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A stony track towards innovation in remote highland regions: agricultural intensification in the apricot sector of Northern Pakistan

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Abstract

Background Traditional farming practices of remote highland regions are usually well adapted to the local agro-ecological and social conditions. There, introduced agricultural innovation geared towards sustainable intensification as a response to changing environments often faces multiple barriers. These may comprise limited market incentives for enhanced production, narrow pathways of knowledge transmission, and infrastructural hurdles. To quantify effects of innovation and sustainable intensification in enhancing smallholders' livelihoods in the Karakoram Mountains of Northern Pakistan, the present study was conducted with 86 small-holder farmers. We chose interviewees who are involved in the cultivation, processing and/or trading of apricot (*Prunus armeniaca* L.), a traditionally important currently eroding fruit crop of the Central Asian highlands. By investigating the *status quo* of apricot production and producers' innovative farming practices, we generated an intensification index based on simple agronomic indicators. Explanatory farm and framers' characteristics, production characteristics, knowledge, and apricot management were tested for their predictive power.

Results Although the data show low average profits of 3.8 US$ tree^{-1}, we found that intensified apricot production can contribute to the provision of nutritious food and increased household income. Age and training of farmers were key factors fostering innovation, while lacking awareness of innovative practices was attributed to slow communication. Rejection of intensification was either due to low-value attribution towards apricot farming or risk aversion. Commonly adopted innovations, particularly sulfur drying, were either well integrated with traditional practices or characterized by low up-front costs and high returns on investment.

Conclusions Management intensification may increase farmers' incomes and retard abandonment of apricot farming and the consecutive loss of associated benefits, such as diversified farm output and improved ecosystem services.

Keywords Agricultural innovation, Livelihood strategy, Remote mountain areas, Smallholder agriculture, Stone fruit production, Value addition

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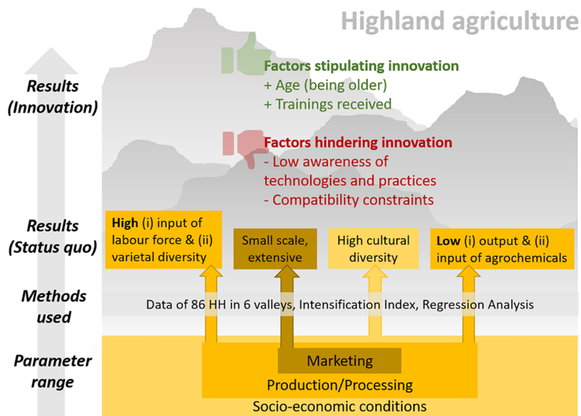
Graphical Abstract



Background

Traditional farming practices are usually well adapted to the local agro-ecological and social conditions of their users. This is particularly the case in remote mountain areas which for long have been secluded from exogenous innovation. Under such conditions, agricultural innovations often face multiple barriers such as lack of market incentives for enhanced production, narrow pathways of knowledge transmission, and infrastructural hurdles [1]. Nevertheless, agricultural innovations often paired with intensification can foster socio-economic growth and food security, may increase income, and can lead to health benefits through better human nutrition. In many countries of the Global South, agricultural innovations are geared towards enhancing production rather than system sustainability. They are often driven by a green revolution approach pushing improved varieties and higher levels of external inputs such as mineral fertilizers, pesticides or irrigation, and the establishment of value chains for agricultural produce [2]. The expected results are increased productivity per unit area and profitability per unit labor rather than improved resilience of the economic, ecological, and social systems [3].

In Northern Pakistan where the agricultural sector is widely characterized by low productivity and profitability [4, 5], intensification strategies paired with diversification and exploitation of value chains can lead to increased livelihood security through improved income [6]. As Pakistan's northern provinces Chitral and Gilgit-Baltistan (GB) are with an annual 65,020 t the country's primary apricot producing regions [7–9], they are showcases for opportunities and limitations of intensification strategies in rural mountain areas of Central Asia.

Despite rising scientific interest in Pakistan's apricots regarding pollination [10, 11], genetic and morphological diversity [12, 13], chemical characteristics of apricot fruits [14], and apricot seed oil [15] with associated value chains [7–9], to our knowledge, little information exist on the status *quo* of apricot cultivation practices and the adoption of innovation. In this context, assessments of traditional and innovative cultivation practices remain largely sketchy. Furthermore, little is known about current intensification strategies in apricot farming and the social, economic and cultural realities that determine the adoption of apricot related innovation in GB. Similarly under-investigated is the role that gender plays in the ongoing agricultural transformation processes. To fill these knowledge gaps, this paper aims to (i) analyze the *status quo* of apricot diversity, apricot farming and processing practices, apricot marketing, gender roles in apricot farming, and related socio-cultural and economic realities in GB, to (ii) assess the role of innovation on household (HH) income from apricots, and (iii) determine key factors driving adoption of intensified farming techniques.

Materials and methods

Study area

Being part of the Karakoram Mountains of Northern Pakistan, GB borders Afghanistan, China, and India (Fig. 1). For many centuries the rugged terrain facilitated the formation of isolated, small, and dispersed settlements along river oases with ancient, sophisticated *Karez* irrigation systems carrying mainly glacier water for kilometers [16]. The high-altitude climate is characterized by mild summers and cold winters with erratic and torrential rainfall [17].

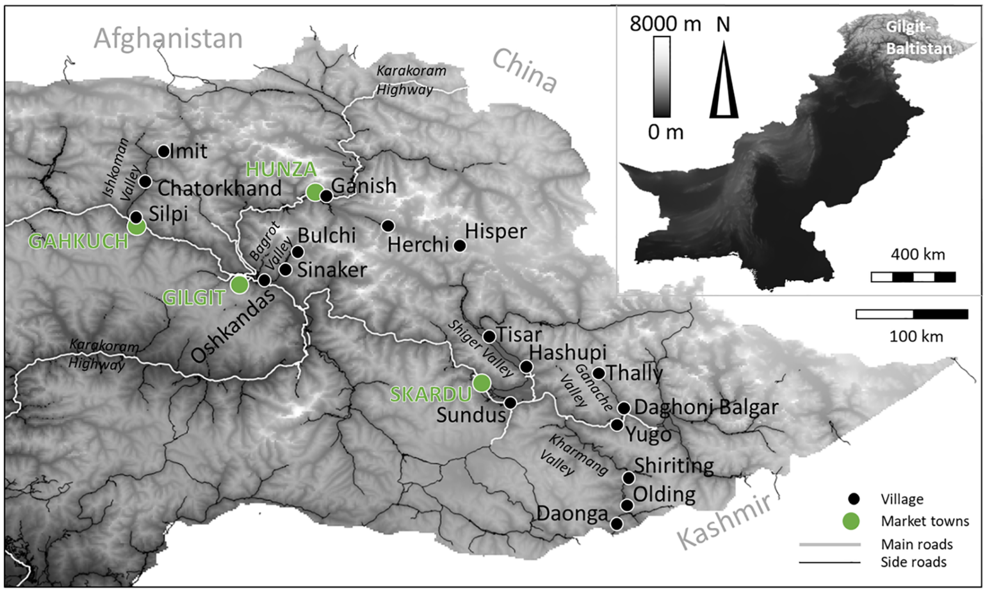


Fig. 1 Selected settlements near main markets in dead-end valleys along the Silk Road, now partly Karakorum Highway, in Gilgit Baltistan, Northern Pakistan, characterized by pronounced apricot production and high varietal richness. Source: DIVA-GIS, www.diva-gis.org/gdata, last accessed 19 November 2022

Table 1 Location, elevation, and number of sampled trees for each selected village in Gilgit-Baltistan, Northern Pakistan. In each valley, villages are sorted by increasing remoteness

Region	Valley	Village	Northing, Easting	Elevation (m)	Sampled trees
Gilgit	Bagrot	Oshikandas	35°35′, 74°28′	1457	14
		Sinaker	36°57′, 74°30′	2085	25
		Bulchi	35°01′, 74°33′	2425	10
	Ishkoman	Silpi	36°11′, 73°46′	1890	0
		Chatorkhand	36°20′, 73°35′	2110	25
		Imit	36°30′, 73°54′	2397	12
	Nagar	Ganish	36°18′, 74°40′	2137	15
		Herchi*	36°16′, 74°43′	2368	15
		Hisper*	36°10′, 74°59′	3123	0
Baltistan	Shiger	Sundus*	35°17′, 75°37′	2251	15
		Hashupi	35°28′, 75°42′	2294	18
		Tisar*	35°40′, 75°27′	2388	10
	Ganache	Yugo	35°11′, 76°09′	2457	0
		Daghoni Balgar	35°14′, 76°11′	2469	0
		Thally	35°19′, 76°09′	2916	0
	Kharmang	Shiriting	35°51′, 76°11′	2533	0
		Olding	34°44′, 76°09′	2729	0
		Daonga	34°45′, 76°05′	3381	0

[*] Indicates villages with four instead of five interviewees

Reflecting its multitude of topographic and ecological niches, the study area harbors a unique cultural, religious, linguistic and ecological diversity [18]. The formerly independent kingdoms of GB were integrated into the political system of Pakistan in 1972 and connected to its lowlands and neighboring China through the Karakoram Highway (KKH) in 1978 [19]. This road that largely follows the ancient Silk Road significantly increased mobility and allowed easier out-migration from remote mountain valleys to seek education and job opportunities in Pakistan's cities [20, 21]. The strong linkage to new outside markets generated many new economic opportunities in GB, such as employment prospects in the tourism industry, small-scale businesses, and the energy sector [22, 23]. Therefore, the previously mainly crop- and livestock-based economy, with low production output [24], was increasingly complemented by a growing, male-dominated off-farm economy [25, 26] resulting in rising shares of off-farm income from 43% in 1994 to 70% in 2020 [25].

Data collection and sampling strategy

Qualitative and quantitative data were collected from June to August 2021 in six 'dead-end valleys' that can be entered only through a single road (Fig. 1). The valleys of Bagrot, Ishkoman, Nagar, and Shigar are characterized by their relative proximity to major market towns, while the Kharmang and Ganache valleys are more remote. In each valley, three settlements were selected based on their location and presence of apricot trees (Table 1). Valley comprised a local market town and two more remote villages at the dead end of the valley. We define remoteness as the distance (> 3 km) and time (> 1 h) to reach the village by road from the main market town. As road conditions varied significantly, a definition by distance alone had little meaning.

Selection of farmer HHs was based on the following principles: (i) the presence and willingness of female and male HH decision-makers (DM) to participate in the survey and (ii) the cultivation of traditional or modern apricot cultivars by both DMs, whereby emphasis was placed on covering as much socio-economic diversity as feasible. Due to lacking official census data of apricot farmers for random sampling, a linear snowball sampling approach [27], was used for HH selection. Through convenience sampling, we identified the first interviewee whom we asked to refer us to contacts who meet the study's criteria. Snowball sampling has been criticized for its selection bias, as well as for the lack of external validity, generalizability and representativeness [28]. However, as discussed [28], snowball sampling is a widely used method in hard-to-reach populations that are relatively homogeneous.

Four to five farmers were interviewed in each village, resulting in 86 interviews across the 18 settlements (Table 1). Local customs and the limitations of snowball sampling limited the spectrum of interviewees to Muslims, mainly following the Twelver-Shi'ism and Ismaili Shi'ism belief. To account for sampling bias and avoid misleading conclusions, local focal persons were consulted to validate the feasibility of reported information by farmers.

Farmer's interviews were digitized using the Census and Survey Processing System (CSPro 7.6, U.S. Census Bureau, Suitland, MD, USA) and ICF International, Fairfax, VA, USA). Each interview comprised three parts. The first semi-structured part was organized in multiple sections covering background information, apricot production, extension systems, and knowledge transmission to answer the aforementioned research questions (Annex 1). The main DM of the HH answered this questionnaire, whereby these were in only 10 cases women. The second questionnaire was a subset of the first survey and answered by mostly female DMs to account for gendered differences in apricot farming. The third questionnaire allowed to collect data on varietal richness and diversity, dendrometric properties, vitality, and management history for one particular tree owned by the interviewee (Table 1).

Twenty-nine local focal persons were consulted through semi-structured interviews. These focal persons consisted of the Local Support Organizations ($n=2$) which were established by the Aga Khan Rural Support Program (AKRSP) to facilitate social mobilization for rural development initiatives, women organizations ($n=3$), newly established farmer co-operative societies ($n=6$), individual entrepreneurs and experts ($n=7$), local processing units ($n=2$), representatives from AKRSP ($n=3$), the local agriculture ($n=3$) and meteorological ($n=1$) department, representatives of the Economic Transformation Initiative (ETI, $n=1$), and a credit institution ($n=1$).

Data analysis

All quantitative data were cleaned, analyzed, and visualized using R v. 4.1.1. (R Core Team, 2023. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria, www.R-project.org) and Microsoft Excel (Microsoft Corporation, 2018, Redmond, WA, USA). Non-parametric Kruskal–Wallis-Tests were used to identify differences within and among groups according to the characteristics of the data. To detect correlations between nominal data, the Cramer V Test was used. Correlations were interpreted following the methodology of Akoglu [30] and accepted as meaningful when the lower limit of the confidence interval was unequal zero. When testing continuous and nominal data, the point biserial correlation with a significant level of $p<0.05$ was used. Simpson's diversity and evenness [31] was calculated to analyze varietal diversity.

Table 2 Indicators for calculating the agronomic intensification index used in the project area of Gilgit-Baltistan, Northern Pakistan

Indicator name	Indicator description	Type of indicator	Central tendency[1]
New varieties	Percentage of new varieties	Continuous (%)	8
Grafting	Percentage of grafted trees	Continuous (%)	67
Farmyard manure (FYM)	Application of manure to trees	Dummy, 1 yes, 0 no	0.72
Compost	Application of compost to trees	Dummy, 1 yes, 0 no	0.07
Mineral fertilizer	Application of mineral fertilizer	Dummy, 1 yes, 0 no	0.16
Pest and disease control	Application of pesticides/fungicide[2]	Dummy, 1 yes, 0 no	0.13
Sulfur drying	Use of sulfur during apricot drying	Dummy, 1 yes, 0 no	0.59

[1] For dummy variables, the percentual frequency of positive response, for continuous variables, the mean according to Hardy [29] was used

[2] Or use of biocontrol agents

Innovation in this study is defined as a product or process that is novel or significantly improved [32] compared with traditional practices in the study region. To determine HHs' innovation and transformative performance, a HH level intensification index was derived by averaging the explanatory power of seven intensifying and innovative farming methods (agronomic indicators) into a single index (Table 2). This index indicates how many agronomic indicators can be attributed a HH cultivating and processing apricots. Adoption and non-adoption of the innovation by each HH was defined using the approach of the International Maize and Wheat Improvement Center (CIMMYT) [33] as a dichotomous category (yes and no) at the time of the survey. Due to this index approach, typical constraints of mis-specified probit, logit, and tobit analysis for modelling the static adoption decision [34] were avoided.

A multiple linear regression model was used to determine if a group of independent variables was a significant predictor of a dependent variable, which is robust to normality violations [35]:

$$\widehat{Y} = m_0 + m_1X_1 + m_2X_2 + m_3X_3 + \cdots + m_nX_n + \varepsilon$$

where $\widehat{Y}$ is the predicted value of the dependent variable; $X_1, X_2, \ldots, X_n$ are the independent variables; m_0 is the intercept, the value of $\widehat{Y}$ if all independent variables are equal to zero; $m_1, m_2, \ldots, m_n$ are the estimated regression coefficients, indicating the magnitude of influence of the independent variable X_i on the depended variable $\widehat{Y}$; ultimately ε is the model's random error term following a normal distribution.

The dependent variable was the previously calculated intensification index, whereas independent variables from four categories (modified from Benitez-Altuna et al. [36]), namely farm and framers' characteristics, production characteristics, knowledge, and apricot management were tested (Table 6). The model output was checked for normality of the residuals, multicollinearity among the predictors, and influential data points (outliers) to avoid overfitting. In the regression analysis, multicollinearity among predictors may render potentially significant variables statistically insignificant by increasing the standard error of the coefficients [37]. Therefore, variables with medium to strong correlations were excluded. If residuals of the model were not normally distributed, but no other assumptions violated, the model was still used for inferences following Schmidt and Finan [35]. They argued that at a sample size > 10, regression models may still show valid results even when the assumption of normality of residuals is violated. Skewed variables were tested for log, ln, square root and box cox transformation. A box cox transformation was rejected if lambda's 95% confidence interval was too wide [38]. The $\widehat{Y}$ for each meaningful X_i were exponentiated to draw inferences from the linear regression model after a log transformation of a predictor. One was subtracted if previously added due to zero values in the original dataset. Differences between $\widehat{Y}(X_i)$ were used to describe nonlinear relationships.

Qualitative data were subjected to for content and narrative analysis whereby inductive coding of answers with thematic categorization was used for the former. For narrative analysis, responses were screened for patterns and themes to better understand the subject and the reasons behind perceptions and decisions.

3. Results and discussion

Status quo of socio-cultural and -economic setting

The interviewees in our six selected valleys spoke five different languages and belonged to three different sections of Islam, which reflects the high ethnical, linguistic and religious diversity of GB [19]. As formal education only recently arrived in Northern Pakistan, most grandparents had received no formal education. This was reflected in a significant negative correlation of -0.41 between age and education level of the sampled population. An average interviewee of 49 years had finished middle school while 25% did not receive any education and 12% had a university degree. The most remote villages had the largest share of uneducated interviewees (36%) compared with market towns (24%) and medium remote areas (17%; Table 7). This seems counterintuitive as the proportion of educated interviewees is expected to decline with increasing remoteness [39]. In view of a stringent explanation for this, we propose that educational interventions may play a more relevant role in medium-remote villages than in urban centers, which are better to reach for people with off-farm working contracts.

Most interviewees (88%) did not own major farm assets, such as a tractor, while almost half (44%) of those who owned a major farm asset had obtained a university degree. This positive relation indicates the advantage of education for improved income and therefore investment(s) into agricultural activities, similarly found in India [40] and Kenya [41]. The majority of all interviewees were men (88%), of whom only two did not own a cell phone, while less than half of female farmers had access to this communication tool. One fifth of the interviewees indicated that farming was their only occupation, while the majority (94%) of HHs derived their average annual income of 4 014 US$ (1 US $ = 163 Pakistani Rupees (PKR), average exchange rate during the study period in 2021) from two or three sources outside the farm. Some HHs likely understated their income, despite our efforts to communicate the importance of a truthful answer, as they may have hoped to receive benefits if perceived as particularly poor. However, we tried to limit the unreliability through asking for all sources of income first, then for the amount from each individual source, and only thereafter summing the sources to the total income amount.

In the region, multiple NGOs, formal and informal lenders, and credit or saving groups provide access to credit. Only two HHs stated that they completely lacked access to credit, while 29% had received a loan before.

Status quo of apricot farming

Since 1981 fruit tree plantings had rapidly expanded in Northern Pakistan [42], where multiple actors distributed traditional and exotic varieties [43]. The introduction of new varieties to the study area led to increased fruit production per unit area sometimes in combination with higher nutritional value [6]. However, the concomitant transformation of local production systems enhances the threat of losing well-adapted, disease resistant, and genetically diverse indigenous tree germplasm. This threat is further augmented by impairing economic factors, such as the high gender-specific workloads with marginal returns for farmers selling ordinary apricot products [9] and the low share of value-added products, which may lead to a loss of farmers' interest in apricot farming. Little financial incentives exist to continue apricot farming in general and especially when using local, traditional varieties. This may cause the abandonment of apricot trees in marginal areas and their replacement by more profitable fruit trees such as cherry [24], which was reported by multiple farmers. While Kousar et al. [9] recommend the introduction, propagation, and distribution of high yielding and drought and disease-resistant varieties of apricot in the study region, we argue that well-adapted local varieties, if managed more intensively, can provide similar or better benefits while contributing to preserving the genetic diversity of the region.

Cultivation

The common apricot cultivation system in Northern Pakistan is extensive and small scale. Apricot trees were traditionally and commonly grown in informal orchards on marginal land, along fields, and around houses, resulting in average planting densities of 316 trees ha^{-1}. This density is two to four times lower than in modern/commercial plantations for instance in Turkey [44]. Trees owned by each HH followed a right-skewed distribution with a median of 40 trees owned per HH, which are half as many as Turkish apricot plantations entail. Also, apricot farmers in GB hold about ten times less trees land than their Turkish counterparts [45, 46].

Systematic fruit thinning was only practiced by one farmer, and apricot trees did not show signs of trimming of branches for easier harvest and improved growth. Interviewees' reactions to questions about trimming practices showed that many farmers were not aware of such practices. Most HH (72%) applied farmyard manure FYM from their livestock to their apricot trees once a year. Only 17% of the farmers applied mineral fertilizer directly, while apricot farms in major apricot growing regions in Turkey, use pesticides and synthetic fertilizer on 70% and 90% of the total cultivated area, respectively [45].

Almost every second farmer named pests and diseases as major production constraints in the region (Table 3), while one-third of the HHs had at least one tree with signs of pest or disease attack. Fruit scab, insect attack (mostly aphids) on leaves and rolled leaves syndrome were among the most frequent (26% share of all diseases each). To combat pests and diseases, 13% of all HHs used pesticides, mainly insecticides and fungicides.

Table 3 Farmers' response to prevailing problems and limitations in apricot production in the study area of Gilgit-Baltistan, Northern Pakistan

Limitation remoteness	Percentage of respondents (n = 86)
Lack of available market	69
Low profit	65
Pest and disease attack	45
Lack of adequate equipment	43
Lack of available transportation	31
Labour shortage	26
Lack of financial input	20
Lack of modern technology	14
Mechanical damage	14
Lack of appropriate packaging	10
Limited knowledge of best practice	10
Lack of storage facilities	9
Lack of packaging facilities	9
Loss of fruit due to over or under maturity of fruits	9
Others (Lack of cooling facility available for fresh fruit, No interest in apricot farming, Low production volumes)	11

Generally, the awareness and knowledge of effective pest control methods was low and existing approaches were often perceived as harmful. Farmers frequently acknowledged their lack of scientific knowledge and were willing to adopt if "someone" provided apparently useful information.

Processing

Local apricot pulp is commonly sun-dried whereby 63% of these apricots are sold, the rest being consumed at home. Surfaces for drying apricots are often dirty, and the flesh adheres to the top. Sun driers, sheds for drying, or foil tunnels have been donated by support agencies on rare occasions. As a result of widespread training efforts, the main form of knowledge acquisition in half of the HHs, and subsequent dissemination of innovative quality management in the villages through contacts (43%). Sixty percent of the farmers used sulfur smoke during the drying process to improve the preservation of color of the product and increase their profit. HHs in very remote villages such as Hisper in Nagar and less remote, but socio-culturally isolated villages, such as Sinaker in Bagrot Valley, did not sulfur-dry at all.

One major benefit of apricot cultivation is that every side-product along the production chain of dried apricot can be used for multiple purposes such as medicinal purposes, cooking, construction as well as fire and animal feedstock. Value-added products such as jams, fresh juices, and baked goods can be produced from fresh and dried fruit. However, such value chains were rare: only one HH produced apricot jam and one vinegar.

It was uncommon to sell fresh apricot fruit (7%). The most frequently sold apricot product was dried fruits (84% of farmers), followed by sweet and bitter seed kernels (37%), and wood (10%). The average farmgate price for one kg of fresh apricot fruit was 0.3 US$, while dried apricots were sold for 0.8 US$ kg^{-1} and kernels fetched the highest price with 2.9 US$ kg^{-1}. HHs that sold apricot seed kernels in addition to fresh and dried fruits had a significantly higher income per tree. However, low overall profitability of apricot farming remained a major problem for 65% of the respondents (Table 3).

Income and marketing

The mean annual income of 158 US$ from apricots contributed 4.5% to total HH income. In Oshikandas, a village with a commercial apricot-processing unit near the local administrative center of Gilgit, the average apricot-related income share was 19%. Spies [24] reported lower average contributions of apricot production to HHs income of 3% (2013) and 2% (2014) for the rather remote district of Nagar. The apricot income share tended to be higher for HHs with lower incomes. Nevertheless, many farmers valued apricot production as a small but reliable income source strengthening HHs' self-sufficiency.

Dried apricots are commonly stored and sold in 40 kg bags without advanced packaging or labeling. Storing facilities and secondary processing units on village levels were rare. About 10% of respondents identified these limitations as problematic (Table 3). For farmers who produced organic (often by default) or other high-quality products, no certification scheme and standardized grading were available to allow participation in international markets. Such incentives to invest labor and financial resources into producing value-added goods were lacking. Throughout the study area processing, packaging, and marketing of apricot were limited. This is supported by Kousar et al. [9], who reported farmers in GB to complain about non-availability of support to small-scale farmers.

Lacking marketing opportunity was the most cited limitation for profitable apricot production (Table 3). Only 16% of the interviewees sold their apricot products directly on markets. Due to insufficient road infrastructure and a scarcity of available transportation, local and national markets were hardly accessible to the average farmer, especially in remote regions as also indicated for apple in GB [47]. As a result, two-thirds of the farmers sold their apricots to a village or wholesale agent who were part of an established middlemen system [9]. This

Table 4 Gendered mode and frequency distribution of workload in apricot production in Gilgit-Baltistan, Northern Pakistan

Variable[1]	Mode	Percentage frequency distribution[2]					
		1	2	3	4	5	0
Growing apricots from seed	1	24.4	1.2	16.3	0	19.8	38.3
Planting of sapling	5	9.3	2.3	17.4	7	60.5	3.5
Watering of saplings and trees	5	15.1	8.1	26.7	5.8	41.9	2.4
Grating trees	5	4.7	0	1.2	0	76.7	17.4
Pruning trees	5	2.3	0	1.2	0	87.2	9.3
Harvesting from a tree by hand	5	8.1	0	11.6	0	26.7	53.6
Collecting from ground	1	62.8	12.8	23.3	0	1.2	0
Transport from orchard to home	3	26.7	16.3	37.2	0	18.6	1.2
Drying of fresh fruit	1	68.6	9.3	19.76	0	0	2.3
Storage of fresh and dried fruit	1	67.4	7	15.1	0	8.1	2.4
Marketing and income possession	5	19.8	3.5	12.8	9.3	44.2	10.4

[1] Catergorical variable from 1 to 5: 1 female, 2 mostly female, 3 equal, 4 mostly male, 5 male

[2] Distribution for each gender category, zero category indicates % of HH where this practice was not used

dependency often results in small bargaining powers of producers. Large (international) traders, who could provide better prices, face a small-scale, scattered, and non-standardized apricot production system and supply chain, which makes it hard to collect a large quantity of homogeneous, high-quality products.

Kousar et al. [9] reported a 0.15 to 0.21 lower probability of interviewees being poor when they produced apricots. Across valleys the most remote HHs showed significantly lower income generation from apricot products, were less likely to sell them, and if sold were only marketed in smaller quantities. According to Kousar et al. [9], remote households faced more poverty than those in less remote areas. This indicates that good road infrastructure and proximity to markets increase the ability of farmers to access input and output markets with a lower cost for information and transport [9], resulting in lower overall transaction costs and higher profits.

Labor

Due to the widespread absence of mechanization and transportation, producing dried apricots in GB is labor intensive. Our data show that for apricot-related work, 88% of the respondents worked collectively with family members or village contacts. In addition to un-paid labor, 14% of the HHs sourced external waged workers for their apricot production, which were on average paid 3.9 US$ per eight hours of work, including lunch. None of the HHs in the most remote villages employed external labor.

In GB the workload for apricot production is highly gendered. Females were generally responsible for harvesting, processing and storing apricots, while men planted, grafted and pruned the trees (Table 4). Other tasks such as propagation of trees and transportation of fruits to homesteads were more equally distributed between genders.

Batool [20] points out that tasks like picking and drying apricots were traditionally done jointly, while now young and educated men increasingly refuse to participate in apricot farming and agricultural activities in general. Similarly, according to Gioli et al. [26], local women complained about low contributions to agricultural labor by men. Increasing rural-to-urban migration and decreasing interest of non-migrated men to take part in agriculture is putting the region's agricultural system into crisis [25]. This leaves women and elderly people with an increased workload [20]. Agricultural labor scarcity is further seasonally exacerbated by the simultaneous harvesting times of apricots, wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.). As a result, remote and marginal areas used for apricot production are increasingly abandoned, partly explaining the decreasing annual national production of apricot [48].

Training and initiatives

In 45% of the HHs, at least one family member had undergone apricot-related training, with 38% also having received technical support. Male HH heads were training recipients in 64% of the cases. Most trainings were provided by AKRSP as reported previously [43]. Since 2019, the International Fund for Agricultural Development (IFAD) funded farmer societies which offered apricot related training in apricot processing and marketing and technical support (trays, crates, buckets, sheets, bamboo stick, sulfur, and sulfur tent), in which 40% of all respondents were members. Some HHs also received training from the Pakistani Department of Agriculture (6%), via the internet (2%), and through other local organizations.

HHs in remote villages had received significantly less training than HHs in market towns and medium remote villages.

Adoption of innovation

The mean intensification index of the study was 0.35 (±0.17), suggesting that the average farmer implemented only one-third of the available intensification technologies (Table 2). In small-scale farming systems of remote mountain areas, the adoption of innovations often depends on the compatibility of innovation-related characteristics with the agro-ecological, social, cultural, economic and personal conditions and norms of the potential adopters [49, 50].

The most used technology by farmers in the study area was the application of farm yard manure to apricot trees, followed by grafting and sulfur drying of apricot fruits (Table 2). The use of grafting methods was, in many cases, related to the overall importance given to apricot farming, hence making it worthwhile to improve existing trees. This was also true for manure application to trees. Sulfur drying, in contrast, seemed to trigger more complex rationales for adoption and non-adoption. Rejection of this innovation was surprisingly common among farmers with high-value attribution to apricot farming given farmers' personal objection towards health risks (one third of HHs stated this), lack of skill and equipment, and in some cases, higher market prices for "organically" produced apricot products. Yet, beneficial characteristics of sulfur drying, such as a small up-front cost, low complexity, and a quick return of investment, overweighed constraints for most HHs.

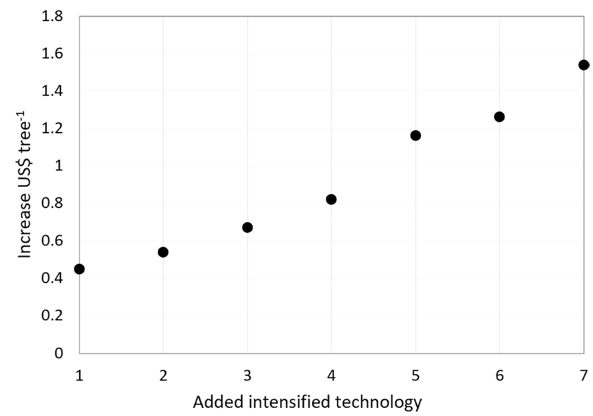


Fig. 3 Back-transformed increase of US\$ tree^{-1} revenue for increased adoption of intensified farming technologies in the study area of Gilgit-Baltistan, Northern Pakistan. The per adoption income increase in US\$ tree^{-1} was calculated using regression analysis, with log-transformed apricot revenue tree^{-1} as the response variable $\widehat{Y}$ and the intensification index as the predicting variable X_1. The regression model is $\widehat{Y} = 0.69 + 1.45X_1$ whereby the index comprises seven technologies. The index has its maximum at 1, each corresponding increase per added technology was calculated with $\widehat{Y}(X_1 + 0.14)$ until $X_1 = 1$

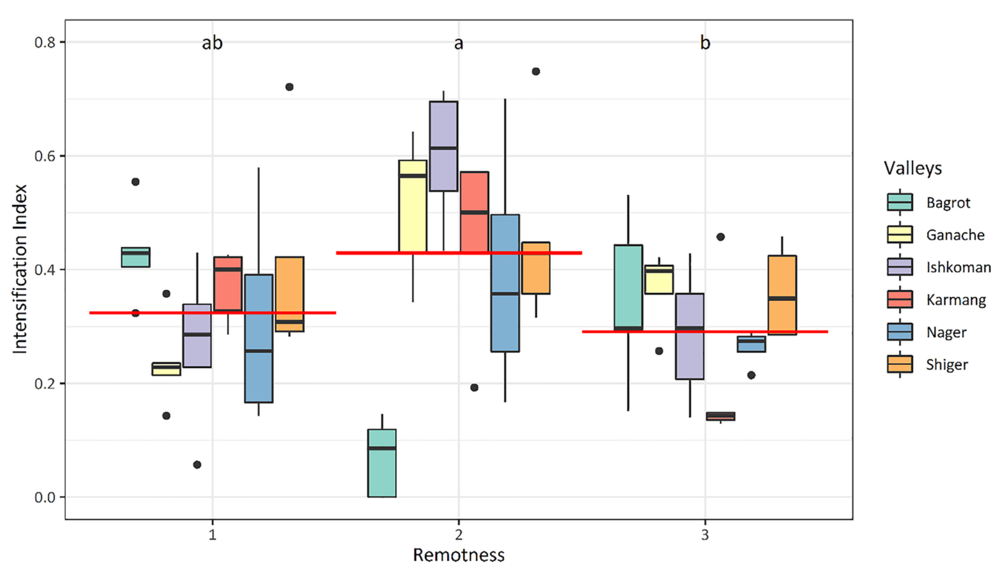


Fig. 2 Boxplots of the intensification index according to remoteness and sampled valleys of Gilgit-Baltistan, Northern Pakistan. The red line indicates the median used for determining significant differences between villages of different remoteness levels. The letters above the boxplots refer to group-wise differences

Compost application, pest and disease control, and mineral fertilizer use were among the least used technologies, with 7%, 13%, and 16% of HHs using this method, respectively. In the study area, the agro-ecological and social conditions make it difficult to do composting, as available feedstock is often used for animal husbandry. In addition, innovations on tree fertilization suffer from slow visibility of effects and therefore a low perceived relative advantage for the local farmers. Pest and disease control, fruit thinning, and systematic trimming of branches were hardly used in the study area due to lacking prerequisites. Specific practices, such as fruit thinning and branch training, were only known to and used by very few HHs. Although the Japan International Research Center for Agricultural Sciences (JIRCAS) distributed information on such practices as part of their project to promote value-added fruit products in GB [51], the knowledge dissemination among interviewees of this study was very low. While in some cases, knowledge and awareness existed, required skills and equipment were lacking [9]. The mean intensification index was significantly

Table 5 Descriptive statistics of major parameters explaining adoption in the study area of Gilgit-Baltistan, Northern Pakistan

Name of variable and unit	Variable description	Type of variable	Min	Central tendency[1]	Max	SD
Farm and Farmers' characteristics						
Education (1 low, 5 high)	Level of formal education	Categorical	1	2	5	
Male	Gender of the farmer	Nominal	0	0.88	1	0.32
Age	Age of farmer	Continuous	20	49	78	12
HH seize	Number of people in one HH	Continuous	3	9.4	22	3.9
Phone	Access to a phone by females	Nominal	0	0.44	1	0.5
Income (US$)	Total income of HH per year	Continuous	158	4 014	19 136	3 261
Loan	A loan taken in the last 12 months	Nominal	0	0.29	1	0.45
Land (ha)	Land for apricot production	Continuous	0	0.3	5.1	0.6
Experience	Number of years cultivating apricots	Continuous	2	20.2	53	11.8
Varieties	Number of cultivated apricot varieties	Continuous	2	6.01	40	5.95
Trees	Number of apricot trees	Continuous	6	60	550	80
Membership	Member of famer association	Nominal	0	0.6	1	0.49
Assets	HH owns mechanized farm equipment (female answer)	Nominal	0	0.11	1	0.31
Attitude	Preference for apricot cultivation	Nominal	0	0.95	1	0.22
Production characteristics						
Fresh sold (kg)	Weight of fresh apricots sold	Continuous	0	267	2000	535
Fresh price (US$)	Price of fresh apricots	Continuous	0.11	0.19	0.25	0.06
Dry yield (kg)	The total yield of dry apricots	Continuous	0	215	1080	193
Dry sold (kg)	Weight of dry apricots sold	Continuous	0	153	1000	171
Dry price (US$)	Price of dry apricots	Continuous	0.08	0.81	2.6	0.51
Working hours (h)	Working hours for apricots average per day during the season	Continuous	0	5.1	16	3.4
Income apricot (US$)	Total income of HH from apricot production per season	Continuous	0	158	1 458	215
Relative income (US$)	Income derived per tree	Continuous	0	3.8	25.7	5.2
Knowledge						
Training	Received training for apricot production and processing	Nominal	0	0.45	1	0.50
Gratis training desired	Gratis training desired	Nominal	0	0.90	1	0.30
Training desired	Training for money desired	Nominal	0	0.86	1	0.35
Apricot management						
Cutting	Weeding through cutting grass	Nominal	0	0.72	1	0.45
Grazing	Weeding through animals	Nominal	0	0.86	2	0.38
Irrigation (h)	Time used for irrigation	Continuous	0.2	3.5	24	4.1

[1] Central tendency (average) values dependent on the scale of data: continuous/numerical data = arithmetic mean; categorical/ordinal = mode; nominal/binary (dummy variables) = proportion of positive response

lower in the most remote villages than in the medium remote villages, while the market towns did not differ significantly from either (Fig. 2).

Increased income

The increase of relative income from apricot trees as a result of the adoption of intensified farming methods was nonlinear (Fig. 3). The regression model indicates a significant positive relationship between the index and the income from apricots, with a low coefficient of determination (R^2=0.07). Nevertheless, the model shows that the adoption of one of the agronomic practices used for the index (Table 2) holds the potential to increase the relative revenue by up to 1.54 US$ tree^{-1}, accounting for more than a third of the average relative income (3.8 US$ tree^{-1}) derived from apricots.

Determining factors

In complex decision-making processes, such as the adoption of intensified apricot farming practices, explanatory variables are often interrelated (Table 5), but the application of a factor analysis which is commonly applied in constraint analysis [9], did not yield meaningful factors. Many variables from Table 5 were excluded from the regression analysis due to their low explanatory power as a result of limited variability within the predictor (gender, attitude, gratis training and paid training desired, grazing) or high multicollinearity with other variables (dummy of fresh and dry sold, fresh price, total and relative income from apricots).

While increasing age of farmers is often found to contribute negatively to adoption of agricultural innovations [46, 52–54], the regression analysis of this study revealed that older farmers were more likely to adopt agricultural intensification innovations. Older-aged farmers were assumed to have gained knowledge and experience over time and were more able to evaluate information on the innovation than younger farmers in Kenya and Indonesia [55, 56]. Younger farmers instead seemed to be less risk averse and more interested in long-term investments [57]. The perception that younger farmers have a longer career horizon, are more technologically oriented, and are hence more likely to adopt innovations, assumes that farming is the DM's primary occupation. As our study investigated the adoption of innovation for apricot as an additional income source of a HH, the expected relationship between age and adoption seems to have reversed.

Table 6 Linear regression result for predicting the intensification index, based on factors affecting adoption decisions in the study area of Northern Pakistan

Variables	Estimators	*p*-Value
Intercept	0.01	-
Age of farmer	0.004	0.01
Training received	0.08	0.05
Adjusted R^2	0.19	0.001

Lack of awareness is an important factor leading to low adoption rates of elsewhere commonly applied innovations in apricot (Table 6). This study found that received training, which increases the awareness of innovations, had a positive influence on adoption. In GB, only a few key farmers are targeted by extension agents, who are expected to disseminate the information in their target villages [58]. As discussed earlier, younger locals seem to have less interest in apricot farming and are hence less frequently targeted by extension.

Conclusions

Apricot cultivation in Gilgit-Baltistan is extensive, small-scale, and an important—but not primary—income source, especially for low-income and remote HHs. Adoption of innovation related to intensification strategies in the region is constrained by lacking awareness, knowledge gaps, low skills, and missing equipment. These hurdles are further aggravated by limitations to the compatibility of innovations', adopters' social and cultural customs, age of farmers and the lacking training received. However, our the data also show the role of education or advanced training by local NGOs on the adoption of agricultural innovations. We, therefore, argue to intensify agricultural training offers to capacitate people in the framework of local cooperatives.

Intensively managed apricot stands coupled with value addition and improved market access have the potential to contribute to enhanced sustainability of HH incomes and thus livelihoods of small-scale farmers in GB. Additional benefits such as biodiversity conservation and the *in-situ* preservation of genetic material of local apricot trees, can be achieved by tree stands and apricot orchards with local varieties. Even using local varieties intensification of apricot cultivation holds the potential to increase and diversify farm incomes and may also contribute to enhanced nutrition for the local population.

Appendix

See Table 7 here.

Table 7 Central tendencies of socio-cultural and –economic parameters based on remoteness in the study area of Gilgit-Baltistan, Northern Pakistan

Name of variable and unit	Variable description	Type of Variable	Least remote	Medium remote	Most remote
Socio-cultural charateristics					
Language	Number of spoken languages	Continuous	3	4	5
Religion	Number of religion practiced	Continuous	3	3	3
Farm and Farmers' characteristics					
Education (1 low, 5 high)	Level of formal education	Categorical	2	3	0
Male[1]	Gender of the farmer	Nominal	0.79	0.9	0.96
Age	Age of farmer	Continuous	51	51	47
HH seize	Number of people in one HH	Continuous	10	8	10
Phone[1]	Access to a phone by females	Nominal	0.24	0.68	0.39
Income (US$)	Total income of HH per year	Continuous	3736	4545	3715
Loan[1]	A loan taken in the last 12 months	Nominal	0.28	0.28	0.32
Land (ha)	Land for apricot production	Continuous	0.19	0.46	0.24
Experience	Number of years cultivating apricots	Continuous	23	19	20
Varieties	Number of cultivated apricot varieties	Continuous	6	8	4
Trees	Number of apricot trees	Continuous	57	78	44
Membership[1]	Member of famer association	Nominal	0.66	0.66	0.5
Assets[1]	HH owns mechanized farm equipment (female answer)	Nominal	0.17	0.07	0.07
Attitude[1]	Preference for apricot cultivation	Nominal	0.91	0.93	1

[1] Dummy variables (i.e. female/male, yes/no, high/low)

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Author contributions

M. Koester: Conceptualization; Formal analysis; Funding acquisition; Data curation; Validation; Visualization; Original draft; Methodology; Software. M. Wiehle: Conceptualization; Supervision; Review and editing; Methodology; Funding acquisition; Project administration; A. Buerkert: Conceptualization; Supervision; Review and editing; Funding acquisition; Project administration; I. Alam: Conceptualization; Data curation; review and editing J. Rana: Supervision.

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Availability of data and materials

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

Declarations

Ethics approval and consent to participate

The research has been approved by the Ethics Commission of the University of Kassel on 06 May 2021 under: zEK-16. The consent to participate was requested from each interviewee prior to the interview.

Consent for publication

All interview respondents were informed that "The results of the study could be published in an article or presentation, but will not include any information that would let others know who you are."

Competing interests

The authors declare that they have no competing interests.

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