timely weather forecasts and better manage and plan orchards. Youth participation in agribusiness was found to be an important element in introducing innovation, modernity, and dynamism in the

sector, whereas farmer training and capacity development programs were viewed as providing growers with climate-sensitive methods and better management skills.

On the whole, the respondents emphasized that unless systemic changes and concerted action occur, the negative impact of climate change on fruit production will only increase. This theme highlights the necessity of an integrated strategy that leverages technological, institutional, and human capacities to maintain orchard productivity, minimize losses, and protect livelihoods in the study area.

This Theme emphasizes the need for an integrated approach to addressing climate change in the fruit industry of District Ghizer. The key suggestion is planting fruit varieties that are resistant to climate change.

• Investment in cold storage, processing, and value-added facilities.

• Improvement of agro-meteorological services to provide timely advisories.

• Promoting youth employment in agriculture and innovation.

• Introduction of agricultural training and capacity development.

The respondents' opinions indicate that the fruit industry can only be resilient to the current and future impacts of climate change through coordinated, multidimensional strategies that yield sustainable production, reduce post-harvest losses, and improve the livelihoods of farming communities.

4.3 Descriptive Analysis:

Primary data were collected from 119 farmers in the District of GZR to examine the impact of climate change on cherries and apricots. Before the survey began, respondents were asked to familiarize themselves with the questions and research objective. The questionnaire was divided into the following sections: demographic characteristics, Tenure Arrangements & Land Information, Labor Composition, Agricultural Inputs, Water Use & Costs, Fruit Production, Outputs & Prices, Climate Impact Assessment, and Supply Chain & Market Access.

4.3.1 Demographic Enquiry of the Respondents:

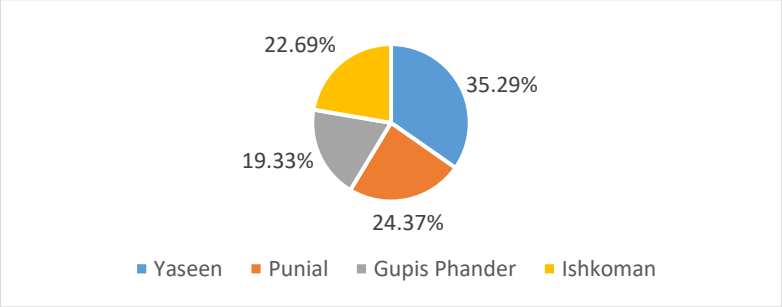
The demographic characteristics of the respondents are explained in tables and a pie chart.

Table 2: Socioeconomic Profile of Respondent

Variable	Average
Age	59 years
Family size	6.3 members
Monthly income	PKR86,017
Annual Income from farming	PKR 0.68 million

The table 2 presented that the average age of respondents is 59 years. The average family size among respondents is 6.3 members. The analysis indicates that the average household spending among surveyed households is about PKR 86,000 per month, which suggests that most households have moderately rated incomes. This average is a composite of lower- and high-income households, and the annual average income from farming is PKR 0.68 million.

Figure 4: Distribution of Respondents by Tehsils



(Author Estimations)

The respondents were distributed across four tehsils of District Ghizer. Most respondents (35.29% of the entire sample) were from Yaseen. Punial accounted for 24.37%, Ishkoman for 22.69%, and Gupis Phander for 19.33%. This distribution reflects the relative representation of respondents across the study's tehsils.

Most respondents were either government or private employees, and farming was their secondary source of income. This analysis indicates that the average household spending of the surveyed households is about PKR 86,000 per month, which means most households have a moderately

rated income. This means that this average is a composite of lmonthly household spending of the surveyed households is about PKR 86,000, suggesting thatower- and higher-income households. The respondents' responses indicate that the mean annual income earned from farming among the surveyed households is about PKR 0.68 million. This average reflects variations in farm earnings, with most farmers clustered in the mid-income range, alongside a few high-income outliers that raise the overall mean. One household (0.84%) out of 119 houses in total in the category of 1-3 members. Households that have 4-6 members makes 47.06%, and most households make 52.10% households, which falls in the 7–10-member family size. Demographic Characteristics of the Respondents

Table 3: Distribution of Respondents by Educational level

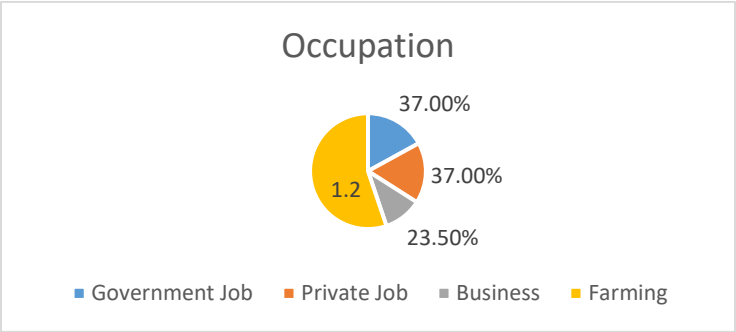
Education level	**Frequency**	**Percentage**
No Formal Education	8	6.67
1-5	18	15.13
6-8	23	25.21
9-12	40	33.61
13-16	30	25.21
Total	119	100

(Author Estimation)

Table 3 summarize the education level of farmers in district Ghizer. Findings revealed that most of the respondents are educated, a very small fraction of farmers were with nor formal education (6.67%).

(33.6%) had completed 9-12 years of education, 25% of the respondents had completed 13-16 years of education,25% had 1-5 years of education, 25.21% had 6-8 years of education, and 6.6% 0f respondent have no formal education.

Figure 5: Distribution of Respondents by Occupation



(Author Estimations)

Distribution of respondents by their primary occupation is displayed in figure 5. Findings revealed that agriculture is not the primary occupation for most of the respondents in the study area. Results showed that most of the respondents were also were government employees, worked in private organizations (37%), owned their own business (23.5%).

Table 4:Farming by Land Size in District Ghizer (n=119)

Land Category (Kanals)	**Cultivated Area** (frequency and %)	**Land Owned** (frequency and %)	**Land Rented Out** (frequency and %)
Small <20	36 (30.3%)	36 (30.3%)	0(0%)
Medium 21–39	24 (20.16%)	21 (17.6%)	3 (2.52%)
Large >40	59 (49.6%)	49 (41.17%)	10 (8.40%)

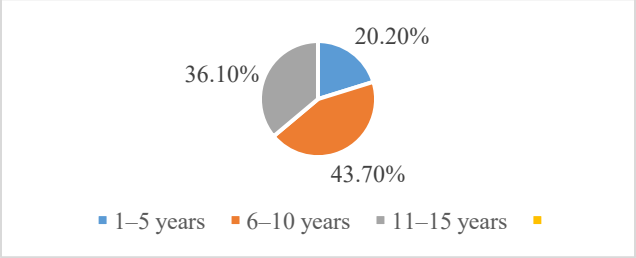
(Author Estimation)

Table 4 indicates the respondents land size that almost half of the farmers (49.6) fall in the large land category (>40 kanals), followed by small farmers (<20 kanals) with 30.3, and finally medium farmers (2139 kanals) with 20.16. This implies that a significant share of arable land is held by large farmers. The same is observed in land ownership, where 41.17% of respondents in the large category own land, compared with 30.3% and 17.6% in the small and medium categories, respectively. When it comes to land rental (land rented out), a minor percentage of the respondents are engaged in land rental. Of small farmers, 0% of the small farmers do not rent out any of their

land, but of the small farmers, 2.52% of medium farmers, and 8.40% of large farmers rent out part of their land. All in all, land rental activity appears relatively inactive and is concentrated in the hands of large landowners.

Nearly all respondents reported that their orchards are located 0.5 km from their residences and that the soil is rich. According to farmers, fertile soil supports the growth of better trees, higher yields, and better fruit quality.

Figure 6: Consistent Land Cultivation by Year

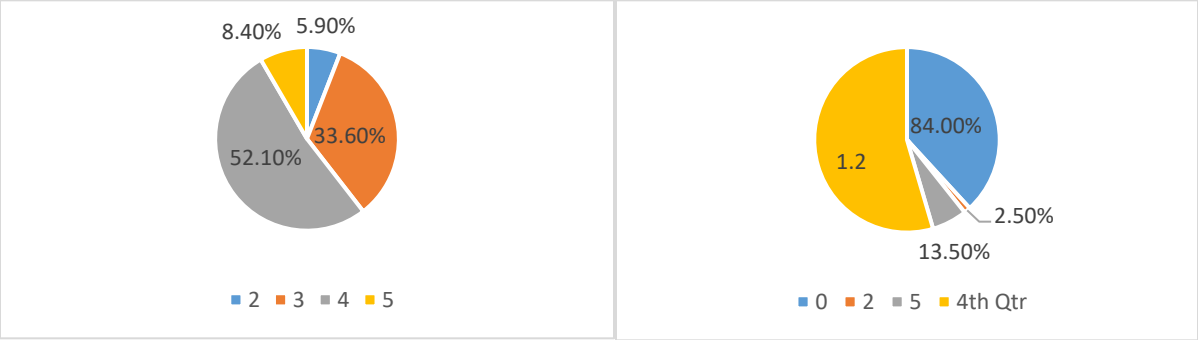


(Author Estimation)

The figure 6 show that the majority of the plots are long-term cultivated. A significant percentage of respondents (43.7%) indicated that they had been farming the same piece of land for 6-10 years, and 36.1% indicated that they had been farming the same piece of land for 11-15 years. Only 20.2% of the respondents had a reduced cultivation period of 1-5 years. In total, these data indicate that land use was stable and farming was long-term, which could lead to enhanced soil fertility, more orchard management, and greater long-term productivity.

All respondents (100 percent) indicated that the water sources used in their orchards are glacier meltwater channeled into canals for irrigation. The farmers depend on this system to provide adequate water at the right time, ensuring proper tree growth and healthy fruit. The integration of glacier-fed water with canal irrigation is especially significant for sustaining orchard productivity during crucial periods, such as flowering and fruit ripening.

Figure 7: Family Member Involved in Land Preparation ***Figure 8: Hired Labor involved in Land Preparation***

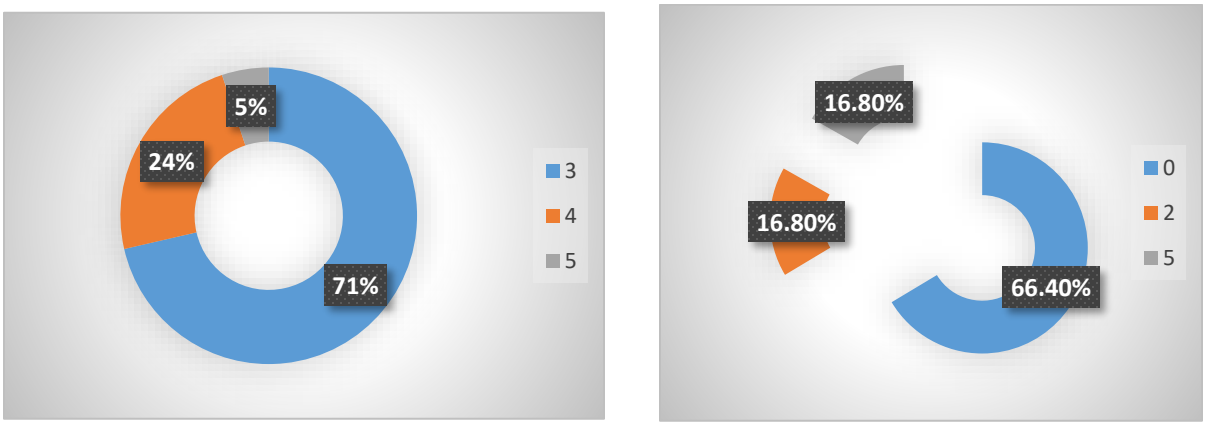


(Authors Estimation)

Figure 7 and 8 presents that respondents' responses indicate that family labor forms the primary workforce when preparing and sowing the land. The majority of respondents (52.1%) reported that 4 family members were working; the next three (33.6%) reported 5, 2, and 3 persons, respectively. By contrast, hired labor is used less frequently. Most (84) of the respondents employed no labor, and only a small proportion (5) employed 5 hired workers, or (2) employed 2 hired workers.

This implies that work on orchard land preparation is mostly done by family labor, with hired labor employed only in isolated cases, likely on large plots or during peak seasons.

Figure 9: Family Member Involved in Field Management ***Figure 10: Hired labour involved in field Management***

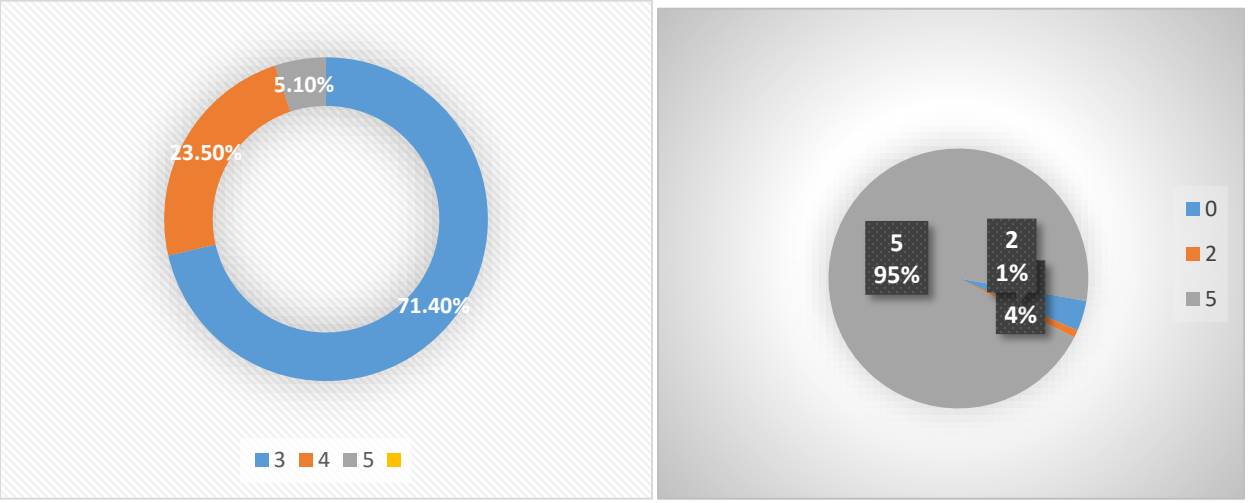


(Author's Estimation)

Figure 9 and 10 shows that respondent's response indicates that field management in the orchards is primarily carried out by family labor. The number of respondents who said 3 relatives were involved in field management was 71.4%, followed by 4 (23.5%) and 5 (5.1%).

Regarding hired labor, the majority of respondents (66.4%) did not employ any hired labor, and the proportions of those employing 2 (16.8) and 5 (16.8) hired laborers were also lower. These findings indicate that orchard field management relies heavily on family labor and that the employment of hired labor is sometimes necessary, perhaps during periods of high workload or when performing unusual tasks.

Figure 11: Family Member Involved in Harvesting ***Figure 12: Hired Labor Involved in Harvesting***



(Author's Estimation)

Figure 11 shows Harvesting is largely contributed to by family labor. The majority of respondents (71.4%) stated that 3 of their family members were involved in harvesting, followed by 4 (23.5%) and 5 (5.1%).

Figure 12 represent hired labor, most (66.4%) hired no workers, while others (16.8%) hired 2, and (16.8%) hired 5 workers. This pattern indicates that harvesting, among other orchard activities, relies primarily on family labor, with occasional hiring, likely during peak harvest seasons or in large orchards.

Nearly all respondents reported applying pesticides to cherry and apricot crops. They said that a single liter of pesticide, when mixed with water, can be used to spray cherry and apricot plants. The average cost of the pesticide is about PKR 2,500 per liter, which is among the highest input costs for fruit growers.

Respondents (almost all of them) also reported that no chemical or organic fertilizers were used in their orchards. According to the farmers, the soil is naturally rich and supports tree growth and fruit production without additional fertilizer. This suggests that orchard management in the study area relies primarily on natural soil fertility, and that farmers use traditional farming practices rather than input-intensive methods.

All respondents said that the water supply during the fruiting season is sufficient. Farmers reported receiving ample water from melted glaciers via canals, which provides adequate irrigation during the most crucial phases, such as flowering, fruit set, and fruit development. A sufficient water supply is linked to healthy tree growth, increased yields, and fruit quality, minimizing the risk of water stress during the most sensitive stages of orchard production.

Table 5: Area Under Cultivation by Cherries and Apricot

Fruits Type	Mean (Kanals)	Minimum (Kanals)	Maximum (Kanals)
Cherries	8.35	3	20
Apricot	5.6	2	20

(Author's Estimation)

The table 5 shows cultivated area that was subjected to the cherry showed significant differences among respondents. The lowest recorded area in the survey was 3 Kanals, and the largest was 20 Kanals. The average size of land under cherry grew was 8.39 Kanals, which means that, on average, farmers can devote a comparatively higher area under the cherry orchards. The total area under cherry cultivation was 999 Kanals, covering all respondents, indicating the economic significance of cherry farming and its broader use in the study region.

Conversely, the area covered with apricot farming was not as large. The lowest area was 2 Kanals, and the highest area was 20 Kanals. The average planted area of apricots was 5.67 Kanals, but it is very small compared with cherries. The area under apricot cultivation was 675 Kanals, indicating that apricot gardens are predominantly operated on a small scale.

The majority of respondents had relatively small land parcels under apricot production, with small-scale, family-level orchards prevalent. The change in the area under cultivation implies disparities in farmers' resource endowments, their ability to produce, and the potential of their incomes. Although individual holdings are small, the cumulative area under apricots underscores the significance of this crop for household food security and additional income, especially given the variability in climate and differences in agricultural conditions across District Ghizer.

Table 6: The Fruit Calendar of Cherries in District Ghizer

Altitude Category	Flowering Date	Harvesting Date
Lower Altitude	1st April	1st June
Higher Altitude	10th April	10th June

(Author's Estimation)

The Table 6 represent that the cherry flowering is highly altitude-dependent. The flowering begins earlier in low-altitude regions, such as Puniyal (April 1st), and later in high-altitude regions (by April 10th), such as Yasin, Ishkoman, and Gupis Phander. It demonstrates that altitude greatly affects apricot flowering, and that low areas with a cool climate have a later flowering onset than high-altitude areas with a warmer climate. These differences are useful for time management and harvest planning. Harvesting day varies with altitude during cherry harvesting. In low-altitude locations like Puniyal, it begins earlier (1st June), but in higher-altitude localities like Yasin, Ishkoman, and Gupis Phander, it is later, around 10th June.

Table 7: The Fruit Calendar of Apricot in District Ghizer

Altitude Category	Flowering Date	Harvesting Date
Lower Altitude	20th march	25th June
Higher Altitude	1st April	10th July

(Author's Estimation)

Table 7 shows flowering date of the apricot depends on altitude. It begins to flower earlier in lower-altitude regions, such as Puniyal, around the 20th of March. At higher altitudes, such as Yasin, Ishkoman, and Gupis Phander, flowering is later, around 1st April.

The date of apricot harvest also depends on altitude. Lower-altitude regions, such as Puniyal, start harvesting earlier, typically around June 25th. Harvesting is later in high-altitude regions like Yasin, Ishkoman, and Gupis Phander, around July 10th.

Table 8: Production of Fruits (Previous Year, 2024)

(KGs)

Fruit Type	Mean	Minimum	Maximum
Cherries	1014.7	200	4400
Apricot	610.08	100	3,000

(Author's Estimation)

The table 8 presents that the volume of cherry production among the respondents (n=119) in the last year. The minimum production was 200 kg, the maximum was 4,400 kg, and the average was 1,014.6 kg per respondent. The total amount of cherries produced last year was 119,400 kg. This variation is due to differences in orchard size, management, and resource availability among the farmers.

The findings reveal moderate variation in apricot production among the 119 respondents in the year before. Production ranged from 100 kg to 3000 kg. The mean production per respondent was 610.08 kg, and the total apricot production was 72,600 kg. This implies that apricots were a significant fruit crop for many farmers last year.

Table 9: Production of Fruits (Current Year, 2025)

(KGs)

Fruits Type	Mean	Minimum	Maximum
Cherries	1299	200	6000
Apricot	391	90	2000

(Author's Estimation)

Table 9 present the production of fruits of this year 2025. Th results show cherry output improved significantly this year. The lower limit was set at 200 kg, with the upper limit at 6,000 kg. The average output per respondent was 1299 kg, and the total production across all respondents was 154,600 kg. This growth indicates a general upward trend in cherry productivity and the expansion of cherry farming.

The respondents' responses indicated that cherry production has grown primarily because of the market's importance. According to farmers, cherries are better paid than other crops, and there is high demand for cherries in the market. As a result, several farmers are turning to cherry production, thereby increasing overall production.

Conversely, there is an evident decrease in current-year apricot production. The minimum production was 90 kg, and the maximum was 2,000 kg. The average production per respondent decreased to 391 kg, and the overall production decreased to 46,550 kg among the same 119 respondents. This massive decline is a bad omen for apricot productivity this year.

Finally, the respondents asserted that apricot production has been reduced due to the heat this year. According to farmers, apricot trees were not provided with an appropriate climate, especially at key growth stages and during fruit set. Due to heat stress and other adverse conditions, farmers experienced low yields, and overall apricot production decreased.

The findings indicate that post-harvest loss among apricot growers averaged about 16.3 percent and was mainly due to rainfall during the harvesting season. This means that a large percentage of the crop was destroyed after it was picked, reducing both the fruit's quality and the quantity available for resale.

Table 10: Average Prices (PKR) of Cherries and Apricot (Per KG)

Altitude	Cherries	Apricot
Lower Altitude (Puniyal) and Yasin	500	400
High Altitude (Gupis Phander, Ishkoman)	400	300

(Author's Estimation)

Table 10 present cherry prices vary by altitude and tehsil. In our high-altitude areas (Ishkoman and Gupis Phander), cherries were sold at 400 PKR/kg. Conversely, low-altitude farmers (Yasin and Puniyal) sold their cherries at 500 PKR/kg. The price of apricots also differs by altitude and tehsil. Cherries sold by high-altitude respondents (Ishkoman and Gupis Phander) fetched 300 PKR/kg. Conversely, low-altitude farmers (Yasin and Puniyal) sold fresh apricots at 400 PKR/kg.

Table 11: Climate Variables Impact on Cherries and Apricots

Climate Impact		Cherries		Apricot	
		Yes	**NO**	**Yes**	**No**
Temperature Rise (Warm Winters)	**Percentage**	89.92%	10.084%	95.80%	4.20%
	Frequency	107	12	114	5
Temperature Rise (Hotter Summers)	**Percentage**	77.31 %	22.69%	96.64%	3.36%
	Frequency	92	27	115	4
Irregular Rainfall (Unpredictable Pattern)	**Percentage**	92.43%	7.56%	92.43%	7.56%
	Frequency	110	9	110	9

Drought (Prolonged Dry Spells)	**Percentage** **Frequency**	8.40% 9	92.43% 119	7.56% 9	92.43% 110
Water Shortage	**Percentage** **Frequency**	4.20% 5	95.80% 114	16.80% 20	83.19% 99
Hailstorms (Spring & Early Summer)	**Percentage** **Frequency**	3.36% 4	96.64% 115	4.20% 5	95.80 % 114
Windstorms	**Percentage** **Frequency**	96.64% 115	3.36% 4	94.95% 113	5.04% 6
Untimely Rain During Flowering (March–April)	**Percentage** **Frequency**	97.47% 116	2.52% 3	98.31% 117	1.6% 2
Untimely Rain During Harvest (June–July)	**Percentage** **Frequency**	94.95% 113	5.04% 6	99.15% 118	0.84% 1

(Author's Estimation)

The table 11 shows that the findings demonstrate strong consensus among respondents on the effects of climate change on cherry and apricot production in the study region. In general, most farmers reported experiencing significant climatic variation, including rising temperatures, erratic rainfall, and extreme weather, which directly affect fruit productivity and quality.

One of the most urgent climatic factors was rising temperatures. In the case of cherries, 89.92% (n = 107) of respondents reported experiencing warmer winters, and 95.80% (n = 114) of apricot growers reported experiencing the same trend. Equally, 77.31% (n = 92) of cherry producers and an overwhelming 96.64% (n = 115) of apricot producers reported that higher summer temperatures were associated with higher production, suggesting that apricot production is especially sensitive to warmer temperatures.

The rainfall pattern was irregular for both crops. Approximately 92.43% (n = 110) of respondents reported experiencing unpredictable rainfall, which affected cherry production, and the same percentage reported being affected by the same factor in apricot production. This kind of rainfall fluctuation interferes with flowering, fruit setting, and harvesting.

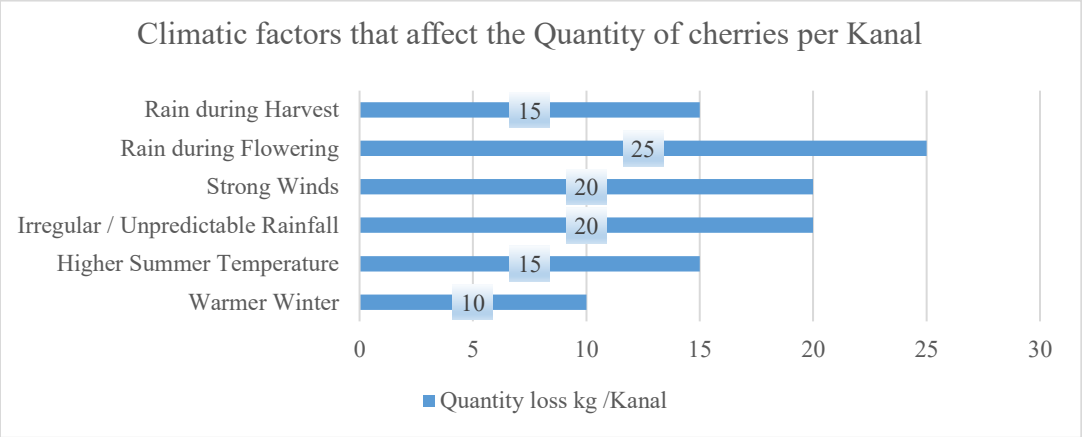
By contrast, prolonged drought was not frequently cited as a direct problem for cherries (8.40%, n = 9), but a significant percentage of respondents (92.43%, n = 110) reported that drought has a serious impact on apricot production. This distinction highlights the sensitivity and water demands of crops.

Cherry growers (n = 114) and apricot growers (n = 99) reported water shortages in 95.80% and 83.19%, respectively, indicating growing pressure on irrigation sources.

Considering extreme weather events, a low number of respondents reported hailstorms with cherries (3.36, n = 4) and apricots (4.20, n = 5). Nevertheless, windstorms were noted as a major problem, especially in cherries (96.64, n = 115) and apricots (94.95, n = 113), as they destroy blossoms and unripe fruit.

Late rainfall during the crop's vital stages proved to be a major problem. Only 97.47% (n = 116) of cherry growers and 98.31% (n = 117) of apricot growers reported rainfall during flowering (March April). Likewise, premature rainfall during harvest (June- July) hit 94.95% (n= 113) of cherry growers, and almost all apricot growers (99.15%, n= 118).

Figure 13: Climatic Factors that Affect the Quantity of Cherries Per Kanal



(Author's Estimation)

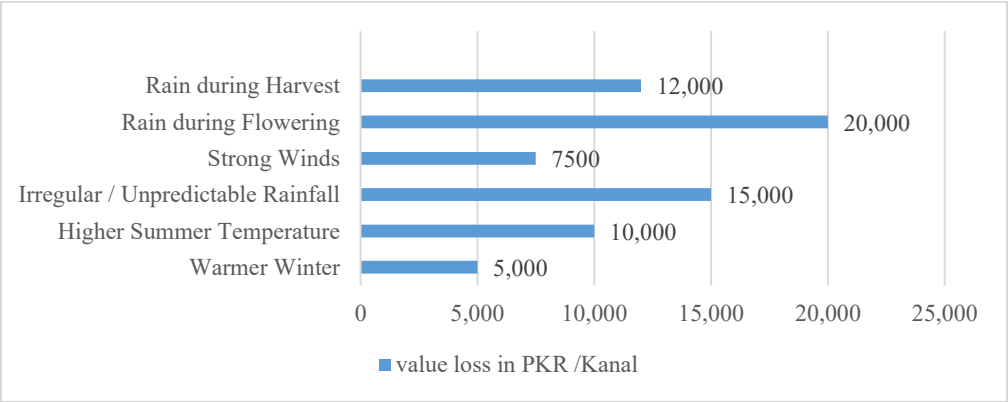
The Figure 13 shows climate variables that influence the number of cherries per Kanal are warm winters, hot summers, uneven and unpredictable rainfall, high wind velocity, rainfall during flowering, and rainfall during the harvest period. The findings were consistent with the responses of 119 respondents. Irregular or unpredictable rainfall was found to be the most important climatic constraint, reported by 64.71% (77 respondents), with an estimated yield loss of 20 kg/Kanal. This indicates that fluctuations in rainfall patterns pose a serious challenge to cherry production in the study area.

The second most noticeable cause, cited by 60.50% of respondents (72), was rainfall during the harvest period, resulting in an average loss of 15 kg/Kanal. Rainfall during harvest has a detrimental impact on fruit quality and increases post-harvest losses, thereby reducing the overall marketable yield.

On the same note, increased temperatures and rainfall during flowering were reported by 55.46 percent of respondents (66) each. Although the loss was 15 kg per Kanal at higher summer temperatures, with rainfall during flowering, the loss was higher, at 25 kg per Kanal, indicating that the crop is more sensitive during the flowering stage.

A report found that 52.10% of respondents (62) experienced warmer winter conditions and strong winds. The yield reduction of 10 kg per Kanal was linked to warmer winters, and a greater reduction of 20 kg per Kanal was linked to strong winds, indicating a combination of the two effects: chilling needs and physical loss of the crop

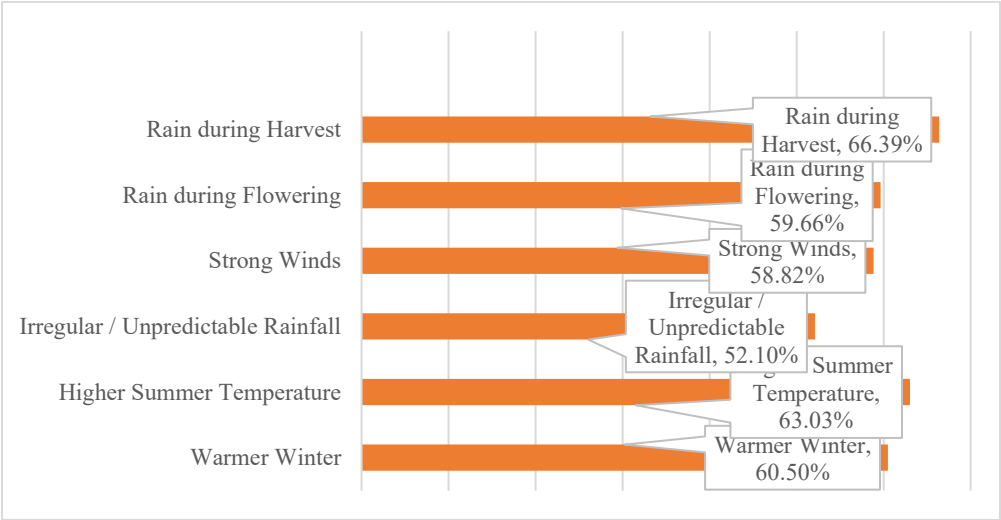
Figure 14: Climatic Factor that Affects the Value of Cherries (In PKR)



(Author's Estimation)

Figure 14 shows the climatic variables influencing cherry market value, with the most significant responses highlighted. Respondents identified increased summer temperatures as the most significant climatic factor affecting cherry value. Sixty-four respondents (62.18%) reported that the average loss of value per kilo of fruit under high-temperature summer conditions was PKR 10,000 per Kanal, indicating that high temperatures have a tremendous impact on heat stress in fruits and their marketability. Sixty percent (60.50) of respondents reported rainfall during the flowering period, and the estimated loss in value was PKR 20,000 per Kanal. This highlights the sensitivity of cherry flowers to untimely rain, which can interfere with pollination, leading to flower abortion and reduced fruit set. Similarly, 71 respondents (59.66%) reported irregular and unpredictable rainfall patterns, resulting in an average loss of PKR 15,000 per Kanal. These findings show that the growing variability in rainfall poses a significant challenge to the sustainability of cherry quality and consistent revenue. Sixty-eight respondents (57.14%) reported losses during the harvest season due to rain, averaging PKR 12,000 per Kanal. Rain during harvest increases fruit cracking, disease, and post-harvest losses, leading to lower market prices. A majority of respondents (64; 53.61%) reported losing PKR 7,500 per Kanal due to strong winds that caused physical damage to fruits and branches, thereby reducing fruit grade and value. Likewise, 64 respondents recorded that the winter is warmer (53.60%), which translates to an average value loss of PKR 5,000 per Kanal. Winter warming can disrupt chilling requirements, ultimately affecting fruit development and quality.

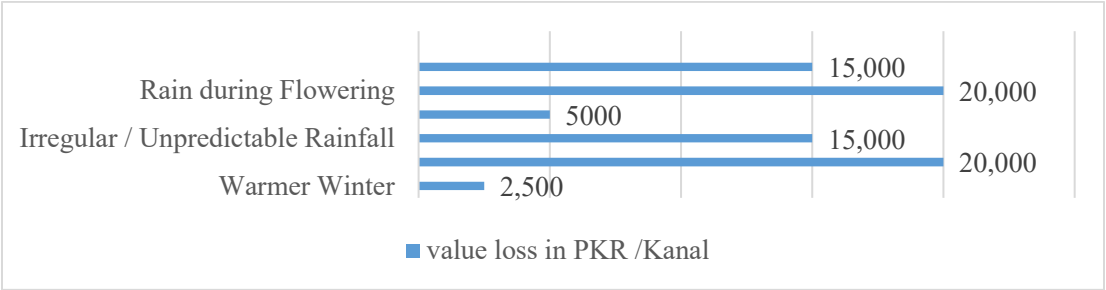
Figure 15: Climatic Factors that Affect the Quantity of Apricots Per Kanal



(Author's Estimation)

Figure 15 shows the percentage of respondents who reported quantity losses due to various climatic factors. The findings indicate that rainfall during harvest is the most common factor influencing apricot quantity. Most respondents (66.39%) reported an average weight loss of 20 kg per Kanal due to untimely rainfall during harvest, which causes fruit drop, rotting, and subsequent post-harvest losses. Another significant factor was higher summer temperatures, reported by 75 respondents (63.03%), with an estimated loss of 20 kg per Kanal. High temperatures hasten fruit maturation and increase moisture stress, which is harmful to yield. Similarly, 72 respondents (60.50%) reported warmer winter conditions, leading to an average loss of 15 kg per Kanal. Warmer winters can interfere with chilling requirements, leading to abnormal flowering and reduced fruit set. Another major loss during the flowering stage was reported by 71 respondents (59.66%), with an estimated loss of 20 kg per Kanal, attributed to the apricot's sensitivity to moisture stress and reduced pollination. Seventy respondents (58.82%) reported strong winds, with an average loss of 10 kg per Kanal due to physical damage to blossoms, young fruits, and branches. Finally, 62 respondents (52.10%) reported irregular and unpredictable rainfall patterns, resulting in the largest estimated loss of 25 kg per Kanal. Thus, rainfall variability is a severe threat to stable apricot production.

Figure 16: Climatic Factor that Affects the Value of Apricots (Per Kanal)

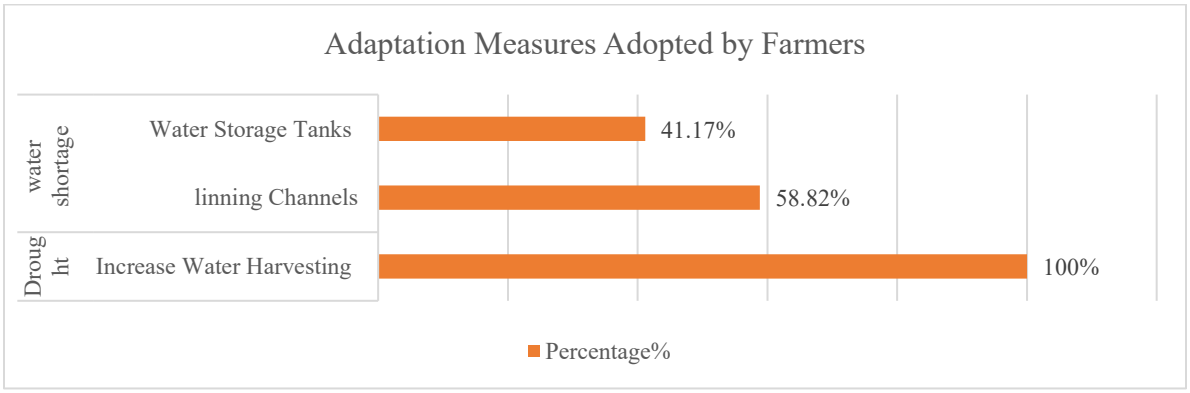


(Author's Estimation)

Figure 16 presents findings on how climatic variables affect the market value of apricots on a per-Kanal basis, based on responses from 119 apricot growers in the District of Ghizer. Figure 16 summarizes the highest reported losses across various climatic stressors. The findings also indicate that apricot value was most strongly influenced by high summer temperatures. The majority of respondents (72.18%) reported that the average value decreased by PKR 20,000 per Kanal due to heat stress, supporting the idea that heat stress significantly impairs fruit quality, size, and marketability. Rain at the flowering stage was reported by 72 respondents (60.50%), with an estimated value loss of PKR 20,000 per Kanal. Premature rainfall during flowering disrupts pollination and increases flower drop, resulting in lower-quality fruits and lower market prices. Similarly, 71 respondents (60.66%) reported irregular and unpredictable rainfall patterns, leading to an average loss of PKR 15000 per Kanal. This indicates increasing uncertainty in precipitation patterns, with negative impacts on apricot quality and price stability. Sixty-eight respondents (57.14%) reported value losses due to rain during the harvest period, averaging PKR 15,000 per Kanal, primarily from fruit spoilage, fungal infections, and reduced shelf life. Over 50% (64 respondents, 53.61%) recorded losses of PKR 5,000 per Kanal due to strong winds, which cause physical damage to fruits and branches, reducing fruit grade. In the same vein, 64 respondents indicated a warmer winter (63.60), with an average loss in value of PKR 2,500 per Kanal. Warmer winters alter chilling patterns, leading to more uniform flowering and poor fruit quality.

Overall, the results indicate that the most significant climate stressors affecting cherry and apricot production are temperature variability, winds, and rainfall-related events, resulting in significant quantitative and economic losses for farmers.

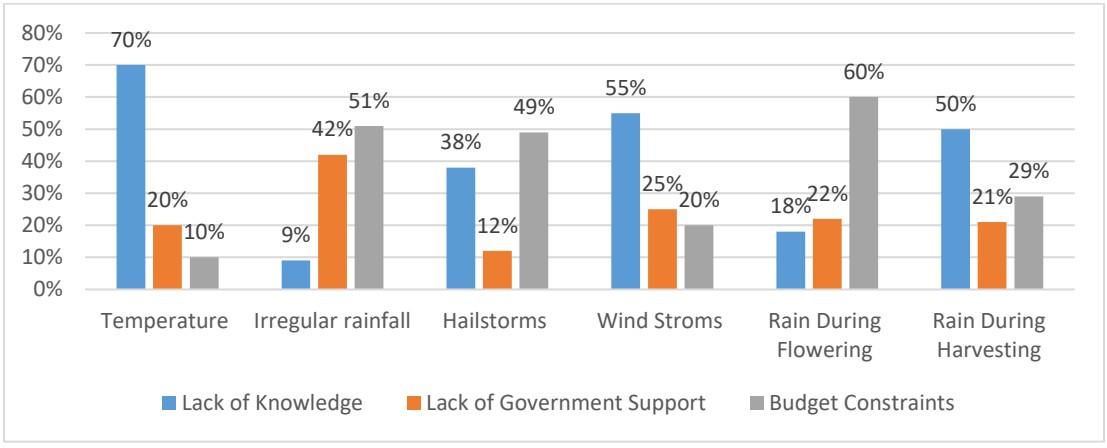
Figure 17: Adaptation Measures Adopted by Farmers



(Author's Estimation)

Figure 17 shows the adaptation measures that farmers in District Ghizer specifically practiced in response to major climate-related stresses. Due to drought, all respondents (100%, n = 119) cited water harvesting as an adaptation measure. This indicates that water harvesting is a strategy universally embraced by farmers to cope with long dry seasons. In the case of water shortages, farmers reported two key adaptation strategies. Sixty (58.82%) respondents reported lining irrigation channels to minimize seepage and water loss. Meanwhile, 49 respondents (41.17%) reported using water storage tanks as an adaptation to cope with water shortages during such periods. These findings indicate that farmers rely largely on water-based adaptation strategies to address drought and water shortages, with a greater inclination to enhance irrigation efficiency through channel lining rather than on-farm water storage.

Figure 18: Climate-Related Constraints to Adaptation Strategies



(Author's Estimation)

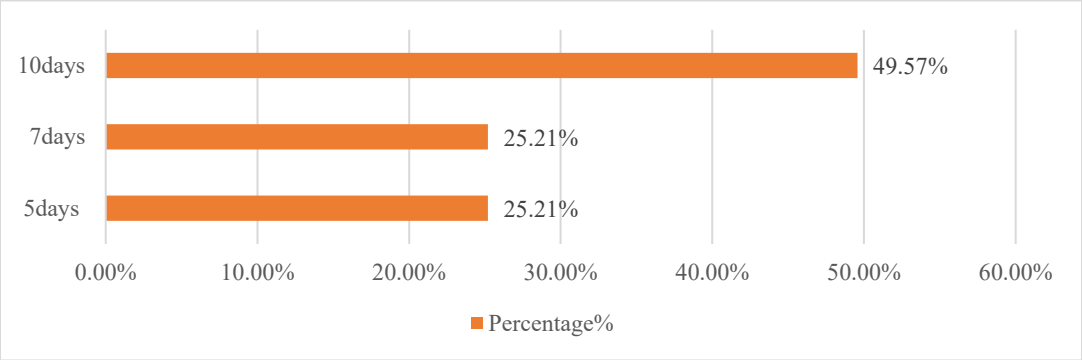
The results in figure 18 reveal that farmers are constrained by several factors in adapting to various climate change impacts on apricot and cherry cultivation. In the case of temperature-related changes, the most cited constraint was lack of knowledge (70%), followed by lack of government support (20%) and budget constraints (10%). In irregular rainfall conditions, budget constraints (51%) and lack of government support (42%) are the major constraints, while only 9% of farmers cite lack of knowledge as the major constraint. Likewise, for hailstorms, budget constraints (49%) are the main constraint, followed by lack of knowledge (38%) and government support (12%).

In the case of windstorms, lack of knowledge (55%) is the main constraint, followed by budget constraints (20%), but there seems to be a slight reporting inconsistency. For rainfall at flowering, financial constraints (60%) are the leading constraint, followed by lack of government support (22%) and lack of knowledge (18%). When it comes to rainfall at harvest, lack of knowledge (50%) is the primary constraint, followed by budget constraints (29%) and lack of government support (21%). In general, the findings show different constraints faced by farmers under different climatic stressors.

The results show that a lack of knowledge, financial resources, and government support are the three primary constraints to adopting adaptation measures. But their significance varies with climatic conditions. Lack of knowledge is more critical regarding temperature, windstorms, and harvest-related issues, indicating that farmers do not know how to adapt to these issues and need improved extension and training. Conversely, financial constraints are more important in cases of erratic rainfall, hailstorms, and flowering rainfall, which require financial resources for adaptation measures such as irrigation and protective structures, respectively.

Additionally, the absence of government support, although not the primary constraint, is a prominent secondary constraint in all climatic conditions. These highlights limited institutional support for subsidies, technical assistance, and climate-proof agricultural policies. In conclusion, the results indicate that farmers' adaptation capacity can be improved by providing them with better knowledge, budgetary support, and policy support to address the effects of climate change on fruit production.

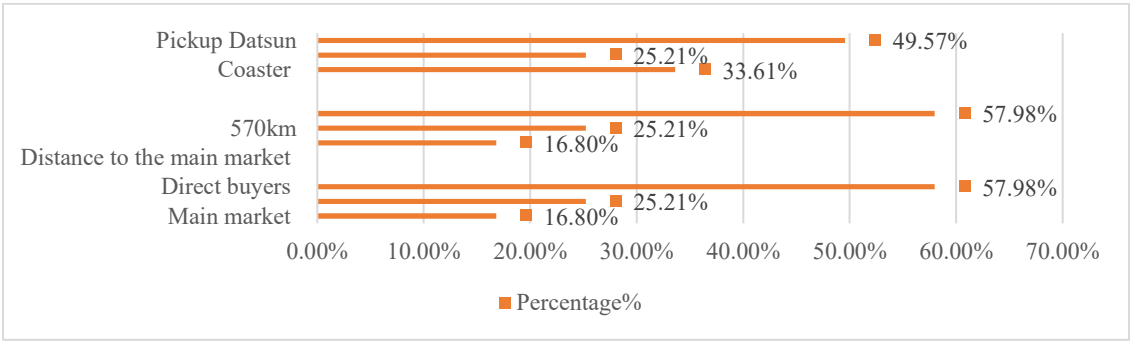
Figure 19: Number of Days of Harvest Delay Attributed to Climate Events



(Author's Estimation)

Figure 19 lists the extent to which climate events contributed to harvesting delays, as reported by 119 District Ghizer respondents. The findings indicate that almost half of the participants experienced substantial delays in harvesting. Of the 59 respondents (49.57%), climate events caused a 10-day delay in harvesting, indicating a severe disruption to the harvesting period. In the meantime, 30 respondents (25.21%) reported a 5-day delay, and 30 respondents (25.21%) reported a 7-day delay due to unfavorable travel conditions. Overall, the results indicate that climate variability has caused apparent and sustained delays in harvesting, with a majority of farmers experiencing delays of seven days or longer, which may escalate post-harvest losses and reduce market value.

Figure 20: Selling Channel, Distance to Main Market, and Transport Method



(Author's Estimation)

The results in figure 20 indicate that most respondents relied on direct buyers as their primary selling channel. Only 69 respondents (57.98%) reported selling their produce at the point of sale,

suggesting a desire to sell as soon as possible and reduce reliance on middlemen. In the meantime, 30 respondents (25.21%) sold their produce in district markets, but only 20 respondents (16.80%) indicated selling in main markets, indicating limited access to larger markets. In terms of market distance, 69 respondents (57.98%) indicated that the primary market was within 500 km. In addition, 30 respondents (25.21%) indicated a distance of 570 km to the main market, and 20 respondents (16.80%) indicated a distance of 600 km. These results show that the majority of farmers are located quite far from big markets, which adds to transport time and marketing expenses. Pickup/Datsun vehicles were the most popular mode of transportation, with 59 respondents (49.57%) reporting using them to transport their produce to remote locations. 40 respondents (33.61%) reported using coasters to transport their produce to markets, whereas 30 respondents (25.21%) reported using wagons. Generally, the findings show that farmers rely on informal selling outlets, long-distance markets, and barebones transport, which can increase post-harvest losses and reduce profitability.

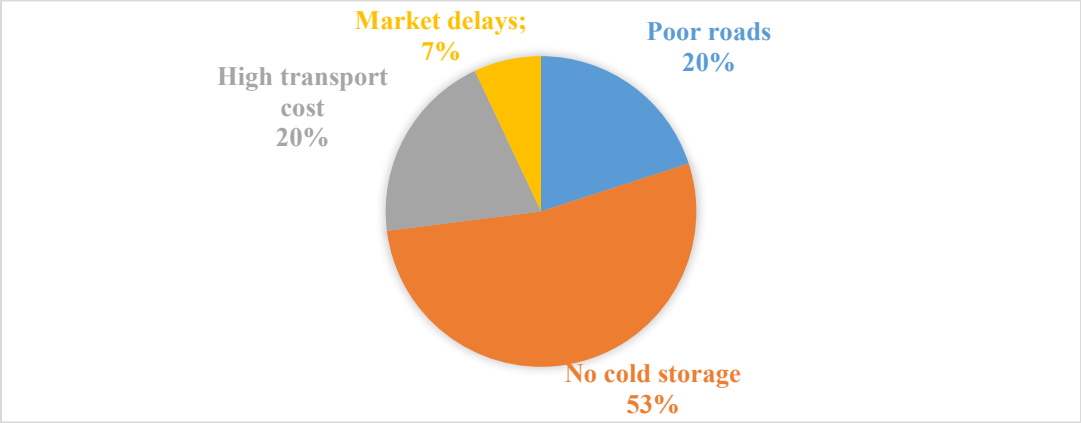
Table 12: Transport Cost to Main Market (In PKR)

Cost of transport	**Mean**	**Minimum**	**Maximum**
	40,546	25,000	80,000

(Author's Estimation)

The table 12 presents a wide variation in transportation costs among farmers. The lowest transportation cost was PKR 25,000, and the highest was PKR 80,000, reflecting differences in distance, market access, and transport mode. According to the frequency distribution, the average transportation cost for cherries and apricots was approximately PKR 40,546. A high percentage of farmers incurred transportation costs between PKR 25,000 and PKR 50,000, suggesting that reaching distant markets involves high financial costs. Overall, the results reveal that high transportation costs are a key challenge for fruit growers in the study region and can reduce net returns, especially when compounded by climate-related yield and value losses.

Figure 21: Major Supply Chain Challenges



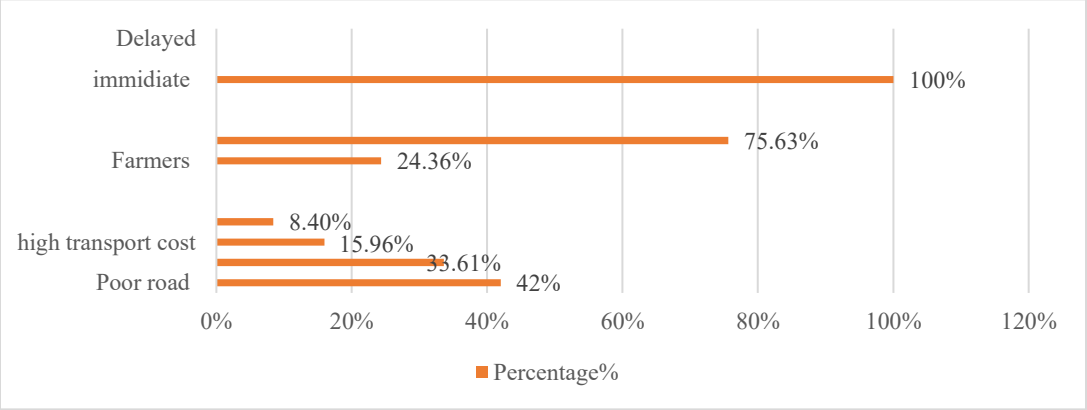
(Author's Estimation)

Figure 21 present the survey conducted among 119 respondents in District Ghizer, Gilgit-Baltistan, identified key supply chain issues impacting the production and market access of fruits under changing climatic conditions. The results indicate that the shortage of cold storage facilities (53%), as reported by some 63 respondents, is the most significant constraint. This will be followed by poor road infrastructure (20%) and high transportation costs (20%), each mentioned by approximately 24 respondents. A smaller percentage of respondents (7 percent, about 8 people) cited market delays as one of the major problems affecting the supply chains of fruits such as cherries and apricots.

The findings clearly show that the fruit supply chain in District Ghizer is highly vulnerable, with infrastructure-related issues as the most prevalent bottleneck. This lack of cold storage facilities (53%), is especially critical because perishable fruits such as cherries and apricots should be preserved at the lowest possible temperature in order to preserve the quality of the foods and reduce post-harvest losses. In the absence of good storage, farmers are compelled to sell fast and at low prices, thereby reducing their overall profitability and their ability to adapt to climate-related disturbances. Likewise, geographical and infrastructural barriers in mountainous regions, further aggravated by climate change-related events such as landslides and floods, result in poor road conditions and high transportation costs (both 20%). The combination of these factors increases transaction costs, slows access to markets, and makes the supply chain less efficient and more fragile. The market delays (7%), although relatively lower, contribute to uncertainty in prices and the low bargaining power of farmers. Generally, the results indicate that the critical policy

interventions to improve the resilience of the fruit sector in District Ghizer when facing the pressures of climate change are strengthening rural infrastructure, introducing cold storage facilities, and enhancing transport logistics.

Figure 22: Major Supply Chain Challenges, Price Set, and Payment Terms



(Author's Estimation)

Figure 22 presents the key supply chain issues faced by farmers, along withS data on price determination and payment terms, based on responses from 119 respondents in District Ghizer. According to the results, poor road conditions were the most commonly reported supply chain issue, cited by 50 respondents (42%). This highlights the challenges farmers face in transporting perishable fruits from remote locations to markets. Forty respondents (33.61%) reported a lack of cold storage facilities, supporting the conclusion that cold chain infrastructure is insufficient in the district and that its absence contributes to post-harvest losses. Ten respondents (15.96%) reported that high transportation costs were a challenge due to the financial strain of long-distance access to the market. Furthermore, some of the respondents (10) noted a lack of packing material (8.40%), indicating an inability to use appropriate packaging to preserve fruit quality during transportation. Regarding pricing, most respondents (90; 75.63%) indicated that the prices of cherries and apricots are determined by buyers. Conversely, 29 (24.36%) respondents said that farmers can set prices. This observation implies that farmers have weak bargaining power in the fruit marketing system. Regarding payment terms, 100% of respondents (n=119) at the point of sale received immediate payment. No respondents reported sales on credit or delayed payment terms. In sum, the findings indicate serious supply chain limitations, limited bargaining power for farmers in setting prices, and dependence on cash transactions in the marketing of cherries and apricots.

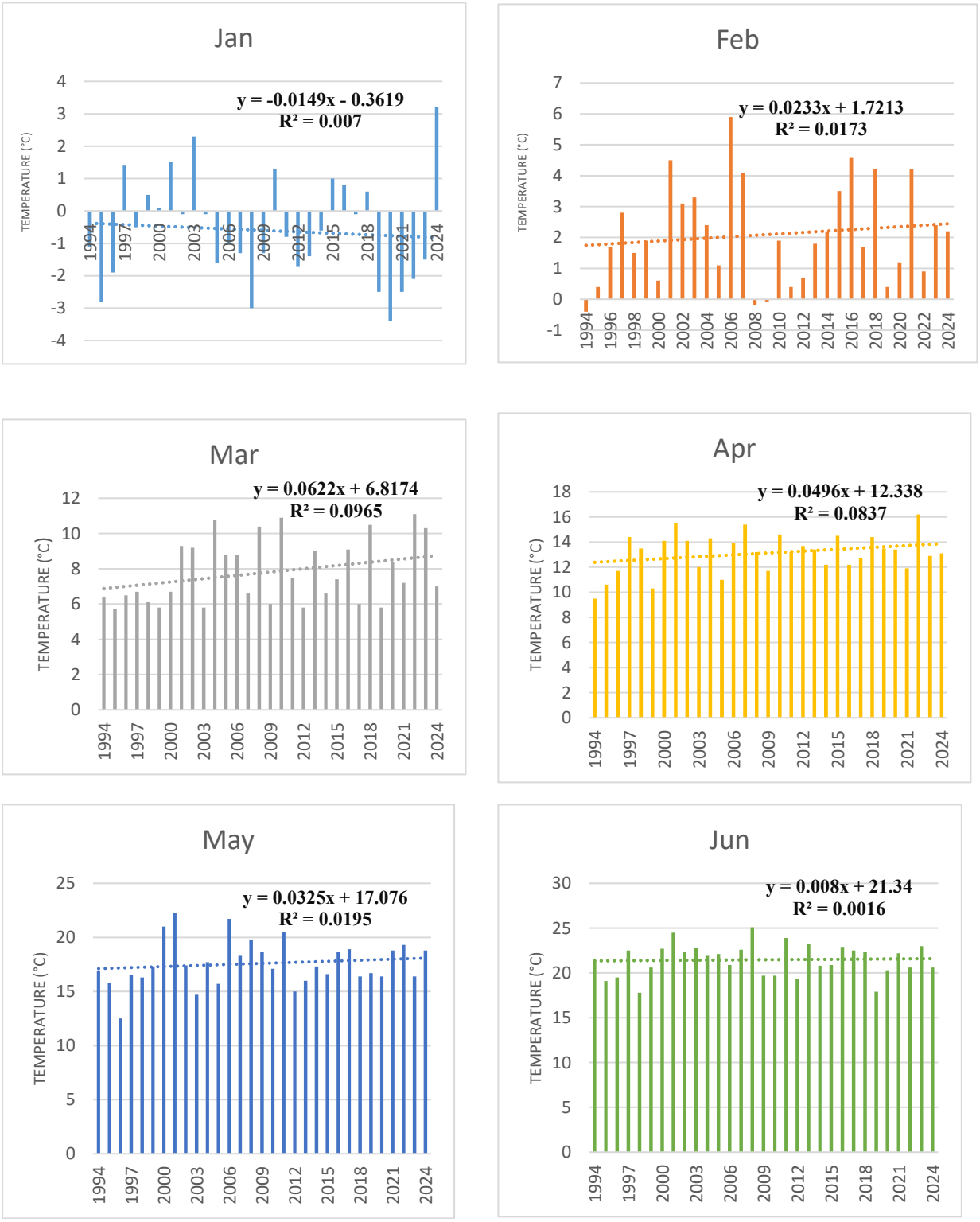
When asked whether climate change has increased the supply chain challenges, all 119 respondents (100%) responded yes. They elaborated that glacial lakes and rainfall-induced landslides, driven by flash floods and high temperatures, have frequently blocked roads and disrupted transportation. The example cited by the respondents was the Talidas accident, in which a glacial lake outburst blocked the road in August and kept it closed until the end of December, leading to significant delays in transporting fruit and, consequently, post-harvesting losses.

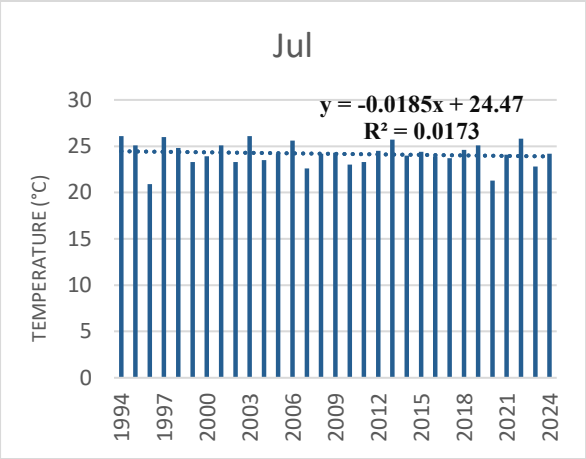
These reactions underscore that climate events directly exacerbate infrastructure weaknesses, thereby affecting the timeliness of marketing and farmers' economic returns.

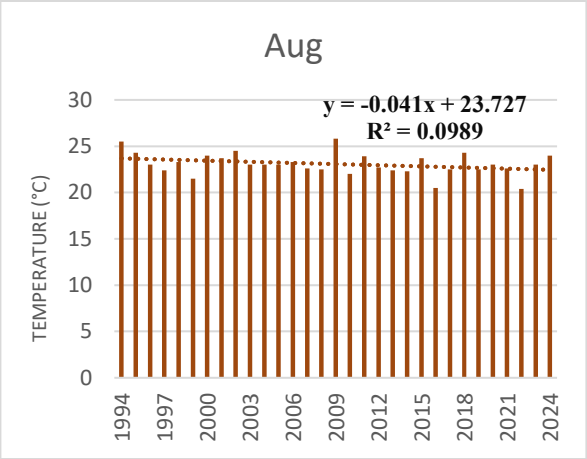
All 119 respondents confirmed that there are price breaks when the crop is being harvested or when transportation is delayed due to climate-related events such as untimely rain, flash floods, or road blockages. Such delays affect the quality and timely delivery of cherries and apricots, resulting in lower market prices. According to the respondents, the selling price of their produce is normally determined by the buyer. Farmers depend on direct buyers, and prices are negotiated at the point of sale. The respondents received payment immediately after the sale. The direct sale system they use does not involve credit or delayed payments, ensuring that farmers receive instant cash for their produce even when faced with climate-related difficulties.

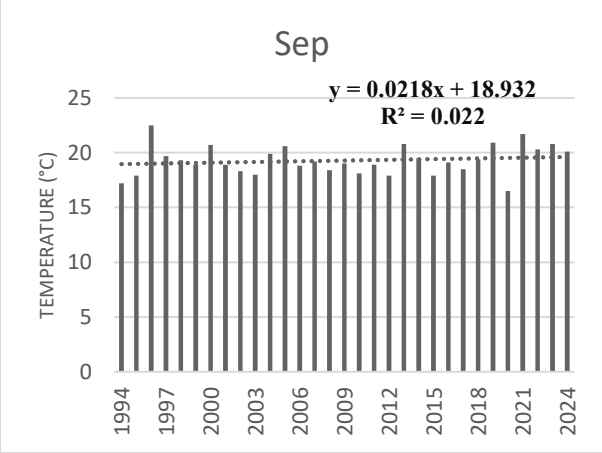
MEAN MONTHLY TEMPERATURE (°C)

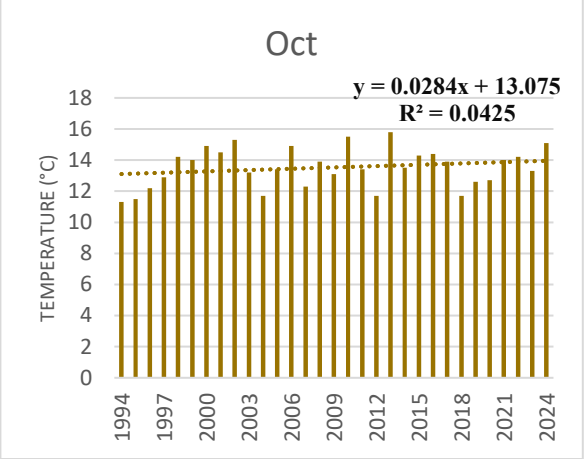
Figure 23: Mean Monthly Temperature (°C) by Month

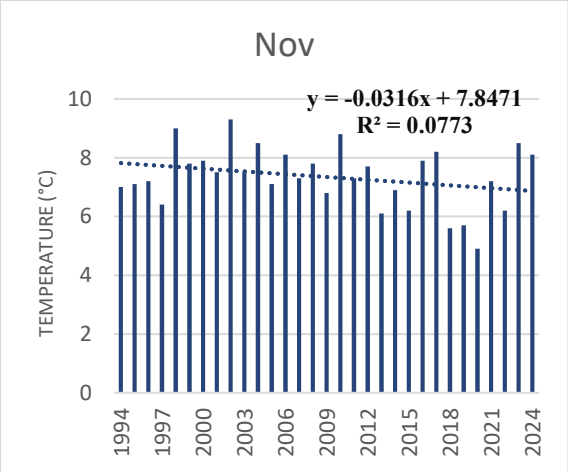


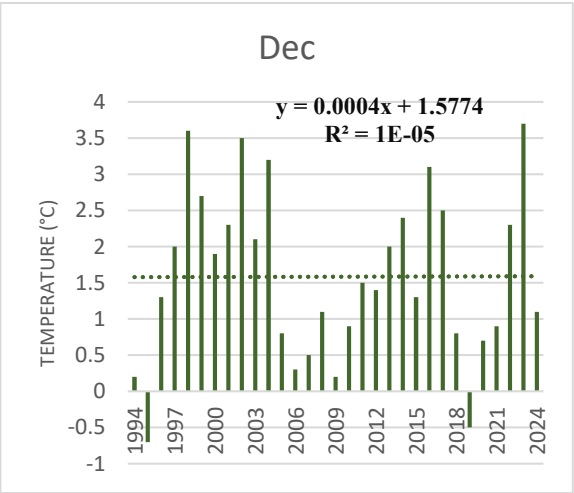








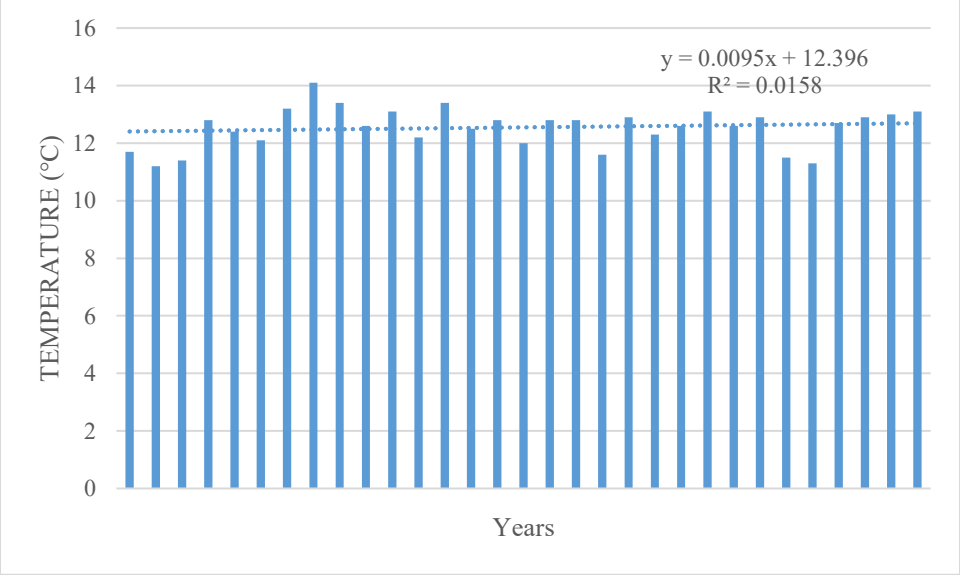




Data Source: Pakistan Meteorological Department

The Figure 23 analysis of mean monthly temperature from 1994 to 2024 indicates a clear warming trend in District Ghizer, consistent with broader climate change impacts across Gilgit-Baltistan and the wider Hindu Kush–Karakoram–Himalayan region. Summers (June–August) remain the warmest months, generally ranging between 22°C and 26°C, while spring (March–April), the critical flowering and pollination period for cherries and apricots, has warmed most sharply, rising from roughly 5.7–6.4°C in the 1990s to above 10°C in several recent years (2004, 2010, 2018, 2022). This shift is corroborated by farmers reporting earlier flowering and fruit ripening. Winters remain cold enough to provide chilling, but growing variability points to a gradual reduction in chilling accumulation, raising the risk of irregular bud break, poor pollination, and lower yields; earlier, warmer springs also expose blossoms to late frost and untimely rain. As orchards depend on glacier-fed irrigation, continued warming is likely to raise evapotranspiration and water stress during the growing season, underscoring the need for climate-smart orchard management, improved irrigation efficiency, localized climate advisories, and climate-resilient fruit varieties.

Figure 24: Mean Annual Temperature (°C)



Source: Pakistan Meteorological Department

Figure 24 presents the variation in mean annual temperature over the study period. The annual mean temperature shows considerable year-to-year fluctuations, ranging from approximately 11.2°C to 14.1°C. The lowest mean annual temperature was recorded at 11.2°C, while the highest reached 14.1°C. Despite these fluctuations, the overall pattern indicates variability in annual temperature, with several years experiencing relatively higher temperatures compared with the

earlier observations. For example, temperatures increased to 13.2°C, 14.1°C, and 13.4°C in successive higher-temperature years before declining again. Towards the later part of the period, temperatures continued to fluctuate, reaching values above 13°C in some years and falling to around 11.3–11.5°C in others. Overall, the figure demonstrates that mean annual temperature has not followed a uniform year-to-year pattern but has experienced noticeable fluctuations, including periods of relatively warmer and cooler conditions. These changes are important for understanding changing climatic conditions and their potential implications for agricultural activities and fruit production in the study area.

Table 13: Rate of Change by Month in Monthly Mean Temperature (°C)

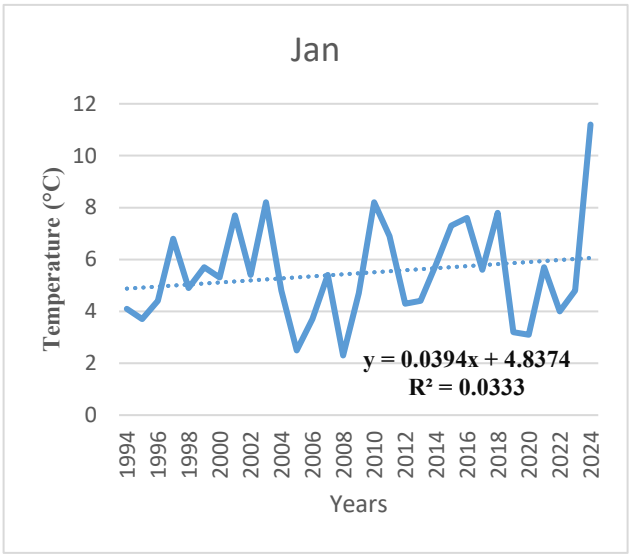
Month	Rate °C / Year	Rate °C / Decade
Jan	−0.015	−0.15
Feb	+0.023	+0.23
Mar	+0.062	+0.62
Apr	+0.050	+0.50
May	+0.033	+0.33
Jun	+0.008	+0.08
Jul	−0.018	−0.18
Aug	−0.041	−0.41
Sep	+0.022	+0.22
Oct	+0.028	+0.28
Nov	−0.032	−0.32
Dec	+0.000	+0.00

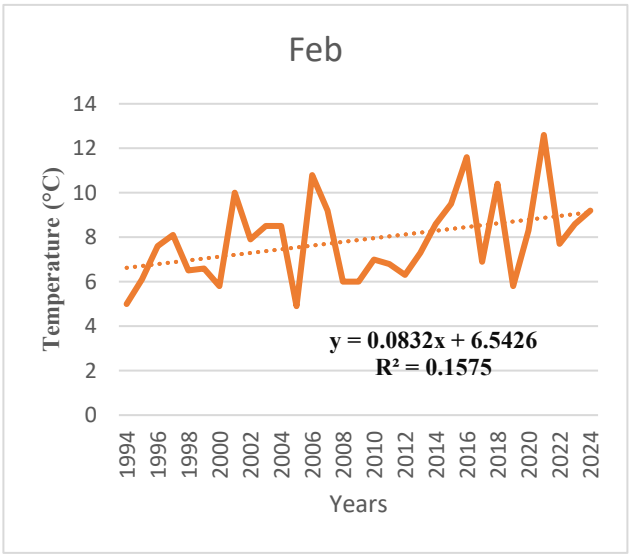
(Author's estimations)

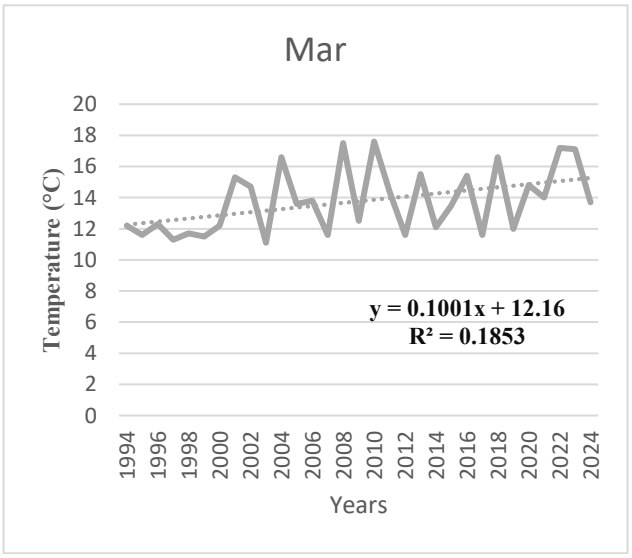
Table 13 shows that spring and early-autumn months are warming fastest, March leads at +0.62°C/decade, with April, September, and October also rising steadily. Peak summer (July–August) shows a slight cooling trend instead. This pattern points to an earlier, warmer spring that can advance flowering, while summer heat extremes are not intensifying at the same pace.

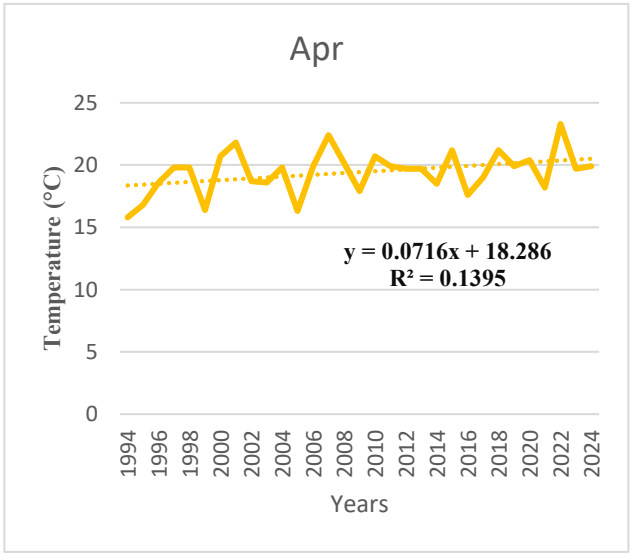
MEAN MONTHLY MAXIMUM TEMPERATURE (MEAN DAILY MAXIMUM TEMPERATURE) (°C)

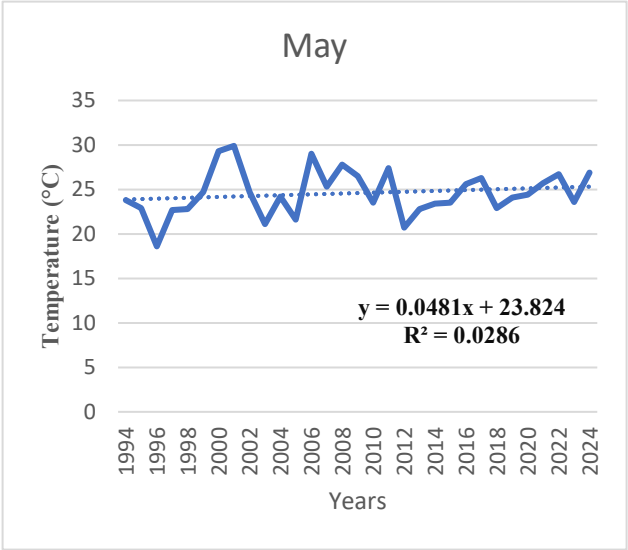
Figure 25: Mean Monthly Maximum Temperature (°C) by Month

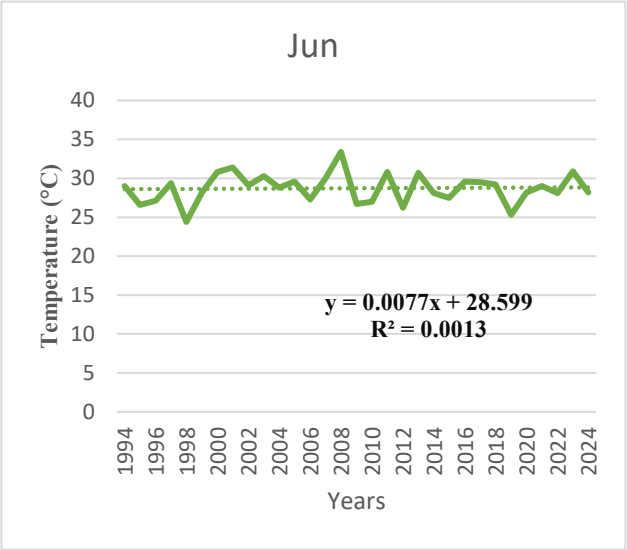


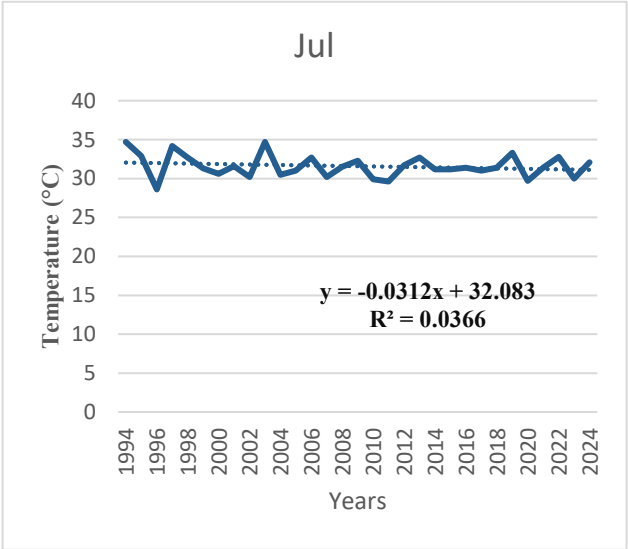


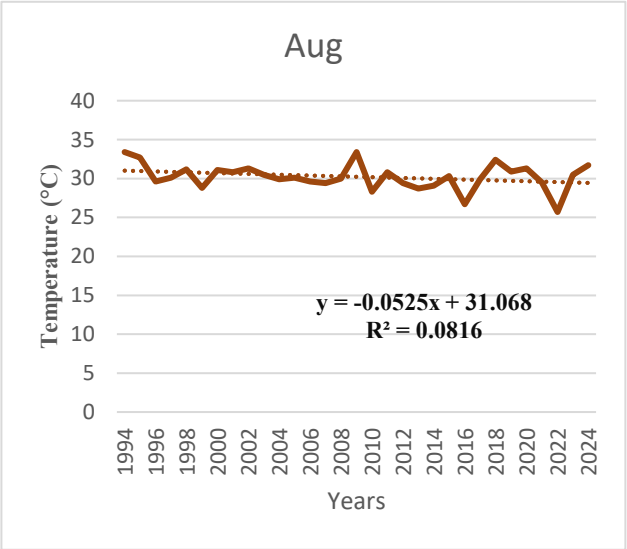


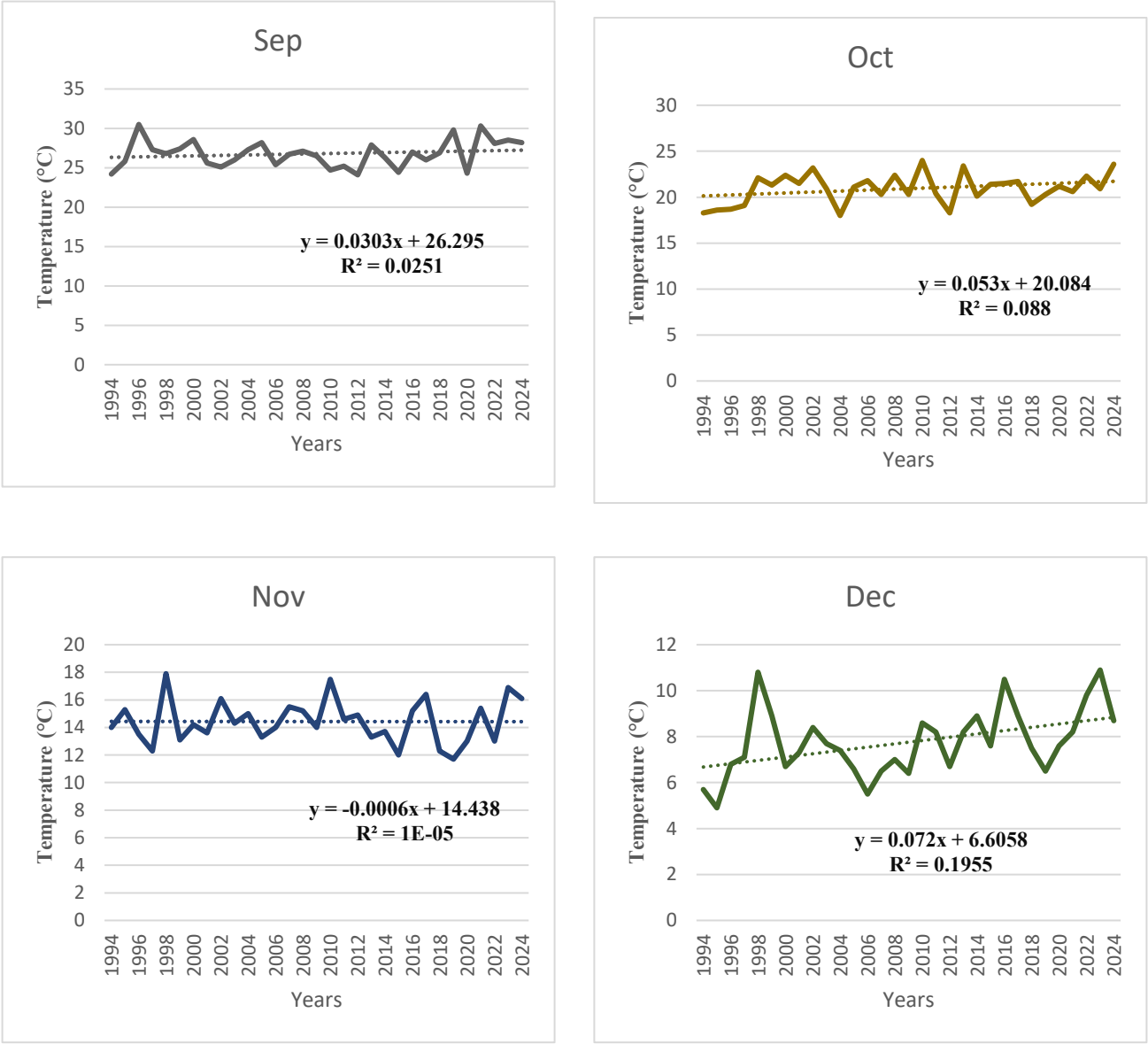



May
Temperature (°C)
35
30
25
20
15
10
5
0
1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022 2024
Years
y = 0.0481x + 23.824
R² = 0.0286


Jun
Temperature (°C)
40
35
30
25
20
15
10
5
0
1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022 2024
Years
y = 0.0077x + 28.599
R² = 0.0013


Jul
Temperature (°C)
40
35
30
25
20
15
10
5
0
1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022 2024
Years
y = -0.0312x + 32.083
R² = 0.0366


Aug
Temperature (°C)
40
35
30
25
20
15
10
5
0
1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022 2024
Years
y = -0.0525x + 31.068
R² = 0.0816

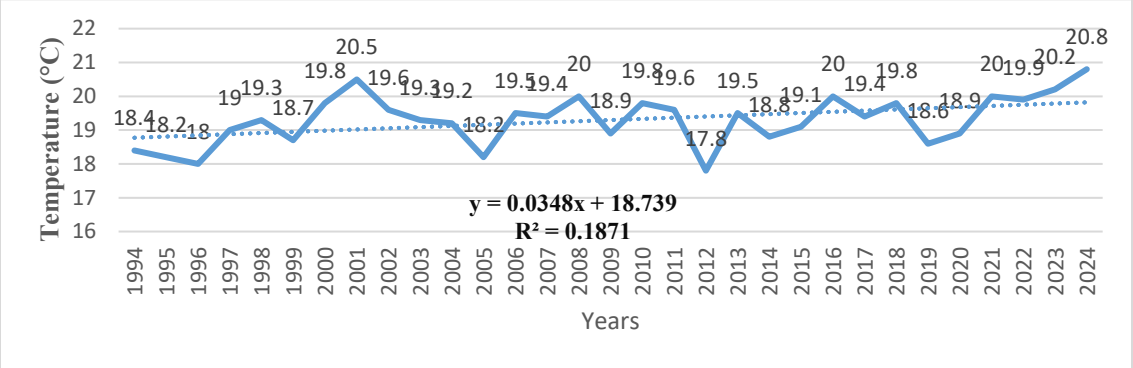


Data Source: Pakistan Meteorological Department

The Figure 25 shows monthly mean maximum temperature considerable variation across the study period from 1994 to 2024. The trend analysis indicates that the maximum temperature increased in most months, although the magnitude of change differed considerably between months. January shows a positive trend of 0.039°C per year, while February records a stronger increase of 0.083°C per year. March has the highest positive rate of change among the months, with an increase of 0.100°C per year, equivalent to approximately 1.00°C per decade. April also shows a positive trend of 0.072°C per year, while May records an increase of 0.048°C per year. June shows only a very small positive trend of 0.008°C per year. In contrast, July and August show declining trends, with

temperatures decreasing by 0.031°C and 0.052°C per year, respectively. September and October again show positive trends of 0.030°C and 0.053°C per year. November shows an almost negligible decline of 0.001°C per year, whereas December records a positive trend of 0.072°C per year. Overall, the monthly analysis indicates that warming is more evident during the late winter and spring months, particularly in March, while July and August show a declining tendency in mean maximum temperature.

Figure 26: Mean Maximum Annual Temperature (°C)



Data Source: Pakistan Metrological Department (PMD)

Figure 26 presents the annual mean maximum temperature for the period 1994–2024. The annual values fluctuate considerably from year to year, indicating substantial inter-annual variability in maximum temperature. The recorded annual mean maximum temperature ranges from approximately 17.8°C to 20.8°C during the study period. Despite these fluctuations, the fitted trend line has a positive slope of approximately 0.035°C per year, equivalent to around 0.35°C per decade. The R^2 value of 0.187 indicates that the linear trend explains a relatively limited proportion of the annual variation. Therefore, while the annual series demonstrates an overall warming tendency in mean maximum temperature, the year-to-year fluctuations are considerable. The highest annual value shown in the figure is approximately 20.8°C, whereas one of the lowest values is around 17.8°C. Overall, the annual analysis suggests a gradual increase in mean maximum temperature over the study period, accompanied by substantial annual variability.

Table 14: Rate of Change by Month in Monthly Mean Maximum Temperature (°C)

Month	Rate °C / Year	Rate °C / Decade
Jan	+0.039	+0.39
Feb	+0.083	+0.83
Mar	+0.100	+1.00
Apr	+0.072	+0.72
May	+0.048	+0.48
Jun	+0.008	+0.08
Jul	−0.031	−0.31
Aug	−0.052	−0.53
Sep	+0.030	+0.30
Oct	+0.053	+0.53
Nov	−0.001	−0.01
Dec	+0.072	+0.72

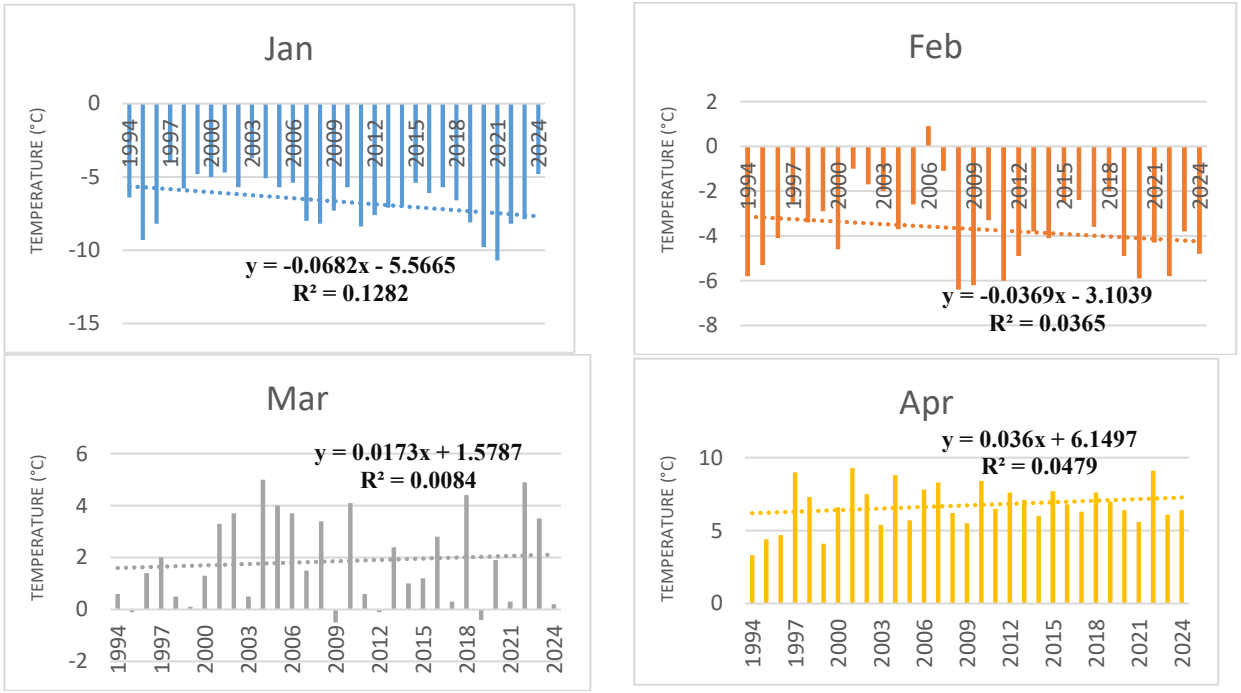
(Author's estimations)

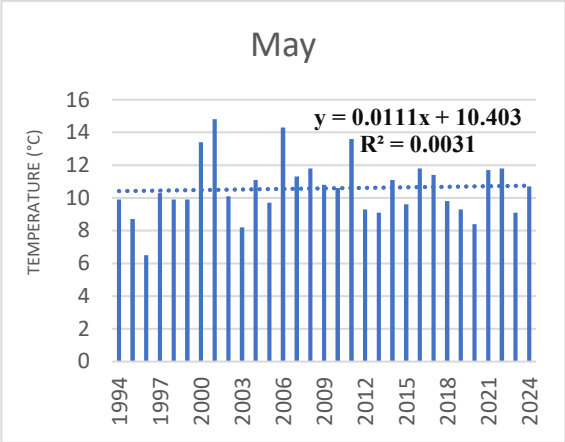
Table 14 summarizes the rate of change in monthly mean maximum temperature on both annual and decadal scales. The results show that most months experienced a positive rate of change during the study period. March recorded the highest warming rate at 0.100°C per year, equivalent to 1.00°C per decade, followed by February at 0.083°C per year or 0.83°C per decade. April and December both show an increase of 0.072°C per year, equivalent to 0.72°C per decade. October recorded a positive change of 0.053°C per year, while May increased by 0.048°C per year. January and September show relatively smaller increases of 0.039°C and 0.030°C per year, respectively. June has only a marginal positive change of 0.008°C per year. In contrast, July and August show

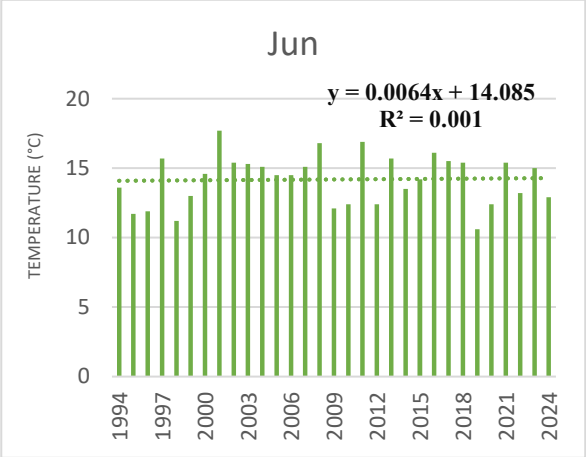
negative rates of change of −0.031°C and −0.052°C per year, corresponding to declines of approximately −0.31°C and −0.53°C per decade. November also shows a very small decline of −0.001°C per year. These results indicate that the strongest warming occurred during March, followed by February, while the most noticeable cooling tendency was observed during August. Overall, the rate-of-change analysis demonstrates that temperature changes were not uniform across the year, with stronger warming during some months and slight cooling tendencies during others.

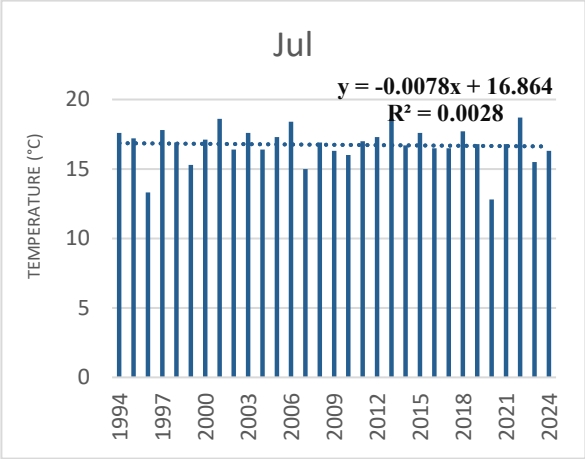
MEAN MONTHLY MINIMUM TEMPERATURE (MEAN DAILY MINIMUM TEMPERATURE) (°C)

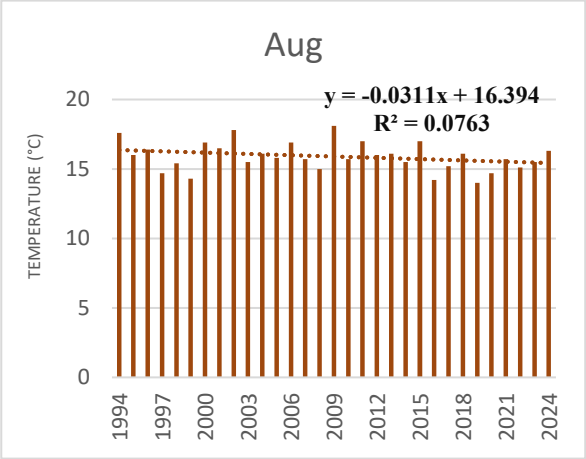
Figure 27: Mean Monthly Minimum Temperature (°C) by Month

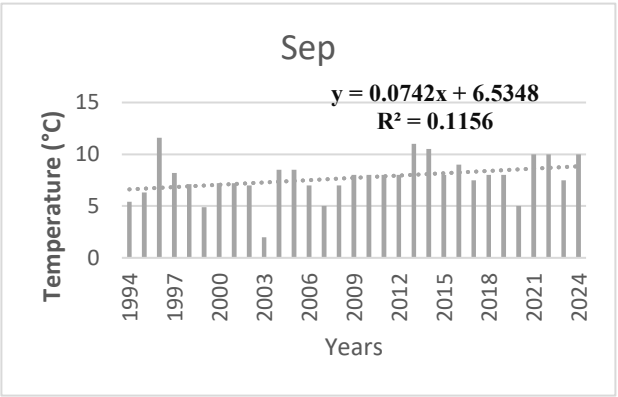


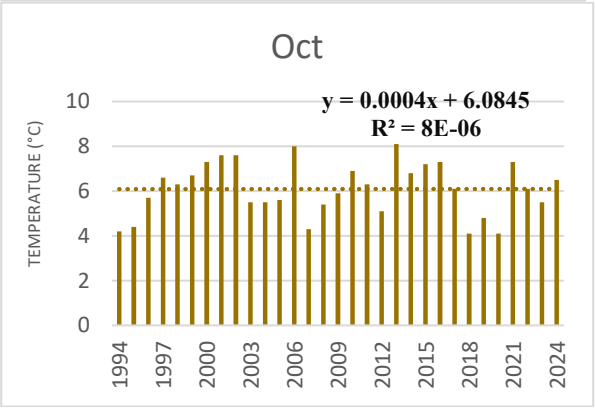

May
y = 0.0111x + 10.403
R² = 0.0031
TEMPERATURE (°C)
0
2
4
6
8
10
12
14
16
1994
1997
2000
2003
2006
2009
2012
2015
2018
2021
2024

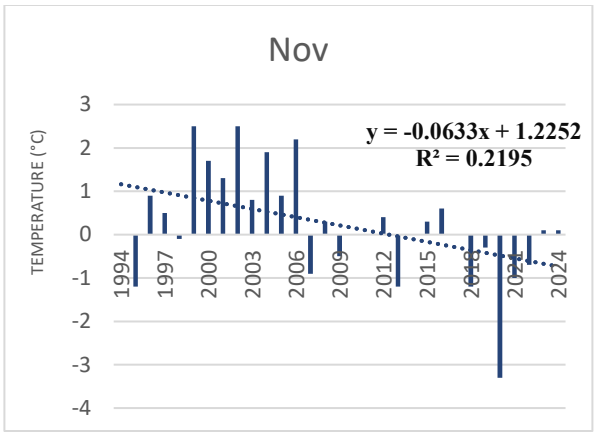

Jun
y = 0.0064x + 14.085
R² = 0.001
TEMPERATURE (°C)
0
5
10
15
20
1994
1997
2000
2003
2006
2009
2012
2015
2018
2021
2024

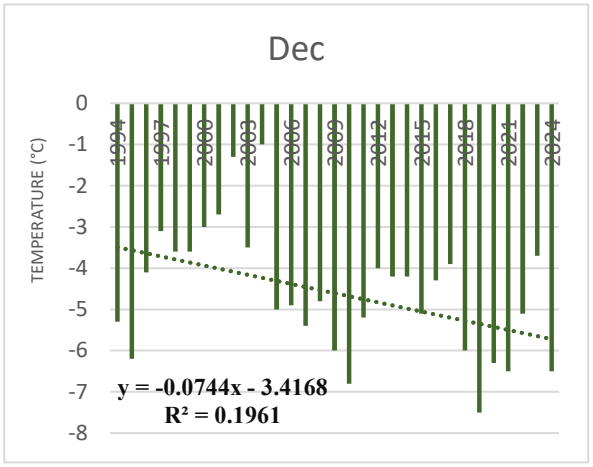

Jul
y = -0.0078x + 16.864
R² = 0.0028
TEMPERATURE (°C)
0
5
10
15
20
1994
1997
2000
2003
2006
2009
2012
2015
2018
2021
2024


Aug
y = -0.0311x + 16.394
R² = 0.0763
TEMPERATURE (°C)
0
5
10
15
20
1994
1997
2000
2003
2006
2009
2012
2015
2018
2021
2024


Sep
y = 0.0742x + 6.5348
R² = 0.1156
Temperature (°C)
0
5
10
15
1994
1997
2000
2003
2006
2009
2012
2015
2018
2021
2024
Years


Oct
y = 0.0004x + 6.0845
R² = 8E-06
TEMPERATURE (°C)
0
2
4
6
8
10
1994
1997
2000
2003
2006
2009
2012
2015
2018
2021
2024

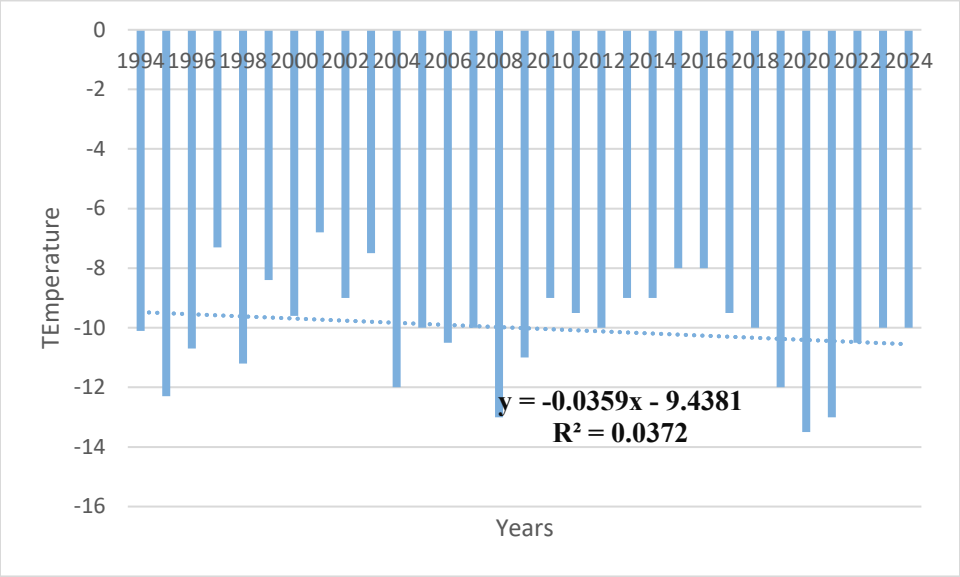




Data Source: Pakistan Metrological Department (PMD)

Figure 27 presents the mean monthly minimum temperature for the period 1994–2024. The monthly trends show considerable variation across the year, with both increasing and decreasing tendencies. During the winter months, January and February show declining trends in minimum temperature, with rates of −0.068°C and −0.037°C per year, respectively. In contrast, minimum temperatures show positive trends from March through June, although the magnitude of increase is relatively small. March records an increase of 0.017°C per year, while April shows a stronger increase of 0.036°C per year. May and June show smaller positive changes of 0.011°C and 0.006°C per year, respectively. During July and August, the trend becomes negative, with minimum temperatures declining by 0.008°C and 0.031°C per year. September shows a positive trend of approximately 0.013°C per year, while October remains almost unchanged, with a rate of approximately 0.000°C per year. The declining tendency becomes more pronounced again in November and December, with rates of −0.063°C and −0.074°C per year, respectively. Overall, the monthly analysis indicates that minimum temperatures do not exhibit a uniform warming pattern throughout the year; rather, the direction and magnitude of change vary substantially by month.

Figure 28: Mean Annual Minimum Temperature (°C)



Data Source: Pakistan Metrological Department (PMD)

Figure 28 illustrates the annual mean minimum temperature over the study period from 1994 to 2024. The annual series shows noticeable year-to-year fluctuations, indicating substantial variability in minimum temperature. The fitted trend line has a negative slope of approximately −0.036°C per year, equivalent to a decline of around 0.36°C per decade. The R^2 value of 0.037 indicates that the linear trend explains only a small proportion of the observed annual variation. Therefore, although the overall annual trend indicates a slight decline in mean minimum temperature, the annual observations fluctuate considerably around the fitted trend. The figure suggests that changes in minimum temperature have not been consistent from year to year, with periods of relatively higher and lower minimum temperatures occurring throughout the study period. Overall, the annual analysis indicates a weak declining tendency in mean minimum temperature during 1994–2024.

Table 15: Rate of Change by Month in Mean Minimum Temperature (°C)

Month	Rate °C / Year	Rate °C / Decade
Jan	−0.068	−0.68
Feb	−0.037	−0.37

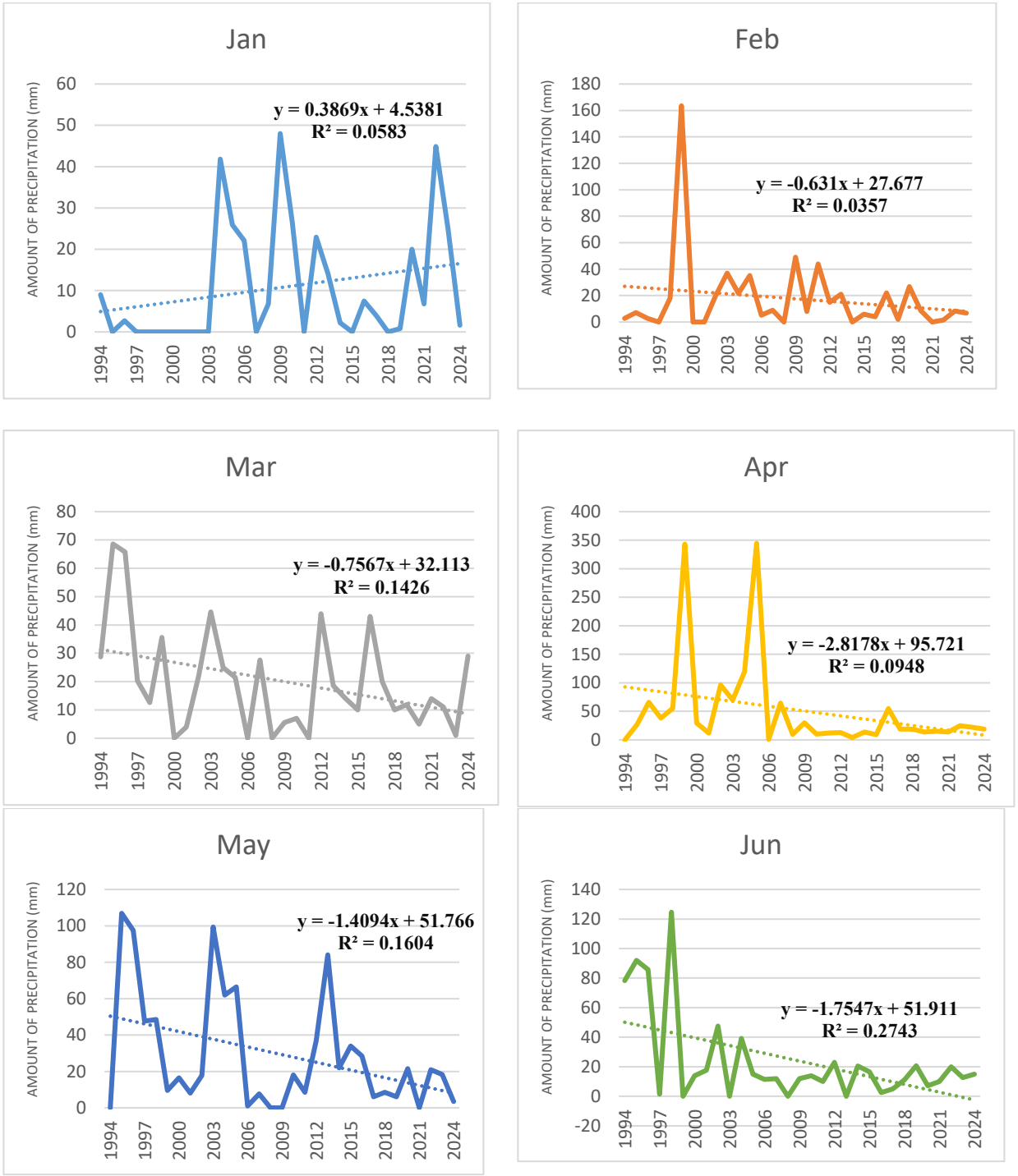
Month	Rate °C / Year	Rate °C / Decade
Mar	+0.017	+0.17
Apr	+0.036	+0.36
May	+0.011	+0.11
Jun	+0.006	+0.06
Jul	−0.008	−0.08
Aug	−0.031	−0.31
Sep	+0.013	**+0.13**
Oct	+0.000	+0.00
Nov	−0.063	−0.63
Dec	−0.074	−0.74

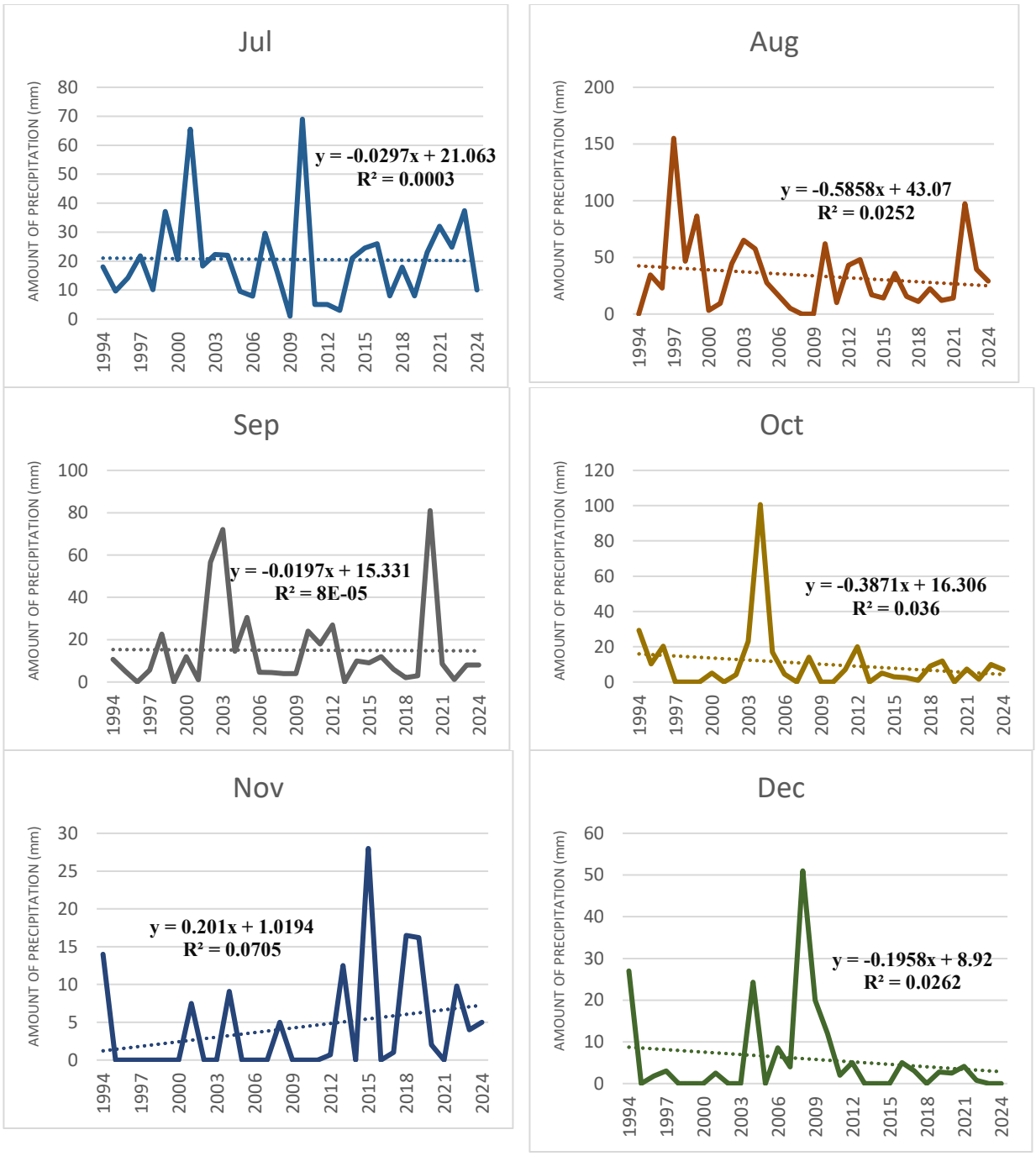
(Author's estimations)

Table 15 presents the rate of change in monthly mean minimum temperature on an annual and decadal basis. The results demonstrate considerable seasonal differences in the direction and magnitude of temperature change. January records the largest decline among the months, at −0.068°C per year or −0.68°C per decade, followed by December at −0.074°C per year or −0.74°C per decade. November also shows a substantial decline of −0.063°C per year, equivalent to −0.63°C per decade. February records a decline of −0.037°C per year or −0.37°C per decade. In contrast, the spring months show positive changes, with March increasing by 0.017°C per year, April by 0.036°C per year, and May by 0.011°C per year. June records only a marginal increase of 0.006°C per year. July and August show negative changes of −0.008°C and −0.031°C per year, respectively. September shows a positive change of 0.013°C per year, while October shows virtually no change. Overall, the rate-of-change analysis indicates that the strongest decreases in minimum temperature occur during the late autumn and winter months, particularly December, January, and November, whereas the clearest increasing tendency is observed during April..

MONTHLY AMOUNT OF PRECIPITATION (mm)

Figure 29: Monthly Amount of Precipitation by Month



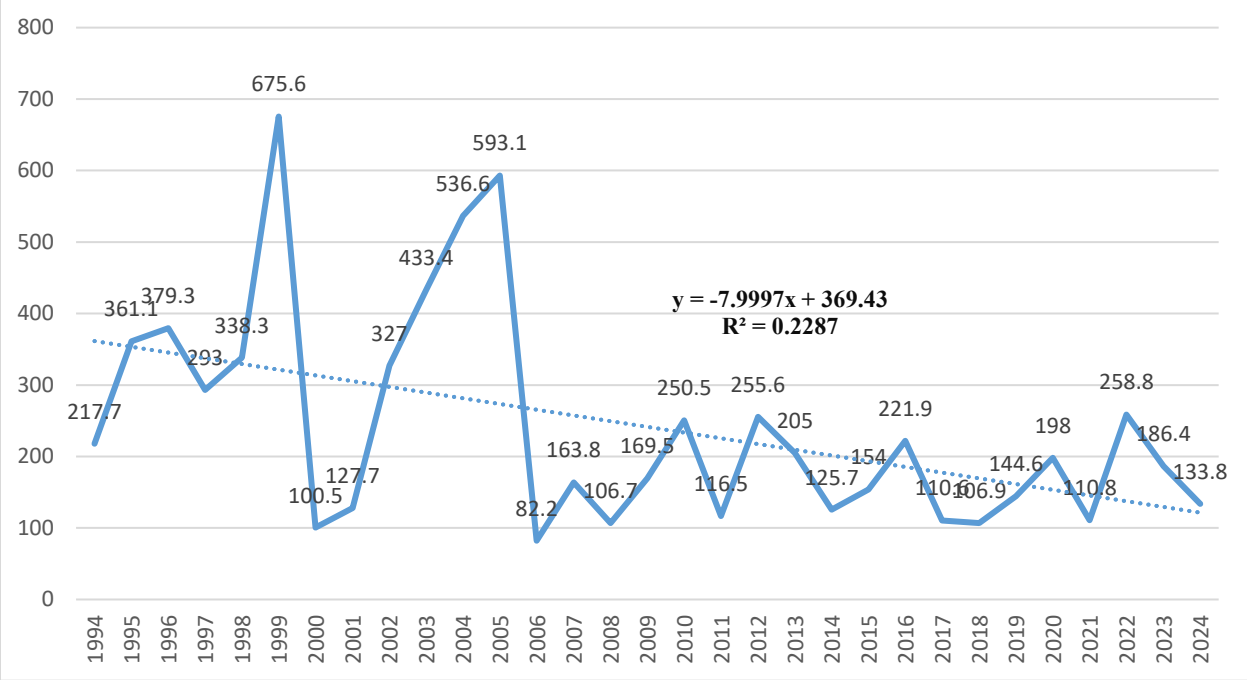


Data Source: Pakistan Metrological Department (PMD)

Figure 29 presents the monthly amount of precipitation for the period 1994–2024. The results indicate considerable variation in precipitation patterns across the different months, with most months showing a declining trend over the study period. January is the only month with a clear positive trend, with precipitation increasing by 0.387 mm per year. In contrast, February and March

show declining trends of 0.631 mm and 0.757 mm per year, respectively. The most pronounced decline is observed in April, where precipitation decreases by approximately 2.818 mm per year. May and June also show substantial declining trends of 1.409 mm and 1.755 mm per year, respectively. During the summer months, July records only a very small decline of 0.030 mm per year, while August shows a larger decrease of 0.586 mm per year. September exhibits a nearly negligible declining trend of 0.020 mm per year. October also shows a decline of approximately 0.387 mm per year. November is the second month showing an upward trend, with precipitation increasing by 0.201 mm per year, whereas December shows a decline of 0.196 mm per year. Overall, the monthly analysis indicates that precipitation has generally decreased across most months, particularly during April, May, and June, while January and November show modest increasing tendencies.

Figure 30: Mean Amount of Precipitation (mm)



Data Source: Pakistan Meteorological Department

Figure 30 illustrates the annual mean amount of precipitation from 1994 to 2024. The annual precipitation series demonstrates substantial year-to-year variability, with considerable differences in the amount of precipitation received across individual years. The recorded annual values range from relatively low levels to substantially higher amounts, with some years receiving more than

500 mm of precipitation and one year reaching approximately 675.6 mm. Other years recorded considerably lower amounts, including values below 100 mm. Despite this strong inter-annual variability, the fitted trend line indicates an overall declining tendency in annual precipitation. The estimated slope is approximately −8.00 mm per year, while the R^2 value of 0.229 indicates that the linear trend explains a limited proportion of the observed annual variation. Thus, the annual precipitation pattern is characterized by both a gradual declining tendency and substantial fluctuations between years.

Table 16: Rate of Change by Month in Amount of Precipitation (MM)

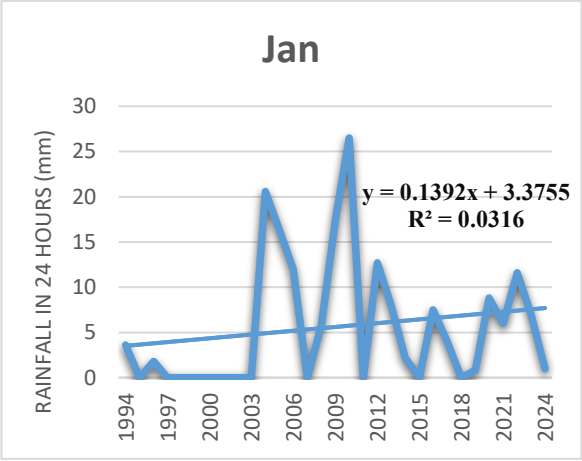
Month	Rate ℃ / Year	Rate ℃ / Decade
Jan	+0.387	+3.87
Feb	−0.631	−6.31
Mar	−0.757	−7.57
Apr	−2.818	−28.18
May	−1.409	−14.09
Jun	−1.755	−17.55
Jul	−0.030	−0.30
Aug	−0.586	−5.86
Sep	−0.020	−0.20
Oct	−0.387	−3.87
Nov	+0.201	+2.01
Dec	−0.196	−1.96

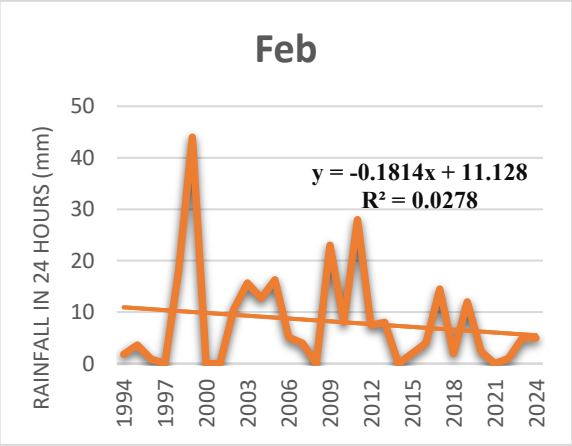
(Author's estimations)

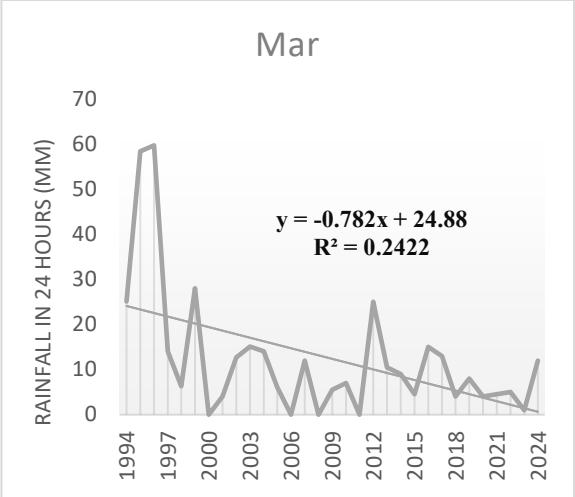
Table 16 summarizes the rate of change in monthly precipitation on an annual and decadal basis. The results show that precipitation has declined in most months of the study period. The strongest decline occurs in April, with a reduction of 2.818 mm per year, equivalent to approximately 28.18 mm per decade. June records the second-largest decline at 1.755 mm per year or 17.55 mm per decade, followed by May at 1.409 mm per year or 14.09 mm per decade. March shows a decline of 0.757 mm per year, equivalent to 7.57 mm per decade, while February decreases by 0.631 mm per year or 6.31 mm per decade. August records a decline of 0.586 mm per year, whereas October decreases by 0.387 mm per year. Smaller declines are observed in December, July, and September, at 0.196, 0.030, and 0.020 mm per year, respectively. In contrast, January and November show positive trends, with precipitation increasing by 0.387 mm and 0.201 mm per year, equivalent to 3.87 mm and 2.01 mm per decade. Overall, the rate-of-change analysis indicates a predominantly declining precipitation pattern, with the most substantial reductions occurring during the spring and early summer months, particularly April, May, and June.

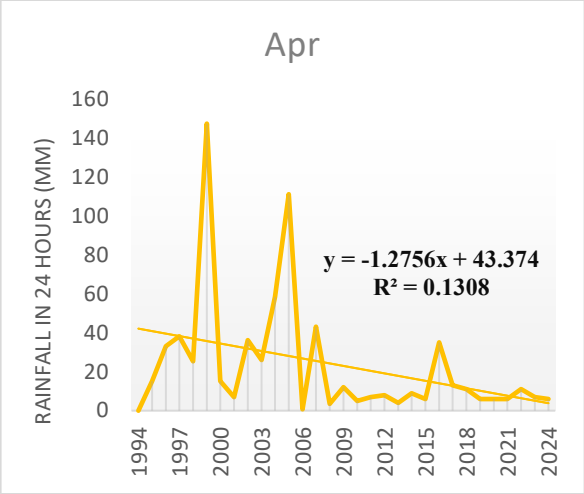
MONTHLY HEAVIEST RAINFALL IN 24 HOURS (mm)

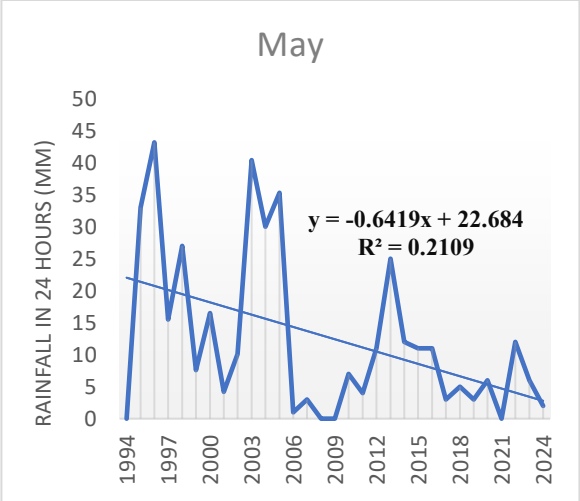
Figure 31: Monthly Heaviest Rainfall by Month

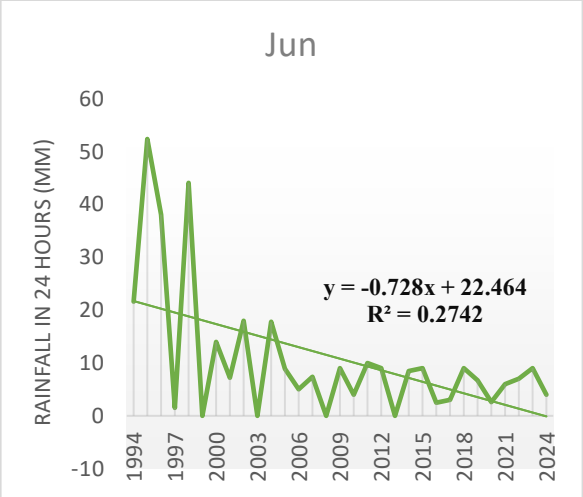


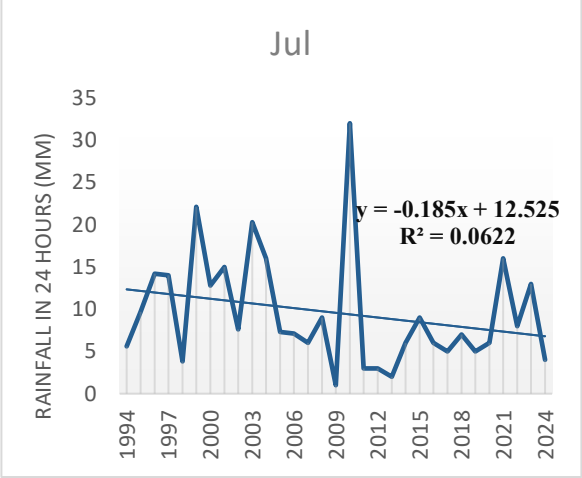


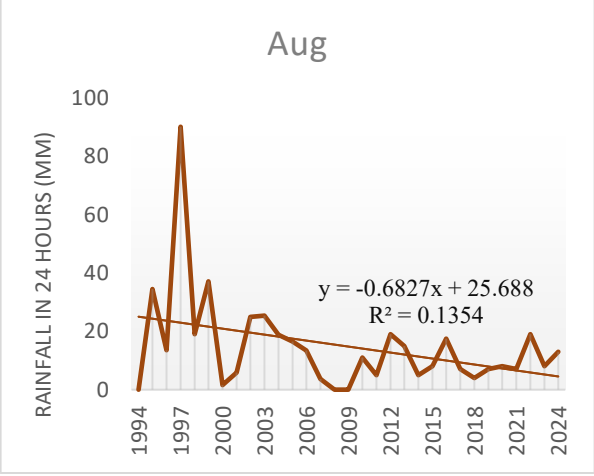

Mar
RAINFALL IN 24 HOURS (MM)
y = -0.782x + 24.88
R² = 0.2422

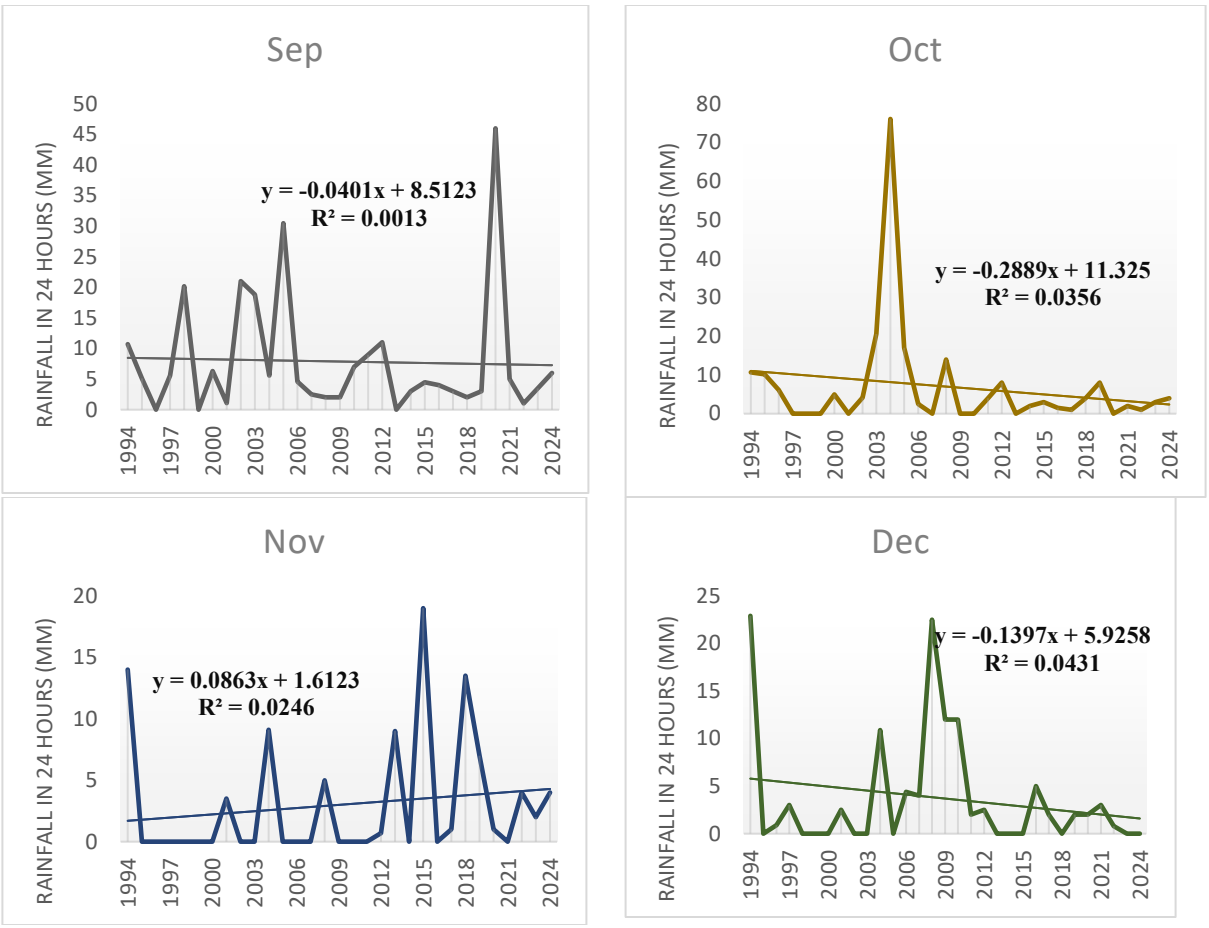

Apr
RAINFALL IN 24 HOURS (MM)
y = -1.2756x + 43.374
R² = 0.1308


May
RAINFALL IN 24 HOURS (MM)
y = -0.6419x + 22.684
R² = 0.2109


Jun
RAINFALL IN 24 HOURS (MM)
y = -0.728x + 22.464
R² = 0.2742


Jul
RAINFALL IN 24 HOURS (MM)
y = -0.185x + 12.525
R² = 0.0622


Aug
RAINFALL IN 24 HOURS (MM)
y = -0.6827x + 25.688
R² = 0.1354



Data Source: Pakistan Metrological Department (PMD)

Figure 31 presents the monthly heaviest rainfall recorded within a 24-hour period for the study period 1994–2024. The results show considerable variation in extreme daily rainfall across the months and years, with most months exhibiting declining trends. January shows a positive trend of approximately 0.139 mm per year, indicating a slight increase in the heaviest 24-hour rainfall events. In contrast, February records a declining trend of 0.181 mm per year, while March shows a more pronounced decrease of 0.782 mm per year. April exhibits a substantial declining trend of approximately 1.276 mm per year. May and June also show declining trends of 0.642 mm and 0.728 mm per year, respectively. During July, the heaviest 24-hour rainfall declines by approximately 0.185 mm per year, while August shows a larger decrease of 0.683 mm per year. September records only a very small decline of 0.040 mm per year, whereas October shows a decrease of 0.289 mm per year. November is the only other month showing a positive trend, with an increase of approximately 0.086 mm per year. December records a declining trend of 0.140 mm

per year. Overall, the monthly figures indicate that the heaviest 24-hour rainfall has generally declined across most months, with the strongest decreases occurring during April, June, and August, while January and November show modest increasing tendencies.

Table 17: Rate of Change by Month of Precipitation (MM)

Month	Rate mm/ Year	Rate mm/ Decade
Jan	+0.387	+3.87
Feb	−0.631	−6.31
Mar	−0.757	−7.57
Apr	−2.818	−28.18
May	−1.409	−14.09
Jun	−1.755	−17.55
Jul	−0.030	−0.30
Aug	−0.586	−5.86
Sep	−0.020	−0.20
Oct	−0.387	−3.87
Nov	+0.201	+2.01
Dec	−0.196	−1.96

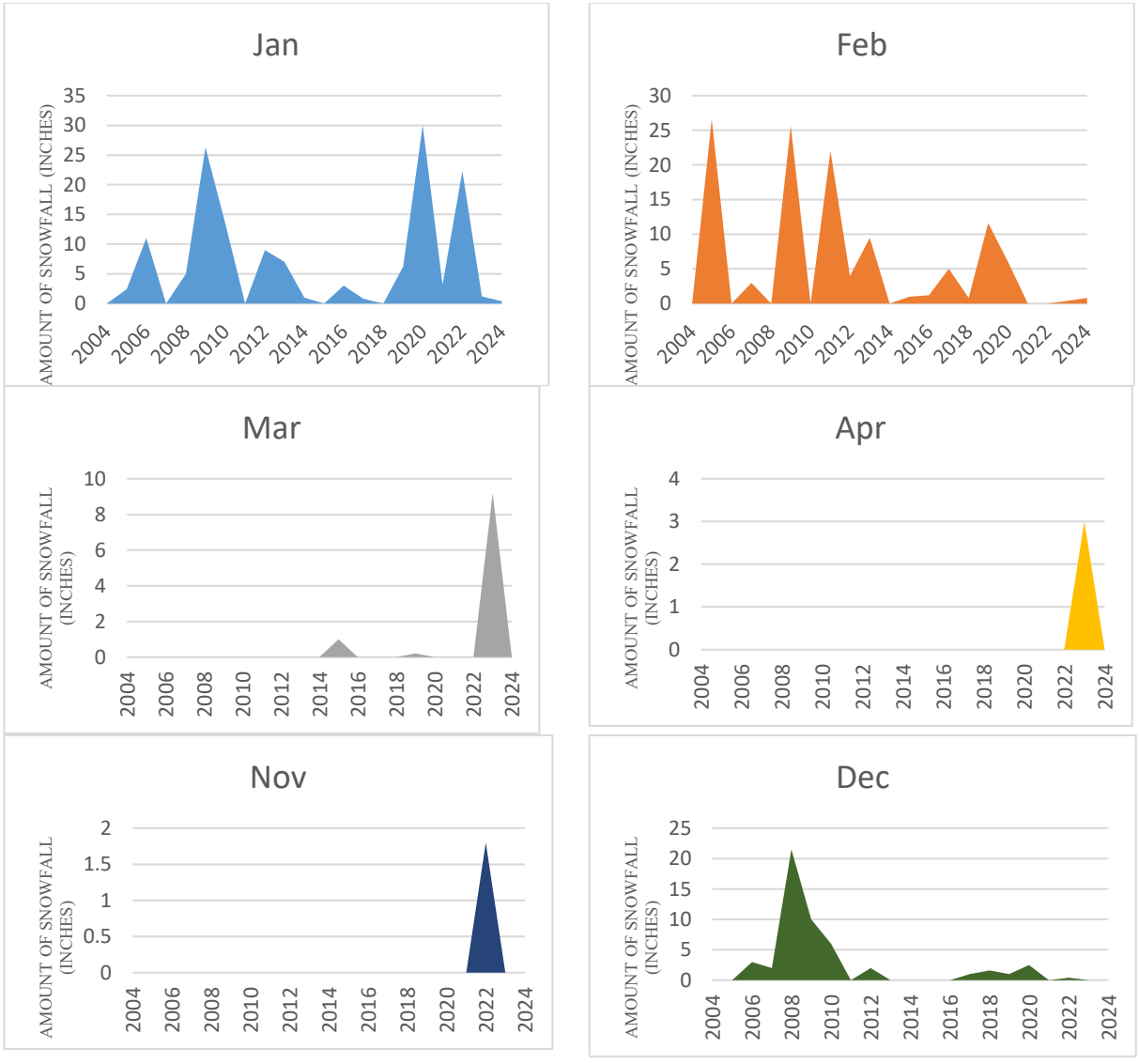
(Author's estimations)

The table 17 show that most months experienced a decline in the heaviest 24-hour rainfall during the study period. The strongest decline is observed in April, at approximately 1.276 mm per year, followed by June at 0.728 mm per year and March at 0.782 mm per year. August also records a substantial decline of approximately 0.683 mm per year, while May decreases by 0.642 mm per year. February and October show smaller declines of 0.181 mm and 0.289 mm per year,

respectively. July, September, and December show relatively small negative trends. In contrast, January and November record positive trends, increasing by approximately 0.139 mm and 0.086 mm per year, respectively. Overall, the results indicate that the heaviest 24-hour rainfall has generally declined across the study period, particularly during April, March, June, and August, while the increases observed in January and November are relatively modest. The variation in trends across months highlights the seasonal nature of changes in extreme rainfall events.

MONTHLY AMOUNT OF SNOWFALL (INCHES)

Figure 32: Monthly Amount of Snowfall (INCHES) by Month



Data Source: Pakistan Metrological Department (PMD)

Figure 32 presents the monthly amount of snowfall in inches for the available months during the study period. The figures show considerable variation in snowfall across the years and between months. January and February generally represent the months with the highest snowfall amounts, with values reaching substantially higher levels than the other observed months. March also receives notable snowfall, although at lower levels compared with January and February. April records considerably smaller amounts of snowfall, indicating a transition toward the warmer season. The available observations for November show relatively limited snowfall, while December again records comparatively higher snowfall amounts. Overall, the monthly figures demonstrate a strong seasonal pattern in snowfall, with snowfall concentrated mainly during the winter months and substantially lower amounts during April and November. The year-to-year variation also indicates that snowfall is not consistent across the study period, with some years experiencing considerably higher or lower snowfall than others.

Table 18: Rate of Change by Month of Snowfall (inches)

Month	Rate Inches/ Year	Rate Inches/ Decade
Jan	+0.110	+1.10
Feb	−0.448	−4.48
Mar	+0.110	+1.10
Apr	+0.035	+0.35
Nov	+0.019	+0.19
Dec	−0.276	−2.76

(Author's estimations)

Table 18 presents the rate of change in monthly snowfall in inches per year and per decade. The results show mixed trends across the observed months. January records an increasing trend of 0.110 inches per year, equivalent to 1.10 inches per decade. February shows the strongest decline, with snowfall decreasing by 0.448 inches per year or 4.48 inches per decade. March shows an increasing trend of 0.110 inches per year, equivalent to 1.10 inches per decade, while April records

a smaller increase of 0.035 inches per year or 0.35 inches per decade. November also shows a modest increase of 0.019 inches per year, equivalent to 0.19 inches per decade. In contrast, December records a declining trend of 0.276 inches per year, corresponding to a decrease of 2.76 inches per decade. Overall, the rate-of-change analysis indicates that snowfall trends vary substantially by month, with increasing trends in January, March, April, and November, while February and December show declining trends. The largest decrease is observed in February, followed by December.

Chapter 5

Conclusion and Recommendations

This chapter concludes the study by presenting the major findings on climate change and its effects on fruit production in District Ghizer, Gilgit-Baltistan. The chapter also presents policy recommendations to improve climate resilience, strengthen agricultural governance, and promote sustainable fruit production in the region.

This thesis aims to gain insight into the effects of climate change on high-value fruit crops such as cherries and apricots in the District Ghizer, with particular focus on climatic variability, farmers' perceptions, institutional responses, and adaptation issues. District Ghizer has been extremely susceptible to climate change, owing to its mountainous geography, reliance on glacier-fed water, and climate-sensitive agriculture. Phenological variations in fruit production, quality, and post-harvest processes have been directly influenced by temperature, precipitation, snowfall, and extreme weather conditions.

Primary data were gathered to support the study's objectives through a structured questionnaire administered to 119 fruit growers and key informant interviews conducted with agricultural officers, extension workers, researchers, and local experts. The analysis of farmers' experience and adaptation responses used descriptive statistics and thematic analysis, whereas secondary climatic data identified long-term trends in temperature and precipitation. The results suggest that increases in temperature and irregular precipitation cycles have triggered significant changes in the flowering and fruiting of cherries and apricots. The main climate-related challenges were early flowering, insufficient chilling hours, increased pest and disease attacks, and rainfall during harvesting. There has been an increasing trend in cherry production, driven by market demand and improved varieties, whereas apricot production has decreased primarily due to temperature stress and lower chilling requirements. Losses after harvesting are also high due to the lack of good cold storage facilities, poor transport infrastructure, and weak market connections.

The thematic analysis demonstrated several major problems influencing the farmers' adaptive capacity, including the inaccessibility of climate information, ineffective extension services, the

inability to use varieties resistant to climate, financial limitations, and the lack of institutionalized support systems. The majority of farmers use traditional agriculture and unofficial coping methods, which are becoming inadequate due to rapidly changing climatic conditions.

The analysis of agricultural and other policies related to climate change in Gilgit-Baltistan identified major institutional gaps. The lack of properly developed and implemented climate change and agriculture policies will restrict the ability to coordinate planning, implement sound adaptation strategies, and build long-term resilience among fruit farmers in District Ghizer.

The study explains climate variability as an important and nuanced driver of fruit production in District Ghizer. Extreme climate events, rather than average climate trends, affect apricot production, while both gradual climate shifts and climate extremes affect cherry production. Increasing average annual temperatures negatively impact cherry production, while more rain positively impacts production, indicating that the climate is more sensitive to producing cherries than apricots. For both crops, the most reliable and significant predictor of production was extreme climate events, defined by annual heaviest rainfall over a 24-hour period (AHR24); this speaks to the importance of climate shocks in shaping agrarian outcomes. Findings point to the need for climate-resilient agrarian policies and adaptive frameworks to climate variability and extreme events that threaten fruit production and the livelihoods that rely on it in District Ghizer.

Overall, the study finds that climate change is a multidimensional threat to fruit production in District Ghizer. These factors, when combined with rising temperatures, unpredictable rainfall, fewer hours to chill fruits, and more occurrences of pests and diseases, have led not only to a decrease in the stability of yield and fruit quality but also to increased production costs and postharvest losses. The agricultural activities of cherry and apricot production are a significant source of family earnings in the area; therefore, these impacts of climate can directly affect farmers' livelihoods and income security. Moreover, the lack of supply in the fruit chains and the drop in productivity endanger the regional economy as a whole, which also relies on horticulture as a source of employment, market presence, and even export opportunities.

Unless timely and coordinated policy interventions are in place, poor institutional capacity and limited access to climate-resilient technologies are likely to increase farmers' vulnerability to climate shocks. Agricultural governance will remain weak, the spread of extension services will not occur, and agricultural practices will not become more climate-smart, as farmers will still use

traditional coping strategies that are ineffective in changing climatic conditions. This means that risks associated with climate on the production of fruits are likely to worsen in the future, and this would place the concepts of sustainable agricultural development, rural livelihoods, and the long-term economic stability of District Ghizer and other high-altitude areas of Gilgit-Baltistan under a serious challenge.

5.2 Recommendations:

1) Policy Recommendations Based on Thematic Analysis:

- The thematic analysis indicates that Gilgit-Baltistan currently lacks dedicated and comprehensive climate change and agricultural policies that specifically address the climate-related challenges faced by the horticulture sector. Therefore, as a first priority, the government should formulate comprehensive climate change and agricultural policies for Gilgit-Baltistan, with specific provisions for climate adaptation in agriculture and fruit production.
- The newly formulated policies should specifically address the impacts of changing temperature and precipitation patterns, water availability, changes in fruit phenology, declining yield and quality, increasing pest and disease risks, and climate-related post-harvest and market challenges affecting major fruits, particularly cherries and apricots.
- Climate-resilient fruit varieties, improved water management, farmer adaptation, access to climate information, agricultural extension services, and post-harvest infrastructure should be incorporated as key components of the proposed climate change and agricultural policies.
- Clear institutional responsibilities should be established among the Agriculture Department, Agriculture Extension Department, Pakistan Meteorological Department, and other relevant institutions to ensure effective coordination in providing climate information, technical assistance, farmer training, and support for implementing climate adaptation measures in the horticulture sector..

2) Responding to Unpredictable Climatic Patterns and Water Variability:

The finding that snowfall is decreasing and shifting later in the season, while rainfall has become sudden and unpredictable, particularly during flowering, calls for investment in localized climate monitoring and early warning.

- Expand localized climate monitoring: Install automatic weather stations across the Yasin, Gupis, Phander, Ishkoman, and Punial valleys to generate valley-specific temperature, rainfall, and snowfall data, rather than relying on regional estimates.
- Establish a farmer-facing early warning system: Issue short-range advisories timed to flowering and harvesting windows so farmers can take protective action ahead of unseasonal rainfall or frost.
- Improve water storage and irrigation infrastructure: Rehabilitate and reinforce traditional irrigation channels (kuhls) damaged by floods, and add small-scale storage (ponds or tanks) to capture excess late-season glacier melt for use during the April–to–February shortage period identified by respondents.

3) Protecting Fruit Phenology, Yield, and Quality:

Because early flowering, disturbed chilling, declining yields, and shorter shelf life were reported as the most direct production-level consequences of climate change, interventions should target both the orchard and the immediate post-harvest window.

- Promote climate-resilient fruit varieties: Introduce and multiply cherry and apricot varieties bred for lower chilling requirements and greater heat and frost tolerance, prioritized by the study's respondents as the single most requested intervention.
- Support orchard-level climate-smart management: Support use of frost protection measures (smoke, wind machines, or protective netting) during the now-earlier flowering window, and provide guidance on adjusted pruning and irrigation schedules aligned with the shifted phenological calendar.
- Strengthen pest and disease management: Introduce integrated pest management training and localized pest/disease surveillance, since warmer and more humid conditions were reported to be driving new fungal and insect pressure.

4) Reducing Post-Harvest Losses and Supply Chain Disruptions:

Respondents consistently linked income loss not only to lower production but to the fruit spoiling before it reached the market. This points to infrastructure gaps as a priority area.

- Invest in cold-chain infrastructure: Establish community or cooperative-level cold storage, grading, and pre-cooling units in the main producing valleys, since the study found that

existing air-conditioned transport is inadequate and inaccessible to most small-scale farmers.

- Improve harvest-season road resilience: Prioritize maintenance of roads prone to flood and landslide blockage during the cherry and apricot harvest window, given that blockages lasting more than five days were reported to cause near-total spoilage of perishable fruit.
- Develop local value-addition options: Support the establishment of small-scale processing (drying, pulping, jam-making) for fruit that cannot reach fresh markets in time, converting a portion of post-harvest losses into saleable value-added products.

5) Strengthening Farmer Adaptive Capacity:

The study found that farmers' adaptation remains largely reactive, constrained by limited awareness, weak extension contacts, and the high cost of climate-resilient inputs.

- Revitalize agricultural extension services: Deliver regular, field-based training on climate-smart orchard management, irrigation scheduling, and post-harvest handling, addressing the gap in extension contact identified by respondents.
- Improve access to affordable technology and finance: Introduce subsidized credit or input-support schemes so that resistant seedlings, drip irrigation, and storage equipment become affordable to small landholders rather than only larger farmers.
- Encourage peer learning: Promote demonstration orchards and farmer-to-farmer knowledge exchange so that successful adaptation practices, such as those already improving cherry yields in some valleys, are shared across the district.

6) Supporting Long-Term Sector Resilience:

- Promote youth engagement in fruit agribusiness: Create structured entry points, such as agribusiness incubation, market linkage support, and value-addition enterprises, to draw younger farmers into fruit production and modernize the sector, as respondents identified youth participation as important for innovation.
- Strengthen market linkages: Facilitate direct linkages between farmer cooperatives and down-country buyers or processors to reduce dependence on delayed trader visits, which the study found to be a major cause of early-ripened fruit going unsold.

5.3 Limitations of the Study:

This study has several limitations that should be considered when interpreting its findings. It was confined to District Ghizer and covered only two fruit crops, cherries and apricots, so the results may not generalize to other districts of Gilgit-Baltistan or to other crops with different climate sensitivities. The sample size was relatively modest, consisting of 119 farmers across four valleys and about 13 key informant interviews, which limited the statistical power of the analysis and the ability to explore subgroup patterns in depth. Finally, as with any qualitative study, the thematic analysis involved a degree of researcher interpretation in coding and theme development, despite following a structured six-step process.

5.3 Directions for Future Research:

Future research should build on these limitations in several ways. Expanding the geographic and crop coverage to other districts of Gilgit-Baltistan and additional fruit varieties would help establish whether the patterns found in Ghizer hold more broadly across the region. Larger, randomly drawn samples combined with inferential statistical methods, such as regression or panel-data analysis, would allow researchers to test the strength and significance of relationships between climate stressors, adaptation behavior, and production outcomes while controlling for factors like farm size and altitude.

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Appendix

Questionnaire: Impact of Climate Change on Fruit Production in District Ghizer of Gilgit Baltistan

Part A: Socio-Economic Information

Field	Response	Field	Response
Tehsil		Village	
Respondent Name		Age	
Gender		Family Size	
Marital Status		Education	
Occupation		Primary Occupation	
Secondary occupation		Household head	
HH age		Respondent Relation to HH	
Principal Means of Livelihood		Secondary Means	
HH Income (PKR)		Income from farming (PKR)	

PART B: Tenure Arrangements & Land Information

Total Cultivated Area (Kanal)	**Own Land (Kanal)**	**Land Rented In (Kanal)**	**Land Rented Out (Acres)**	**Distance field-home (km)**	**Soil Quality**

Quality of Soil (1=Low;2=Med;3 =High)		Years continuously used this plot.	
Rent paid/received if leased (PKR/year)		Owner of tube well (if any)	
Water source (1=Canal;2=Tube well;3=Rainfed;4 =Other)		Irrigation method	
Fuel expense (PKR)		Rent if borrowed (PKR/hr)	

Part C. Labor Composition

Stage	**Family Labour (Nos)**	**Hired Labour (Nos)**	**Days per person**	**Opportunity cost**	**Type (Family/Hired/ Mixed)**
Land Preparation & Sowing					
Field Management (Irrigation, Fertilizer, Weeding)					
Harvesting					
Post-harvesting					

Part D. Agricultural Inputs, Water Use & Costs

Crop		Pesticides Used (Yes/No & Qty)	Fertilizer (Qty/PKR)	Water Source	Fuel Expense (PKR)	Other Costs/Notes
Cherries	Quantity					
	Price/ unit					
Apricot	Quantity					
	Price/ unit					

1. Did you increase pesticide use due to climate-related pest attacks? (Yes/No). If yes, by how much?
2. Water availability during fruit season: Adequate / Shortage / Critical shortage
3. Have irrigation needs increased due to the climate? (Yes/No)

Part E. Fruit Production, Outputs & Prices

Crop	Area (Kanal)	Flowering Date (D-M)	Harvest Date (D-M)	Avg Prod (Prev year) In kg	Avg Prod (current) in kg	Post-harvest Losses	Quantity Sold (Maund) / Price (PKR)
Cherries							
Apricot							

Part F. Climate Impact Assessment

Table 1: Climate Impacts on Cherries and Apricots

Climate Impact	Cherries (Yes/No)	Quantity Loss (kg/Kanal)	Value Loss (Rs.)	Apricot (Yes/No)	Quantity Loss (kg/Kanal)	Value Loss (Rs.)
Temperature Rise (Warm Winters)						
Temperature Rise (Hotter Summers)						
Irregular Rainfall (Unpredictable Pattern)						
Drought (Prolonged Dry Spells)						
Water Shortage						
Hailstorms (Spring & Early Summer)						

Windstorms						
Untimely Rain During Flowering (March–April)						
Untimely Rain During Harvest (June–July)						

Table 2: Adaptation Measures Adopted by Farmers

Climate Impact	**Adaptation Adopted (Yes/No)**	**Adaptation Measures**
Temperature Rise		Mulching / Early pruning / Shifting varieties / Shade nets
Irregular Rainfall		Improved drainage / Soil moisture conservation / Tunnel farming
Drought		Drip irrigation / Water harvesting / Mulching
Water Shortage		Lining channels / Water storage tanks / Shared water rotation
Hailstorms		Protective nets / Insurance (if available)
Windstorms		Windbreak trees / Branch support

Rain During Flowering		Foliar sprays / Adjusted pruning time
Rain During Harvest		Early picking / Covered storage / Improved drying

F. What are the main constraints in adopting these measures?

☐ High cost ☐ Lack of knowledge ☐ Lack of water ☐ Lack of government support ☐ Other

Part G: Supply Chain & Market Access

Question	Response
1. Have climate events caused delays in harvesting? (Yes/No). If yes, how many days?	
1. Main selling channel (Local market/District market/Middleman/Direct buyer/Exporter)	
2. Distance to main market (km)	
3. Transport method used for fruit delivery	
4. Price of transport (PKR)	
5. Do you have access to cold storage? (Yes/No). If yes, location & capacity	
6. Do you use packaging material? (Yes/No). If yes, specify type and cost	

7. Major supply chain challenges (Poor roads; No cold storage; High transport cost; Market delays; Lack of packaging; Low bargaining power)	
8. Does climate change worsen these supply chain challenges? (Yes/No). If yes, explain	
9. Have price reductions occurred due to climate-related delays? (Yes/No)	
10. Who usually sets the selling price? (Farmer/Middleman/Buyer/Market committee/Government)	
11. Payment terms (Immediate/Credit/Delayed). If credit, typical delay (days)	
Other notes/observations	

Thank you for your time and cooperation.

Questions for interviews

KIIs Questions for Agriculture & Climate Experts

My name is Raja Abdullah Khan, an MPhil Public Policy student at PIDE. I am researching the impact of climate change on cherry and apricot production in District Ghizer. For this purpose, I would like to ask you a few questions regarding your expertise and experience in this area.

1. Could you please describe your current role and responsibilities in [institution/organization]?
2. How long have you been working in the agriculture sector, and what areas of expertise do you focus on, particularly related to fruit farming or climate change?
3. How do you view the recent changes in temperature and rainfall patterns in Gilgit-Baltistan, especially in District Ghizer?
4. In your expert opinion, which climate variables (temperature, rainfall, snowmelt) are affecting fruit farming the most?
5. Have you observed any shifts in flowering time or fruit-setting period in cherries and apricots?
6. How has climate change affected the yield and quality of cherries and apricots in Ghizer?
7. Which major climate-related challenges (heat stress, irregular rain, frost, pests, water scarcity) are currently impacting production?
8. Are you seeing more pest or disease outbreaks due to changing climate conditions?
9. In your view, how do heavy rains, floods, or landslides affect the fruit supply chain in Ghizer?
10. What are the major weaknesses in harvesting, storage, and transportation systems that increase post-harvest losses?
11. What adaptation measures are local farmers currently using to deal with climate change?
12. Which adaptation practices do you consider most effective for cherry and apricot growers?

13. What are the biggest barriers preventing farmers from adopting modern climate-smart agriculture?
14. How effective is the Provincial Agriculture Sector Policy in addressing climate-related issues for fruit growers?
15. What type of institutional support (extension services, training, early warning systems) do farmers need urgently?
16. What policy gaps exist that hinder climate-resilient fruit farming in District Ghizer?
17. What interventions or policies would you recommend to improve fruit production under changing climate conditions?
18. What specific investments or reforms are needed to make the cherry and apricot sector more resilient?