



Analyzing Climate Change Perception and Adaptation Methods of Indigenous People in the North-Western Himalayas, Kashmir

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Abstract

This study examines how indigenous people in Bandipora, Jammu and Kashmir, India, perceive climate change and their adaptive strategies to cope with environmental changes. It also investigates their beliefs about the implications of climate change. The study employed purposive sampling to select the area and random sampling to choose 400 household respondents from Quailmuqam, Malangam, and Panar areas. Data was collected using semi-structured interviews and focus group discussions. The findings indicate that 82.6% of respondents observed rising temperatures, 91.8% noted a decline in snowfall frequency, 89.3% reported reduced snowfall intensity, 89.5% saw a decrease in rainfall frequency, and 90.8% experienced lower rainfall intensity. Additionally, respondents reported deteriorating forest and pasture lands, shrinking snow cover, and diminished water availability. Most respondents believe extreme weather events are becoming more frequent and will continue to do so, with 80% anticipating increased glacial outbursts, landslides, and floods, potentially harming their livelihoods. To address these challenges, respondents have adopted measures such as social forestry, water conservation, fire control, intercropping, crop rotation, and soil conservation techniques like mulching and terracing. This study provides valuable insights into indigenous perceptions and adaptive practices, aiding policymakers in developing more effective climate resilience strategies for the Himalayan region.

Keywords: Tribals; Himalayas; Indigenous; Climate change; Mitigation strategies; Perception; Bandipora.

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1. Introduction

Climate change is posing the most serious challenges to humankind and its survival in the present era. Rising temperatures, irregular rainfall patterns, extreme weather

conditions, flash floods, droughts, *etc.*, are visible throughout the world, causing significant damage to natural ecosystems, biological diversity, agriculture, livelihoods, food security, and the well-being of humans.^[1-3] This global challenge has caused an increase in average temperature of over 0.85 °C over the century,^[4] irregularity in snowfall and rainfall patterns,^[5] and is expected to rise further by over 1.5 °C by the end of the century.^[6] Temperature in India has increased by about 0.7 °C between 1901 and 2018 and is expected to increase further up to 4.4 °C by the end of 2100 Anno Domini (AD).^[7] Over the last century, temperature has risen by 1.6 °C in the northwestern Himalayas, causing receding of glaciers and an increase in natural disasters that cause massive damage to human properties, assets, and life,^[8] economic and livelihood damage, and an increase in the vulnerability of people.^[9]

World over, millions of people are being affected by the changing climate, particularly indigenous, poor, and marginalized people, who rely on local resources, ecosystems,

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forests, biodiversity, agriculture, and subsistence farming for a living.^[10-12] According to the International Labour Organisation,^[13] there are approximately 370 million indigenous people worldwide who live in and around forest ecosystems. India has about 8.6% (84.33 million) of the tribal population, while the Jammu and Kashmir region has approximately 1,493,299, which makes up about 11.9% of the total population, with Gujjars and Bakarwals being the largest communities.^[14]

Climate change is having a substantial influence on indigenous people in the Himalayan areas, especially Jammu and Kashmir, through glacial lake outbursts, extreme rainfall events, and impact on food and drinking water.^[15,16] Rising temperatures, declining snowfall and rainfall, unpredictable weather, glacier shrinkage, increased floods, decrease in precipitation and winter duration, longer summer periods, and increased temperatures are the major impacts observed in the region.^[17-20] The Northern Himalayan region, including the Kashmir Valley, has seen an increase in annual average temperature of over 1.55 °C, a reduction in glacier mass and volume, and a non-significant decline in precipitation from 1980 to 2020.^[21] posing a serious risk to mountainous and indigenous people due to their heavy reliance on glacier meltwater for drinking and irrigation purposes.^[22]

Indigenous and tribal communities are critical players in achieving successful climate resilience. These people have observed and witnessed local changes in climatic conditions in their surroundings, gaining valuable knowledge about the rhythmic changes in seasons, temperature variations, alterations in climate and weather patterns, increased pests and disease, decreases in rainfall patterns, and so on.^[23,24] These people contain critical knowledge and information of climate risk in their surroundings,^[25,26] as well as a vast repository of

knowledge and experiences with adaptive and coping techniques for changing climatic adversities at the local scale.^[27] Therefore, the perception of these populations is seen as a crucial prerequisite for learning their coping and mitigating techniques and ensuring their participation.^[28-30]

The climate changes have a significant impact in the northwestern part of the Kashmir Himalayas, and the local communities living in these mountainous areas have been hit the hardest because of their association and reliance on natural ecosystems for a living.^[31,32] A few studies have been conducted on the perception of local residents and farmers on climatic characteristics such as rising temperatures, frequent droughts, decreased snowfall, *etc.* However, research on indigenous/tribal people and their perception of changes in climate and adaptation techniques is inadequate, and the region lacks substantial documentation for developing climate policies and mitigating the impacts of climate risk. As a result, conducting a detailed investigation of indigenous and tribal populations' perspectives of climatic variability and adaptation mechanisms in Kashmir is critical. Recognizing the aforementioned urgency, this study attempts to highlight the views of indigenous people towards climate change in the northern area of the Kashmir Himalayas, with an emphasis on:

1. To comprehend the perception of indigenous people towards climate change and its relevance to scientific data reported from the region.
2. To examine whether socio-demographic factors influence people's views towards climate adaptation measures.
3. To investigate the beliefs of indigenous people towards climate variability and its impact on their livelihood sources.
4. To analyze the local adaptation measures taken by indigenous people in response to climate change.

2. Experimental process

2.1 Study area

Jammu and Kashmir is situated in the northwestern Himalayas, having coordinates between 32°17' and 37°5'N latitude and 73°26' and 80°30'E longitude. The region covers an area of 42,241 km² and has a population of 12,267,013 (Census of India, 2011). Kashmir Valley experiences a yearly temperature range of -10 °C to 35 °C and receives approximately 680 mm of precipitation, usually from December to May. Summers are usually dry and warm, and winters are cold and harsh, with frequent snow, rain, and frost. The research area is in the northern district of Bandipora, Kashmir, located between 31.4167 °N and 74.6500 °E, with an altitude range of 1578 to 1581 meters above sea level. The mountainous district has rough topography and covers 345 km², with 295.37 km² of agricultural land and 49.63 km² of urban area. The study region contains the second highest indigenous population in Jammu and Kashmir, with approximately 75374, including

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Gujjars, Paharis, and Shinas (Indian Census, 2011). The three areas, namely Quailmuqam, Malangam, and Panar of District Bandipora, were selected for the study. The people in these areas are mostly small-scale farmers or connected with horticulture and forestry.

2.2 Sampling

The sample population consists of Gujjar and Pahari tribal/indigenous people from the Bandipora District in Jammu and Kashmir, India. The study included ethnic communities from three areas: Quailmuqam, Panar, and Malangam, which are linked to forests and reside in mountain areas. The area has a similar ethnic composition, including considerable Gujjar and Pahari indigenous populations. The statistically significant sample size of around 400 respondents was selected at a confidence level of 95% and a 5% margin of error. The sampling was done between April 2023 and August 2024.

2.3 Data collection

To understand the perception of indigenous/tribal people towards the changing climate and its mitigation measures, a mixed-method research approach was used by combining qualitative and quantitative methods. Both the primary and secondary data were collected from the area. The primary data was obtained using a quantitative technique, with a pre-tested, semi-structured interview schedule of Poudyal *et al.*^[33] and Sahoo *et al.*^[34] questionnaires. Key informants provided additional information through the focus group discussions. The purposive sample method was used to determine the study region, whereas the random sampling method was utilized to choose the respondents. To guarantee enough representation, heads/households from the Gujjar and Pahari communities of the Quailmuqam, Malangam, and Panar areas in District Bandipora were carefully selected. A face-to-face interview was done, and interviewees, preferably over the age of 30, with local expertise, were included in the study. The representative sample was examined with descriptive statistics to determine the mean and variance and stochastic dominance, if any. A total of 400 household heads from all selected locations were interviewed on the changes in climate indicators and adaptation measures.

The selected questionnaire was used to collect the responses with the assistance of a local translator. It was divided into four sections, having statements on the socioeconomic characteristics, views, attitudes, hazards of climate change, and adopted mitigation measures. In the first section, the respondents' observed changes in the region were tested using a set of nine questions on a 3-point Likert scale with scores of 1, 2, and 3 for "improving," "no change," and "worsening." In the second portion, respondents were asked nine statements on a Likert scale with 1, 2, and 3 scores for replies of "Increasing," "No change," and "Decreasing" to determine whether they had experienced or witnessed changes in weather patterns. In order to gain deeper insights into their

perceptions and to validate the data, three focus group discussions (FGDs) involving participants of various age groups and genders were held with four to five people each in three villages that were not sampled for household surveys but were located in the same area. This was updated and verified using published climate data from the past 40 years (1980-2020). The secondary data was obtained from published and unpublished books, journals, international and national organizations, and government agencies.

2.4 Data analysis

The quantitative data gathered from the study area involving the indigenous/tribal population were coded for statistical analysis. The adopted scales' reliability and validity were calculated, and a single-factor analysis of variance (ANOVA) was done, with the means, standard deviation, and correlation estimated by using Microsoft Excel and Statistical Package for Social Science (SPSS 22.0). The paraphrased translations of qualitative data were performed to highlight the important areas.

3. Results and discussion

3.1 Data analysis

The Cronbach's alpha (α) values measured for climate perception and adaptation scales are 0.897 and 0.908, respectively, in Table 1. All the variables have more than a 0.8 Cronbach's α value, which is excellent for the measurements, as a value of 0.70 is considered the minimum acceptable threshold for basic research.^[35]

Table 1: Reliability analysis of research scales.

Constructs	Item loading	Cronbach's alpha
Climate change perception	0.71-0.86	0.897
Adaptation measures	0.70-0.83	0.908

The composite reliability (CR) value for the climate perception and adaptation scale is 0.897 and 0.909, and the average variance extracted (AVE) value is 0.592 and 0.589, respectively, in Table 2. Both variables have greater than 0.7 CR values, indicating that the construct's composite reliability is satisfactory.^[36] Similarly, the AVE, a more conservative metric, was found to be more than 0.5 for all variables, indicating that the convergent validity is adequate and the latent construct accounts for about 50% of the variance in its indicators.^[37]

3.2 Socio-economic and demographic features

Among the study population, 62.50% are males while 37.50% are females, with more than 75% of them over 40 years of age in Table 3 and Fig. 1. The lesser number of females is attributed to their reserved attitude towards being interviewed. Approximately 91.50% of respondents appeared native to the region, while the remaining 8.50% had moved in from other locations and stayed for an average of 27 years in the study

Table 2: Convergent and discriminant validity.

Variable	Composite reliability (CR)	Average variance extracted (AVE)	Correlation
Climate change perception (CCP)	0.897	0.592	0.769
Adaptation measures (AM)	0.909	0.589	0.661

Table 3: Demographic/socioeconomic information.

Particulars	Frequency	Percentage
Place		
native	366	91.5
Non-native	34	8.5
Gender		
Male	250	62.5
Female	150	37.5
Age group		
20-30	29	7.3
30-40	74	18.5
40-50	99	24.8
50-60	118	29.5
60-70	63	15.8
Above 70	17	4.3
Education level		
Primary	97	24.3
Secondary	46	11.5
College	22	5.5
University	2	0.5
Illiterate	233	58.3
Occupation		
Labour	94	23.5
Farming/Husbandry	155	38.8
Business	43	10.8
Govt. Employee	22	5.5
Other	86	21.5
Annual income (in Rs.)		
Up to 15000	269	67.3
Between 15000-30000	72	18.0
30000-45000	46	11.5
45000-60000	11	2.8
Above 60000	2	0.5

area. The majority of respondents (58.30%) claimed to be illiterate, with 24.3% having completed primary education, 11.5% finishing secondary education, 5.5% finishing college, and only 0.5% finishing university. The bulk of respondents work in farming/animal husbandry (38.80%), followed by labour (23.50%), others notably housekeeping (21.50%), business (10.50%), and the smallest group is government personnel (5.5%). The majority of respondents (67.30%) reported earning up to Indian rupee (INR) 15,000/month, 18% earn between INR 15,000 and 30,000, 46% earn between INR

30,000 and 45,000, 11% earn between INR 45,000 and 60,000/month, and only 0.5% make more than INR 60,000/month. The respondents also possess horses/mules, cattle, and other livestock in numbers ranging from two to twelve. There are both nuclear and joint families in the area, with an average size of 3.70 (min. 02 and max. 07), living together and sharing strong cultural links.

3.3 Source of climate-related information

Regarding the source of climate-related knowledge, 44.80% of participants reported learning from personal experience, 18% from media such as radio/TV, and 13.3% from friends and neighbours in Table 4 and Fig. 2. A low percentage of respondents have reported learning from the schools/teachers (13%), non-governmental organisations/project personnel (6.0%) and a very small number from tourists (2.5%) and other sources (2.5%). The findings show that citizens' knowledge of climate change is mostly linked to their own experiences, as has been previously reported in another study.^[38] About 18% of the respondents mentioned having received information through the radio/TV, while 13.3% obtained it from friends/neighbours (13.3%). The climate-related programs run on the local and national radio/TV stations, and strong socialisation of these people is attributed to it. The results obtained while studying the indigenous people of the Rangamati Sadar area of the Rangamati district in Bangladesh have revealed comparable results of knowing about climatic changes through experience and various media sources, such as television, FM radio, local newspapers, peer groups, *etc.*^[39] The climate-related information through teachers/schools, NGOs/project staff, and visitors is low, probably due to low literacy rates, a lack of campaigns at the grassroots level, and fewer tourists who visit the area.

Table 4: Source of climate change-related information.

Source of information	Frequency	Percentage
Friends/Neighbours	53	13.3
NGOs/Project staff	24	6.0
Media (Radio/TV)	72	18.0
Tourists	10	2.5
Experience	179	44.8
Teacher/School	52	13.0
Others	10	2.5

3.4 Climate changes perceived in the region

To learn about perceived climate changes in the region, respondents were asked if circumstances were improving, worsening, or not changing. The majority admitted that they observed phenomenal climatic changes in the locality over the decades in Table 5 and Fig. 3. Approximately 78.0% of respondents agreed that forest acreage was deteriorating, while 72.30% indicated deterioration in forest conditions (tree density), 87.30% reported deterioration in grazing land area, 72.50% pasture lands, and 85.0% in wild animals. Similar

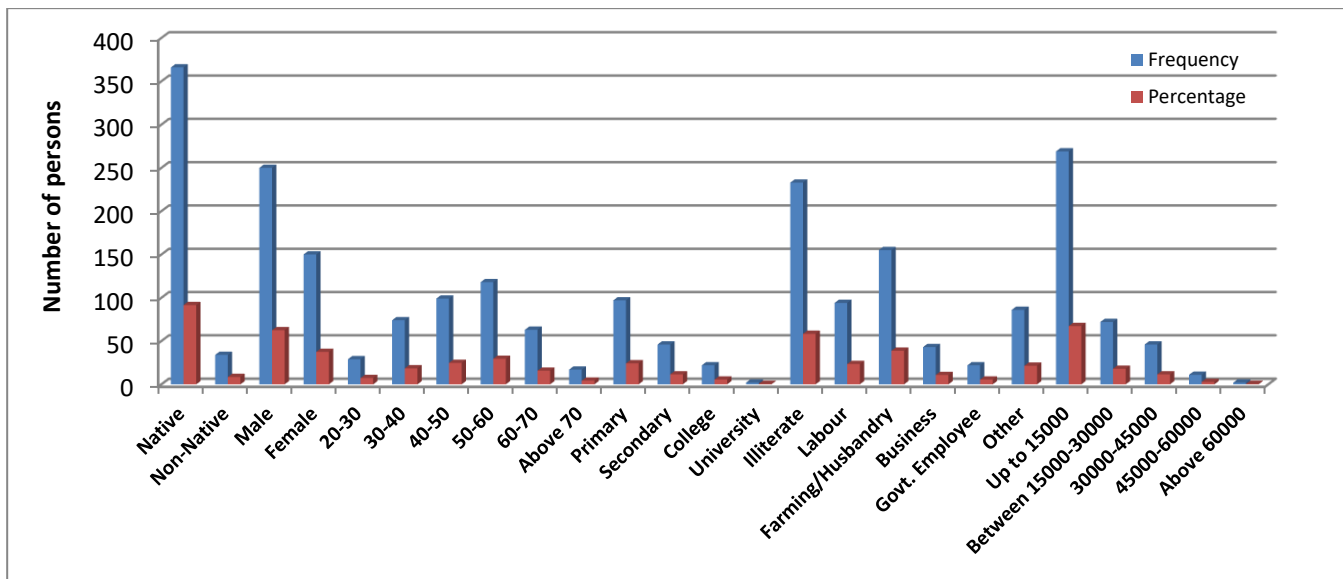


Fig. 1: Socio-demographic attributes of respondents.

Table 5: Perception of respondents towards changes in the area.

Statement	Mean	Standard deviation (S.D)	Improving	No change	Worsening	Don't know
Forest area	2.65	0.72	10.0	10.5	78.0	1.5
Forest conditions (tree density)	2.54	0.80	14.0	11.8	72.3	2.0
Grazing land area	2.79	0.60	4.0	6.8	87.3	2.0
Pasteur conditions (yield)	2.52	0.83	15.3	10.0	72.5	2.3
Wild animals	2.77	0.62	2.5	9.8	85.0	2.8
Trail conditions	2.64	0.70	8.5	14.3	75.8	1.5
Solid waste	2.78	0.62	6.0	4.0	88.3	1.8
Water quantity (availability)	2.77	0.60	3.8	9.3	85.0	2.0
Area under snow cover	2.81	0.53	4.5	7.3	87.5	0.8

observed detrimental effects of climate change on the forest areas, grazing fields, land-use patterns, etc, were reported by the people of various regions in the Indian Himalayas.^[40]

Approximately 85% of respondents reported a drop in water quantity (availability), with 87.50% citing a decline of snow cover area in the study region. The decrease in snow cover and water availability is due to shifting precipitation patterns and rising temperatures, which cause glaciers to

recede and, as a result, the availability of water decreases. The comparable findings from indigenous people living in Everest National Nature Preserve areas, including a decline in the ice-snow landscape and water availability, have been reported.^[41] Besides, some other researchers have also reported changes in rainfall patterns and the faster retreat of glaciers, and a decrease in glaciers and water sources in the Himalayan areas.^[42,43]

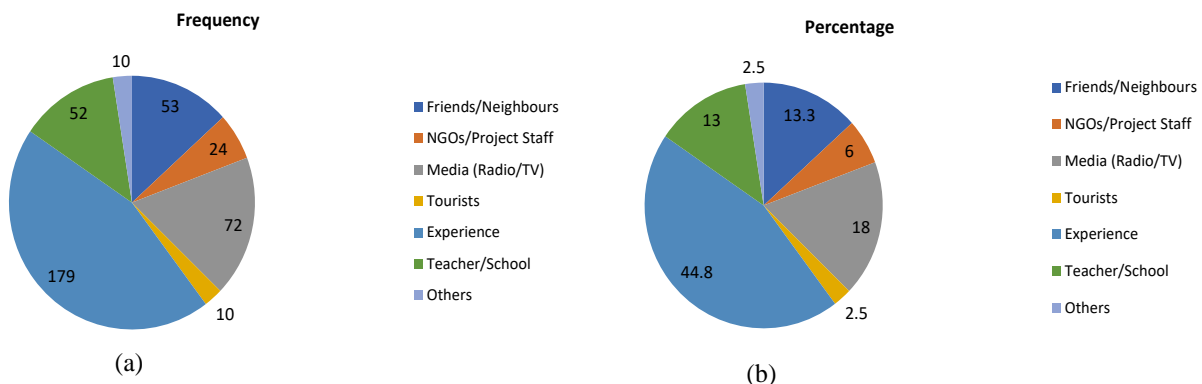


Fig. 2: Frequency (a) and percentage (b) of the source of climate information.

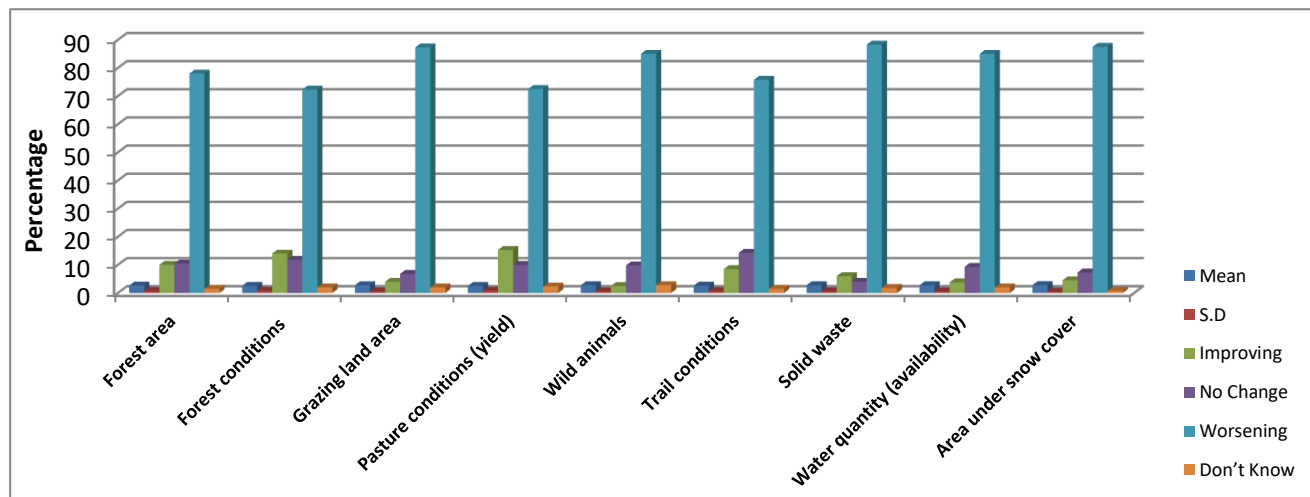


Fig. 3: Respondents' perception towards changes in the area.

Table 6: Respondents' personal experience with changing climatic conditions.

Statement	Mean	S.D	Increasing	No change	Decreasing	Don't know
Snowfall frequency	2.87	0.47	3.3	4.3	91.8	0.8
Snowfall intensity	2.82	0.53	5.0	5.0	89.3	0.8
Rainfall frequency	2.83	0.52	4.0	5.5	89.5	1.0
Rainfall intensity	2.85	0.50	4.0	4.5	90.8	0.8
Temperature	1.20	0.53	82.0	11.5	5.0	1.5
Drought	1.23	0.58	75.0	16.8	5.0	3.3
Dust	1.32	0.60	71.3	21.3	6.3	1.3
Winter length	2.73	0.64	7.5	7.8	83.5	1.3
Windy days	1.25	0.60	78.5	12.5	7.3	1.8

3.5 Perception of respondents towards climatic parameters

Concerning the meteorological parameter changes, the majority (>70%) of respondents indicated significant changes in the region in Table 6 and Fig. 4. Approximately 91.80% of participants reported a decrease in snowfall frequency, and 89.30% a decrease in snowfall intensity in the region. Furthermore, 89.50% of respondents agree on the drop in rainfall frequency and 90.80% on the decrease in rainfall intensity. The findings are not surprising, given that many meteorological studies have already highlighted or warned of similar changes in precipitation variability in the Himalayan regions due to climate change. In the Nepal regions of the Himalayas, the impressions of shifting weather patterns, rising summer heat, decreased winter rainfall/snowfall, and increased droughts have been reported by the local people and herders.^[44,45] The perturbations in the seasonal mobility of Kashmir's Gujjar and Bakarwal groups in recent years as a result of climate change, such as exceptional dry seasons, unseasonal snowfall, and summer rainfall, were also reported.^[46]

The perceptions on climatic changes among the respondents of the study area are inconsistent with the recent

studies done on climate changes in the Hindu Kush Himalayan region,^[47] and the agreement with a decline in precipitation variations has also been reported by people of the Himalayan 'cold desert' Ladakh, India.^[48] With respect to the precipitation trends in the region of Kashmir a non-significant decline rate of -5.1 mm/year from 1980-2020 AD was reported in Lone *et al.*,^[49] a widespread evidence of a drop of -19.44% in average daily rainfall and a decline of -24.10% in the number of rainy days with a sharper decline in winter.^[50] Similarly, a decrease of -1.1 mm/year in winter precipitation from 1980 to 2016 AD and a declining trend in annual precipitation, along with a projected loss of 6.1 mm by 2031 AD, have been reported in Kashmir.^[51,52]

Most of the respondents from the study region agreed that they have observed a rise in temperatures (82.0%), droughts (75.0%), dust (71.30%), windy days (78.5%), and a decrease in winter length (83.5%) throughout time. Similar agreement on rising temperatures and greater frequency of droughts due to shorter winters and longer summers was found among the farmers of Himalayan region,^[53] and among the farmers in Jammu and Kashmir's Anantnag district who agreed more on erratic and unequal rainfall patterns, frequent droughts, rising

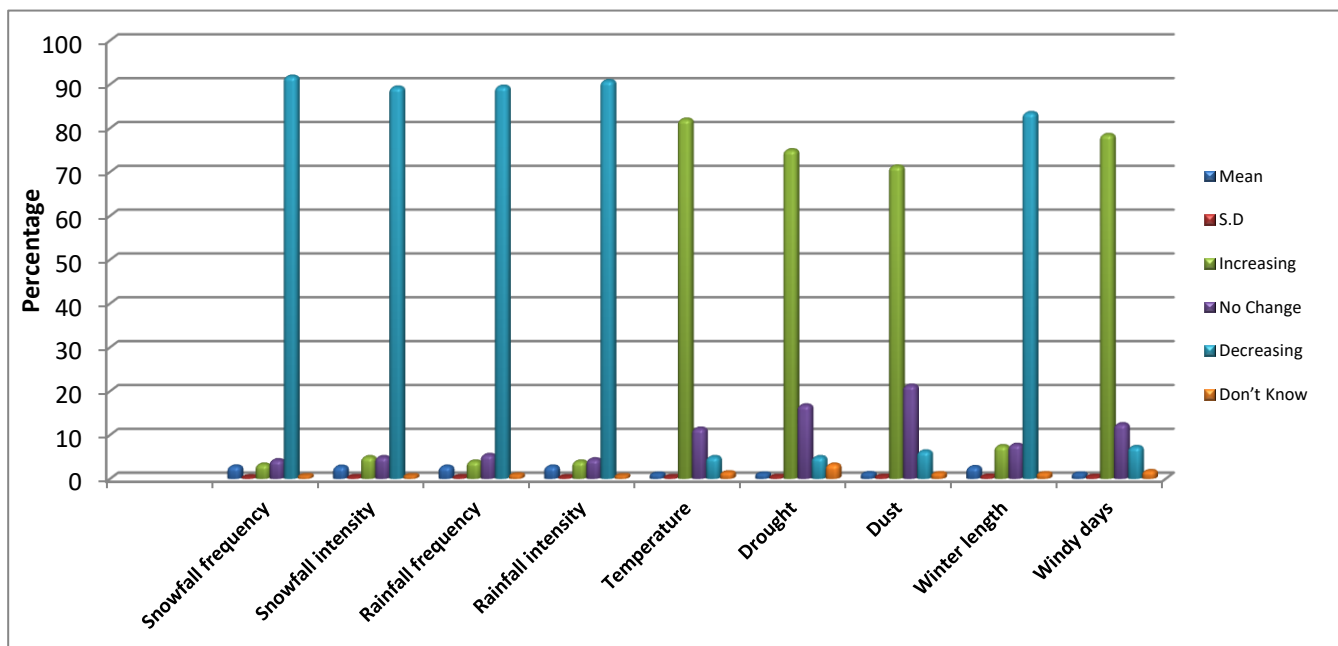


Fig. 4: The experience of respondents of climate change.

temperatures, and dry winters with low precipitation and snowfall.^[54]

The meteorological data of the Kashmir region validates the results from the study population with an observed increase in average annual temperature of over 0.8 °C for a 37-year period.^[55] Similarly, a temperature increase in TMax (0.035 °C) and TMin (0.022 °C) in the Kashmir Himalaya from 1980 to 2017 A and an increase of 1.5 °C in temperature in the northwestern Himalayas,^[56] as compared to a global increase of 0.74 °C during the 100 years further validates the results.^[57] Furthermore, it was predicted that mean maximum and minimum temperatures will climb by over 0.36-1.48 °C and 0.65-1.07 °C, respectively, till 2080 AD.^[58]

3.6 Beliefs about the implications of climate change

Concerning respondents' belief regarding the occurrence and influence of climatic variability on the lives of

communities, the majority (82.5%) claimed to have observed extreme weather events in Table 7 and Fig. 5. Approximately 82.0% of respondents believe that climatic and weather conditions in the region are now unpredictable, and 83.0% think that such conditions will remain less reliable in the future as well. The findings are in agreement with the results of respondents from the Indian Himalayan region.^[59] Approximately 87.3% of respondents agreed on the statement that changes in weather patterns are already affecting their farmlands and pastures, while 86.30% felt that altering weather patterns would also harm their livelihood and business. Furthermore, 91.30% of respondents believed that changes in weather conditions would lead to an increase in landslides and floods, while 80.50% said it would make their living conditions worse. Similar beliefs have been observed among the people living in high-altitude regions of Mount Everest, Nepal.^[60]

Table 7: Respondents' beliefs regarding the impacts of climate change.

Statement	Mean	S.D	Agree	Neutral	Disagree
There have been more extreme weather events recently in the region	1.25	0.58	82.5	10.0	7.5
Weather conditions in the region have been less reliable over the years	1.25	0.57	82.0	10.8	7.3
Weather patterns in the region will be less reliable in the future	1.24	0.57	83.0	9.8	7.3
Talks of changing weather patterns are exaggerated	2.51	0.76	17.0	15.0	6.8
Changing weather patterns are hurting my farmlands and pastures	1.19	0.53	87.3	6.3	6.5
Changing climate will lead to glacial outbursts	1.13	0.46	91.3	4.0	4.8
Changing weather conditions will make my living conditions more worse	1.27	0.60	80.5	11.3	8.3
Changing weather patterns will cause more floods and landslides	1.17	0.47	87.3	8.5	4.3
Changing weather patterns will hurt the livelihood/business	1.19	0.51	86.3	8.3	5.5
Human activities contribute to the increase in global temperature, leading to unreliable weather	1.32	0.62	76.0	15.8	8.3

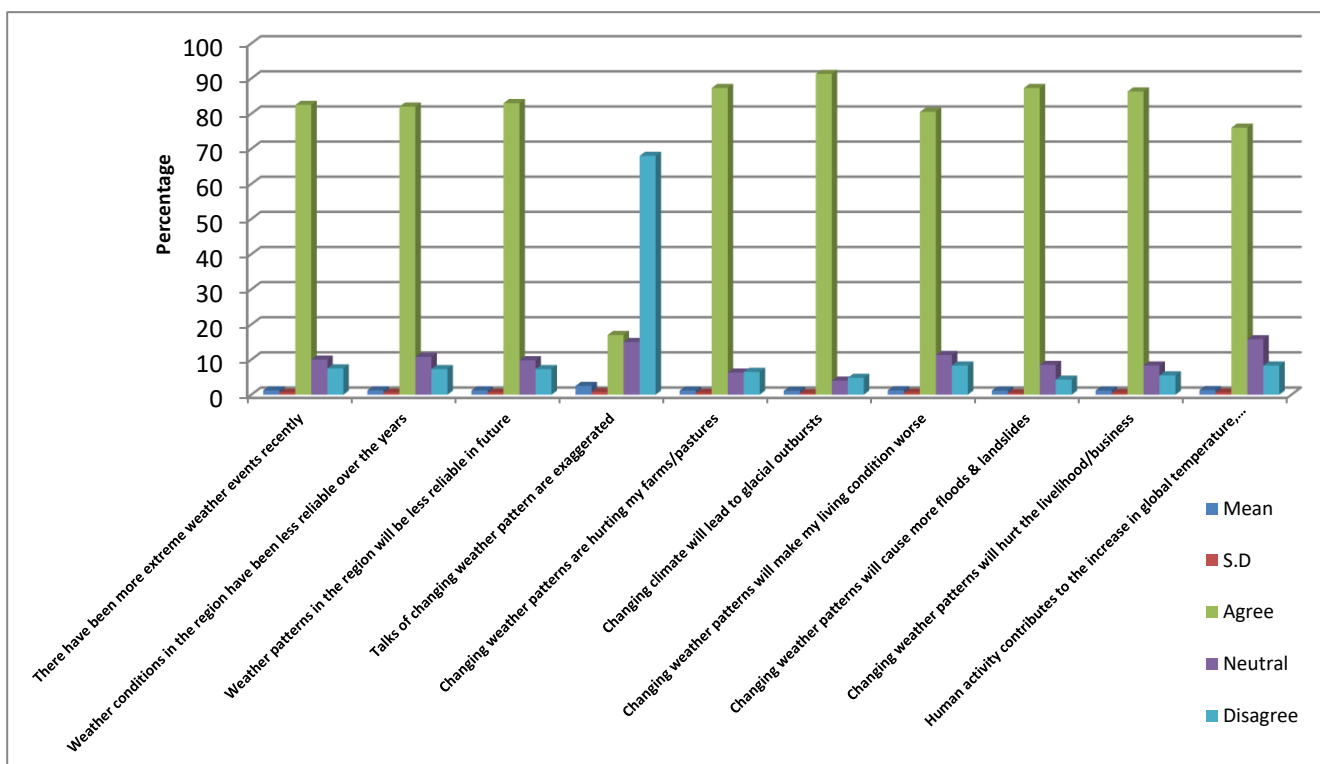


Fig. 5: Respondents' beliefs on the impacts of climate change.

3.7 Adaptation strategies in response to climate change

Concerning the adaptation measures among the study population, high levels of adoption values were observed for the adoption of disease, insect, and pest control through chemicals (1.78), mulching practices (1.74), adoption of forest fire protection activities (1.74), social forestry activities (1.73), adoption of intercropping practices (1.61), use of water conservation techniques (1.50), adoption of crop rotation practices (1.24), and adoption of agro-forestry practices (1.28)

in Table 8 and Fig. 6. Similar types of adaptation strategies such as plantation, terracing, improving irrigation facilities, and water harvesting, etc., were reported among farmers in the Lidder watershed and other regions of the Kashmir Himalayas.^[61,62] The adaptation measures, such as tree plantations, organic farming, mixed farming, and crop rotations, have been adopted by the locals of the cold desert Ladakh, India, and the indigenous people of Lepcha, Kanchandzonga Biosphere Reserve.^[63,64]

Table 8: Adaptation strategies adopted by the indigenous communities.

Statement	Mean	S.D	Don't know	Not adopted	Adopted
Dry seeding prior to the rainy season	1.0	0.28	3.8	91.8	4.5
Adoption of agroforestry practices	1.24	0.50	3.5	68.5	28.0
Adoption of crop rotation practices	1.49	0.54	2.5	46.0	51.5
Changing the timing of farm operations	1.09	0.38	3.0	84.3	12.8
Adoption of inter-cropping practices	1.61	0.52	2.0	35.0	63.0
Mulching practices	1.74	0.47	1.8	22.0	76.3
Rainwater harvesting	1.06	0.36	3.5	86.5	10.0
Zero tillage practices	1.02	0.24	1.8	94.0	4.3
Use of short-duration crop varieties	1.01	0.22	1.8	95.0	3.3
Use of drought-tolerant crop varieties	1.01	0.22	2.0	95.0	3.0
Adoption of soil conservation techniques	1.71	0.49	1.8	25.5	72.8
Use of water conservation techniques	1.50	0.52	1.0	47.8	51.8
Insect control through traditional knowledge	1.10	0.38	2.8	84.3	13.0
Control disease, insects, and pests with chemicals	1.78	0.46	2.3	17.3	80.3
Adoption of social forestry activities	1.73	0.47	1.8	23.0	75.3
Forest fire protection activities	1.74	0.48	2.0	21.8	76.3
Investments for crop insurance	1.0	0.19	1.5	96.25	2.25

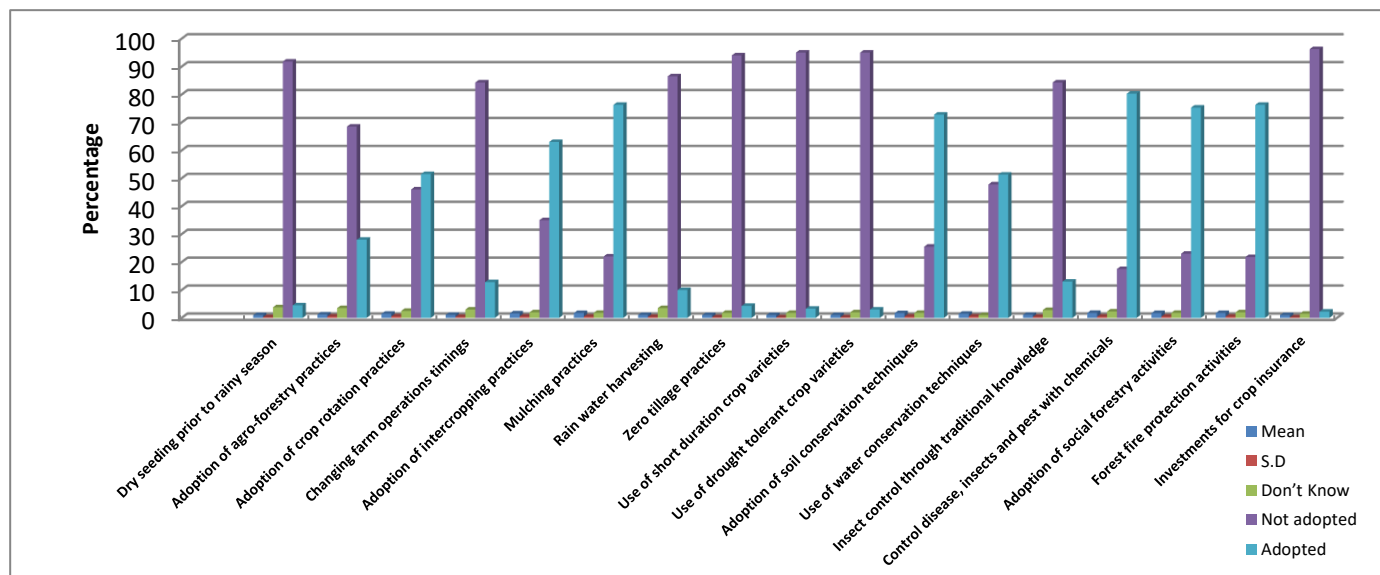


Fig. 6: Adaptation strategies taken by the indigenous communities.

3.8 Indigenous people’s perception of climate change and adaptation measures for their socio-economic attributes

In terms of the relationship between indigenous people's socio-demographic attributes and their perception of climate change, it is observed that there is no significant difference

concerning their gender ($t = 1.776, p = 0.077$), age groups ($F = 0.871, p = 0.500$), education ($F = 1.490, p = 0.204$), occupation ($F = 1.421, p = 0.226$) and income ($F = 1.329, p = 0.258$) as the p-value was not found to be less than 0.05 for any socio-demographic attribute in Table 9.

Table 9: Tribal people’s climate change perception with respect to their socio-demographic attributes.

Gender	Mean	S.D	t-value	p-value
Male	2.04	0.13	1.776	0.077
Female	2.02	0.12		
Age group	Mean	S.D	F-value	p-value
20-30	2.03	0.115	0.871	0.500
30-40	2.05	0.130		
40-50	2.03	0.133		
50-60	2.02	0.131		
60-70	2.03	0.136		
Above 70	1.98	0.138		
Education level	Mean	S.D	F-value	p-value
Primary	2.04	0.15	1.490	0.204
Secondary	2.06	0.11		
College	1.98	0.17		
University	2.08	0.02		
Illiterate	2.03	0.11		
Occupation	Mean	S.D	F-value	p-value
Labour	2.03	0.141	1.421	0.226
Farming/Husbandry	2.03	0.130		
Business	2.03	0.123		
Govt. Employee	1.97	0.155		
Other	2.04	0.119		
Income (in Rs.)	Mean	S.D	F-value	p-value
Up to 15000	2.04	0.131	1.329	0.258
15000-30000	2.03	0.125		
30000-45000	2.00	0.129		
45000-60000	1.99	0.182		
Above 60000	1.96	0.151		

Table 10: Tribal people's adaptation measures with respect to their socio-demographic attributes.

Gender	Mean	S.D	t-value	p-value
Male	1.34	0.12	1.123	0.262
Female	1.35	0.11		
Age group	Mean	S.D	F-value	p-value
20-30	1.32	0.096	0.561	0.730
30-40	1.35	0.125		
40-50	1.34	0.122		
50-60	1.34	0.135		
60-70	1.33	0.085		
Above 70	1.37	0.121		
Education level	Mean	S.D	F-value	p-value
Primary	1.36	0.11	1.061	0.375
Secondary	1.33	0.11		
College	1.34	0.13		
University	1.29	0.08		
Illiterate	1.34	0.12		
Occupation	Mean	S.D	F-value	p-value
Labour	1.33	0.138	0.456	0.768
Farming/Husbandry	1.35	0.117		
Business	1.34	0.116		
Govt. Employee	1.34	0.114		
Other	1.34	0.109		
Income (in Rs.)	Mean	S.D	F-value	p-value
Up to 15000	1.34	0.120	1.017	0.398
15000-30000	1.36	0.123		
30000-45000	1.33	0.104		
45000-60000	1.31	0.151		
Above 60000	1.32	0.124		

The results mentioned in Table 10 revealed that there was no significant difference in climate change adaptation measures among indigenous people based on gender ($t = 1.123$, $p = 0.262$), age groups ($F = 0.561$, $p = 0.730$), education ($F = 1.061$, $p = 0.375$), occupation ($F = 1.34$, $p = 0.109$) and income ($F = 1.017$, $p = 0.398$) as the p-value was not found to be less than 0.05 for any socio-demographic attributes.

No significant difference among respondents' perceptions of climate change and adaptation strategies with respect to their socio-demographic characteristics, like gender, education, income, or occupation, was found in Tables 9 and 10. This is probably due to their low education levels and similar socioeconomic backgrounds. The context and culture have been found to have a similar role in adaptation techniques among indigenous farmers in Tanzania's Udzungwa and Mount Kilimanjaro regions, regardless of gender or socioeconomic status.^[64]

The study shows that tribal people have observed the changes in climatic factors and weather patterns and agreed on their impacts on the surroundings, resources, and livelihood sources. The indigenous people residing in the study area have perceived the variability in climate and have adopted certain measures. Therefore, perception, which is a significant

predictor of behaviour and crucial to adaptation, needs to be taken into account to help in making an effective mitigation plan.^[65,66] Besides, implementing a climate predictive system that makes use of climate and remote sensing data can be more informative about the climate variability in an economical way.^[67] The present research is an attempt to explore and document the residents' perspectives and activities to assist policymakers in developing a better and more effective climate policy and plans by involving the local people of the region.

4. Conclusion

The findings of the study reveal that the majority of people have perceived a change in climate variables over the last few decades. The study discovered evidence that the majority of respondents saw climatic changes from personal experience, contrary to the widely held view that public climate change beliefs are heavily affected by mass media, NGOs, and other sources. Most of the respondents have personally experienced changes in climatic parameters, such as rising temperatures and decreased snowfall/rainfall frequency and intensity. The findings suggest that the majority of respondents saw an increase in droughts and windy days, a drop in winter length

and snow cover, a deterioration of forest area, grazing land, and pasture areas, and a decrease in water quantity (availability). The majority of respondents felt that more extreme weather has occurred in recent times and will continue in the future, providing a threat of increasing floods and landslides that would harm their livelihoods and businesses. Because of their previous experience, respondents have implemented some adaptation strategies such as soil conservation measures like mulching and terracing, intercropping and crop rotation practices, water conservation techniques, social forestry, *etc.* However, the adaptation strategies, such as crop insurance, the use of short-duration crop varieties, drought-tolerant crop varieties, zero-tillage practices, *etc.*, have not been widely adopted, probably due to low literacy rates and a lack of awareness programs at the grassroots level. The study finds no significant difference among the respondents on their socioeconomic attributes, such as gender, age, occupation, education, and income, with respect to climate change perception and adaptation measures. The study gives an interesting observation of a high-elevation geographical region to better understand indigenous people's perceptions and adaptive mechanisms, as well as novelty for future research with large representative samples. The findings would assist policymakers and government institutions in developing better adaptation plans and implementing climate policies at all levels (local, national, and international).

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Conflict of Interest

The authors declare that there are no potential conflicts of interest regarding the research, ownership, and publication of the study.

Supporting Information

Not applicable.

References

- [1] M. A. R. Khan, S. Singh, P. Pandey, A. Bhardwaj, S. N. Ali, V. Chaturvedi, P. K. C. Ray, Modelling permafrost distribution in Western Himalaya using remote sensing and field observations, *Remote Sensing*, 2021, **13**, 4403, doi: 10.3390/rs13214403.
- [2] T. Wheeler, J. Von Braun, Climate change impacts on global food security, *Science*, 2013, **341**, 508-513, doi: 10.1126/science.1239402.
- [3] S. Asseng, F. Ewert, P. Martre, R. P. Rötter, D. B. Lobell, D. Cammarano, B. A. Kimball, M. J. Ottman, G. W. Wall, J. W. White, M. P. Reynolds, Rising temperatures reduce global wheat production, *Nature Climate Change*, 2015, **5**, 143-147. doi: 10.1038/nclimate2470.
- [4] A. Hussain, F. M. Qamar, L. Adhikari, A. I. Hunzai, A. U. Rehman, K. Bano, Climate change, mountain food systems, and emerging opportunities: A study from the Hindu Kush Karakoram Pamir Landscape, Pakistan, *Sustainability*, 2021, **13**, 3057, doi: 10.3390/su13063057.
- [5] B. Marzeion, R. Hock, B. Anderson, A. Bliss, N. Champollion, K. Fujita, Partitioning the uncertainty of ensemble projections of global glacier mass change, *Climate Earth's Future*, 2020, **8**, 1-25, doi: 10.1029/2019EF001470.
- [6] B. Vinodhkumar, S. Ullah, T. L. Kumar, S. G. Al-Ghamdi, Amplification of temperature extremes in Arabian Peninsula under warmer worlds, *Scientific Reports*, 2024, **14**, 16604, doi: 10.1038/s41598-024-67514-8.
- [7] R. Krishnan, J. Sanjay, C. Gnanaseelan, M. Mujumdar, A. Kulkarni, S. Chakraborty, Correction to: Assessment of climate change over the Indian Region, A Report of the Ministry of Earth Sciences, MoES, Government of India, 2020, doi: 10.1007/978-981-15-4327-2.
- [8] R. A. Kumar, S. Zaman, S. Bhattacharyya, K. Banerjee, K. Sengupta, B.S. Bikash, Climate change and sustainable livelihood programmes: A case study from the Indian Sundarbans, *The Journal of Ecology*, 2013, **107**, 335-348, doi: 10.13140/2.1.2868.0328.
- [9] A. Chevuturi, A. P. Dimri, R. J. Thayyen, Climate change over Leh (Ladakh), India, *Theoretical and Applied Climatology*, 2018, **131**, 531-545, doi: 10.1007/s00704-016-1989-1.
- [10] M. A. Bhat, P. G. Wadhvani, Tribal involvement in forest conservation post implementation of forest rights act, 2006 in Jammu and Kashmir, *AIP Conference Proceedings*, 2023, **2800**, 81-84, doi: 10.1063/5.0163486.
- [11] K. Hameed, K. Sirwan, Z. O. Omar, E. F. Mohammed, S. Sourkan, A. M. Salih, K. Q. Yaqub, Addressing the issue of Poverty, Economic Growth, Health Matters, and Environmental Challenges, *International Journal of Scientific Research in Modern Science and Technology*, 2025, **4**, 18-32, doi.org/10.59828/ijrmst.v4i3.303.
- [12] G. Matta, A. Kumar, D. Singh Tomar, R. Kumar, Climate change in the Himalayan region: susceptible impacts on environment and human settlements, *Frontiers in Environmental Science*, 2025, **13**, 1550843, doi: 10.3389/fenvs.2025.1550843.
- [13] D. B. L. Farias, Multiple hierarchies within the 'civilized' world: Country ranking and regional power in the International Labour Organization (1919-1922), *European Journal of International Relations*, 2024, **30**, 333-358, doi: 10.1177/13540661231168773.
- [14] M. Ahmed, M. Mushtaq, Issues and challenges of tribal in the context of health care system in Jammu and Kashmir, *International Journal of Emerging Knowledge Studies*, 2023, **2**, 249-254.
- [15] P. Arora, S. N. Ali, P. Morthekai, Local perceptions and

- trends of climate change in the Sikkim Himalaya, North-East India, *Journal of Climate Change*, 2021, **7**, 1-26, doi: 10.3233/JCC210008.
- [16] H. Nagai, K. Fujita, A. Sakai, T. Nuimura, T. Tadono, Comparison of multiple glacier inventories with a new inventory derived from high resolution ALOS imagery in the Bhutan Himalaya, *Cryosphere*, 2016, **10**, 65-85, doi: 10.5194/tc-10-65-2016.
- [17] U. Khanal, C. Wilson, V. N. Hoang, B. Lee, Farmers' adaptation to climate change, its determinants and impacts on rice yield in Nepal, *Ecological Economics*, 2018, **144**, 139-147, doi: 10.1016/j.ecolecon.2017.08.006.
- [18] B. Paudel, J. Gao, Y. Zhang, X. Wu, S. Li, J. Yan, Changes in cropland status and their driving factors in the Koshi River Basin of the central Himalayas, Nepal, *Sustainability*, 2016, **8**, 933, doi: 10.3390/su80909333.
- [19] K. O. Murtaza, S. A. Romshoo, Recent glacier changes in the Kashmir Alpine Himalayas, India, *Geocarto International*, 2016, **32**, 188-205, doi: 10.1080/10106049.2015.11324822.
- [20] J. N. Khan, A. Jillani, S. R. Ali, Z. Rashid, Z. Rehman, I. Ashraf, Modeling climate change in cold arid regions of north western Himalayas using multiple linear regression modeling, *Journal of Agro-meteorology*, 2019, **21**, 474-479, doi: 10.54386/jam.v21i4.283.
- [21] S. A. Romshoo, R. A. Dar, I. Rashid, A. Marazi, N. Ali, S. N. Zaz, Implications of shrinking cryosphere under changing climate on the stream flow in the Lidder catchment in the Upper Indus Basin, India, *Arctic, Antarctic and Alpine Research*, 2015, **47**, 627-644, doi: 10.1657/AAAR0014-0888.
- [22] E. Sharma, D. Molden, A. Rahman, Y. R. Khatiwada, L. Zhang, S. P. Singh, T. Yao, P. Wester, Introduction to the Hindu Kush Himalaya assessment: Mountains, climate change, sustainability and people, The Hindu Kush Himalaya assessment: Mountains, climate change, sustainability and people, Springer Nature, Switzerland, 2019, 1-16, ISBN: 978-3-319-92287-4.
- [23] R. K. Meena, T. P. Vikas, R. P. Verma, S. K. Yadav, Mahapatra, N. S. Jaya, D. Singh, S. K. Singh, Local Perceptions and Adaptation of Indigenous communities to Climate Change: Evidences from High Mountain Pangri Valley of Indian Himalayas, *Indian Journal of Traditional Knowledge*, 2019, **18**, 58-67, doi: 10.5173/ijtk.2019.18.1.58-67.
- [24] R. K. Sharma, D. G. Shrestha, Climate perceptions of local communities validated through scientific signals in Sikkim Himalaya, India, *Environmental Monitoring and Assessment*, 2016, **188**, 1-11, doi: 10.1007/s10661-016-5582-y.
- [25] N. Hosen, H. Nakamura, A. Hamzah, Adaptation to climate change: Does traditional ecological knowledge hold the key, *Sustainability*, 2020, **12**, 676, doi: 10.3390/su12020676.
- [26] T. Van-Gevelt, H. Abok, M. Bennett, S. Fam, F. George, N. Kulathuramaiyer, T. Zamane, Indigenous perceptions of climate anomalies in Malaysian Borneo, *Global Environmental Change*, 2019, **58**, 1-11, doi: 10.1016/j.gloenvcha.2019.101974.
- [27] S. Osaka, R. Bellamy, Natural variability or climate change? Stakeholder and citizen perceptions of extreme event attribution, *Global Environmental Change*, 2020, **62**, 102070, doi: 10.1016/j.gloenvcha.2020.102070.
- [28] J. D. Ford, L. Cameron, J. Rubis, M. Maillet, D. Nakashima, A. C. Willox, T. Pearce, Including indigenous knowledge and experience in IPCC assessment reports, *Nature Climate Change*, 2016, **6**, 349-353, doi: 10.1038/nclimate2954.
- [29] M. D. K. Hasan, L. Kumar, Comparison between meteorological data and farmer perceptions of climate change and vulnerability in relation to adaptation, *Journal of Environmental Management*, 2019, **237**, 54-62, doi: 10.1016/j.jenvman.2019.02.028.
- [30] Y. Hein, K. Vijitsrikamol, W. Attavanich, P. Janekarnkij, Do farmers perceive the trends of local climate variability accurately? An analysis of farmers' perceptions and meteorological data in Myanmar, *Climate*, 2019, **7**, 1-21, doi: 10.3390/cli7050064.
- [31] S. Jamal, T. Namkha, Climate change, rural livelihood, and sustainability: In higher Himalayas of Kishtwar, Jammu and Kashmir, *Research Square*, 2022, **4**, 1-16, doi.org/10.21203/rs.3.rs-1681101/v1.
- [32] R. Shukla, A. Agarwal, K. Sachdeva, J. Kurths, Climate change perception: An analysis of climate change and risk perceptions among farmer types of Indian Western Himalayas, *Climate Change*, 2019, **152**, 103-119, doi: 10.1007/s10584-018-2314-z.
- [33] N. C. Poudyal, O. Joshi, D. G. Hodges, H. Bhandari, P. Bhattarai, Climate change, risk perception and protection motivation among high-altitude residents of the Mt. Everest region in Nepal, *Ambio*, 2021, **50**, 505-518, doi: 10.1007/s13280-020-01369-x.
- [34] U. K. Sahoo, S. Singh, S. S. Sahoo, L. Nundanga, L. Nuntluanga, A. S. Devi, J. Zothansiam, Forest dwellers' perception on climate change and their adaptive strategies to withstand impacts in Mizoram, North-East India, *Journal of Environmental Protection*, 2018, **9**, 1372-1392, doi: 10.4236/jep.2018.913085.
- [35] J. C. Nunnally, I. H. Bernstein, Psychometric theory, McGraw-Hill, New York, USA, 1994, 784, ISBN: 10007047849X.
- [36] J. F. Hair, G. T. M. Hult, C. M. Ringle, M. Sarstedt, A primer on partial least squares structural equation modeling (PLS-SEM), Sage Publications Inc, Thousand Oaks, California, United States, 2022, 384, ISBN: 978-1-5443-9640-8.
- [37] G. W. Cheung, H. D. Cooper-Thomas, R. S. Lau, L. C. Wang, Reporting reliability, convergent and discriminant validity with structural equation modeling: A review and best-practice recommendations, *Asia Pacific Journal of Management*, 2024, **41**, 745-783, doi: 10.1007/s10490-023-09871-y.
- [38] V. Tripathi, R. Akhtar, G. S. Preetha, Perceptions regarding climate change and its health impact: Reflections from a community-based study in India, *Indian Journal of Community Medicine*, 2021, **46**, 206-209, doi: 0.4103/ijcm.IJCM_120_20.
- [39] J. Garai, H. B. Ku, Y. Zhan, Climate change and cultural responses of indigenous people: A case from Bangladesh, *Current Research in Environmental Sustainability*, 2022, **4**, 100130, doi: 10.1016/j.crust.2022.100130.
- [40] J. C. Kuniyal, N. Kanwar, A. S. Bhoj, K. S. Rautela, P. Joshi,

- K. Kumar, H. B. Singh, Climate change impacts on glacier-fed and non-glacier-fed ecosystems of the Indian Himalayan Region: people's perception and adaptive strategies, *Current Science*, 2021, **120**, 888-899, doi: 10.18520/cs/v120/i5/888-899.
- [41] W. Shijin, Perception of indigenous people of climate change and its impact on the everest national nature preserve, *Meteorological Applications*, 2021, **28**, e1987, doi.org/10.1002/met.1987.
- [42] J. Liu, G. Rasul, Climate change, the Himalayan mountains, and ICIMOD, *Sustainable Mountain Development*, 2007, **53**, 11-14, doi: 10.1007/s11842-007-0017-x
- [43] A. K. Taloor, G. C. Kothyari, D. S. Manhas, H. Bisht, P. Mehta, M. Sharma, S. Ali, Spatio-temporal changes in the Machoi glacier Zaskar Himalaya India using geospatial technology, *Quaternary Science Advances*, 2021, **4**, 100031, doi: 10.1016/j.qsa.2021.100031.
- [44] U. B. Shrestha, A. M. Shrestha, S. Aryal, S. Shrestha, M. S. Gautam, H. Ojha, Climate change in Nepal: a comprehensive analysis of instrumental data and people's perceptions, *Climate Change*, 2019, **154**, 315-334, doi: 10.1007/s10584-019-02418-5.
- [45] S. Aryal, T. N. Maraseni, G. Cockfield, Climate change and indigenous people: Perceptions of transhumant herders and implications to the transhumance system in the Himalayas, *Geology and Geosciences*, 2014, **3**, 1-5, doi: 10.4172/2329-6755.10001622.
- [46] M. Tufail, Impact of the climatic change on the seasonal movement of the Gujjar and Bakarwals: Community perceptions, *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 2014, **8**, 41-46, doi: 10.9790/2402-080102146.
- [47] P. Wester, A. Mishra, A. Mukherji, and A. B. Shrestha, The Hindu Kush Himalaya assessment: Mountains, climate change, sustainability and people, Springer Nature, Geneva, Switzerland, 2019, 638, ISBN: 978-3-319-92287-4.
- [48] S. N. Ali, R. Singh, P. Morthekai, A. Sharma, B. Phartiyal, M. F. Quamar, P. Arora, Perception of climate change from the Himalayan 'cold desert' Ladakh, India, *Journal of Palaeosciences*, 2022, **71**, 89-111, doi: 0031-0174/2022.
- [49] B. A. Lone, S. Qayoom, A. Nazir, S. A. Ahanger, U. Basu, T. A. Bhat, R. Fathallah El-Agamy, Climatic trends of variable temperate environment: A complete time series analysis during 1980-2020, *Atmosphere*, 2022, **13**, 749, doi: 10.3390/atmos13050749.
- [50] M. H. Wani, S. H. Baba, N. H. Bazaz, H. Sehar H, Climate change in Kashmir valley: Is it initiating transformation of mountain agriculture?, *Indian Journal of Economics and Development*, 2015, **3**, 142-154, doi: 2320-9836.
- [51] M. Shafiq, P. Ahmed, A. A. Mir, H. Hassan, Trend analysis of winter precipitation over Kashmir valley from 1980-2016, *International Journal of Advance Research in Science and Engineering*, 2018, **7**, 1769-1777, doi: 10.15819/ijarse.2018.7.4.1769.
- [52] H. Qadri, I. A. Dar, A preliminary study on the changing patterns of temperature and precipitation of Srinagar, Kashmir, India, *International Research Journal of Modernization in Engineering Science*, 2020, **2**, 411-419, doi: 10.1007/s00382-021-05984-6.
- [53] K. R. Dahal, P. Dahal, R. K. Adhikari, V. Naukkarinen, D. Panday, N. Bista, G. Marambe, Climate change impacts and adaptation in a hill farming system of the Himalayan region: climatic trends, farmers' perceptions and practices, *Climate*, 2022, **11**, 11, doi: 10.3390/cli11010011.
- [54] A. Hussain, D. Arya, Farmers perceptions on climate change and its impacts in Anantnag District of Jammu and Kashmir (India), *Imperial Journal of Interdisciplinary Research*, 2016, **2**, 853-854.
- [55] S. N. Zaz, S. A. Romshoo, R. T. Krishnamoorthy, Y. Viswanadhapalli, Analyses of temperature and precipitation in the Indian Jammu and Kashmir region for the 1980-2016 period: implications for remote influence and extreme events, *Atmospheric Chemistry and Physics*, 2019, **19**, 15-37, doi: 10.5194/acp-19-15-2019.
- [56] J. M. Dad, M. Muslim, I. Rashid, Z. A. Reshi, Time series analysis of climate variability and trends in Kashmir Himalaya, *Ecological Indicators*, 2021, **126**, 107690, doi: 10.1016/j.ecolind.2021.107690.
- [57] V. S. Negi, D. C. Tiwari, L. Singh, S. Thakur, I. D. Bhatt, Review and synthesis of climate change studies in the Himalayan region, *Environment, Development and Sustainability*, 2022, **24**, 10471-10502, doi: 10.1007/s10668-021-01880-5.
- [58] S. Ahsan, M. S. Bhat, A. Alam, H. Farooq, H. A. Shiekh, Evaluating the impact of climate change on extreme temperature and precipitation events over the Kashmir Himalaya, *Climate Dynamics*, 2022, **58**, 1651-1669, doi: 10.1007/s00382-021-05984-6.
- [59] J. C. Kuniyal, N. Kanwar, S. S. Bhoj, K. S. Rautela, P. Joshi, K. Kumar, H. B. Singh, Climate change impacts on glacier-fed and non-glacier-fed ecosystems of the Indian Himalayan Region: people's perception and adaptive strategies, *Current Science*, 2021, **120**, 888-899, doi: 10.18520/cs/v120/i5/888-899.
- [60] S. F. Sherpa, M. Shrestha, H. Eakin, C. G. Boone, Cryospheric hazards and risk perceptions in the Sagarmatha (Mt. Everest) national park and buffer zone, Nepal, *Natural Hazards*, 2019, **96**, 607-626, doi: 10.1007/s11069-018-3560-0.
- [61] S. S. Mahdi, R. Jan, I. A. Jehangir, A. Hussain, M. A. Bhat, B. Dhekale, F. A. Bahar, Farmer's perception of climate change and adaptation strategies under temperate environmental conditions of Kashmir, India, *Journal of Agro-meteorology*, 2021, **23**, 442-451, doi.org/10.54386/jam.v23i4.161.
- [62] T. Tashi, F. K. Sudan, Perceived impacts of climate change on economic activities and adaptation strategies: A case study from cold desert of Ladakh, India, *Regional Economic Development Research*, 2021, **2**, 193-210, doi: org/10.37256/redr.2220211068.
- [63] G. Shukla, A. Kumar, N. A. Pala, S. Chakravarty, Farmer's perception and awareness of climate change: a case study from Kanchandzonga Biosphere Reserve, India, *Environment, Development and Sustainability*, 2015, **18**, 1167-1176, doi: 10.1007/s10668-015-9694-2.
- [64] K. R. Kaganzi, A. Cuni-Sanchez, F. Mcharazo, E. H. Martin, R. A. Marchant, J. P. R. Thorn, Local perceptions of climate

change and adaptation responses from two mountain regions in Tanzania, *Land*, 2021, **10**, 999, doi: 10.3390/land10100999.

[65] J. J. G. Arbuckle, L. W. Morton, J. Hobbs, Farmer Beliefs and Concerns about Climate Change and Attitudes toward Adaptation and Mitigation: Evidence from Iowa, *Climatic Change*, 2013, **118**, 551-563, doi: 10.1007/s10584-013-0700-0.

[66] S. M. Howden, J. F. Soussana, F. N. Tubiello, N. Chhetri, M. Dunlop, H. Meinke, Adapting Agriculture to Climate Change, *Proceedings of the National Academy of Sciences*, 2007, **104**, 19691-19696, doi: 10.1073/pnas.0701890104.

[67] A. Kairanbayeva, Z. Zhantayev, S. Nurakynov, M. Nurtas, G. Nurpeissova, D. Panyukova, M. Kudaibergenov, Predictive system for road condition monitoring based on open climate and remote sensing data - A case study with mountain roads, *Engineered Science*, 2024, **28**, 1081, doi: 10.30919/es1081.

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