

# Sustainable Livelihoods and Socio-Economic Determinants of Chilgoza Pine Income in Diamer District, Gilgit-Baltistan, Pakistan

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## Research Article

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# **Sustainable Livelihoods and Socio-Economic Determinants of Chilgoza Pine Income in Diamer District, Gilgit-Baltistan, Pakistan**

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## **Abstract**

Chilgoza pine (*Pinus gerardiana*) is an important natural asset for rural living in mountainous northern Pakistan (such as in the Diamer District of Gilgit-Baltistan). Chilgoza nuts are classified as a high-value non-timber forest product (NTFP). They can provide significant amounts to household economies, which are increasingly being challenged by ecological and socio-economic stressors. This research explores the relationships between chilgoza harvesting, household income portfolios, and the livelihood strategies of forest-dependent communities in the context of the Sustainable Rural Livelihoods Framework (SRLF). The study uses a mixed-methods technique that combines household surveys, participatory focus groups, and institutional analysis in four villages to represent the Chilas Valley. The findings show that chilgoza harvesting represents a vital piece of livelihood diversification plans, including households without many or any alternative income sources. The study shows important socio-economic determinants that are impacting harvesting, such as household Labour, traditional ecological knowledge, and access to forests. However, these socio-economic benefit streams were all becoming constrained as a result of ongoing systemic issues such as climate variability, inadequate market access, and poor governance frameworks for the sustainable management of forests. Theoretical implications underscore the need to re-evaluate NTFP-based livelihoods as they are either discussed or excluded in popular and academic literature on sustainable development or climate resilience. Practical recommendations highlight areas of necessary improvement, such as enhanced local institutional strength or equitable value chain distribution, and the development of integrated conservation strategies that balance ecological integrity with local economic needs. Overall, this research contributes to wider academic debates related to the governance of natural resources in fragile mountain ecosystems and provides useful policy-relevant input into the region's planning for development. Ultimately, the research underlines the need for more holistic approaches that view chilgoza pine beyond that of an economic commodity, but as a keystone species which assists the proportional integrity of people living sustainably with the ecological and cultural integrity of the Hindu Kush-Himalayan region.

**Keywords:** Non-timber forest products, livelihood sustainability, mountain ecosystems, resource governance, sustainable harvesting, rural development.

## **Introduction**

For centuries, non-wood forest products have been important for rural and forest-dweller communities worldwide, even in the world's most mountainous and ecologically precarious regions. These include *Pinus gerardiana*, popularly known as chilgoza pine: an invaluable tree species from ecological, economic, and cultural perspectives under the dry temperate conditions

of the Hindu Kush-Himalaya, Pakistan's Diamer District of Gilgit-Baltistan as host. While critical, little empirical research exists on the understanding of socio-economic determinants of chilgoza pine income at the household level. Therefore, this study will bridge this gap by demonstrating how socio-economic factors influence the perception of chilgoza pine income across selected villages of Diamer.

The forest resources of Pakistan are limited, amounting to only 5.1% of the total land area under forest cover. Coniferous forests account for almost 37% of the total area of evergreen forests ("Economic Survey (Economic survey of Pakistan. 2023). Forest timber is still the prime forest product, whereas NTFPs, especially chilgoza pine, are gaining increasing recognition regarding their importance for the local economy as well as for ecological sustainability. Chilgoza pine is a high-altitude species occurring largely in Gilgit-Baltistan, Baluchistan, and Khyber Pakhtunkhwa, where it constitutes an important non-timber forest product harvested seasonally for its edible and nutrient-rich seeds. Pakistan is among the three main producing countries, after Russia and China, for global supplies of chilgoza pine nuts (Aziz et al. 2017).

Chilgoza pine trees grow in the dry temperate forests of Gilgit-Baltistan, which provide very important economic resources to remote communities. Particularly in the Diamer District, where forested land predominates, those collecting chilgoza nuts for income through collection, processing, packaging, and marketing have opportunities. The general reported area under pine forest in the region is nearly 359,392 hectares; of this area, Diamer alone accounts for 177,324 hectares (Tufail et al. 2021). Hence, such extensive forest cover makes the chilgoza pine an important source of livelihood. District-wise, according to statistics, Shirani District has a recorded annual chilgoza pine production of PKR 4.553 billion, followed by Diamer District, which has had an annual production amounting to PKR 599 million (Tufail et al. 2021).

Agriculture, livestock, and forestry are the primary sources of livelihood for residents of the far-flung villages of Diamer, including Khinar, Boto Gha, Naitt, and Gonar Farm. The economic contributions of NTFPs, particularly chilgoza pine, are very important to the economic security of these villages. Nevertheless, several dynamic factors influencing the collection and trade of chilgoza include changing market prices, climatic variation, labor availability, and accessibility to forest resources. The dependence of local households upon a single forest resource places them in the domain of socio-economic vulnerability and environmental risk, especially concerning climate change (Shalizi et al. 2018).

The Sustainable Rural Livelihoods Framework (SRLF) - as advanced by DFID (1999) and further elaborated on by Scoones (1998) is a powerful tool for understanding the significance of the chilgoza pine in supporting rural livelihoods. A livelihood is termed sustainable, according to this framework, when it copes and recovers from stress and shocks while sustaining or increasing its capabilities and assets, without ultimately degrading the natural resource base. Chilgoza pine is a financial resource and also a natural resource, which adds to rural resilience and sustainability in Diamer. Studies like that of Paumgarten and Shackleton (2011) and Tufail, Khan, and Ali (2021) have reiterated the contribution of chilgoza pine in household incomes, indicating that research is required for the socio-economic dynamics conditioning its role.

Although much research has been done on the larger economic and ecological significance of chilgoza pine, fewer studies have explored the micro-level socio-economic impact of chilgoza harvesting. For example, Ali et al. (2020) found that chilgoza gathering generated income that directly increased a household's financial resilience after daily necessities were covered, and was applied to savings and investments beyond daily expenses. Most research, however, provides broad regional descriptions, without data breakdown below the regional level, particularly regarding the remoteness of the settlement units in the case of Diamer. Micro-level understanding of the differences between households and the characteristics that lead to chilgoza income could provide specific pathways in policy options to improve livelihoods with sustainable harvesting.

Moreover, previous literature emphasises the importance of socio-economic factors such as land ownership, education, access to markets, availability of labour, and gender roles as factors influencing the profitability of NTFPs (Rahimzadeh 2022; Spies 2023). For example, households with higher levels of education and market access obtain higher income from chilgoza pine due to their negotiation and marketing skills. The size of landholding and access to labour also describe how much a household can harvest and sell. These findings indicate a need to look at how these factors operate in the Diamer context specifically.

Global studies clearly illustrate a common theme regarding the economic importance of NTFPs. Liu (2016) in Myanmar reports that approximately 44% of rural livelihoods are tied to NTFPs. Likewise, in Namibia, Ghana, and Southern Africa, it has been documented that NTFPs play a crucial role in food security, gendered livelihoods, and the fight against poverty (Shackleton et al. 2007; Cheikhyoussef and Embashu 2013; Asamoah et al. 2024). The case of chilgoza pine fits with these global studies, but requires country-specific policies to reflect the fragile mountain ecosystem and socio-economic realities of Gilgit-Baltistan.

Atif (2021) and Shalizi and Khurram (2016) acknowledged the chilgoza pine's substantial economic benefits and difficulties with regeneration and sustainability in Afghanistan. Studies conducted in Pakistan by Akbar et al. (2014) and Urooj & Jabeen (2015) pointed to the threats posed by overexploitation and poor management as risks to the sustainability of chilgoza pine. Consequently, studying the socio-economic aspects of chilgoza pine income is important, not only for the area's economy but also for environmental protection.

This study builds on the themes outlined above and uses the central research question of whether socio-economic aspects directly affect households' chilgoza pine income levels in the Diamer District. In answering this question, this research aims to quantify the economic value of chilgoza pine for local households, examine the socio-economic aspects that may explain the differences in income levels, and provide policy recommendations that are based on evidence to improve the management and sustainability of forest products.

Specifically, the study pursues the following objectives:

1. Calculate the economic contribution of chilgoza pine from the households of the Diamer District.
2. To estimate the impact of socio-economic factors on the economic contribution of chilgoza pine.

3. To examine the existing issues encountered by the harvesters and recommend policy actions.

The integrated perspective employed in this research emphasises both the importance of non-timber forest products to rural households and the overarching conversation surrounding sustainable and climate-resilient natural resource governance within the context of Diamer's unique socio-ecological system. This research is situated within a rigorous theoretical framework, particularly the sustainable livelihoods framework, which provides a systematic perspective to investigate how households in rural contexts mobilise assets, engage in livelihood strategies, and gain access to important resources. This study situates chilgoza pine harvesting within this analytical frame. This lens furthers our understanding of how forest-based resources and extraction can support household resilience and economic security. Moreover, through the socio-economic analysis of chilgoza pine income, the study engages with the broader discourses on development economics to provide empirical content to theoretical frameworks on agricultural and rural development, focusing on relationships between natural resource use, income generation, and sustainable livelihoods.

### **Theoretical framework and model identification**

This analysis draws from the Sustainable Rural Livelihood Framework (SRLF) as a framework for understanding household strategies, asset management in household livelihoods and the corresponding livelihood outcomes. It is multidimensional, with an emphasis on how different forms of capital (natural, human, social, financial, and physical) work together to produce income-generating activities, and how access to these forms of capital informs the extent to which households can access income. This study investigates the contributions of *Pinus gerardiana* (chilgoza pine) collection as an important aspect of natural capital that ultimately contributes to rural livelihoods in the Diamer District.

The framework is especially applicable regarding understanding the role of chilgoza pine income in the livelihoods of households under conditions of regional fragility - including geographic isolation and limited infrastructure. It enables a methodical examination of how certain household characteristics - such as the age, education, and experience of householders/harvesters, the size of the household, the area under agricultural land, the distance and Time spent harvesting chilgoza nuts, and sources of alternative income - moderate dependence on and income from chilgoza pine. Furthermore, the framework highlights the need for institutional responsiveness and governance structures to improve community access to forest resources and to maintain sustainable management practices.

Consistent with this theoretical lens, the study applies an income accounting model within a linear regression framework to estimate relationships between chilgoza pine income and other socioeconomic factors. The model allows for empirical testing of the influence of these factors on household earnings from forest products. The general form of the model is specified as:

$$\text{ICN} = f(\text{AGE, EDU, HHS, DST, EXP, TSP, HHL, OI})$$

Where:

**ICN** = Income from chilgoza pine (dependent variable)

**AGE** = age of the harvester (years)  
**EDU** = Education level (years of schooling)  
**HHS** = Household size (number of persons)  
**DST** = Distance travelled for harvesting (kilometres)  
**EXP** = experience in harvesting (years)  
**TSP** = Time spent in harvesting (days)  
**HHL** = Household agricultural land (kanals)  
**OI** = Other income (PKR)

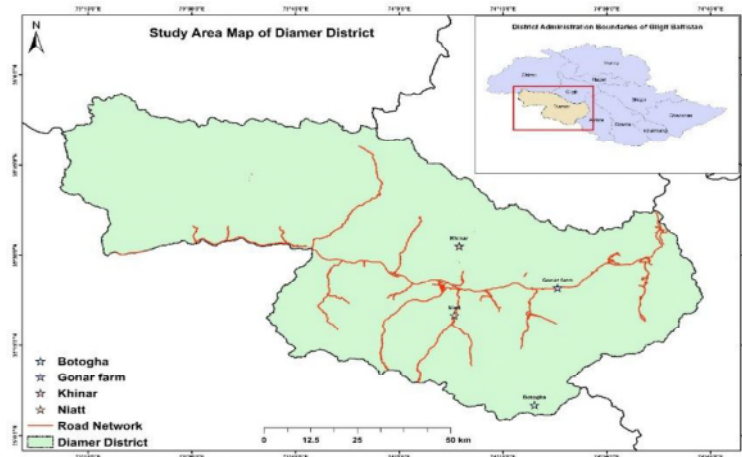
That is further refined into the following econometric specification:

$$ICN = \beta_0 + \beta_1 AGE + \beta_2 EDU + \beta_3 HHS + \beta_4 DST + \beta_5 EXP + \beta_6 TSP + \beta_7 HHL + \beta_8 OI + \mu$$

Here,  $\beta_0$  represents the intercept,  $\beta_1$  through  $\beta_8$  denote the coefficients of the respective predictors, and  $\mu$  captures the error term, reflecting unobserved heterogeneity and random disturbances.

## Research methodology

### 3.1. Research Site:



The research study is located in the Diamer District of Gilgit-Baltistan, a mountainous region in northern Pakistan that covers about 10,936 square kilometres (Qasim et al. 2024). The region is famous for its rugged topography. Some of the most prominent natural features of the district are the Nanga Parbat (the ninth tallest mountain in the world) and the picturesque Fairy Meadows, which are high-altitude grasslands. The capital of Diamer is Chilas, which lies along the Karakoram Highway, at an altitude of 1,260 meters above sea level (Aneel et al. 2023). The climate of the region is characterised by hot summer months (with temperatures reaching 43°C) and cold winter months (with temperatures sometimes dipping to 1 °C). More importantly, the local soils and climatic conditions provide an excellent environment to grow and harvest chilgoza pine (Khan et al. 2020).

This research is primarily centred on four villages situated in Chilas Valley, namely: Butoga, Gonar Farm, Khinar, and Niatt. These villages have been purposely selected for the research as they actively engage in harvesting chilgoza pine, and they are largely dependent on forest livelihoods. The total number of households in this area, according to the Gilgit-Baltistan Census Report 2023, is 931 in Butoga, 1,887 in Gonar Farm, 1,502 in Khinar, and 1,976 in Niatt. Community-based forest governance is practised in the

area through local institutions and committees that play a key role in conserving the forests, which include prohibiting felling trees for timber or fuel and imposing fines to dissuade them from exploiting this area. That led to chilgoza pines only being conserved for nut collection and used for harvesting by hand through traditional methods without the use of chemicals or equipment.

The villages' large dependence on chilgoza pine as a source of income and food security renders these locations as valuable case study sites for analysing the socioeconomic dimensions of non-timber forest product (NTFP) use. The purpose of the study is to examine the complex relationship between household characteristics and dependence on chilgoza pine income, specifically in the context of culturally and economically important forest-based resources, as well as a community that is reliant on non-timber forest product resources. The study will examine these four valleys to develop local-level insight into sustainable forest management practices, rural livelihoods, and socio-ecological systems in Gilgit-Baltistan.

### **Data collection and income accounting methodology**

A mixed-method approach was used to collect data for the study, which allowed the researcher to study income sources and livelihoods in detail among the households of *Pinus gerardiana* (chilgoza pine) harvesters in the Diamer District of Gilgit-Baltistan. Data were obtained from four purposively selected villages in the Chilas Valley - Butoga, Gonar Farm, Khinar, and Niatt. These four villages were chosen to have variation in terms of geography, socio-economic conditions, and the households' dependence on forest-based income sources. Each village comprises a community where chilgoza pine harvesting is one of the primary livelihood activities. As such, these villages were ideally situated for examining socio-economic correlates to forest-based incomes.

In May to June of 2024, primary data were collected through interviews using a semi-structured questionnaire. The instrument was designed to collect quantitative and qualitative data about household sources of income and labour use, the demographic profile of the households, harvesting practices, and institutional arrangements. A total of 450 households were interviewed, although only 416 valid cases were analysed (due to the exclusion of households that did not directly collect chilgoza pine). Interviews using the semi-structured questionnaire were conducted by trained local enumerators in the Shina language to deliver accurate and culturally sensitive data. They were often facilitated in the presence of village chairpersons to ensure improved response validity and community trust.

Household interviews were designed to interview the main chilgoza pine harvester and to collect data for the past 12 months. Respondents were asked about income from distinct income activities, such as agriculture, off-farm labor, livestock, chilgoza pine harvesting, and other non-timber forest products (NTFPs) that they sold or utilised. Besides structured interviews, focus group discussions were conducted with 6–10 individuals from each of the villages they visited (harvesters, local traders, supply chain actors, etc.) to obtain contextual information regarding forest governance, local traditional labor sharing activities, and local seasonal migration patterns. The focus group discussions were supplementary to the survey data and assisted the researchers in triangulating findings and obtaining detailed level contacts.

We gathered secondary data from census documents, district forest inventories, and community administrative materials. That contributed background information on household structure, allocation of forest resources, and the policy context that created the conditions for these resources

to be managed. Though important supplements to a small number of primary data sources, these all provided important context for analysis of the socioeconomic aspects of chilgoza pine harvest.

The empirical approach to this study relied heavily upon the Income Accounting Model to compile and analyse data for household income sources. For this analysis, household income is conceived of as the total of the cash income earned plus the imputed value of subsistence consumption (Cavendish 2012). Therefore, according to the model, the income sources can be derived from five sources: agriculture, off-farm income, livestock, chilgoza harvesting, and other forest-related income. By disaggregating these income sources, the model allows for livelihood diversification and the extent of overall economic dependence to be captured.

The model also had complete data on gross income and all input costs (e.g. seeds, fertilisers, transport and hired labour) and did not assign any monetary value to household labour in the analysis, which is consistent with current methods of rural accounting for households. Net income for each livelihood activity was determined by calculating total input costs against gross revenues, thus providing a precise estimate for economic margins. Subsequently, this framework allowed the study to isolate chilgoza pine's contribution to total household income and understand how chilgoza pine's contribution varied across households with distinct socioeconomic characteristics.

**i. Agricultural Income**, we used the total output of each crop, and current local market prices after accounting for different production inputs. Importantly, labour to conduct agricultural practices was not procured externally. People in the Agricultural community continue to follow customary systems of mutual support, so there would be no direct financial costs incurred.

**ii. Off-Farm Income** includes earnings from wage labor (either employed or self-employed); all government and private earnings; earnings from remittances; rental income; and earnings from small business activities. Many respondents indicated that they participated in seasonal migration to urban areas for the winter months to supplement their household income using their skills and/or experience through construction, retail, and service-related work. Wage data were calculated using the number of days worked for the year, with a skill-specific daily wage rate of between PKR 1,200 and PKR 3,000.

**iii. Livestock income** included the sale of animals and animal products obtained during the year. While this practice is common among the households surveyed, the economic role played by the livestock sector was minor, as the majority of dairy and meat was consumed in the household at subsistence levels.

**iv. Chilgoza Pine income** was calculated by taking the total volume of pine nuts sold and multiplying it by current market prices. Collection of chilgoza pine nuts is traditional and has a low monetary input, generating a high overall net profit and having cultural significance in the area of study.

**v. Other Forest-Based Income** referred to the value derived from NTFPs other than Chilgoza Pine (e.g. culinary uses of wild apricots, honey, and medicinal plants). These products either supplemented income through market sales or supported subsistence needs. In keeping with FAO (2023) definitions, these products were harvested sustainably, and without timber extraction, indicating the broader value of forests to the community.

Accommodating structured survey data, qualitative data, and secondary sources of information, guided by the Income Accounting Model, offered a thorough understanding of household livelihood strategies within the Chilgoza Pine-dependent communities of the Diamer District. This methodology offered a framework for analysing the social and economic factors that contributed to variability in incomes. It ultimately helped to inform policy recommendations for the sustainable management of forest resources.

## Results and discussion

This section will present and discuss the empirical results by grouping households based on specific socioeconomic characteristics. We want to identify patterns and differences in chilgoza pine income based on demographic and structural household variables to understand how these factors influence livelihood outcomes in the study site.

### 4.1. Socioeconomic Features of Households Involved in Chilgoza Pine Nut Collection:

Table 1 presents the socioeconomic features of households that were collecting (chilgoza pine) harvesters in the Chilas Valley based on the following variables:

*Table 1: Socioeconomic Profile*

| Household Characteristic                  | Mean  | SE   | Min | Max |
|-------------------------------------------|-------|------|-----|-----|
| 1. Age (years)                            | 38    | 0.61 | 18  | 75  |
| 2. Education (years)                      | 3     | 0.26 | 0   | 16  |
| 3. Household size (persons)               | 10    | 0.21 | 2   | 45  |
| 4. Distance travelled for harvesting (km) | 28.21 | 2.21 | 1   | 187 |
| 5. Experience in harvesting (years)       | 15    | 0.28 | 5   | 31  |
| 6. Time spent for harvesting (days)       | 7.18  | 0.13 | 1   | 20  |
| 7. Household agricultural land (Kanal)    | 7.09  | 0.59 | 0   | 110 |

The table provides a summary of essential socioeconomic characteristics of households involved in harvesting chilgoza pine in the Diamer District. On average, harvesters were 38 years old, had participated in just over three years of education, and had little formal schooling in the region; therefore, education and formal schooling are limited. The household size is large, at an average of 10 members. Often, rural households have as many as 30 members, who live together in extended family structures; thus, ten is an above-average number of members living in a household. Harvesters, on average, travelled 28 km to their harvesting sites, but some households travelled as far as 187 km, indicating various accessibility issues. Due to the deep nature of their involvement in harvesting chilgoza pine, harvesters averaged 15 years of harvesting experience. The harvesters averaged just over 7 days spent harvesting in each season, which is surprisingly less than I expected! The average agricultural landholding was 7.09 kanals per household; however, the range of holdings was enormous, with one household having nothing, and one household owning 110 kanals. This disparity reveals the varied access to land among the harvesters. The low standard errors of the majority of the variables suggest that the data were fairly consistent.

In Table 2, we are provided with the age-wise distribution of the 416 collectors participating in the study. As we can see, the majority (47.11%) were aged 35-54 years old, while 42.06% were aged 34 or younger, indicating that we have a somewhat younger and middle-aged sample. Only a limited number (10.81%) were aged 55+, which shows that older individuals are under-represented in voluntary activity.

Table 2: Age Demographics of Chilgoza pine Harvesters

| Age          | No. of Collectors | Percentage (%) |
|--------------|-------------------|----------------|
| Below-34     | 175               | 42.06          |
| 35-54        | 196               | 47.11          |
| 55-74        | 38                | 9.13           |
| 75 and above | 7                 | 1.68           |
| Total        | 416               | 100            |

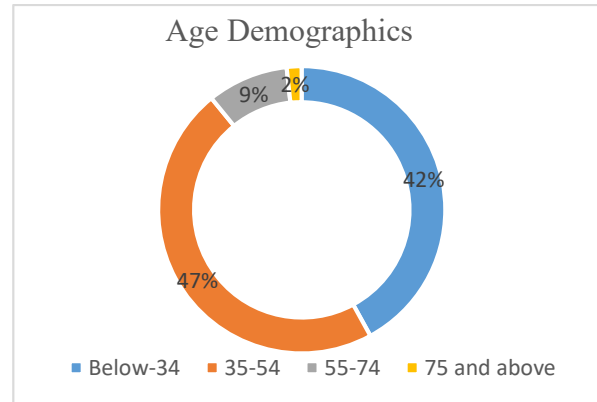


Fig 1: Age Demographics

Table 3 displays the educational achievement of 416 harvesters and shows a very high level of illiteracy (64.18%). Additionally, those who have primary to ordinary level education comprise 22.36% and those with advanced or university level education make up 13.46%. The data identify a generally low educational profile for the harvesting population.

Table 3: Distribution of Harvesters by Education Level

| Education Level                 | No. of Harvesters | Percentage (%) |
|---------------------------------|-------------------|----------------|
| Illiterate                      | 267               | 64.18          |
| Primary (1-5 years)             | 44                | 10.58          |
| Ordinary level (6-10 years)     | 49                | 11.78          |
| Advance Level (11-13 years)     | 23                | 5.53           |
| University (More than 13 years) | 33                | 7.93           |
| <b>Total</b>                    | <b>416</b>        | <b>100</b>     |

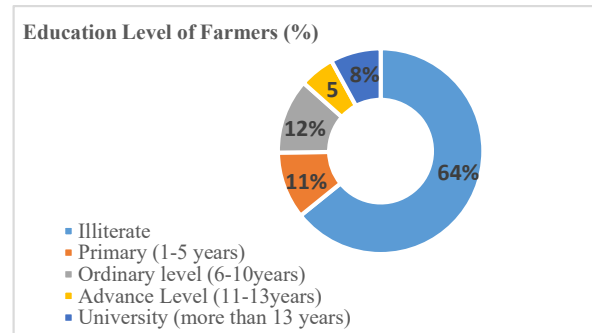


Fig 2: Education Level

The research revealed significant findings related to the practices and challenges faced by Chilgoza pine harvesters in the Chilas Valley. On average, collectors travelled around 28.20 kilometres to harvest and market chilgoza pine, with distances ranging from 1 km to 187 km. Most of the collectors were close to the forest, which means they were close to the nut-bearing trees, thus allowing access to the trees and making it easy to harvest. Although collectors were typically close to the forests, a primary concern among respondents was regarding the trees' declining health, with almost all collectors reporting a steady decline in availability of nuts over the years.

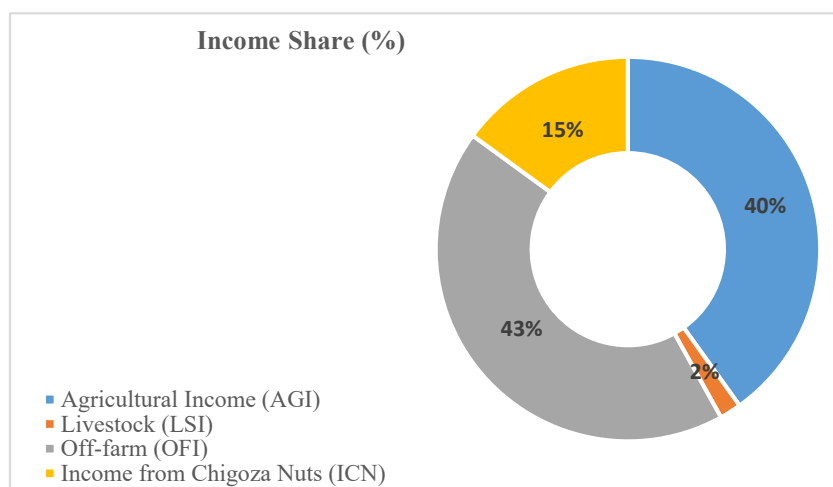
Harvest periods varied considerably from year to year (e.g., ranging from 12 to 130 days and averaging around 71 days), highlighting the economic value of the crop. In addition, the average agricultural landholding per collector was noted to be 7.09 Kanal of land per household, suggesting land ownership provides an important supplementary income source. Overall, these findings highlight the importance of Chilgoza pine to livelihoods and the necessity of conservation efforts in light of the deteriorating status of these species.

### The economic impacts of different sources of income

The data regarding household income sources illustrates a diversified economic structure comprised of agriculture, off-farm activities, and forest-based livelihoods that collectively support rural households. As highlighted by its 40.14% contribution to aggregate household income, agriculture plays a central role in the local economy. It is reasonable to presume that households' reliance on agricultural income supports both subsistence and market-oriented production for food security and income stability. If agricultural production improves and/or farming households improve their access to markets, the potential positive impact on household welfare can be significant. In contrast to agriculture, livestock made up 1.82% of household income, indicating that livestock is a supplementary income source. While livestock (e.g., goats, sheep, cattle, yaks, poultry) are indeed produced for household consumption (e.g., milk, meat, and eggs), the limited contribution to income suggests that many households, at best, have small herd sizes or produce at subsistence levels. Regardless, livestock remains an important contribution to households through their role in nutritional security and as a small source of cash income through sales to local traders.

*Table 4. 1 Average Income and Income Share by Various Sources*

| <b>Income source</b>            | <b>Average Income<br/>(Rs/year/household)</b> | <b>Income<br/>share (%)</b> |
|---------------------------------|-----------------------------------------------|-----------------------------|
| Agricultural Income (AGI)       | 808581.73                                     | 40.14                       |
| Livestock (LSI)                 | 36595.19                                      | 1.82                        |
| Off-farm (OFI)                  | 868250                                        | 43.11                       |
| Income from Chilgoza pine (ICN) | 300812.5                                      | 14.93                       |
| <b>Total</b>                    | <b>2014239.42</b>                             | <b>100</b>                  |



*Fig 4: Income Share by Sources*

Off-farm income is the most significant contributor at 43.11%, which shows households are increasingly reliant on non-farm sources of income, such as wage labour, small businesses, and other ventures. Households are working to shift their reliance away from agricultural income and are working on other non-agricultural risk management approaches (for example, crop failures, dips in the market, etc.). In addition to off-farm income, Chilgoza pine makes significant contributions of 14.93% to the household as a forest-based cash crop. Although households rarely consume the product, they sell the higher-value marketable amount of Chilgoza orientation because it is mainly grown in very rural areas with structural constraints on ecologically oriented communities that can farm. The average generation of copious amounts of 300,812.5 PKR would

supplement agricultural income. Overall, the income structure represents a strategy for households that is well adapted to combining traditional lifestyles as well as alternative means to make a living, which offers changed resilience and economic viability in changing environmental and market developments.

### Estimating income sources

Household income from different sources was measured using the income definition approach suggested by Pokhriyal et al. (2010). All income values were exchanged from Pakistan Rupees (PKR) to US Dollars at the rate of 1 US dollar = 275 PKR. The total annual household income was calculated as follows:

$$\text{Total household income} = \Sigma (\text{Agricultural income} + \text{Livestock income} + \text{Off-farm income} + \text{Chilgoza pine income} + \text{Other income}).$$

Agricultural income comprised income from the production of commodities like potatoes, apricots, walnuts, grapes, and cherries. Livestock income included income from selling animals (goats, cows, sheep, bulls, poultry) and other livestock-related jobs. Off-farm income included wages from government employment, business and daily labor, as well as pensions and employment in the private sector. Chilgoza pine income included income from selling nuts and value-added products of the nuts, such as roasted Chilgoza pine nuts and value-added oil products. Other income included income from non-timber forest products (NTFPs) such as fuelwood, honey, fodder, timber, and medicinal plants, which was generated from collections made primarily for household needs. Overall, the user-defined categories for livelihood strategies provided an insight into household livelihood strategies and emphasised the economic importance of Chilgoza pine from households' perspectives.

*Table 4: Household Demographics and Socio-Economic Profile*

| Characteristics                   | Mean    | SD       |
|-----------------------------------|---------|----------|
| Demographic                       |         |          |
| • Age (Years)                     | 38      | 13.10    |
| • Education (years)               | 3       | 5.67     |
| • Household Size (No. of Persons) | 10      | 6.96     |
| Agricultural Income               |         |          |
| • Potatoes                        | 341579  | 332795   |
| • Apricots                        | 728386  | 97262    |
| • Walnuts                         | 11493   | 59148.3  |
| • Grapes                          | 54689.5 | 63831.8  |
| • Cherry                          | 201983  | 287864.7 |
| Livestock income                  |         |          |
| • Goat                            | 63484   | 72660.4  |
| • Cow                             | 23095.2 | 43972.2  |
| • Sheep                           | 8456    | 20652    |
| • Bull                            | 17644.4 | 34295.6  |
| • Poultry                         | 1269.36 | 3257.52  |
| Off-farm income                   |         |          |
| • Government servant              | 74182   | 79294.8  |
| • Businessman                     | 583578  | 832362.4 |
| • Daily wage labor                | 291940  | 453496.3 |
| Income from Pine Nuts             |         |          |

|                            |          |          |
|----------------------------|----------|----------|
| • Sale of Pine Nuts        | 198816.5 | 209278.7 |
| • Additional uses of Pines | 86567.9  | 176386.2 |

The table provides descriptive statistics regarding demographic characteristics and sources of income for households. The respondents' average age is 38 years (SD = 13.10), with low average educational attainment (only 3 years [SD = 5.67]) reflecting limited formal schooling. Households are relatively larger, consisting of an average of 10 members (SD = 6.96). Concerning agricultural sources of income; apricots provide the highest contribution to income (mean = PKR 728,386; SD = 97,262), followed by potatoes, then cherries, though these also exhibit higher levels of variation, especially in the case of the potatoes (SD = 332,795), and cherries (SD = 287,864.7), indicating varying yields or market returns. However, livestock income is not substantial, with goats being the main income contributor (mean = PKR 63,484) and demonstrating high variation across all of these categories. Poultry income is negligible, reflecting limited economic activity. Off-farm income shows a significant level of contribution and variation; the highest off-farm source of income (PKR 583,578; SD = 832,362.4) was from income as a businessman, followed by daily wage labor, and government employment, which indicates that non-agricultural activities are important, and to some degree, risky sources of income. Considering income from Chilgoza pine nuts is also imparting economic importance, as a household reported an average income of PKR 198,816.5 from sales, and PKR 86,567.9 from additional uses (e.g., oil, roasted nuts), but again reporting high Standard Deviations (209,278.7 and 176,386.2, respectively), indicating variation across households. The table shows evidence of a highly diversified livelihood structure, with important variations across sources of income and household profiles, and a large dependence on both types of income.

### **Analysing chilgoza pine income using ols regression: the influence of socioeconomic factors**

Table 6 outlines the findings of an OLS regression exploring how various socioeconomic characteristics influence household income received from chilgoza (*Pinus gerardiana*) harvesting in the Diamer District. The model was statistically significant ( $F = 15.20$ ,  $p < 0.001$ ), meaning strong explanatory power. Harvesters' age was negatively associated with income received from harvesting chilgoza ( $-0.30$ ,  $p = 0.02$ ). This finding is likely because older individuals may experience decreased physical capacity, limiting the amount of chilgoza they could harvest. Similarly, Hong, Su, and Chang (2023) found a negative association between age and forest income in China. Education also displays a negative association ( $-0.06$ ,  $p = 0.06$ ), indicating that higher education may indicate lesser reliance on forest income, possibly due to income earned from better job opportunities - similar to statements by Bwalya (2011) and Mulenga et al. (2011). Household size has a positive relationship with Chilgoza income ( $0.44$ ,  $p = 0.04$ ) because there is more labor available to harvest the nuts. Distance travelled for harvesting, along with years of experience harvesting, had no statistical significance (the years of experience had a positive coefficient), suggesting little marginal benefit with experience. The Time spent harvesting was positively significantly associated with income ( $0.02$ ,  $p = 0.03$ ) and completely aligns with logical expectations and what Kalaba, Chirwa, and Prozesky (2009) found with their analysis of labor input directly impacting forestry income levels.

Agricultural landholding had a positive association with Chilgoza income ( $0.14$ ,  $p = 0.06$ ), which is consistent with Leßmeister et al. (2018) and Maraseni, Maroulis, and Cockfield (2008), who observe that households with more landholdings diversify the land and use NTFPs to supplement

household income. Total income, excluding the income from Chilgoza pine, was highly significant (0.78, < 0.001), suggesting that better-off households had more means to invest in harvesting and were essentially generating economic returns on their investment. Collectively, these findings demonstrate that socioeconomic characteristics, land ownership and wealth capacity plays a vital role in household dependency and income generation from NTFPs.

*Table 4. OLS Regression Analysis of Chilgoza Pine Income by Socioeconomic Variables*

| <b>Variables</b>                                | <b>Estimated coefficients</b> | <b>Standard Errors</b> | <b>t statistic</b> | <b>P &gt; [t]</b> |
|-------------------------------------------------|-------------------------------|------------------------|--------------------|-------------------|
| Age of harvester (years)                        | -0.30                         | 0.30                   | -0.96              | 0.02              |
| Education of harvester (years)                  | -0.06                         | 0.05                   | -1.63              | 0.06              |
| Household size (persons)                        | 0.44                          | 0.36                   | -2.53              | 0.04              |
| Distance travelled for harvesting (km)          | -0.07                         | 0.10                   | 0.47               | 0.79              |
| Experience in harvesting Chilgoza pine (years)  | 0.13                          | 0.12                   | -0.33              | 0.00              |
| Time spent for harvesting (days)                | 0.02                          | 0.09                   | 0.23               | 0.03              |
| Household agricultural land (Kanal)             | 0.14                          | 0.11                   | 1.63               | 0.06              |
| Total income excluding chilgoza pine Income     | 0.78                          | 0.16                   | 8.13               | 0.00              |
| Constant                                        | 3.44                          | 1.73                   | 2.71               | 0.00              |
| <b>n = 416, F = 15.20, Prob &gt; F = 0.0000</b> |                               |                        |                    |                   |

## Discussion

The OLS regression analysis provides important information about the effects of different socioeconomic factors on income from the harvesting of Chilgoza pine in the Diamer District. The results suggested a slight, but statistically insignificant negative relationship between harvester age and income, implying that while older harvesters may have physical limitations, the impact is not significant enough to suggest conclusive outcomes. Education has a marginally significant negative association, suggesting that more educated harvesters may be looking for other income opportunities, and therefore, reducing their income from pine nut harvesting (Basu and Van 1998). However, household size has a significant positive effect, as larger households are likely to have more labor available (Lee 2015). Similarly, Time spent harvesting has a positive association with income, supporting that longer Time spent typically returns more returns (Akhtar et al. 2023).

Distance travelled for harvesting does not significantly influence income, possibly due to equal access or dominance of other factors (Dash and Behera 2016). Experience for harvesting has a positive and significant association with income, suggesting that skill acquisition leads to better performance efficiency. The agricultural landholding also has a positive association, emphasising the importance of integrated land use that contributes to increased income. The last factor is that the higher total household income strongly correlates to more Chilgoza income, perhaps relating to greater availability of resources and capacity for investment.

## Conclusion, recommendation and limitation of the research

This study has gathered data on the aspects of the socioeconomic contributions of chilgoza pine harvesting in four isolated villages in the Diamer District - Khinar, Boto Gha, Naitt and Gonar Farm, indicating the extent to which chilgoza provides rural livelihoods and contributes to household income and other household-reliant factors on chilgoza as an alternative means of income. Overall, this study indicates that chilgoza serves as an important income source, especially

for those households with larger family sizes, more agricultural land, and more Time Dedicated to harvesting chilgoza. Although age and education have a minimal influence on income and income levels, factors such as experience and total household income levels were positively related to chilgoza income. The results show that a complex relationship exists between socio-economic conditions and forest-based income, which means inclusive and sustainable approaches must be developed to enhance livelihoods with a focus on long-term resource sustainability.

Based on the study's results, recommendations for specific policy interventions to benefit Chilgoza pine harvesters are provided. The harvesting efficiency of smaller households could be increased with skill-improvement training and better harvesting tools, as this would increase equity of benefits. Financial support mechanisms such as microcredit or micro-grants could be particularly beneficial for households with low incomes to invest in better harvesting techniques. To ensure the sustainability of the ecosystem, community-based education and regulations around harvesting, minimal sale of unnecessary wood, and Collaboration will be most effective. Meanwhile, strengthening cooperatives, improving access to markets, and reducing the power of intermediaries to improve market access will help to stabilise harvesting income for households. Policy should also consider enhancing the security of tenure of land for harvesting households and ensure alternative income opportunities are made available, through a combination of education and vocational training, to reduce over-dependency on Chilgoza pine harvesting.

This study is restricted to four villages in one district and one harvest season, limiting its wider applicability. The study is limited to self-reported data, which can result in response bias, and no gender analysis is provided. Future research should focus on increasing geographic scope and shifting towards panel research to capture seasonal and market variability. Future assessments of market dynamics, inclusion of value chains, and assessment of gendered labor roles would provide more nuance to current understandings. Environmental assessments will be important to determine the sustainability of current harvesting approaches. Lastly, exploring the role of technology, institutional support, and community-based ownership or governance context of forests would add significant depth in terms of developing useful policy frameworks.

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