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Indigenous people's perception of indigenous agricultural knowledge for climate change adaptation in Khumbu, Nepal

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Introduction: There is a dearth of empirical work on indigenous people's perception of the effectiveness of indigenous agricultural knowledge and practices for climate change adaptation, especially in the mountain region. Existing scholarships in Nepal are concentrated on people's perception of climate change and verifying the effects of socio-economic variables on adopting adaptation strategies. There is a lack of application of a socio-psychological model to scrutinize subjective and cognitive factors influencing adaptation.

Methods: This study aims to utilize the Protection Motivation Theory (PMT) to provide insights into the risk perception of climate change and the perception of adaptation efficacy of indigenous agricultural knowledge and practices. A randomly sampled questionnaire survey and focus group discussions were conducted in five villages in the Khumbu region of Nepal.

Results and discussion: The results indicated that indigenous peoples had observed changes in seasonality, a decrease in snowfall frequency, and an increase in rainfall, posing a significant threat to their lives and livelihood. The perception of adaptation efficacy assessment disclosed that indigenous knowledge is effective in adapting to changing climatic conditions. It was found that the knowledge has been evolving and remains dynamic and relevant even in the backdrop of climate change. However, there is a lack of formal recognition of indigenous knowledge by the government authorities. Hence, the study's findings accredit the significance of indigenous knowledge. From the viewpoint of the generational succession of knowledge and devising cost-effective climate change adaptation strategy, it indicates a dire need for its incorporation into local climate policies and action plans.

KEYWORDS

indigenous knowledge, agriculture, climate change, cognitive factors, adaptation efficacy, mountain region

1. Introduction

The impacts of climate change (CC) are ubiquitous, and Nepal is no exception. The average temperature increase in the country is reported to be 0.06°C annually. Still, the warming rate is more significant and pronounced in the higher altitude regions of Nepal, with the figure said to be 0.08°C (Shrestha et al., 1999). The Global Climatic models project a potential increase of 0.5–2.0°C by 2030, further rising to 3.0–6.3°C by 2090 (NCVST, 2009). Climate change threatens to cause irreversible damage to Nepal, which relies heavily on natural resources for the economy and livelihoods. Among the many affected sectors, agriculture is the most hard-hit sector. Almost 65% of the population practice agriculture as their primary occupation, contributing to about 36% of the country's gross domestic product (GDP) (MoALD, 2018). Over half of the working population (above 15 years of age) is involved in subsistence agriculture (ADB, 2019). Likewise, most communities in remote mountain areas practice subsistence farming and pastoralism to sustain themselves in harsh climatic conditions.

Khumbu region, a remote mountain area, located in the eastern Himalayas of Nepal, is facing warm winters, extended periods of droughts, and erratic rainfall patterns affecting the region's fragile agricultural sector (Tse-ring et al., 2010). The inhabitants are at the forefront of experiencing climate change symptoms since they reside in ecologically fragile and marginal areas, having nature-based livelihoods and underprivileged socio-economic conditions. Climate change will reportedly alter crop productivity caused by a reduction in crop yields, changes in soil moisture, and increase of crop damage (Sharma, 2011). Their vulnerability is further exacerbated by their reliance on the monsoon cycle for subsistence farming and the constant threat of retreating glaciers. In addition to the low productivity and crop failure, there is an increasing incidence of pests and diseases and irrigation issues, causing scarcity of agricultural-based food items at the household level and leading to food insecurity (McDowell et al., 2013).

In recent years, there has been a growing realization that solving the climate crisis requires more than scientific knowledge (Finucane, 2009). There is burgeoning recognition of the knowledge possessed by indigenous peoples (IPs), termed as indigenous knowledge. Indigenous knowledge is defined as "knowledge and know-how linked to a specific place, culture or society developed in several generations; these knowledge systems are dynamic in nature and exist among people who live as a part of the natural ecosystem" (Nakashima et al., 2012). The knowledge was earlier regarded as obsolete because compared to the western knowledge, it does not have scientific backing which raises concern regarding its credibility. Moreover, the knowledge is orally passed down to the succeeding generation without any proper documentation and is highly context-specific to a particular community (Dube and Munsaka, 2018). There is a misconception that indigenous knowledge is a static knowledge without any feedback system to adjust according to the external factors (Muir et al., 2010). However, in recent years, it has gained traction for climate change adaptation and building climate resilience. The adaptive capacity of an individual is governed by factors including flexibility, the ability to learn, manage uncertainty, and culturally appropriate adaptation options. According to Granderson (2017), indigenous knowledge influences factors determining adaptive capacity in crucial ways that entail identifying climatic changes and impacts, guiding resource use and management, shaping governance structures and social relations, and cultural attitudes, identity, values, and worldviews. Hence, indigenous knowledge is essential for building adaptive capacity (Berkes, 2008; Boillat and Berkes, 2013).

Indigenous knowledge is pivotal in agroforestry, natural resource management, food security, and biodiversity conservation. In the context of climate change, it holds great significance for developing and planning local adaptation strategies (Nyong et al., 2007). It plays a prominent role in facilitating adaptation to climate variability for marginalized and vulnerable indigenous communities. The indigenous knowledge of remote mountain people is unique to their cultural environment. It cannot be generalized for indigenous communities inhabiting other areas since it accumulates generations of struggle to survive the rugged nature of mountains with limited resources and arable land. People inhabiting remote mountain terrain have cultivated indigenous species of crops. However, it is pointless to preserve the genetic variety without preserving the farming system and the knowledge associated with its cultivation and use. The consequences of overlooking and undermining farmers' indigenous knowledge can generate over-dependence on outside expertise (Warren, 1990). It takes away the building blocks of the adaptive capacity of individuals and leaves them susceptible when they cannot receive external support. Since Nepal has insufficient skilled human resources, technology, and financial resources, it cannot efficiently assist its vulnerable population. Nevertheless, if the national and sub-national governments can leverage on the indigenous knowledge by utilizing the local skills and resources, they can tailor low-cost and effective adaptation strategies that will be a boon for the resource-constraint country.

A farmer's knowledge and perception of climate change are crucial for making adaptive decisions (Maddison, 2007; Mertz et al., 2009). It is understood that indigenous peoples' knowledge and perception help devise locally relevant and sustainable climate change adaptation strategies. However, its integration into scientific inquiry and formal adaptation strategies are still limited. The Himalayan region lacks long-term climate measurements, and the paucity of data constrains the scientific capacity to measure the magnitude of climate change and its potential impacts on local people (Ingty, 2017). Even though obtaining farmers' perception of long-term continuous changes is challenging, it is vital for devising adaptation plans, especially in remote mountain areas. There is a plethora of literature on farmers' perception of climate change (Bhusal, 2009; Manandhar et al., 2011; Baul and Mc Donald, 2014) and determinants of adaptation strategies in Nepal (Devkota et al., 2013; Piya et al., 2013; Paudel et al., 2020). However, there is a dearth of empirical work available on indigenous peoples' perception of the effectiveness of indigenous agricultural practices in mountain areas to adapt to constantly varying climates. Esham and Garforth (2013) assert that perception of the effectiveness of adaptation measures is a significant factor in governing the level of adaptation. People's perception eventually governs their adaptation behavior/intention against climate change (Evans et al., 2016). In turn, it is shaped by their cognitive structures, including climate change beliefs, perceived risk, coping abilities, and socio-economic characteristics like age, education, farming experience, and farm area (Wolf et al., 2013). However, most studies have focused on the significance of socio-economic and institutional factors rather than cognitive factors. The cognitive factors, including risk perception and perceived adaptive capacity, have influenced farmers' adaptive capacity and decisions (Grothmann and Patt, 2005; Grothmann and Reusswig, 2006). Demographic and socio-economic factors further influence these cognitive factors, but only limited studies have examined them (Choi and Yamaji, 2017). Thus, it is essential to understand the factors motivating them to perform adaptation measures.

Existing scholarships on the determinants of climate change adaptation in Nepal are limited to verifying the effects of socio-economic variables on adaptation strategies. There is a lack of application of a socio-psychological model to scrutinize subjective factors determining adaptation. Among the few studies available for other countries, Taremwa et al. (2016) and Anyan (2018) have employed socio-psychological models like the theory of planned behavior (TPB). TPB regards intention as a predictor of behavior, and the intention, in turn, is predicated upon attitudes toward behavior, subjective norms, and perceived behavior control. This study will use Protection Motivation Theory (PMT) (Rogers, 1975). Compared to conceptual models like TPB, PMT is better equipped to understand the predictors of behavior in decision-making under risk and uncertainty since it emphasizes the role of risk perception (Le Dang et al., 2014). However, this model has not been widely used in understanding indigenous agricultural practices' perception of climate change.

PMT is a socio-psychological theory initially developed by Rogers (1975) to assess the protective behavior of people against health threats or risks and their motivation to respond to the threats. In the field of climate change, the PMT model has been widely used to examine the adaptive behavior of farmers (Gebrehiwot and Van der Veen, 2015; Truelove et al., 2015). The theory posits that fear encourages people to respond to perceived threats such as climate change by adopting risk-preventive measures (Cismaru et al., 2011). It is governed by two critical cognition or perception processes: threat appraisal and coping appraisal, as shown in Figure 1. The underlying objective is to apply the PMT model to determine whether indigenous peoples regard themselves as susceptible to climate-related hazards (perception of vulnerability) and the degree of harm they anticipate suffering from the hazard (perception of severity) under the threat appraisal. While under the coping appraisal, the study strives to understand indigenous people's perception of the adaptation efficacy of indigenous agricultural practices. It provides insights into how effective they consider the indigenous agricultural knowledge and practices to adapt to the changes brought by climate change (perception of response efficacy), how capable they consider themselves in performing the indigenous agricultural practices (perception of self-efficacy), and how costly they find its application in terms of time, money and labor (perception of response cost), along with identifying socio-demographic factors correlated with their perception.

2. Methodology

2.1. Study area

Khumbu region is a rural mountain area located in the northeastern part of Nepal (∼28 6'N, 86 42'E), ∼140 km away from the capital city, Kathmandu. It is one of the most fragile ecosystems in the Eastern Himalayas, with an altitude ranging from 3,300 to 8,848 m above mean sea level. It has a rugged topography and extremely mountainous terrain occupying about 1,100 km^2. The region is located in a very remote area, accessible only by foot, and requires several days of hiking from the nearest motorable road or airport. Khumbu is known for Mt. Everest, the tallest mountain in the world, and its pristine environment, which is slowly deteriorating due to climate change and the rapid growth of tourism.

Majority of Khumbu residents (90%) belong to Sherpa ethnicity. Sherpas also regarded as people of the east, migrated to Khumbu, northern region of the Himalayas of Nepal, from the eastern Tibetan province in 1533 (Ortner, 1989). They moved to inhabit the rugged Great Himalayan highland valleys with the land elevations typically above 3,000 m. They share cultural commonalities and similar social structure of exogamous patrilineal clan with the Tibetans (Stevens, 1993). In the last five centuries, they have developed a culture unique to themselves in the region. They perform specialized agro-pastoralism which relies on high-altitude varieties of crops and livestock which is made possible by trade with locals from lower regions, or trips to capital city, Kathmandu.

Seasonal transhumance is carried out in the village whereby the cattle are moved around the rangeland at different altitudes based on the climatic cycles. They are taken to highland for pasture in summer and are brought down to lower elevation during autumn (Inamura, 2002). Upper elevation pastoral settlement are built which is only occupied during summer due to harsh winter season. Such subsidiary settlements are referred to as "settlements" in this study. The main settlements are categorized as "villages" which are located at lower elevation and are inhabited year-round. Approximately 3,500 people reside in the Khumbu region, with 63 settlements ranging from 2,805 to 5,179 m, but only seven are considered major year-round villages, namely, Namche, Thame, Thamo, Khumjung, Khunde, Phortse and Pangboche (Sherpa and Bajracharya, 2009).

There are three primary livelihood sources in Khumbu: subsistence agriculture, pastoralism, and tourism. The agropastoral system is adapted to the mountainous Khumbu region's intrinsic and fragile environmental characteristics. It is characterized as multi-elevational, whereby the cropping and grazing patterns are determined by seasons (Stevens, 1993). Subsistence agriculture is widely practiced by the residents who cultivate a limited number of crops, mainly potatoes, wheat, barley, and buckwheat, that can withstand Khumbu's harsh climate and environment (Byers and Thakali, 2014). They constitute staple crops of the region. There are mainly two types of people engaged in agriculture in Khumbu: those who solely rely upon agriculture for household sustenance and livelihood source and those who have diversified livelihood sources but still produce a significant share of the food they consume. The pastoralists practice transhumance pastoralism with yak (male), *nak* (female yak), and yak/cow hybrids (Sherpa and Kayastha, 2009). However, there has been a significant decline in herding numbers due to diminishing availability and accessibility to quality pastures and changing social values (Bhusal et al., 2018).

2.2. Data collection

Five villages (Dingboche, Khunde, Khumjung, Pheriche, and Thame) in ward number 4 of Khumbu Pasang Lhamu Rural Municipality of Solukhumbu District, Province no.1 were selected to conduct a questionnaire survey between May-June 2021 (shown in Figure 2). The questionnaire survey was administered and pre-tested with ten respondents to modify any difficulties encountered while filling in the form. It was found that some respondents were unfamiliar with the term "climate change", others were uncomfortable giving out information regarding their income, and few struggled to answer open-ended questions about the impacts of climate change on agriculture. Necessary revisions were made based on the feedback. The term climate change was avoided, and instead

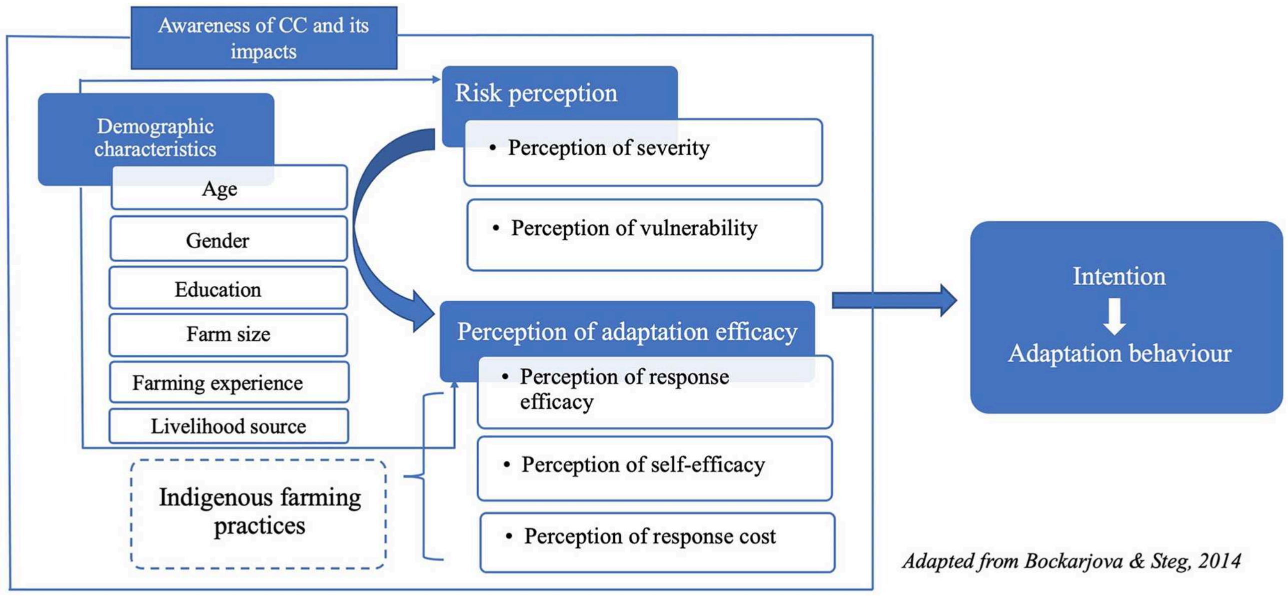

FIGURE 1
Analytical framework for the study (Adapted from Bockarjova and Steg, 2014).

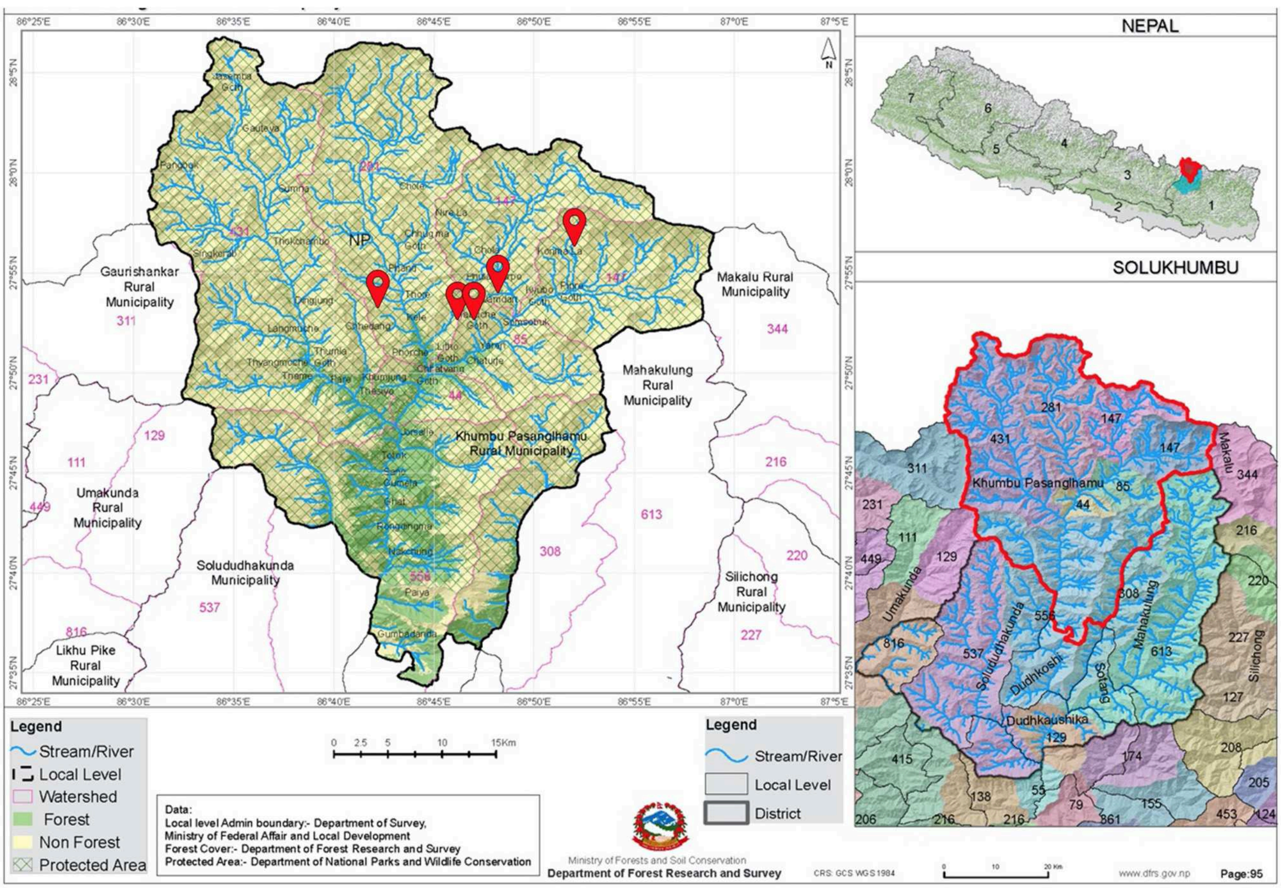

FIGURE 2
Map of Khumbu Pasang Lhamu Rural Municipality showing study sites with red markers [Department of Forest Research and Survey (DFRS), 2018].

of changing climatic conditions was used, rather than directly asking about their income, farm size was taken as a proxy.

Furthermore, a list of impacts was provided in the question about the effects of climate change on agriculture, with the option to add if they have any other input for ease of filling in. The reliability of the questionnaire was tested to ensure the stability and consistency of developed items for the perception of adaptation efficacy. The mean Cronbach value was calculated to be 0.61, which is within the acceptable index according to Griethuijsen et al. (2014). The items for the perception of severity and vulnerability are taken from Poudyal et al. (2020), so the Cronbach value was not calculated, assuming that the value is within the acceptable range.

Due to constraints in human resources and fear instilled by the rampant spread of SARS-CoV-2, a novel corona virus strain, only 112 households took part in the survey. COVID-19 caused high mortality worldwide and became a public health concern since its outbreak in 2019 (Islam et al., 2022). The author could not personally conduct the survey due to imposition of travel restrictions. A local correspondent was recruited to support the data collection. The local focal point selected the respondents through random sampling based on whether they were engaged in farming, owned farmland, or had any farming experience. The questionnaire had mainly close-ended questions with four sections. The first three sections were developed, taking reference from Poudyal et al. (2020) for structuring questions on socio-demographic characteristics, perception of climate change and its impact on agriculture, and risk perception. Risk perception was further divided into the perception of severity (weather events becoming more extreme, less reliable, and increase in climate-related hazards) and perception of vulnerability (impacts on farmland, productivity, physical health, physical assets, and livelihood).

The fourth section of the questionnaire was on the perception of adaptation efficacy of indigenous knowledge and practices. A list of fifteen indigenous agricultural knowledge and practices was compiled from Stevens (1993) and Lama and Devkota (2009). After consultation with the locals, the indigenous agricultural knowledge and practices were further skimmed to fit into relevant categories of moisture management, pest management, crop diversification, soil fertility, environmental indicators for planting, and crop storage and preservation. The final list includes nine indigenous agricultural knowledge and practices (Table 1). A 5-point Likert Scale was used to capture their perception of risk and adaptation efficacy. The respondents were asked to score the indigenous agricultural knowledge and practice on a scale of 1–5. For the perception of response efficacy, 1=very ineffective, 2=ineffective, 3=neutral, 4=effective, 5=very effective; for the perception of self-efficacy, 1=strongly unable to perform, 2=unable to perform, 3=neutral, 4=able to perform, 5=strongly able to perform; for the perception of adaptation costs, 1=high costly, 2=costly, 3=neutral, 4=not so costly, 5=not costly at all. The means of responses to the statements were categorized by adopting Bagheri et al. (2008) and Bagheri (2010) perception analysis (Table 2). The questionnaire was developed in English but later translated into Nepali for the ease of the respondents.

To validate the quantitative data and get deeper insights into their perception and reliance upon indigenous knowledge, two focus group discussions (FGDs) were held with four and five people, respectively. The FGDs had a mixture of participants from different age groups and gender. The majority of the participants were seasoned farmers, but few were involved in other livelihood activities in addition to farming.

2.3. Analysis

To analyze the quantitative data (available in supporting file), Microsoft Excel was used to obtain descriptive data, including mean and percentages on demographic and socio-economic characteristics, risk perception, and perception of adaptation efficacy. JMP software 15.1 was used to conduct the inferential analysis to extrapolate the correlation between an individual's perception of indigenous knowledge's adaptation efficacy and socio-demographic characteristics. Spearman's Rank Correlation Test was conducted to identify the correlation since the numeric data were non-parametric, while the Chi-square test was used for nominal data. The qualitative data were transcribed verbatim and analyzed through content analysis to identify new themes, patterns, and trends.

3. Results

3.1. Demographic and socio-economic characteristics

The respondents ranged from 19 to 90 years old, averaging 41.49 years. The gender ratio is almost equal, with 52% female

TABLE 1 List of indigenous agricultural knowledge and practices exercised in Khumbu, Nepal.

	Indigenous agricultural knowledge and practices
Moisture management	1. Covering crops with bamboo nets or dry leaves to retain soil moisture
	2. Plant as soon as possible after the soil has been initially broken in the spring in order to provide the potatoes with optimal moisture conditions for sprouting
Pest management	3. Use of indigenous plant material such as mug wort *(Titepati)* to combat pests
	4. Bans on bringing freshly cut timber, fuelwood, and bamboo in the settlement for fear of introducing invasive species or contagion by keeping humans and livestock from accelerating its spread
Crop Diversification	5. Cropping a variety of seeds either stored from the last harvest or procured through friends
Soil fertility	6. Rhododendron and birch leaves are the best resources for plant manure (for people without livestock) or use of female yak *(Nak)* manure as a fertilizer (for people with livestock)
Environmental indicators for planting	7. Use of planting calendars
	8. Environmental indicators like blooming of iris *(Themi mendok)*, bird migration or sun and shadow markers for planting crops
Crop storage and preservation	9. Store potatoes on the lower floor of the house either in open, wooden bins or inside large, cylindrical containers (*Miktung*) made from bamboo

and 48% male. 82% received either elementary, middle, or high school education, and 17.69% reported having no formal education. When asked about their farming experience, over half of the respondents were found to have 1–10 years of farming experience, the remaining 20% with 11–20 years of experience, and 26% with above 20 years. 35% have "Agriculture" as their primary source of livelihood; however, the remaining 65% stated that together with agriculture, they have diverse income sources, including yak farming, service-related businesses, and occupations like running hotels and lodges, trekking, porter, etc. The average farm size of the place is 3.37 ropanies (equivalent to 1,714.44 m^2), which indicates that the majority are smallholder farmers. Though 35.39% of respondents replied that they have agriculture as the primary livelihood source, it was found that it cannot be regarded as their only livelihood source because when they were asked if agriculture is their only livelihood source, 81% of the total respondents responded "No" and only 19% responded "Yes". The majority practice subsistence farming, but it does not suffice throughout the year, so they engage in profitable businesses like running hotels, lodges, and trekking. Since the region is a renowned tourist destination site, most respondents were directly or indirectly involved in the tourism sector.

3.2. Perception of changes in climate parameters

Regarding the changes in the precipitation pattern, 65% of participants responded that the snowfall frequency is decreasing, but 67% stated that its intensity has increased in the last 10 years. Similar to snowfall, the respondents also observed a similar trend for rainfall; 76% said rainfall frequency decreased in the last 10 years, and over half of them agreed that the rainfall intensity is increasing. However, people seemed to be divided in their opinions about the temperature: 44% reported that the average temperature is increasing, whereas 43% said the average temperature is decreasing.

3.3. Perception of climate change impacts on agriculture

Over 70% stated there had been a decline in crop yield and increased crop failure, crop damage, and weed. 68% of the respondents answered that they had decreased planting to curb the impacts, while half of them stated that they had applied more fertilizer and insecticides to increase crop yield and combat pests. However, most did not change the crop variety, switch crops, or shift planting time.

3.4. Risk perception of climate change

Over 91% of respondents agreed or strongly agreed that weather events have become more extreme in the past 10 years for the four statements characterizing perception of severity. 86% agreed or strongly agreed that there is a threat of glacial lake outbursts, and 71% agreed or strongly agreed that there has been an increase in the frequency of floods and landslides. Whereas for the four statements characterizing perception of vulnerability, 91% agreed or strongly agreed that climate change will impact their farmland and productivity, and 78% agreed or strongly agreed that it will negatively influence their physical health. 68% agreed or strongly agreed that it would affect their physical assets, and 85% agreed or strongly agreed that it would hamper their livelihood.

3.5. Perception of adaptation efficacy of indigenous agricultural knowledge and practices

For the perception of response efficacy and response cost, "Rhododendron and birch leaves are the best resources for plant manure (for people without livestock) or use of *Nak* manure as a fertilizer (for people with livestock)" had the highest mean of 4.50 and 3.74, respectively (Table 3). While for the perception of self-efficacy, "Storing potatoes on the house's lower floor either in open, wooden bins or inside large, cylindrical containers locally called *Miktung* made from bamboo" had the highest mean of 4.42 among the indigenous agricultural practices (Table 3). On the contrary, the practice of "Planting as soon as possible after the soil has been initially broken in the spring to provide the potatoes with optimal moisture conditions for sprouting" had the lowest mean for all components of perception of adaptation efficacy, 2.77 for response efficacy, 2.82 for self-efficacy and 2.05 for response cost. The average mean responses for all the agricultural practices were 3.76, 3.72, and 2.76, respectively. This indicates that respondents generally consider the indigenous agricultural

TABLE 2 Categorization of the mean of responses for the perception of adaptation efficacy.

Range of mean	Reference (Bagheri et al., 2008; Bagheri, 2010)	Perception of response efficacy	Perception of self-efficacy	Perception of response cost
1.00–1.49	Strongly Disagree	Very ineffective	Strongly unable to perform	Highly costly
1.50–2.49	Disagree	Ineffective	Unable to perform	Costly
2.50–3.49	Neutral	Neutral	Neutral	Neutral
3.50–4.49	Agree	Effective	Able to perform	Not so costly
4.50–5.00	Strongly Agree	Very effective	Strongly able to perform	Not costly at all

TABLE 3 Mean and standard deviation (S.D.) for the responses on the perception of adaptation efficacy.

S.N.	Indigenous practices	Response efficacy		Self-efficacy		Response cost	
		Mean	S.D.	Mean	S.D.	Mean	S.D
1.	Covering crops with bamboo nets or dry leaves to retain soil moisture	3.37	0.87	3.17	1.09	2.81	0.99
2.	Use of indigenous plant material such as mugwort (*Titepati*) to combat pests	3.59	0.78	3.24	1.10	2.21	1.00
3.	Bans on bringing freshly cut timber, fuelwood, bamboo in the settlement for fear of introducing invasive species or contagion by keeping humans and livestock from accelerating its spread	3.77	0.98	3.82	1.09	3.16	1.12
4.	Cropping variety of seeds either stored from the last harvest or procured through friends	4.04	1.01	3.96	1.12	3.18	0.84
5.	Rhododendron and birch leaves are the best resources for plant manure (for people without livestock) or the use of *Nak* manure as a fertilizer (for people with livestock)	4.50	0.75	4.35	0.85	3.74	1.13
6.	Use of planting calendars	3.70	0.79	3.83	0.77	2.48	0.95
7.	Environmental indicators like blooming of iris (*Themi mendok*), bird migration or sun and shadow markers for planting crops	3.81	0.79	3.85	0.82	2.12	1.17
8.	Plant as soon as possible after the soil has been initially broken in the spring to provide the potatoes with optimal moisture conditions for sprouting	2.77	1.41	2.82	1.44	2.05	1.17
9.	Store potatoes on the lower floor of the house either in open, wooden bins or inside large, cylindrical containers (*Miktung*) made from bamboo	4.27	0.89	4.42	0.86	3.06	0.99
	Average of the mean	3.76	0.92	3.72	1.02	2.76	1.04

practices effective and capable of carrying out the practices while having neutral responses concerning the cost of applying indigenous agricultural practices.

3.6. Relationship between the perception of adaptation efficacy and socio-demographic factors

Age, farming experience, farm size and livelihood source were the sociodemographic factors found to have correlation with the perception of adaptation efficacy among the six factors that were analyzed. Among the three components of perception of adaptation efficacy, the Spearman Rank's correlation test results showed that age had a small but significant positive correlation with the perception of response efficacy, having a correlation coefficient (ρ) of 0.187 and a corresponding p-value < 0.05 (Table 4). For the perception of self-efficacy, farming experience had a small but significant positive correlation with Spearman Rank's coefficient (ρ) of 0.231 (p-value $<$ 0.05) (Table 4). While the perception of response cost (time, money, and labor) had a significant negative correlation with education, farm size, and livelihood source, with Spearman Rank's coefficient (ρ) of -0.217 (p-value < 0.05), -0.255 (p-value < 0.01) and -0.238 (p-value < 0.05) respectively (Table 4).

4. Discussion

4.1. Perception of climate parameters

The precipitation trend noted by the respondents concurs with Byers and Thakali (2014), Nyaupane et al. (2014), and Poudyal et al. (2020), who reported changing precipitation patterns and unseasonal heavy rainfall in Khumbu. The rainfall and snowfall amounts are estimated to have declined in general (McDowell et al., 2013). Compared to the past, when the precipitation pattern was more consistent and predictable, it arrived in the form of heavy storms and blizzards that negatively affected human life, property, and the environment. Analogous observations were made by Salerno et al. (2015), i.e., a substantial reduction in rainfall during the monsoon season and decreased snowfall frequency by 11% between 1994 and 2013. The observations emanating from the questionnaire data correspond to inputs provided by participants from the FGD. All of the participants agreed that changes in climatic parameters are occurring. They mainly highlighted the seasonality changes, decrease in snowfall frequency and increase in rainfall as noticeable changes. They were asked whether the cause of climate change was natural or anthropogenic, and most of them shared the view that ongoing climate change is mainly a byproduct of human activities.

There was a disparity in the observation of snowfall intensity between this study and past studies. There have been many unusual heavy snowfalls in 2020 (Prasain, 2020) and 2021, which could

TABLE 4 Correlation between the perception of adaptation efficacy and socio-demographic characteristics.

S.No.	Variables	Response efficacy		Self-efficacy		Response cost	
		Spearman rank's correlation coefficient (ρ)	*P*-value	Spearman rank's correlation coefficient (ρ)	*P*-value	Spearman rank's correlation coefficient (ρ)	*P*-value
1.	Age	0.187	0.0479*	0.129	0.1739	0.022	0.8175
2.	Education	−0.178	0.0600	−0.162	0.0870	−0.217	0.0211*
3.	Farm size	0.005	0.9599	−0.063	0.5058	−0.255	0.0065**
4.	Farming experience	0.159	0.0924	0.231	0.0140*	0.052	0.5815
5.	Livelihood source	−0.180	0.0562	−0.1727	0.0674	−0.238	0.0112*
6.	Gender	0.038	0.9810	0.131	0.9365	0.005	0.9976

Where $^{*}P \leq 0.05$ and $^{**}P \leq 0.01$, $\alpha = 0.05$.

have caused contradicting perceptions among the respondents. Some participants during the FGD affirmed that seasons have become unpredictable, winters are getting colder, and glaciers are melting due to increasing temperature. It is contradicting with the findings of Salerno et al. (2015) who reported winters getting warmer with significant temperature increase during the non-monsoon period. The differing opinion regarding the temperature change could likely be due to temperature anomalies and inconsistent weather patterns as the Himalayan region is acutely sensitive to even a slight change in temperature (Shrestha et al., 2015). There are a number of weather stations operating in the Khumbu region but due to the limited meteorological and hydrological network coverage we cannot draw definitive localized effects of climate change in the study area (Matthews et al., 2020). This paucity of data still remains a challenge yet to be resolved in the region. Nevertheless, the climate change perception emerging from the questionnaire results is consistent with a more general and broader-scale assessment in the Hindu Kush Himalayan region (Wester et al., 2019).

4.2. Perception of climate change impacts on agriculture

The observations concur with the report by Byers and Thakali (2014). The authors conducted community consultations to collect baseline information to formulate Local Adaptation Plans for Action (LAPA) for Khumbu. The study reported that lack of rainfall in recent times had caused crop failure in some years, whereas climate-related hazards like strong storm events or blizzards have caused crop damage. Moreover, due to untimely seasons, there has been inconsistent planting, which could adversely affect crop yield. During the FGD, participants also confirmed the questionnaire results by mentioning that the most prominent influence of climate change has been the decline in crop yield. The respondents answered that they had decreased planting and increased the application of fertilizer and insecticides in response to curbing the impacts. However, most did not change the crop variety, switch crops, or shift planting time since there is little flexibility due to limited favorable climatic and soil conditions for farming in the mountainous region (Stevens, 1993). They reaffirmed that indigenous agricultural practices are still dominantly practiced in the region. In regards to modern techniques, they spelled out that they have started utilizing modern tools for planting and harvesting that help save them time, energy, and labor.

Nevertheless, they said they had not adopted other modern agricultural practices like synthetic fertilizers or insecticides. They also expressed unwillingness to adopt modern agricultural practices since they wanted to avoid risk and suffer from any loss since its application does not guarantee a positive outcome. They seemed to have a positive outlook on indigenous agricultural practices and projected no interest in shifting to modern techniques. It establishes that the indigenous knowledge is faring well against the varying climatic conditions but the concern is lack of its recognition and uptake in the climate change adaptation strategies.

There is a lack of comprehensive documentation of the indigenous agricultural knowledge and practices raising concerns regarding the knowledge dying out if prompt actions are not taken. When asked if the local government provided any assistance to preserve the indigenous agricultural knowledge or employ an integrated form of practice combining modern and indigenous agricultural practices, they stated that the local government had not made significant interventions. The participants noted that the local government had distributed modern tools, but training, further information, and assistance were not provided. One participant mentioned that the reason could probably be because of the relatively small scale of farming that did not bring their problem to the attention of the concerned authorities. Despite the farming scale, climate change could lead to considerable impacts. Their vulnerability should not be overlooked, and appropriate measures should be taken immediately. The nearest agricultural extension service is in Phaplu, Solukhumbu district, which takes over 4 days from Khumbu. Nepal adopted federal system of governance in 2015 with the first and second phases of local elections held in 2017 and 2022 respectively. With the recent state restructuring, the study area is now under the Khumbu Pasang Lhamu Rural Municipality. It has become mandatory for each municipality to establish an agricultural extension service center. However, the municipal office was still being built in Khumbu at the time of data collection. Due to lack of local planning and budget processes and work division, the status quo was the same even post the transition (Joshi and Djalante, 2021). Nevertheless, once the new institutional system is settled in the region, we can expect the local authorities to take necessary actions to deliver on the national and local climate agenda relating to climate change adaptation.

4.3. Risk perception of climate change

The observation of respondents about the weather events becoming more extreme and weather patterns becoming less reliable is confirmed by Perry et al. (2020). Likewise, their observations on the increase in the frequency of floods and landslides and the constant threat of glacier lake outbursts (GLOFs) are in accordance with Tse-ring et al. (2010) and Devkota et al. (2013). Between 1980 and 2015, floods, landslides, and epidemics were the significant causes of disaster-related human loss in Nepal. Furthermore, risk assessment studies conducted in the Himalayan region identified several factors contributing to GLOF, including ice avalanches and melting glaciers. Sherpa (2014) cited that locals might have been informed or made aware of the potential threat of GLOFs from institutions, entailing local authorities, NGOs, INGOs, or mass media, thereby contributing to their perception that climate change is a severe threat.

Regarding the statements concerning the perception of vulnerability, they reported that climate change had impacted their farmland, physical health, physical assets, and livelihoods. Their perception is justified since various climate-related hazards like flooding, landslides, glacier lake outbursts, and temperature and precipitation anomalies have led to damage and harm. For example, in 1985, an outburst of Lake Dig Tsho due to the retreat of the Langmoche glacier incurred a massive loss of infrastructure, land, and life in the Langmoche valley above the village of Thame, Khumbu. It destroyed a hydropower station, a dozen bridges, more than 20 houses, several hectares of agricultural land, and at least five casualties (Vuichard and Zimmermann, 1987). According to Kattelmann (2003), a rough estimate of the frequency of GLOFs demonstrated that it is a relatively common event because, since the 1960s, there has been an average of one GLOF event every 3–4 years in the region. Khumbu region is now under the threat of the potential outburst of Imja Lake, one of the fastest-growing lakes in the Himalayas (Bajracharya et al., 2007). Due to these ongoing and constant threats, fear might have been instilled about the negative consequences of climate change, consequently influencing their perception regarding their vulnerability toward it.

From the statements' signaling perception of severity and vulnerability, the conclusion can be drawn that indigenous peoples perceive climate change as occurring and as a severe threat, posing a substantial threat to their lives and livelihood. Keshavarz and Karami (2016) stated that if the threshold for threat appraisal is satisfied, i.e., the perceived risk is higher than the acceptable limit, individuals tend to adopt measures to alleviate the threat. Hence, it can be understood that indigenous peoples have fear and are willing to adapt to climate change by adopting counteractive measures to reduce its impacts.

4.4. Perception of adaptation efficacy of indigenous agricultural knowledge and practices

The questionnaire spelled out the perception of adaptation efficacy of indigenous agricultural knowledge and practices, characterized by the perception of response efficacy, self-efficacy, and adaptation costs. "Rhododendron and birch leaves are the best resources for plant manure (for people without livestock) or use of *Nak* manure as a fertilizer (for people with livestock)" had relatively high mean value for all components of adaptation efficacy. One plausible reason could be that respondents perceiving this practice consider it effective for maintaining agricultural output. Though they reported a decline in agricultural yield, they expressed that manure still yields satisfactory results, explaining their positive outlook on its use. The people with livestock use the enriching forest-floor products with dung and urine, a common composting practice among Khumbu farmers. Those who do not have livestock utilize birch, rhododendron leaves, and conifer needles to make the compost. The first two are considered preferred resources since they rot more quickly. In addition, the items are easily accessible and lower in cost than procuring synthetic fertilizers, making them feel competent to apply these agricultural practices. The satisfactory yield produced by using plant and animal manure might offset the time and energy invested in making it, instilling that its use does not incur much cost.

Likewise, "Storing potatoes on the lower floor of the house either in open, wooden bins…" also had a high mean value. This could be attributed to the reliability of the outdoor underground storage pits that keeps the potatoes in good condition for an extended period unless there is any event of a flood or landslide. The storage pits are roughly 1–1.25 m deep and lined with straw or juniper boughs. Another layer of straw is used to cover the potatoes from the top, and a firmly packed-down layer of mud is used to make them waterproof (Stevens, 1993). In the absence of moisture, the potatoes can be preserved for 10–11 months. Although the locals do not solely rely upon it as the primary food source, this contributes to ensuring food security. Since it is common for households to have outdoor underground storage pits to store the potatoes year-round, they might be more familiar with its set-up, which might have fostered the notion of being able to carry out this practice.

On the contrary, the practice of "Planting as soon as possible after the soil has been initially broken in the spring…" had the lowest mean (Table 3). Usually, in late February or early March, women start re-digging the fields using *tokzi* (Nepali-style hoes) to prepare and fertilize the field for planting season. The digging is done twice: the first is to loosen the hardened topsoil to facilitate moist soil to surface on the ground, and the second time, is to add fertilizer and plant the crop in parallel (Stevens, 1993). Seasonal uncertainties caused by climate change could be primarily responsible for the respondents perceiving it to be relatively less effective than other practices. This was confirmed by responses emanating from the FGD in which participants mentioned that fluctuation in seasonal timing and erratic rainfall patterns hindered optimal moisture conditions for the soils, which could have led to a low evaluation of its reliance and effectiveness. The untimely season might have made them unable to perform this activity at the appropriate time. Thus, it fostered the notion among the respondents that they are unable to carry out the practice. It provides an entry point for integrating indigenous knowledge with modern tools that concerned authorities can leverage to make the indigenous practices less labor-intensive and time-consuming.

The average of the mean responses for all the agricultural practices was above 3.5, except for the perception of response cost, indicating respondents generally consider the indigenous agricultural practices effective. Taking the reference of the index developed by

Bagheri et al. (2008) shown in Table 2, most indigenous peoples agree that indigenous knowledge is effective in adapting to climate change. This finding is supported by Ahmed and Atiqul Haq (2017) and Van Huynh et al. (2020), as both reported that the indigenous communities in Bangladesh and Viet Nam, respectively, have adhered to their indigenous agricultural knowledge and practices, which have undergone alterations to adapt to the fluctuating climatic conditions. These studies showcased the effectiveness and dynamic nature of the generational old knowledge that contributes to survive through unprecedented changes bestowed by climate change. It indicates that the changes inflicted by varying climatic conditions have not greatly impacted their ability to continue their practice. Taremwa et al. (2016) argued that due to the familiarity and simplicity of the indigenous knowledge system, easier replication, and affordability, the indigenous peoples are carrying out the knowledge to foster climate change resilience in Rwanda.

4.5. Relationship between the perception of adaptation efficacy and socio-demographic factors

A significant positive correlation between the perception of response efficacy and age was also observed by Okunlola and Adekunle (2000), Owolabi and Okunlola (2015), and Anyan (2018). The studies found that age significantly influences the use of indigenous agricultural knowledge. This result confirms that the older an individual is, the more positive perception they have regarding the use of indigenous agricultural knowledge. Almas and Conway (2017) asserted that inhabitants of a local area who have been living in a specified location for extended periods would possess greater knowledge and understanding of their environment. In general, older generations are holders of the indigenous and traditional knowledge accumulated through years of trial and error in farming compared to their younger counterparts. Van Huynh et al. (2020) made similar assertions that long-term inhabitance can familiarize an individual with different parameters of the local environment. It consequently instigates them to apply the indigenous knowledge tailored to the local environment. The positive perception could be administered by the affinity toward their generational old knowledge and practices. It could also be due to the unwillingness of older people to take risks to adopt modern agricultural practices even amidst the negative consequences bestowed by climate change on their agricultural yield. During the FGD, the respondents mentioned that they would not want to risk adopting novel technologies since their existing practices were adequate to cope with climate change.

The perception of self-efficacy had a small but significant positive correlation with farming experience. It implies that the older an individual is, the more capable one considers oneself of applying the practice. The more the farming experience, the more competent one regards oneself in conducting the practice. A study by Hassan et al. (2008) analyzed the determinants of farm-level adaptation and reported similar relation between age and farming experience with their perceived notion but not in particular about indigenous practices. It can be inferred that long-term engagement in farming builds self-confidence to carry out indigenous agricultural practices. Other than climate change exclusive adaptation strategies, studies on farmer's perception of the adoption of soil fertility management practices like Warren et al. (2003), Reimer et al. (2012) and Meijer et al. (2015), have asserted the influence of perception of the introduced or existing technology/practice on making adaptation decisions in response to environmental, social or economic changes. The studies suggest that farmers' experiences and knowledge regarding the practices strongly influence their perception.

Furthermore, regarding the perception of response cost, education, farm size, and livelihood source were found to have a significant negative correlation. Farm size is taken as a proxy of a household's income or wealth, meaning the bigger the farm size, the wealthier the household is, making them equipped to afford chemical fertilizers or buy modern farming tools. It could likely instill the notion among the higher-income households that indigenous agricultural practice is time-consuming and labor-intensive. As opposed to them, the lower-income households have limited financial resources, leaving them with the only option of employing indigenous agricultural practices despite investing more time, money, and labor. Hence, it could be plausible for smaller farm-size farmers to have positive and individuals with bigger sizes to have a relatively less positive perception of the response cost. This finding corroborates with Choi and Yamaji (2017), who assessed factors influencing farmers' perception of adaptation behaviors in Cheongsong, Korea. The study did not specifically look into indigenous farming but more into the adaptation measures but its implications can be relevant for this study. The study results showed that individuals with relatively bigger farm sizes perceived the adaptive measures as more costly. The authors justified the finding by stating that with increasing farm size, the farmers will need to pay more for crop insurance and invest more human resources and time, likely fostering the notion that the adaptation measure is expensive.

The results also exhibited that the higher the education level, the more costly one considers the indigenous knowledge and practices. Generally, within higher-income households, the education level is also relatively high. Henceforth, formal education may have exposed more educated people to modern scientific knowledge and equipment that can efficiently save time and human resources. A study conducted by Spoon (2011) in the same region also stated that the younger generations who are generally more educated are devoid of the traditional ecological knowledge/indigenous knowledge. The author claimed the reason behind is the negligence of the knowledge by the local political actors and incorporation of western perspectives in the school curriculum. Likewise, individuals with diverse income sources were found to consider indigenous knowledge more costly, which could be attributed to their engagement in lucrative businesses in the tourism sector, which yields more monetary benefits for the time and effort devoted compared to having only agriculture as the livelihood source.

Generally, women play an essential role in providing for households as men are away to earn money from non-farm-related income-generating activities (Shisanya, 2017). This explains the recognition of the role of women in fostering the traditional knowledge of indigenous peoples in agriculture compared to their male counterparts. In this study, however, gender was found to have an insignificant association with the perception of adaptation efficacy. This means that despite the relatively high engagement of women compared to men in farming in the study area, their perception regarding adaptation efficacy of indigenous agricultural knowledge and practices may not be significantly associated with their gender. Mase et al. (2017) also found that gender was not significant in the overall model of adaptive behavior. Significant proportion of women in Khumbu are getting involved in tourism-related jobs like running lodges, teashops unlike in the past when they were mainly engaged in domestic tasks and farm work (Sherpa, 2014). Fisher (1991) found that women residing alongside the tourist area in the Khumbu region are less engaged in agropastoral activity and more in service-oriented business catering to tourists. Spoon (2012) supported this finding as his study disclosed that tourism had reconfigured gender roles in Khumbu with women leading a more sedentary lifestyle owing to their involvement in running lodges or teashops. This could perpetuate a different perspective of indigenous knowledge rather than a homogenous one instilled by their extensive engagement in farming. Hence, the perception of adaptation efficacy of indigenous knowledge could not be generalized for gender in the study. The study's findings should not propagate the idea that gender does not hold substantial influence and provide an empirical basis to disregard the significant role of women in agriculture and climate change adaptation since women still have higher engagement compared to men in Khumbu.

5. Conclusion and policy recommendations

In this study, we found that the indigenous peoples in the Khumbu region have observed changes in the climatic parameters, indicating their awareness of climate change. They also recorded its impacts on agriculture, but there seems to be negligence from the concerned authorities due to the small scale of farming in the area. The assessment of the risk perception characterized by the perception of severity and vulnerability revealed that indigenous peoples consider climate change an imminent threat to their lives and livelihood. They consider themselves capable of performing the practices with a neutral view on the response cost. Furthermore, the assessment of the perception of adaptation efficacy disclosed that indigenous agricultural knowledge is effective against changing climatic conditions. The knowledge has been evolving with constant changes in the environmental conditions, hence remains dynamic and relevant even in the backdrop of climate change. The high-risk perception and considerably high perception of adaptation efficacy regarding indigenous agricultural knowledge and practices observed in this study signal the potential intention of adapting to climate change. The findings from this study identified the relevant indigenous practices that can withstand the climate change impacts in the mountainous region. Those practices can further be modified and improved to develop long-term climate change adaptation strategies for the rural mountain communities of the Khumbu region of Nepal. In addition, the correlation of socio-demographics with the perception of adaptation efficacy helped identify target entities within the indigenous community to formulate an overarching and inclusive policy which are spelled out below:

i) The study showed that the younger age group was found to have comparatively lesser positive perceptions regarding the use of indigenous agricultural knowledge than the older age groups. Moreover, the indigenous peoples were found to autonomously implement the indigenous agricultural knowledge without any institutional support, either from the local authorities or non-governmental organizations. The two findings are essential, especially from the viewpoint of generational succession of indigenous knowledge and formulation of an effective local climate action plan. There is an urgency to incorporate indigenous agricultural knowledge and practices into local governmental policies and action plans to address climate change issues. Support should be provided for assigning/establishing an institutional body to document and advocate its use, integrating indigenous knowledge into adaptation plans such as Community-based Climate Change Adaptation Plan of Action (CAPA), undertaking local-level initiatives to promote its use, and scaling up the initiatives for its wider application.

ii) Education level was found to correlate negatively with the perception of adaptation efficacy. The relatively older indigenous peoples with greater farming experience can be consulted to develop school curriculums. It will help inculcate positive notions regarding indigenous knowledge from an early age. The Constitution of Nepal authorizes the local government to design school curriculum integrating the peculiarities of the local community that is responsive to their priorities and issues. However, the implementation part is severely lagging including in Khumbu region. Thereby, the concerned authorities should exercise their power and redesign the curriculum bearing in mind the importance of generational succession of the indigenous knowledge together with imparting knowledge regarding climate change risk and management to build their adaptive capacity. Additionally, since there is an overall positive perception of using indigenous knowledge for climate change adaptation, there is a necessity to strengthen collective action within the community. It will allow the community members to communicate, share knowledge and support each other in applying indigenous knowledge to adapt to gradual and sudden climatic changes.

Hence, this study offers a pragmatic case study for evidence-based policymaking and supports formal recognition to be given to indigenous knowledge and practices by integrating such knowledge into institutionally developed plans and policies. Nevertheless, the study does not intend to establish indigenous knowledge as the panacea to the impacts of burgeoning climate change. It can neither be regarded as superior nor be taken as a replacement for modern scientific knowledge. The negative and obsolete connotations surrounding its use should be negated, and untapped potential should be realized and utilized to the optimal level. Rather than idealizing indigenous knowledge, the purpose of the study is to highlight the potential of the knowledge for climate change adaptation and obtain empirical evidence to advocate for its recognition as a complementary knowledge system to develop cost-effective, participatory, and sustainable climate adaptation strategies.

This study highlighted the comparative advantages and limitations in indigenous agricultural knowledge to cope with climate change. The study was limited to identifying the relationship between socio-demographic factors and indigenous people's perception of indigenous agricultural knowledge and practices in the backdrop of climate change. However, analyzing the influence of factors, including external support and risk experience, could have provided a more in-depth understanding of their perception. Taking this as a baseline information, further studies can scope their research around providing a framework including additional influencing factors. The two knowledge systems are distinct entities, making the integration process difficult and irrelevant for use beyond the context under which it is developed. A framework could be formulated that can be tailored to dovetail location-specific factors, which will facilitate integrating indigenous knowledge with scientific knowledge to devise effective climate change adaptation solutions.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Written informed consent from the participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

TS contributed to the design and implementation of the research, analysis of the results, and manuscript writing.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2022.1067630/full#supplementary-material

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