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Perceptions of Glacier Grafting: An Indigenous Technique of Water Conservation for Food Security in Gilgit-Baltistan, Pakistan

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Abstract: Climate change and disruption in the water cycle patterns are leading to water scarcity. This unsustained water provision is drastically affecting the areas of limited water resources. This research has studied the impacts of climate change on water availability and the localized indigenous technique of glacier grafting for sustained water provision. This adaptation strategy helps the water-stressed locality to conserve water for food security. For this reason, 160 self-administered questionnaires were deployed at the household level, and the primary data were analyzed through STATA Software for ordinal logit regression to estimate the results for both restricted and unrestricted models, against the three dependent variables of glacier grafting, glacier melt water and food security. It is found that glacier grafting ensures sustained water provision for irrigation. It increases fertile land and agricultural production to achieve food security. The income of the households from non-/agricultural products leads to afford a better standard of living. The extension of the glacier grafting strategy to curb climatic effects can help global societies to address the food insecurity issue for sustained living.

Keywords: climate change; glacier melt water; glacier grafting; agriculture; Gilgit-Baltistan

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Citation: Munir, R.; Bano, T.; Adil, I.H.; Khayyam, U. Perceptions of Glacier Grafting: An Indigenous Technique of Water Conservation for Food Security in Gilgit-Baltistan, Pakistan. *Sustainability* **2021**, *13*, 5208. https://doi.org/10.3390/su13095208

Academic Editor: Franco Salerno

Received: 24 February 2021
Accepted: 26 April 2021
Published: 7 May 2021
Corrected: 22 August 2022

1. Introduction

Climate change has hampered natural weather events, besides disturbing natural water cycle patterns. It is leading to water scarcity across different regions, both regionally and globally. The issue of disrupted water provision is drastically affecting the areas of extremely limited water resources. In this way, the decreased quantity of fresh water is becoming a serious problem for the world's communities. In the wake of sudden climatic changes, the communities, who were living in water abundant constituencies, are now declared water-stressed societies [1–3]. Here, community dwellings, especially in developing countries, are faced with pressing issues such as water scarcity, poor water quality, and reduced management and adaptation strategies [4,5]. On the global scale, the warmer and drier climatic conditions (under global climate change) have hampered agricultural production, leading to food insecurity [6–8]. Pakistan is, by exception, facing the consequences of changing climatic patterns. The non-availability of irrigation water and low levels of management in the country is leading to low agriculture production, low consumption and less utilization of the agricultural products [9].

The lower provision of water is because of the severe effects of global climate change on water resources. The enhanced global warming effect has strongly reduced the total snow area with very little snow accumulation, thus impacting the hydrological processes [10]. The on-going worldwide glacier mass retreat is influencing human societies by causing a rise in the ocean level, changing seasonal water accessibility, losing frozen water reserves and expanding geo-hazards [11]. The climatic issue of water scarcity is giving birth to an increasing number of societal conflicts between different stakeholders over water competition [12]. Over the years, incidences of water-related violence around the world at the national and regional level have increased. This is depicting the role of water in the development of disputes and conflicts [13]. Lower provision of water can affect plants and fruits, (historically) synchronized pollination of crops, food for migrating birds, the spawning of fish, water supplies for drinking and irrigation, forest health, and more [14]. Likewise, global climate change is affecting many sectors, including water resources, agriculture and food security, ecosystems and biodiversity, human health and coastal zones [15,16]. Specifically, the glacial-fed regions, where glacial water is the only source of agricultural activities, face severe impacts of climate change. On the one hand, frequent flash floods destroy the crops, while on the other hand, the extended droughts have severe negative impacts on food security [3,17,18].

Likewise, due to the lack of adequate water provision, many Asian countries are also at risk [19]. The disappearance of glaciers due to global warming is causing changes in the streams—affecting water availability that damages agricultural growth [20]. Admittedly, agriculture plays an important role to meet the daily dietary needs of people for achieving food security [21]. Many developing nations in South Asia have been failing to meet these challenges of adequate food requirements for their people [22]. Overall, an 8% reduction in agriculture yield in South Asia is identified with a significant 12%, 7%, and 9% reduction in wheat, maize and millet, respectively [23]. Climate change affects food systems in several ways, extending from direct effects on crop production to changes in market food prices and changes in supply chain infrastructure. According to an estimate, currently, 124 million people in over 51 countries are facing a food insecurity issue, whereas 74 million food-insecure people are in need of urgent assistance [24].

Genesis of the Problem: Agricultural Production and Food (In-)Security

According to UN estimates, about 1 billion people living in the dry areas will face complete water shortage by the end of 2025. This water scarcity is related to water unavailability for food production [25]. It is coupled with changes in the global hydrological cycle that is expected to vary the patterns of demand and supply of water for agriculture—the dominant user of freshwater. The extent and productivity of both irrigated and rain-fed agriculture can be expected to change [26]. It is also estimated that 25% of the worldwide cultivable areas are irrigated land, and 44% of total cereal productions were determined to come from irrigated agriculture globally. However, due to water shortage, productivity has declined [27].

In Asia and the Middle East, the major issue is the depletion of groundwater, which is a great threat to food security, reducing domestic food production and increasing imports of food commodities [28]. In the least developed countries of Asia and Africa, the agricultural growth is showing a trend of decline as compared to the developed countries, where the agriculture productivity is increasing by every unit [29]. Among the Asian countries, the agriculture growth rate in Pakistan is decreasing. It has already decreased from 4.10% per year in 2007 to 3.50% per year in 2017, whereas the population growth has increased four times. It is raising pressure on the cultivatable land [30]. Water scarcity and droughts are also posing serious threats to both the livelihood of farming communities as well as the economies around the world. To address these negative effects of the ongoing climate change, communities are more likely to adopt counter (adaptation) strategies [31].

One of the counter strategies being adopted by the Himalayan people of Pakistan is an indigenous method of glacier grafting or glacier growing, to increase water bodies [32]. As the Karakoram and the Himalayan ranges of northern Pakistan is a dry land and do not receive monsoon rain, the agriculture depends on irrigation thorough glacial water melt, which remains the main source to irrigate the land [33]. Due to the climatic changeability, the glaciers in the northern areas are disappearing, making the region water-stressed [34]. Additionally, the growing issue of water scarcity in Pakistan is creating competition over the use of water [35]. In 2010, Pakistan was declared as a water-stressed country. It has seriously harmed the agrarian economy of Pakistan, besides making thousands of people food insecure [36]. The reduction in food and agriculture production has seriously affected the local people by making the situation worse for them [37]. Pakistan's agricultural performance is closely linked with the supply of irrigation water. Overall, Kharif, as well as Rabi production, is dependent on water availability, which is reported to be less than what is required, i.e., only 2.5% in 2005–2006 and 20.6% in 2004–2005. Hence, to address the issue, especially in the northern parts of Pakistan, glacier growing remains an effective ancient technique to increase availability [38]. Thus, this research study aims to analyze the negative effects of climate change on water availability for agricultural production and food security through public perception. Further, how glacier grafting is helping the locality to improve socio-economic status is studied. The specific research questions of the study are:

1. What is respondents' perception of climate change for water availability and agricultural production for food security?
2. What is respondents' perception regarding glacier grafting for water provision for agricultural production and food security?
3. What is respondents' perception about the contribution of glacier melt water in improving socio-economics dynamics?

2. Literature Review

2.1. Glacier-Grating: A Technique

Glacier grafting is an important activity in the villages of Gilgit-Baltistan, which is helping/supporting to achieve SDGs number three: "good health and wellbeing" and number 13: "climate change" [39]. Glacier grafting is a technique that is used to encourage the growth of ice patches at high altitude, i.e., catchments of Gilgit-Baltistan [38]. The total area under cultivation is roughly one percent of the total area of Gilgit-Baltistan. It constitutes 73,000 hectares that require a non-stop supply of water for irrigation purposes, while another 90,000 hectares in every district can be developed for cultivation purposes through sustained water provision [40,41]. Therefore, glacier grafting technique has the potential to transfer 90,000 hectares of land per district into arable land for food security. This conventional method of breeding male and female glaciers has been becoming successful in Gilgit-Baltistan, since 2001. The breeding takes place at an altitude of 1200 feet in high mountains and it costs almost USD 2300 per glacier for activities such as digging, preparing, transportation, surveys, etc. [42]. For glacier grafting, the first step is the selection of a suitable place; the preferred terrain is a shadowed slope located between 4000 to 5000 m above sea level and then carry pieces of male and female glaciers to the sites [43].

According to local understanding, there are two categories of glaciers: male and female. The male and female glaciers are differentiated through the color of ice/glacier, water providing capacity and surging activity. The color of a female glacier is white or bluish, whereas that of male is black, covered in soil and rocks. It is locally believed that the female glacier has the ability to grow and provide more water than the male glacier. The male glaciers are perceived to provide little water and move slowly. Further, the female glacier should be added to the male glacier to make the glacier grow [44]. The total area being used for glacier grafting in the region is estimated to be (approx.) 100 hectares [45,46].

It is hard to mention the total number of farmers/community members involved in glacier grafting in the whole region as it varies from year to year and as per need of water, yet roughly one person from every household is involved in the said activity, thus estimating up to 70,000 individuals in the study area (i.e., Skardu, Ghanche, Kharmang). These individuals climb the mountain (in groups) up to the shaded areas during September–October every year. The area/sites being used for glacier grafting (on the mountains) is owned by the locality. In the process of GG, the local community takes packs of glacial ice (300 kg) and containers of Indus River water (120 kg) along with other ingredients (sawdust and salt, etc.) and places them in the caves and then covers them with soil [47]. The covered storage of ice then starts melting during summer times as the temperature rises. The local people then use this meltwater for irrigation purposes and to fulfil their water needs [48]. This ancient technique of glacier growing is crucial for the supply of water in this dry area. It remains a brilliant indigenous practice that can resist ongoing climate change [16]. This adaptive technique (glacier grafting) in Gilgit-Baltistan is not only saving the region from water scarcity but helping to increase water resources in the area [39]. It is being caried out without (non-/tangible) assistance from the government. This indigenous technique is based on the natural process of water conservation that seems to improve environmental sustainability, yet whether glacier grafting technique is scientifically proven to be environmentally sustainable is beyond the scope of this study.

2.2. Community Participation for Glacier Grafting

Community participation in climate protection plans is equally crucial as government's plans. This is because the community remain the main actors in the implementation of climate protection plans [49]. Communities need to focus more on measures to efficiently use the limited resources [5]. It is therefore important to recognize the community's role in climate protection. Many communities around the world are playing their important roles by using indigenous knowledge in controlling the environment and protecting the planet [50]. The indigenous knowledge includes both traditional and non-traditional knowledge and non-/ecological knowledge that proposes a solution to allow indigenous people (and others) to adapt to the environment [51]. Indigenous people are essential agents of environmental conservation, e.g., the indigenous communities in the Amazonian region have resisted the deforestation of land since the 1990s. Many of them are aware of their responsibility to protect the forests in the interests of combating climate change [52]. Hence, community participation is a vital strategy to fight against climate change. Besides, their involvement remains crucial for the effective plans [53].

Similarly, mountainous communities of Gilgit-Baltistan practice glacier grafting, which not only leads to better and optimal use of the available freshwater, but also helps to avoid the potential water conflicts through fostering community cooperation [54]. The Aga Khan Rural Support Program (AKRSP) has motivated the local people to participate in making glaciers. It is behind the fact that it is cost-effective, sustainable and promotes the importance of climate action. The ancient skills of glacier grafting or glacier growing in the Himalayan and Karakorum ranges of Pakistan guarantee year-round water in mountain villages for agricultural purposes [32].

2.3. Water for Food Security

The availability of sustained water provision plays a critical role in food production. It is the sustained water availability that ensures efficiency of agriculture production [55]. The literature is evidence that by a reduction in water losses and by improving the ways of water usage, the availability of water increases. This water availability enhances agricultural production [56]. For instance, in Zhangye city of China, with improving water use for agriculture, the GDP has increased by 0.10% [55]. Similarly, the people of Skara (village of Ladakh) have adopted a local technique to mitigate with the climate prompted water stress via forming huge masses of snow and ice to manage water supply for the dry seasons, which have enhanced their crop production [57]. Regrettably, Pakistan's production is lower than China, India, and the USA, etc. One of the reasons for the declined production in Pakistan is droughts and water unavailability [58]. Correspondingly, the recent spikes in food prices, partially caused by the increasing demand for agricultural products in non-food uses, underline the urgent need to invest in agricultural production. Water management is a crucial part [59]. On the other side, due to the grafted glaciers, the irrigation water in the streams of Gilgit-Baltistan has increased. It is leading to more agricultural production. It is also helping the locality to grow more crops. This output is leading to the involvement of more men and women in the agricultural activities [39].

Agricultural adaptation to climate change is highly focused, mainly due to the growing concern over climate change [60]. The relationship between agriculture and climate is not a new phenomenon. In the rural areas, farmers have been trying to encounter the effects of climate change and weather variability for centuries, by using their indigenous knowledge [61]. Universally, the community-based adaptations to climate change aimed at improving agricultural crops. However, these adaptations unavoidably favor some crops and regions over others [62]. An adaptation that adds to socially and ecologically sustainable development pathways and contains social justice and ecological integrity is required in this century [63].

2.4. Conceptual Framework

The global climate change results in a decrease in glacial snow and a reduction in precipitation patterns. The immediate impacts' bearers of climate change are water scarcity/shortage and food insecurity. As an adaptation strategy, glacier grafting by the local community has the potential to sustain water provision, and increase agricultural production and food security, further leading to positive socio-economic impacts on the dependent communities (Figure 1).

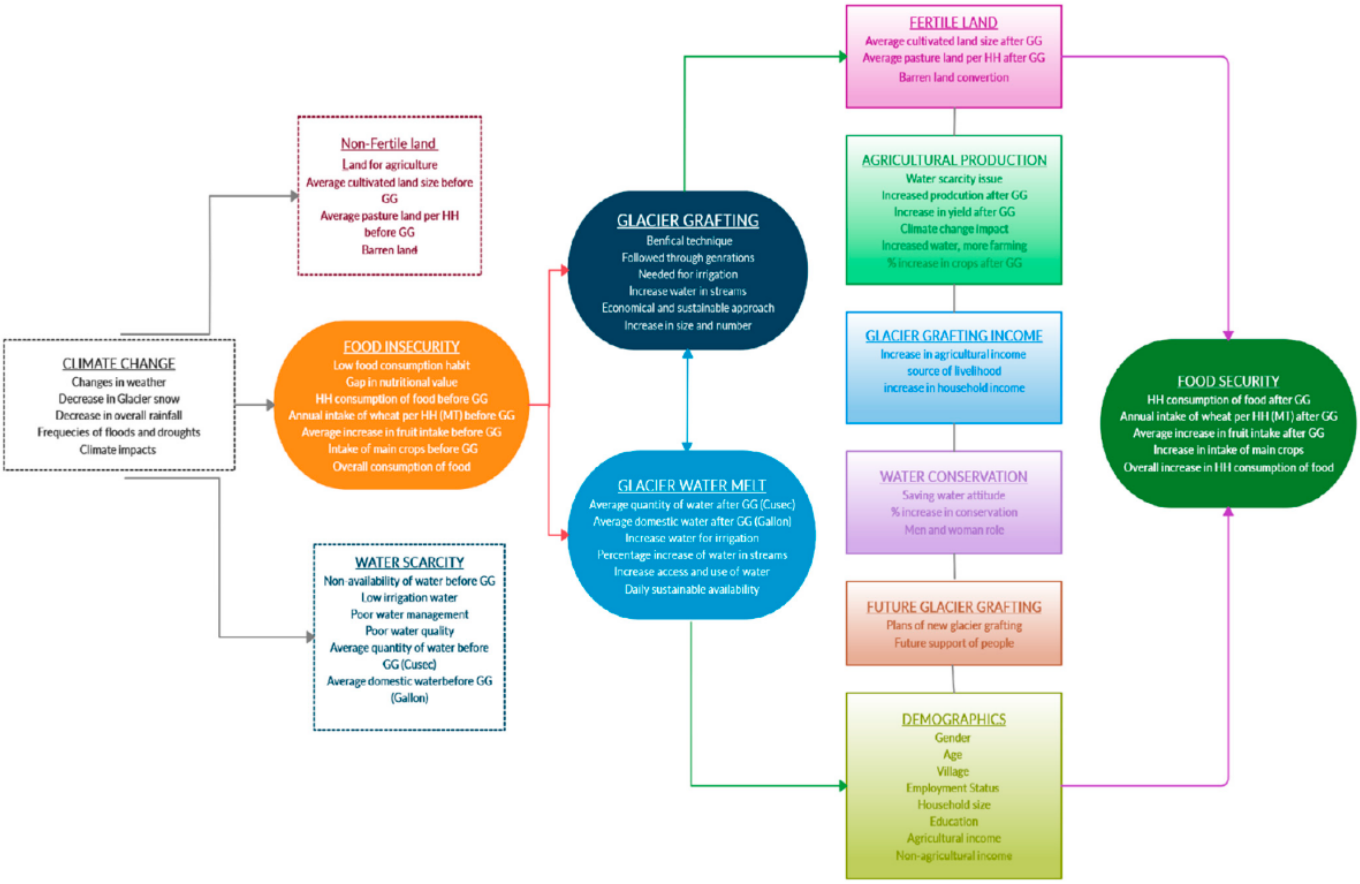

Figure 1. Conceptual framework.

3. Research Methodology

3.1. Study Area

Gilgit-Baltistan is situated at 35.8026° N, 74.9832° E with a total area of 72,971 km^2 (28,174 mi^2) and a total population of 1.249 million [39]. The study area is located Southeast of Kargil District, East of Ghanche District, Northeast of Xinjiang Province (China), South of Baramulla, West of Astore and North of Gilgit District. The selected areas of this research study are three villages, where glacier grafting is practiced, i.e., Gole from district Skardu, Pari from district Kharmang and Balghar from district Ghanche (Figure 2).

Figure 2. Map of the study area.

3.2. Sampling Technique and Data Collection

This study deployed a systematic random sampling technique for selecting the first house on a random basis, followed by selecting the rest of the houses at an interval of 4, i.e., every fourth house from the reference point was selected. As glacier grafting is being practiced widely in the study areas by all the houses/families, no exclusion criteria were used against any house/family/individual. In this way, 160 households (HHs) were selected, i.e., 60 from Balghar, 60 from Gole and 40 from Pari (Table 1).

Table 1. Total HHS and sample size.

District	Glacier Site	Total HHs	HH Size	Sample HH	Consulted HHs (*n*) *
Skardu	Gole	27,902	7.7	50	60
Ghanche	Balghar	22,727	7.7	50	60
Kharmang	Pari	20,000	7.7	40	40

* CI 90 with ±5 ME. Source: [39].

For primary (quantitative) data collection, 160 close-ended questionnaires were deployed at the HH level [39]. It necessary is to mention that out of total 160 respondents, 15% were women, and 85% were men. This shows that the majority of the respondents who participated in this study were men. This is because glacier grafting is a male-oriented activity in the study area. The majority of the respondents who participated in this study ranged from the age of 25 to 44 years, constituting 76.87% of the total population. Similarly, a fair number of respondents, i.e., 36.88% of the population, were of the age of 45 and above.

The results further indicate that the lack of schools and inaccessibility to educational facilities result in illiteracy (55%). Out of the total, 27.5% of the respondents had completed secondary education, and only 3.75% of the respondents had obtained higher education. Moreover, due to a high rate of illiteracy, the majority of the population (79.37%) were unemployed, while 11.25% were self-employed and 9.38.3% were employed in different sectors. Agriculture was the primary source of livelihood of the people in the study area. They have been practicing traditional farming on a subsistence level. They grow food crops to feed themselves and their families. Merely 11.87% of the respondents were earning from agriculture between USD 200 to USD400 per year, while 73.12% of respondents were earning less than USD 200 per year. The main crops are wheat and barley, whereas livestock rearing maintains their lives (Table 2).

Table 2. Demographic information of the respondents.

Description	Frequency	Percentage (%)
	Age Composition	
18–24	26	16.25
25–44	75	46.87
45>	59	36.88
	Agriculture Income (US $)	
Zero	11	6.87
<200	117	73.12
200–400	19	11.87
>400	13	8.14
	Respondent by Sex	
Female	24	15.0
Male	136	85.0
	Respondent by Education	
Illiterate	88	55.0
Primary	22	13.75
Secondary	44	27.5
Higher Education	6	3.75
	Respondent by Occupation	
Unemployed	127	79.37
Employed	18	11.25
Self-employed	15	9.38

This study consulted secondary data from sources such as government reports, journal articles, books and credible national/international newspaper articles. It was carried out by sorting out data from the existing literature, as recommended in social science research [64].

3.3. Estimation of Variables and Statistical Modeling (Construction of Variables)

The response data were configured into variables that are best explained by the survey questions. The number of questions for each variable were computed with reverse coding (where required), and variables were constructed through SPSS and MS-EXCEL software. The constructed variables include: demographics (V = village, age = age, G = gender, AI = agricultural income, NAI = non-agricultural income, ES = employment status, ED = education and HHS = household size), climate change (CC), water unavailability (WA), glacier melt water (GMW), glacier grafting (GG), agricultural land (before GG) (AL), fertile land (after GG) (FL), agricultural production (AP), GG generated income (GGI), water conservation (WC) and future GG (FGG).

Dependent Variables

The dependent variables were taken as glacier melt water, glacier grafting, food security and converted into categories as “low”, “medium” and “high” levels. The cut off points were used and a value of “1” was allotted to low values, “2” was allotted to medium values and “3” was allocated to high values. Using STATA software, the ordered logit model (ologit) was used to estimate results as restricted and unrestricted. Due to glacier grafting, glacier melt water was increased in the streams and had a positive impact on food security in the study regions. The correlation among the dependent and independent variables were estimated through the ordered logit model through the following regression equations:

(1) Glacier Grafting = f (demographics, glacier melt water, water unavailability, climate change, agricultural land, fertile land, agricultural production, food security, food insecurity, glacier grafting income, water conservation, future glacier grafting).

(2) Glacier Melt Water = *f* (demographics, glacier grafting, water unavailability, climate change, agricultural land, fertile land, agricultural production, food security, food insecurity, glacier grafting income, water conservation, future glacier grafting).
(3) Food Security = *f* (demographics, glacier grafting, glacier melt water, agricultural land, fertile land, agricultural production, glacier grafting income, water conservation, future glacier grafting) (Tables 3 and 4).

Table 3. Dimensions of variables with explanation.

Dimensions	Explanations
Glacier Grafting	Benefits of glacier grafting to communities
Glacier Melt Water	Water availability after GG for domestic and agricultural use
Food Security	Food consumption and utilization after GG
Food Insecurity	Food consumption and utilization before GG
Domestic Agricultural Yield/Production	Agricultural output due to GG
Water provision	Water unavailability for domestic and agricultural use
Irrigation water for lands	Agricultural land before GG; agricultural land after GG
Climate Change	Rainfall/snowfall changes and natural disasters
Water conservation	Saving water after GG
GG Income	Changes in HH income after GG
Future GG	Beneficial for GG to be continued in future

Table 4. Variables and sources.

Variables	Indicator	Source
Agricultural Production	Agriculture production per household (MT). Average annual agriculture income per HH (USD). Average cultivated land size per household (Kanal).	[65]
Food consumption	Annual intake of wheat and barley per household (MT). People who consume vegetable and fruit in the village (%).	[66]
Water utilization	% of men and women started conserving water.	[67]
Increase in water	Average quantity of water in irrigation channels (Cusec). Use of domestic water per HH (gallon). Average annual time on watering crop fields per HH (h). Increase access and use of water after GG (%).	[43,68,69]
Increase Production/Consumption	Average forest and fruit trees per HH (No).	[33]

The categorical dependent variables are used in observing the outcomes that relate to the probability of estimated linear function, plus random error within the range of cut points estimated for results are as:

Model 1 = **Glacier Grafting =** $\alpha_0 + \alpha_1$ GMW + α_2 CC + α_3 AL + α_4 FL + α_5 AP + α_6 FS + α_7 FI + α_8 GGI + α_9 WC + α_9 FGG+ α_{10} D + μ_i (a)

Model 2 = **Glacier Melt Water =** $\alpha_0 + \alpha_1$ GG + α_2 CC + α_3 AL + α_4 FL + α_5 AP + α_6 FS + α_7 FI + α_8 GGI + α_9 WC + α_9 FGG+ α_{10} D + μ_i (b)

Model 3 = **Food Security =** $\alpha_0 + \alpha_1$ GG + α_2 GMW + α_3 AL + α_4 FL + α_5 AP + α_6 GGI + α_7 WC + α_8 FGG + α_9 D + μ_i (c)

(Here, μ_i is the random disturbance term and α_{0}- α_9 denotes the coefficient values of these variables).

3.4. Data Analysis Techniques

The dependent variables are classified in their order of magnitude for which ordered logistic regression is used. It follows the proportional odds assumption, assuming that a coefficient in the model does not differentiate between ranks, i.e., odds for any independent variable is the same across ranks. The dependent variables glacier grafting, glacier-melt water and food security are categorized as low, medium and high for modelling purposes. The log-likelihoods iteration is used in the ordered logit model. The first iteration (0 iteration) is the null or empty model with no predictors, whereas the next iterations include "predictors" in the model. As the maximum likelihood is required, when the differences between successive iteration are negligible and seem to have converged, the iteration stops. The log-likelihood chi^2 tests of all predictors of regression coefficient in the model are tested, and LR chi^2 is given. The significant probability of obtaining the LR test is zero, so a small *p*-value (<0.00001). It confirms the significance of the model, as the probability of obtaining chi^2 statistics, if there is no effect of predictor variables [70]. The ologit model is estimated as unrestricted and restricted to evaluate the best models of the two by comparing their chi^2 and Pseudo R^2.

4. Results and Discussion

4.1. GG and GMW for Food Security

Glacier grafting has a maximum frequency at high glacier grafting (67.50%), whereas glacier melt water has the greatest percentage in medium GMW (53.13%). For food security, the maximum percentage persists in medium food security (high level = 59.38%) (Table 5). The relationship between the dependent variables and independent variables shows that glacier grafting is significantly related to glacier melt water (chi^2 =48.16 at 1% *p*-value). Results are found to be significant for fertile land, agricultural production, future glacier grafting and village/area selection of glacier grafting (chi^2= 55.9, 47.95, 24.22 and 8.97 with p = 1% each for the first three and 10% for area selection). Glacier melt water is estimated to have 49.0 chi^2 (significance at 1% with glacier grafting). Agricultural land, fertile land, agricultural production, glacier grafting income, and future glacier grafting are also significant with glacier melt water. These results align with the global studies' findings that the ancient water-harvesting technique (e.g., GG) increases water for crop irrigation, especially in the water-stressed regions [71]. Further, the demographics such as a village, gender, employment status, income and education have a significant correlation with glacier melt water (Table 6). Glacier grafting, income, gender and education have a significant relationship with climate change, water unavailability, and glacier melt water.

Table 5. Frequencies of dependent variables.

	Glacier Grafting	Glacier Melt Water	Food Security
Low	9.38%	12.50%	10.63%
Medium	23.13%	53.13%	56.25%
High	67.50%	34.38%	33.13%

4.2. Significance of Glacier Grafting

In estimating the dependent variable, i.e., glacier grafting, with independent variables, the study's results found two models: restricted and unrestricted (-2 log-likelihood of the unrestricted model at −98.04 and restricted model at −93.50, at iteration 5). All the 160 observations for both models were found to be significant (p = 0.0000). The values in Table 7 denote the coefficient values for each variable $\alpha_0 \ldots \alpha_9$. The chi^2 value of the restricted model is lower at 68.19 than the unrestricted model at 77.28, whereas the Pseudo R^2 is 0.2924 for unrestricted model and 0.2580 for restricted model (Table 7). The -2 log likelihood denotes the best fit model, if its value is smaller between the two models. Hence, the restricted model is the best fit model among the two ologit models.

Table 6. Variables—cross tabulation and chi2 tests.

	Cross Tabulation (Chi^2)		
Variables	**Glacier Grafting**	**Glacier Melt Water**	**Food Security**
Climate change	3.13	6.74	5.50
Water Unavailability	10.20	17.13	15.85
Glacier Grafting	48.16 ***	49.00 ***	10.55
Glacier Melt Water	-	-	25.97
Agricultural Land	8.98	17.48 *	9.56
Fertile Land	55.79 ***	28.63 ***	2.52
Food Insecurity	5.5772	8.7762	13.2354
Food Security	10.99	20.55	-
Agricultural Production	47.95 ***	28.12 **	13.81
Glacier Grafting Income	25.47	10.83 **	7.87 *
Water Conservation	10.47	13.89	25.25
Future Glacier Grafting	24.22 ***	28.00 ***	0.72
Village/area	8.98 *	13.55 ***	5.85
Gender	3.25	13.27 ***	6.44 **
Age	1.84	2.26	2.37
Employment Status	0.22	11.62 **	6.51
Household Size	0.07	3.16	1.16
Agricultural Income	6.72	8.20	6.20
Non-Agricultural Income	1.34	7.64	5.32
Education	7.79	14.25 **	12.39 *

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table 7. Glacier grafting restricted and unrestricted ordered logit modeling.

	Ordered Logistic Regression: Glacier Grafting	
	Unrestricted Ologit	**Restricted Ologit**
-2 Log likelihood	−93.494206 (Iteration 5)	−98.038437 (Iteration 5)
No of obs	160	160
LR chi^2	77.28	68.19
p value	0.0000	0.0000
Pseudo R^2	0.2924	0.2580
Better Fit model		✓

The glacier grafting has a negative and insignificant relationship with climate change (odds ratio = 0.99 for the unrestricted and restricted model). The reason behind this is that climate change has prominent negative impacts on agriculture due to the shortage of water availability [72]. The proportional odds ratio for a one-unit increase in climate change leads to glacier grafting, given that other variables in the model are held constant. Thus, for the unrestricted model, a one-unit increase in climate change, the odds of high glacier grafting versus the combined middle and lower glacier grafting are 0.99 times lower, again given that all other variables are constant in the model. Likewise, for a one-unit increase in climate change, the odds of the combined high and medium glacier grafting versus the low glacier grafting are 0.99 times lesser, given other variables are held constant (Table 8). This shows that as climate change increases, there is a reduction in rainfall, glacier snow and low water availability. It further leads to low glacier melt water, hence more glacier grafting being practiced. This result coincides with the global trend that snow dominated regions such as South Asia are being seriously affected due to water non-availability under climate change [73].

Water unavailability and glacier grafting have a positive relationship (p = 10%). It shows that as water unavailability increases, glacier grafting benefits the community. With a one-unit increase in water unavailability, the odds of high glacier grafting versus the combined middle and lower glacier grafting are 1.03 times higher (all other variables are kept constant). Likewise, for a one-unit increase in water unavailability, the odds of the combined high and medium glacier grafting versus low glacier grafting are 1.03 times higher. Hence, as water availability decreases, formations of glaciers are beneficial for the local dependent communities.

Table 8. Glacier grafting restricted and unrestricted ordered logit modeling.

Ordered Logistic Model: Glacier Grafting					
		Unrestricted		Restricted	
DV	**IV**	**Odds Ratio**	**Coefficient (Z-Value)**	**Odds Ratio**	**Coefficient (Z-Value)**
Glacier Grafting	Climate change		−0.005 (0.75)	0.9943794	−0.006 (1.02)
	Water Unavailability	1.03	0.028 (1.79) *	1.02	0.024 (1.72) *
	Glacier Melt Water	1.03	0.028 (2.03) **	1.03	0.027 (2.27) **
	Agricultural Land	1.01	0.010 (0.91)	1.01	0.010 (1.04)
	Fertile Land	1.02	0.017 (1.43)	1.03	0.025 (2.26) **
	Food Insecurity	0.98	−0.020 (2.16) **	.98	−0.017 (1.99) **
	Food Security	0.991	−0.009 (0.75)	0.99	−0.010 (0.95)
	Agricultural Production	1.05	0.044 (3.38) ***	1.04	0.041 (3.71) ***
	Glacier Grafting Income	1.02	0.022 (2.84) ***	1.02	0.018 (2.77) ***
	Water Conservation	1.00	0.001 (0.09)	1.00	0.001 (0.14)
	Future Glacier Grafting	1.01	0.007 (0.80)		
	Village	0.65	−0.438 (1.34)		
	Gender	1.56	0.443 (0.64)		
	Age	1.27	0.240 (0.58)		
	Employment Status	0.78	−0.254 (0.48)		
	Household Size	2.07	0.726 (1.16)		
	Agricultural Income	1.72	0.541 (1.29)		
	Non-Agricultural Income	1.26	0.228 (0.42)		
	Education	1.44	0.362 (1.10)		
cut1	_cons	7.80	7.804 (2.31) **	3.71	3.706 (2.31) **
cut2	_cons	10.16	10.156 (2.96) ***	5.92	5.920 (3.55) ***
N			160		160

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Likewise, GMW and GG have a positive relationship (at 5% level of significance). It shows that as glacier grafting increases, glacier melt water increases. With a one-unit increase in GMW, the odds of high glacier grafting versus the combined middle and lower glacier grafting are 1.03 times higher (all other variables are kept constant). Likewise, for a one-unit increase in GMW, the odds of the combined high and medium glacier grafting versus low glacier grafting are 1.03 times higher. Hence, as the glacier melt water increases, artificial glaciers are formed to provide water security for agricultural purposes in the study regions. This result of the study is backed by the study conducted by [33], that showed water for agricultural purposes taken from glacial water melt remains the main source to irrigate the land in water-stressed regions.

Fertile land for agricultural purposes is found to be positively correlated with GG in the restricted model (5% *p*-value). It shows that fertile land increases as glacier grafting are practiced in the region, so with a one-unit increase in the fertile land, the odds of high glacier grafting versus the combined middle and lower glacier grafting are 1.02 times higher (other variables are kept constant). Likewise, for a one-unit increase in fertile land, the odds of the combined high and medium glacier grafting versus the low glacier grafting are 1.02 times higher. Hence, practicing GG ensures more glacier melt water for irrigation purposes that increase the percentage of fertile land. This same is reported by [48] that glacier melt water is used extensively for irrigation purposes to address water shortages in areas of low water availability.

This increase in fertile land leads to an enhancement in agricultural production (relationship is found significant at 1% *p*-value). The results denote that by practicing glacier grafting, agricultural yield increases. With the one-unit increase in agricultural production, the odds of high glacier grafting versus the combined middle and lower glacier grafting are 1.05 times higher (other variables are kept constant). It confirms that practicing glacier grafting positively impacts agriculture production to meet the local food consumption needs than importing food items.

Food insecurity and food security are negatively related to glacier grafting with food insecurity, having a significance level at 5%. It shows that as food insecurity rises (due to lower glacier grafting) it ends in a one unit increase in food insecurity. Here, the odds of high glacier grafting versus the combined middle and lower glacier grafting are 0.98 times lower, given all other variables are constant in the model. Likewise, for a one unit increase in food insecurity, the odds of the combined high and medium glacier grafting versus the low glacier grafting are 0.98 times lesser, given other variables are held constant. Once the food insecurity increases, glacier grafting benefits more.

The increase in food production and enhanced agriculture livelihood (due to GG) has positive impacts on households' income (1% *p*-value). The one-unit increase in GG raises the income level (odds of high GG versus the combined middle and lower GG = 1.02 times higher—other variables are kept). It remains 1.02 times higher for combined high and medium GG versus the low GG. Therefore, the households experience a rise in their income to afford other social facilities (e.g., education, health, etc.) due to GG. Likewise, water conservation and glacier grafting are found to be positively related; as water conservation increases so the need to have more glaciers, besides encouraging the local communities to conserve water (both male and female).

Is has also been cited that sustained water provision is necessary to fight climate change to address the food insecurity issues [74]. The relationship between demographics and GG is insignificant with gender, age, household size, education, agricultural and non-agricultural income (odds ratio >1), whereas the village/area and employment status have negative relationship with GG.

4.3. Glacier Melt Water (GMW)

The relationship between the dependent variable (i.e., GMW) and independent variables is found in two models: restricted and unrestricted, with -2 log-likelihood for the restricted model = −114.97 and for unrestricted model = −144.37 (at iteration 5 and *p* = 0.0000 for all the 160 observations). The values in the table denote the coefficient values for each variable $\alpha_0 \dots \alpha_9$. The chi^2 value of a restricted model is lower at 78.32 than the unrestricted model (at 79.43), so the Pseudo R^2 remains 0.2578 for unrestricted and 0.2539 for the restricted model. The best fit model is a restricted model, as its -2 log-likelihood is smaller than the unrestricted model and its percentage correct is smaller too (Table 9).

Table 9. Glacier melt water unrestricted and restricted ordered logit modeling.

Glacier Melt Water: Ordered Logisitc Model		
	Unrestricted Ologit	**Restricted Ologit**
-2 Log likelihood	−114.36797 (Iteration 5)	−114.96709 (Iteration 5)
No of obs	160	160
LR chi^2	79.43	78.23
P value	0.0000	0.0000
Pseudo R^2	0.2578	0.2539
Better Fit model		✓

The GMW has a positive but insignificant relationship with climate change (odds ratio = 1.00 for both the models). Therefore, as climate change accelerates, the need for GMW accelerates. For the unrestricted model, with a one-unit increase in climate change, the odds of high glacier melt water versus the combined middle and lower glacier melt water are 1.00 times greater (all other variables are held constant). Likewise, for a one-unit increase in climate change, the odds of the combined high and medium glacier melt water versus low glacier melt water are 1.00 times greater. Furthermore, the GMW and water unavailability have a negative and insignificant relationship in both the restricted and unrestricted model, showing that with an increase in water unavailability, there is a decrease in GMW. It shows that as water availability decreases, there is need for increased GMW. With the one-unit increase in water unavailability, the odds of high GMW versus the combined middle and lower GMW are 0.997 times lower (other variables as constant). Likewise, for a one-unit increase in water unavailability, the odds of the combined high and medium GMW versus low GMW are 0.997 times lower.

The relationship of GMW with glacier grafting is positively significant (p = 5%) and depicts that the more glacier grafting, the higher the GMW in the area. With the one-unit increase in glacier grafting, the odds of high GMW versus the combined middle and lower GMW are 1.03 times greater (other variables as constant). Likewise, for a one-unit increase in glacier grafting, the odds of the combined high and medium GMW versus low GMW are 1.03 times higher. Similarly, agricultural land requires more glacier melt water for irrigation, so for a one-unit increase in agricultural land, the odds of high GMW versus the combined middle and lower GMW = 0.977 times lower (all other variables as constant). The odds of the combined high and medium GMW versus low GMW are 10.977 times lower for the same one-unit increase in the agricultural land. This trend coincides with the literature that the indigenous knowledge of glacier grafting is associated with water availability, especially in the water-stressed mountainous villages [75].

Similarly, the correlation between fertile land and GMW is positively significant in both the restricted and unrestricted models (p = 5% each). With a one-unit increase in the fertile land, the odds of high GMW versus the combined middle and lower GMW are 1.03 times higher, whereas the odd value remains 1.03 times higher for combined high and medium GMW versus low GMW. It shows that GMW increases the percentage of fertile land due to more water availability for the irrigation purposes. Yet interestingly, GG has a negative and significant relationship with the income of the communities associated only to GG. It confirms that the more the individual is involved in activities associated to GG (e.g., uplifting water to mountain tops/caves, making gullies and water channels, etc.), the less the income they earn, which is due to their lack of time to engage in other income-generating activities. The results are highly significant (1% p-value) showing that with a one-unit increase in income due to GG the odds of high GMW versus the combined middle and lower GMW are 1.03 times higher (other variables as constant). It corresponds to water availability from glacier melt for irrigation that increases the quantity of fertile land for agricultural purposes [33].

Food insecurity has a negative relationship at the significance level of 10% with GMW, both for the unrestricted model and restricted model. It depicts that as food insecurity increases, GMW lowers. Lower GMW denotes that glacier grafting is not practiced, agricultural production is reduced, and food production and consumption are reduced in response. It ultimately results in food insecurity in the Gilgit-Baltistan region. With the one unit increase in food insecurity, the odds of high GMW versus the combined middle and lower GMW are 0.988 times lower, given all other variables are constant in the model. Likewise, for a one unit increase in food insecurity, the odds of the combined high and medium GMW versus low GMW are 0.988 times lower (other variables are held constant). Hence, an increase in GMW reduces food insecurity in the region.

There is a positive association between food security and GMW (significant at 5% *p*-value), denoting that an increase in irrigation water leads to more fertile land, improved agriculture production and results in food security in the area. More specifically, the one-unit increase in food security leads to odds of high GMW (versus the combined middle and lower GMW) are 1.03 times higher (all other variables as constant). On the other hand, water conservation and glacier melt water have a negative and insignificant relationship. Communities are careful in saving water when they have low water availability. Hence, when glacier melt water increases, the water conservation of communities is lower (results are insignificant). With the one-unit increase in water conservation, the odds of high GMW versus the combined middle and lower GMW are 0.998 times lower. Likewise, for a one-unit increase in water conservation, the odds of the combined high and medium GMW versus low GMW are 0.998 times lower (all other variables are held constant).

The results also denote that the correlation of GMW and future glacier grafting is positive (significance at 1% *p*-value) (Table 10). Due to the visible benefits of glacier grafting, glacier melt water is deemed essential and most likely to induce high demand for future glacier grafting in the region. Hence, the decision towards the future practice of glacier grafting is dependent on glacier melt water and its benefits at present, as recognized by the local communities. Amongst the relationship of demographics (village/area, gender, age, income, household size) with GMW, only agricultural income is seen as insignificant, whereas other independent variables such as employment status, non-agricultural income and education has a significant relationship with GMW. Similarly, for females, the odds ratio of high GMW (versus combined middle and low GMW) are 0.60 times lower than for males. Yet, it remains 0.60 times lower than males (high and medium) for the same one-unit increase in the odds ratio of females of low GMW. This shows that female participation is relatively lower than their male counterparts. It confirms that GG is a highly male-oriented technique due to lower women involvement in glacier grafting activities. Age and GMW has a positive association with GMW (odds ratio of high GMW = 1.08 times higher and low GMW at 1.08 times lower, taking all other variables as constant). It shows that as the age bracket of the individuals involved in the practice increases, so does the GG or GMW. It confirms that people with a higher age (i.e., >25 years) are participating more in glacier grafting than the teenage group. In the debate, employment status is positively associated with glacier melt water (significance at 10%). The individuals both (self-employed and employed for wage) are participating relatively more actively in glacier grafting than their unemployed community members, even though they have more spare time. With the one-unit increase in employment status, the odds of high GMW versus the combined middle and lower GMW are 2.155 times higher. Furthermore, the household size is negatively related to GMW, showing that the more the household members, the less meltwater is available per person. The odds ratio for household size (with high GMW (as compared to medium and lower GMW) is 0.76 times lower.

Table 10. Glacier melt water unrestricted and restricted ordered logit modeling.

Ordered Logistic Model					
		Unrestricted		Restricted	
DV	IV	Odds Ratio	Coefficient (Z-Value)	Odds Ratio	Coefficient (Z-Value)
Glacier Melt Water	Climate change	1.00	0.003 (0.63)	1.00	0.003 (0.55)
	Water Unavailability	0.996	−0.003 (0.26)	0.998	−0.002 (0.16)
	Glacier Grafting	1.02	0.025 (2.27) **	1.024	0.024 (2.24) **
	Agricultural Land	0.977	−0.023 (2.62) ***	0.976	−0.024 (2.80) ***
	Fertile Land	1.02	0.025 (2.23) **	1.026	0.026 (2.34) **
	Food Insecurity	0.988	−0.012 (1.66) *	0.987	−0.013 (1.82) *
	Food Security	1.03	0.028 (2.57) **	1.028	0.028 (2.77) ***
	Agricultural Production	1.02	0.022 (2.19) **	1.022	0.022 (2.41) **
	Glacier Grafting Income	0.977	−0.022 (2.99) ***	0.978	-0.022 (3.04) ***
	Water Conservation	0.998	−0.002 (0.20)	0.997	−0.003 (0.39)
	Future Glacier Grafting	1.028	0.028 (3.29) ***	1.028	0.028 (3.34) ***
	Village	1.049	0.048 (0.18)		
	Gender	0.595	−0.518 (0.87)		
	Age	1.08	0.078 (0.23)		
	Employment Status	2.155	0.768 (1.75) *	2.098	0.741 (1.71) *
	Household Size	0.758	−0.277 (0.50)		
	Agricultural Income	1.362	0.309 (0.89)	1.321	0.278 (0.82)
	Non-Agricultural Income	0.479	−0.736 (1.82) *	0.489	−0.714 (1.79)*
	Education	0.568	−0.564 (2.20) **	0.531	−0.632 (2.73) ***
cut1	_cons	1.704	1.704 (0.60)	2.98	2.985 (1.74)
cut2	_cons	5.66	5.660 (1.96)	6.928	6.928 (3.78) ***
N			160		160

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Agricultural income (AI) is positively associated, whereas non-agricultural income (NAI) is negatively associated with glacier melt water (AI is insignificant and NAI is significant). It depicts that agricultural income increases with an increase in glacier melt water, as more agricultural yield is extracted from the fertile land due to more water availability.

NAI has a negative association with GMW; as NAI increases more people are focused on non-agricultural activities. It leads to a decline in participation in GG that further results in lower GMW. Furthermore, education is negatively associated with glacier melt water (5% *p*-value). It depicts that (relatively) the more educated people are—the less GG practice. It is mainly true for the higher educated class that they usually find less time to participate in GG actively. The odds ratio for them (at low GMW versus combined categories of high and medium) is 0.57 times lower (other variables as held constant). This shows that primarily, the uneducated/illiterate individuals (self-employed and employed for some wage) are struggling to increase the GMW for both irrigation and household consumption purposes.

4.4. GMW and Food Security

The final study's results found that the relationship between the dependent variable (i.e., food security) with independent variables for two models (i.e., restricted and unrestricted) as the -2 log-likelihood of unrestricted model at −128.2144 and the restricted model at −130.18 (at iteration 4). The significance level remains at p = 1% for all the 160 observation in both the models. The chi^2 value of the restricted model is lower at 36.55 than the unrestricted model at 40.48. The Pseudo R^2 is 0.1363 and 0.1231 for the unrestricted and restricted models, respectively. The best fit model is a restricted model, and the -2 log-likelihood is smaller amongst both the models (Table 11).

Table 11. Restricted and unrestricted model for food security with ordered logit modeling.

Ordered Logit Model: Food Security		
	Unrestricted Ologit	**Restricted Ologit**
-2 Log likelihood	−128.2144 (Iteration 4)	−130.18002 (Iteration 4)
No of obs	160	160
LR chi2	40.48	36.55
P value	0.0011	0.0001
Pseudo R^2	0.1363	0.1231
Better Fit model		✓

Table 12 shows that glacier melt water is positively associated with food security (significance at 5%). This indicates that as GMW increases, food security increases. It concludes that due to glacier melt water, agricultural yield and food consumption increases, resulting in food security in the region. With a one unit increase in GMW, the odds of high food security versus the combined middle and low food security are 2.00 times higher (given all other variables are constant in the model). Likewise, for a one unit increase in GMW, the odds of combined high and medium food security versus low food security are 2.00 times higher (given other variables are held constant). These results reinforce the global finding that capturing and storing water boosts food production [71].

Agricultural land has a positive association with food security. It shows that as agricultural land increases, food security also increases. It is also found that the agricultural land (with or without irrigation water from glacier grafting) contributes towards food security in the region. Here, the significant results denote that glacier grafting increases agricultural land. Fertile land has a positive relationship with food security, but with insignificant results—showing that fertile land (from glacier grafting) is not necessarily resulting in high food security. Glacier grafting is contributing to food security, but not to the expected level that will be beneficial for all the communities. It also means that not all respondents are achieving food security through agricultural production. The reason is that even though they have fertile land, they do not have the money or resources to increase their production.

Agricultural production is negatively related to food security (i.e., insignificant results), showing that high agricultural production is resulting in low food security. It depicts that people have low food consumption, even if agricultural production has increased. The probable reasons are that they are not utilizing the extra food for themselves, and instead they are selling their yields to earn money. Another reason could also be that few HHs are not food insecure, so they are not focused on agricultural production, rather non-agricultural products. This shows that with a one unit increase in agriculture, the odds of high food security versus the combined middle and low food security are 0.72 times lower (given all other variables are constant in the model). Likewise, for a one unit increase in agricultural production, the odds of combined high and medium food security versus low food security are 0.72 times lower (given other variables are held constant). It also hints that agricultural production is not (always) resulting in the food security of people. The significant results of agricultural land show that even without GG, agricultural land is the reason for food security.

Table 12. Food security.

Ordered Logit Model: Food Security					
		Unrestricted		Restricted	
DV	**IV**	**Odds Ratio**	**Coefficient (Z-Value)**	**Odds Ratio**	**Coefficient (Z-Value)**
Food Security	Climate Change	1.22	0.196 (0.51)	1.26	0.234 (0.64)
	Glacier Melt Water	1.68	0.520 (1.67) **	2.00	0.692 (2.35) **
	Water Unavailability	1.38	0.324 (1.05)	1.41	0.344 (1.14)
	Agricultural Land	1.64	0.497 (1.52) *	1.69	0.523 (1.65) *
	Fertile Land	1.25	0.227 (0.71)	1.18	0.169 (0.54)
	Agricultural Production	0.71	−0.338 (1.24)	0.72	−0.331 (1.23)
	Glacier Grafting Income	3.85	1.347 (3.13) ***	4.03	1.394 (3.36) ***
	Water Conservation	0.46	−0.768 (2.84) **	0.48	−0.742 (2.98) **
	Future Glacier Grafting	0.15	−1.881 (2.49) ***	0.13	−2.006 (2.69) ***
	Village	0.61	−0.487 (1.97) **	0.59	−0.527 (2.20) **
	Gender	0.78	−0.246 (0.45)		
	Age	1.01	0.010 (0.03)		
	Employment Status	1.15	0.141 (0.35)		
	Education	0.82	−0.193 (0.83)		
	Household size	0.56	−0.578 (1.10)		
	Agricultural Income	0.53	−0.630 (1.91) *	0.51	−0.682 (2.14) **
	Non-Agricultural Income	0.81	−0.208 (0.56)		
cut1	_cons		−6.64 (2.45) ***		−4.01 (2.25) ***
cut2	_cons		−3.22 (−1.20)		−0.64 (−0.36)
N			160		160

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Glacier grafting generates income that has a positive relationship with food security (highly significance at *p*-value of 1%). It is evaluated that due to an increase in income (after glacier grafting) has resulted in food security. It confirms that access to more money, due to glacier grafting, gives the communities access to food and affordability of the necessary food products for consumption per day. Hence, it secures food utilization for families in Gilgit-Baltistan. With a one unit increase in glacier grafting generated income, the odds of high food security versus the combined middle and low food security are 4.03 times higher (given all other variables are constant in the model). Likewise, for a one unit increase in glacier grafting generated income, the odds of combined high and medium food security versus low food security are 4.03 times higher (given other variables are held constant). Hence, income generated through glacier grafting plays an essential role in ensuring food security amongst the communities. Water conservation and food security have a negative and significant relationship (5% *p*-value in the model). This shows that as people start conserving more water (depicting that there is low water availability due to low glacier melt) so water consumption becomes low, which leads to low food security. With a one unit increase in water conservation, the odds of high food security versus the combined middle and low food security are 0.48 times lower (given all other variables are constant in the model). Likewise, for a one unit increase in water conservation, the odds of combined high and medium food security versus low food security are 0.48 times lower (given other variables are held constant). Hence, as water conservation increases, food security becomes low. The global trends also suggest that the ancient glacier grafting technique remains crucial for water supply in the dry zones, besides fighting climate change [16].

Future glacier grafting has a negative relationship with food security (significant results at 1% *p*-value). An increase in glacier grafting practices in the future is expected to decrease food security, as it is strenuous work and more people will be involved in the formation of artificial glaciers, which will lead to food insecurity. With a one unit increase in future glacier grafting, the odds of high food security versus the combined middle and low food security are 0.13 times lower (given all other variables are constant in the model). Likewise, for a one unit increase in future glacier grafting, the odds of combined high and medium food security versus low food security are 0.13 times lower (given other variables are held constant). The results depict that future glacier grafting might not specifically result in food security as more glacier melt water leads to more water availability for non-/agriculture use. As land is limited in the region, food production and consumption might not increase. The chances are great for the commercial use of glacier melt water. These findings reinforce the extension of the GG technique in areas where the non-availability of irrigation water is leading to low agriculture production, low consumption and less utilization [9].

For demographics (i.e., village, gender, employment status, income and education), villages and food security have a negative and significant relationship (10% significance in the unrestricted model and 5% significance in the restricted model). It shows that Pari and Gori have lower food security, as compared to Balghar village. For Balghar village, the odds ratio of high food security versus combined middle and low food security are 0.59 times lower than other two villages (given the other variables are constant). Similarly, a one unit increase in the odds ratio of Balghari village of food security versus combined categories of high and medium food security is 0.59 times lower than Gole and Pari villages (given other variables are held constant). Employment status is positively associated with food security and education is negatively associated with food security (both having insignificant results). It shows that as employment status increases, income stability is expected to increase, which contributes towards food security, whereas illiterate individuals, who are most likely to work in agricultural production, will have more food security as compared to those not working in the agriculture sector. The study's results further explain the negative association between agricultural income and food security, as a one unit increase in agricultural income leads to an odds ratio of high food security, compared to middle and low food security being 0.51 times lower and a one unit increase in agricultural income leads to the odds ratio of high and medium combined food security versus low food security being 0.51 times lower (given all other variables are constant). This shows that agricultural income does not necessarily lead to food security, but the generated income from agriculture is used for other necessities instead of food consumption. Non-agricultural income has a negative relationship with food security, depicting that non-agricultural income is also not contributing towards higher food security as money is spent on non-food commodities (Table 12).

5. Conclusions

The study concludes the perception of the local community of Gilgit-Baltistan regarding: the impacts of climate change on water non-availability for agricultural production; the importance of glacier grafting for sustained water provision for agricultural production and food security; and the contribution of glacier melt water in improving socio-economics dynamics. The studied population perceives that climate change reduces (natural) glacier melt water, which is being tackled with (artificial) glacier grafting. Thus, water provision through glacier grafting is found to enhance the fertile land in the region. Water availability for irrigation, through glacier melt tater, is observed as a leading source to increase the agricultural production round the year, thus ensuring food security in the area. Furthermore, the locality hints that although increased food production is helping to meet the local food consumption needs, it is not benefitting the whole community due to the lack of money and lack of tools to increase agricultural production per hectare. Nevertheless, increased food production addresses the earlier food insecurity issues and is currently less dependent on imported food items.

Interestingly, glacier grafting is found to be negatively associated with the HH income of those who are only associated with glacier grating practices, e.g., uplifting water to mountain tops/caves, making gullies and water channels, etc.). Thus, glacier grafting has a positive relationship with income and educational attainment. Their lower income is due to lack of time to engage in other income-generating activities. The participation of the female community members also remains low, mainly due to the hardness of the action. The employment status and income from non-agricultural sources are found to be enhanced due to glacier water. Additionally, water conservation and glacier grafting are perceived to be positively correlated, i.e., greater the conservation, the more glaciers. The results depict that future GG might not specifically result in food security as more glacier melt water also leads to non-agricultural use, as land is limited in such mountainous regions. There are great chances of the use of glacier melt water for commercial purposes. Lastly, water conservation and glacier melt water are perceived to have a negative relationship. The studied population is found to be careful in saving water at times of low water availability, but when glacier melt water increases, the water conservation of communities becomes lower. The environmental sustainability of the glacier grafting technique needs to be analyzed to further extend this technique to other areas in the region and beyond.

Author Contributions: Conceptualization, R.M.; methodology, R.M. and U.K.; software, R.M. and I.H.A.; validation, I.H.A.; formal analysis, R.M. and U.K.; investigation, R.M. and U.K.; resources, U.K.; data curation, T.B.; data curation supervision, U.K.; writing—original draft preparation, R.M. and U.K.; writing—review and editing, U.K.; visualization, I.H.A.; supervision, U.K. and I.H.A.; project administration, R.M. and U.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki. Ethical review and approval were waived for this study, due to the reason that no sensitive/personal information (e.g., names, contact details, codes etc.) were asked/gathered during data collection or at any stage of this research.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: All the data used are incorporated in this manuscript.

Acknowledgments: The authors owe thanks to Tehzeeb Bano and anonymous enumerators for collecting primary data in harsh weather conditions and simultaneous data entry. Thanks also to Alyssa Ren for effectively handing the manuscript and the anonymous reviewers for their valuable comments that have greatly uplifted the manuscript's quality.

Conflicts of Interest: The authors declare no conflict of interest.

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