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Perception of transhumant herders on climate change and their adaptation strategies

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Abstract

Climate change is becoming one of the greatest challenges of our times questioning the survival of humanity and the coexistence of biodiversity. Its impact is realized globally in aspects of climate-induced disasters, water stresses, rangeland, agricultural, and food production. This case study confers the extent and impact of climate change on transhumant herders along with their coping strategies in Lho and Sirdibas of Chumnurbi Rural Municipality, Gorkha. Focus group discussion, key informant interview, and questionnaire survey were carried out in two wards covering herder's perception towards various climatic variability, impacts on transhumance system, and adaptation strategies undertaken for resilience. Data were analyzed using descriptive, inferential statistics and GIS such as percentage, frequency, weighted mean, index of relative ranking, Chi-square test, Normalized Difference Vegetation Index (NDVI), Normalized Difference Snow Index (NDSI), etc. were presented in figures and charts. This study showed that temperature is rising and precipitation is falling in the rural mountainous areas along with a decrease in snow cover and an increase in vegetation cover over a period of time. Seasonal movement of livestock is mainly guided by the search of forage resources and for adjusting the temperature. The impacts such as the decrease in pasture resources, increase in drought, decrease in agricultural production, etc. were perceived by the herders. Adaptation strategies such as the seasonal movement of livestock, diversification of income sources, and grazing resources were most noticed. Most of them were autonomous based on indigenous knowledge and innovation. The study recommends that the perceived changes and possible impacts of climate change to the transhumance systems need to be monitored scientifically over time. Further, more programs and policies should be developed for the resilience of the community.

Keywords: Adaptation strategies, climate change, perception, resilience, transhumance

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Introduction

Transhumance is a form of pastoralism prevalent and connected especially with the indigenous knowledge, culture, and lifestyle of the mountainous region. In transhumance, livestock raised is moved between fixed points (horizontal) or altitudes (vertical) with the aim of harnessing low and seasonally available grazing resources (Bhusal *et al.,* 2018). In Nepal, it involves cyclic movement of herders from the residential areas, viz; from lower altitudes to the higher altitudes during summer and returning back to the lower altitudes in winter. These movements could be recognized as coping and subsistence strategies in response to the severe climate (Rayamajhi and Manandhar, 2020). The transhumance system of the western mountainous part of Nepal has observed a change in socio-economy, policies, and climate (Aryal, 2015). Similarly, gradual shrinkage and decline of productive pastureland and resources, shifting growth patterns of vegetation, and uncertainties due to harsh climates are significant noticeable factors affecting the transhumance (Bhusal *et al*., 2018). Some of the generalized climatic events are the timing of rainfall, agricultural seasons, occurrence and melting of snow in rangelands, availability of water nearby grazing zones, and so on (Aryal *et al.,* 2017). Trends in temperature and change in precipitations forms (from rainfall to snowfall) are more extreme and elevated in a mountainous region (NAPA, 2010; Shrestha and Aryal, 2011), affecting the livelihood of people and rangeland vegetation (Godde *et al.,* 2020). Especially, pastoralists are being affected by such climatic events, whose means of subsistence rely on the seasonal farming systems (Gentle and Maraseni, 2012; Kimaro *et al.,* 2018).

The mountains are prominent landforms characterized by fragility, marginality, inaccessibility, and poverty (Jodha, 2000). Besides, expansion or creation of conservation areas in mountainous areas posed restriction of herders' movement that could add burdens to their livelihoods and declining of such indigenous practices (Bhusal *et al.,* 2018; Tiwari *et al.,* 2020). Studies in the last two decades have focused on biophysical impacts assessments of climate change (Kilroy, 2015) while few addressed socio-economic responses to climate change from the lens of human values, attitudes, and beliefs within conservation areas (Carleton and Hsiang, 2016; Tiwari *et al.*, 2020). Recently, human percept and insight have been recognized as major components of climate science to understand human adaptability, and transformability (Chaudhary and Bawa, 2011; Shi *et al.,* 2015). This study explores the current practices of transhumance in response to climate change in the Chumnurbi rural municipality area within the conservation area of the Gorkha district, representing the Western mountain of Nepal.

Materials and Methods

Study area

The study was carried out in two different wards i.e Lho-2 and Sridibas-3 of Chumnurbi Rural Municipality of Gorkha district situated in the Central Himalayan region of Nepal (Figure 1). These wards were selected based on the existence of transhumance systems and the availability of herders where a large number of herders grazed livestock as compared to other wards for their livelihoods (Table 1). The study area falls under the Manaslu Conservation Area (MCA) is a protected area declared in 1998, harbors 33 species of mammals, 110 species of birds, 11 species of butterflies, and 3 species of reptiles (Aryal and Subedi, 2011). MCA covers an area of 1,663 sq. km and the area comprises mountains, glaciers, and watercourses. The altitudinal range varies from 1,400 to 8,156 masl at the peak of Manaslu.

Table 1. General overview of the selected study area.

S.N.	Features	Lho-2	Sirdibas-3
1	Total no. of HHs	259	573
2	Total population	711	2510
3	Area	200 sq. km	258 sq. km
4	HHs rearing livestock	151	334
5	Major Ethnicity	Indigenous (Lama)	Indigenous (Gurung)
6	Major Religion	Buddhism	Buddhism
7	Major Occupation	Agriculture	Agriculture
8	Livestock type	Cattle, Buffalo, Yak	Cattle, Buffalo, Sheep, Goat

9	Tourism	Low	High
10	Major Crop	Millet, Barley, Maize	Potato, Maize, Barley
11	Transhumance system	Presence	Presence

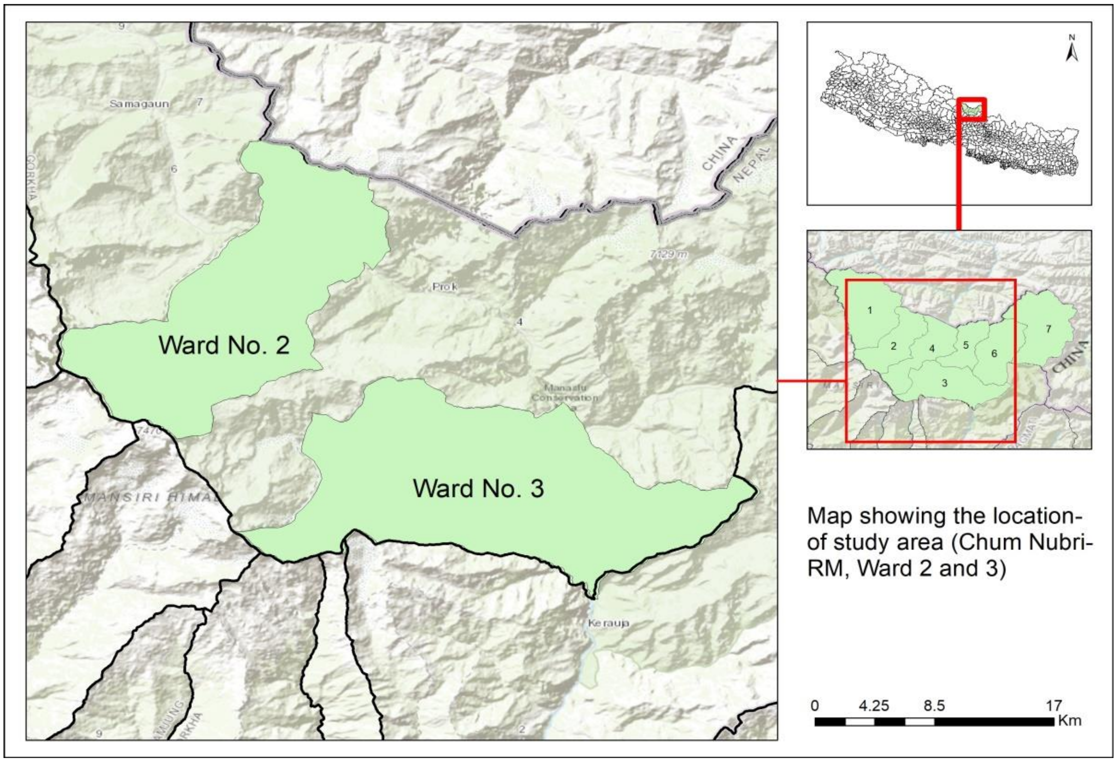

Figure 1. Map of the study area.

Methods of data collection

For this study, both primary and secondary information was collected during the year 2018-19 to identify the impact of climate change on the transhumance systems and their adaptation strategies. PRA tools like direct observation, household survey, key informant interview, focus group discussion; formal and informal interviews were used for this purpose. Direct observation was carried out at the potential site of both wards to acquire in-depth information on biophysical changes, challenges, and local adaptation measures for the seasonal movement cycle of herders. Altogether 63 HHs rearing livestock were surveyed from both wards (22 herders from Lho and 41 herders) by using semi-structured and pre-testing methods. The questionnaire was finalized by the research advisor and climate change expert based on the pre-testing technique. HHs were carried out to extract information on socio-economic status, and personal information about climate change for analyzing its impact and their coping strategies. A purposive sampling method with 10% sampling intensity was used for the selection of households because the transhumance system was being practiced by only a few HHs. Similarly, the snowball sampling technique was employed to identify transhumant herders. A total of 16 KII (equal to each ward) representing the local community in terms of their social status, economic well-being, knowledge, and ecological regions were interviewed. FGD was carried out separately with the local community, herders, and women groups to elicit information on climate change, socio-economic dimension, present adaptation practices, and coping strategies of herders to climate change. Furthermore, secondary data i.e., data related to climatic variables for the period of 32 years (1985-2017) were collected from the nearby meteorological station of Pokhara, Kaski district to study the climatic variations of the Rural Municipality.

Data Analysis

Qualitative and quantitative analysis methods were applied to analyze the data in this research. The data were analyzed using the Microsoft Excel program and later exported to Statistical Package for Social Sciences (SPSS) for further analysis. A non-parametric Chi-square test was performed on the perception of herders agreeing or disagreeing to different parameters. Similarly, general linear regression was used to find out the trends of temperature and precipitation of the research site from data of nearby stations. The Likert scale was used to measure the perceptions of herders towards climate change. Index of Relative Ranking (IRR) was used to rank and measure the different variables.

Climatic variability trend analysis

To find a linear trend in the data, simple linear regression was used. Equation 1 depicts the linear trend between time-series data (y) and time (t).

$Y = a + bt$ …………(1)

where, y= temperature or rainfall, t= time (year), 'a' and 'b' are constants estimated by the principle of least squares.

Calculation of IRR (Miller, 1986)

$IRR = (R_1S_1 + R_2S_2 + \ldots + R_nS_n)/nr$

R_1=rank of I^{st} order R_n= rank of last order

S_1= score of first-order   n= no of observations

S_n= score of last order   r= total rank given to particular attribute

Results

Socio-economic characteristics of respondents

The Lho and Sirdibas was the major study site where the transhumance system exists. The dominant inhabitants of Lho and Sirdibas were Lama and Gurung respectively. Out of 63 respondents, livestock was mainly taken by male herders from lower altitudes to higher altitudes. The herders were found to be moved to higher altitudes in summer and return to lower altitudes in the winter season. Almost 87% of the respondents involved in the herding system were male with the age group of 30-40 whereas 40-50 age group respondents were found mainly involved in the transhumance system. Most of the herders were illiterate (71%) and their economic status was not well off. The majority are poor and their major livelihood strategy was agriculture followed by livestock rearing (Table 2).

Table 2. Socio-economic characteristics of respondents.

S.N.	Characteristics		Percentage (%)
		Male	87
1.	Sex	Female	13
		20-30	10
		30-40	35
2.	Age	40-50	35
		50-60	17
		60 above	3
		Literate	29
3.	Education	Illiterate	71
		Poor	57
4.	Well-being status	Non-poor	43
		Agriculture	35
		Livestock	29
5.	Livelihood strategies	NTFPs and forest products	20
		Remittance	5
		Labour	11

Livestock holding

Livestock rearing was one of the main sources of income for the people residing in the study area. Livestock as cattle, yak (Nak/Chauri), goats, pigs, buffaloes were reared by them to meet their daily needs. The people of Lho mainly rear cattle, buffaloes, and yak whereas the people of Sirdibas mainly kept cattle, buffaloes, sheep, goats, and pigs to meet their subsistence needs (Figure 2).

Status of transhumance system

There were 259 households in Lho and 573 households in Sirdibas. Out of total households, 151 and 334 kept livestock in Lho and Sirdibas respectively. The transhumance system is being practiced by 63 and 131 households in Lho and Sirdibas respectively (Figure 3).

Seasonal movement of livestock

The elevation of Lho ranges from 1700 to 7600 meters above sea level. In the winter season, they graze their livestock around their local periphery. However, seasonal movement is accompanied by them in summer. According to FGD and key informants, cattle were moved between 2000 and 3000 m above sea level. In contrast, sheep, goats, and horses were more adaptable and moved between 1200-4000 masl and yak (Chauri) above 4500 m above sea level. Rangelands at higher altitudes were only accessible in the summer (July–September) season. Herds were moved to low-lying areas in the winter (December-February) season (Figure 4).

Reasons for livestock movement

There are several reasons for the seasonal movement of herds. The main reason for livestock movement was to search for forage availability followed by adjusting the temperature. Adjusting the period of NTFPs collection might be a minor reason for seasonal movement (Table 3).

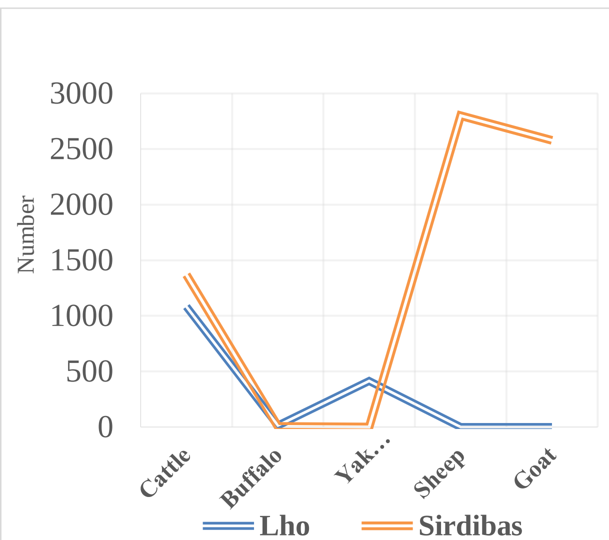

Figure 2. Livestock details of the study site.

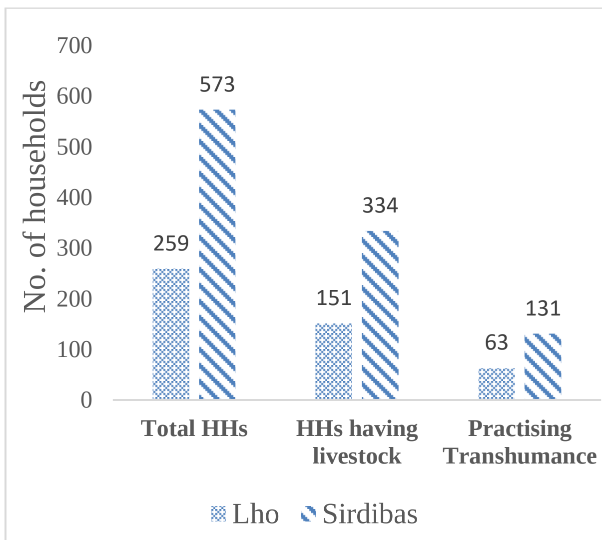

Figure 3. Status of transhumance system in the study site.

Table 3. Reasons for livestock movement.

Reasons for seasonal movement	IRR values	Rank
Adjusting temperature	0.82	II
Avoiding overgrazing in rangelands	0.49	IV
Searching for forage availability	0.86	I
Examining for water availability	0.55	III
Adjusting the time of medicinal plant collection	0.45	V

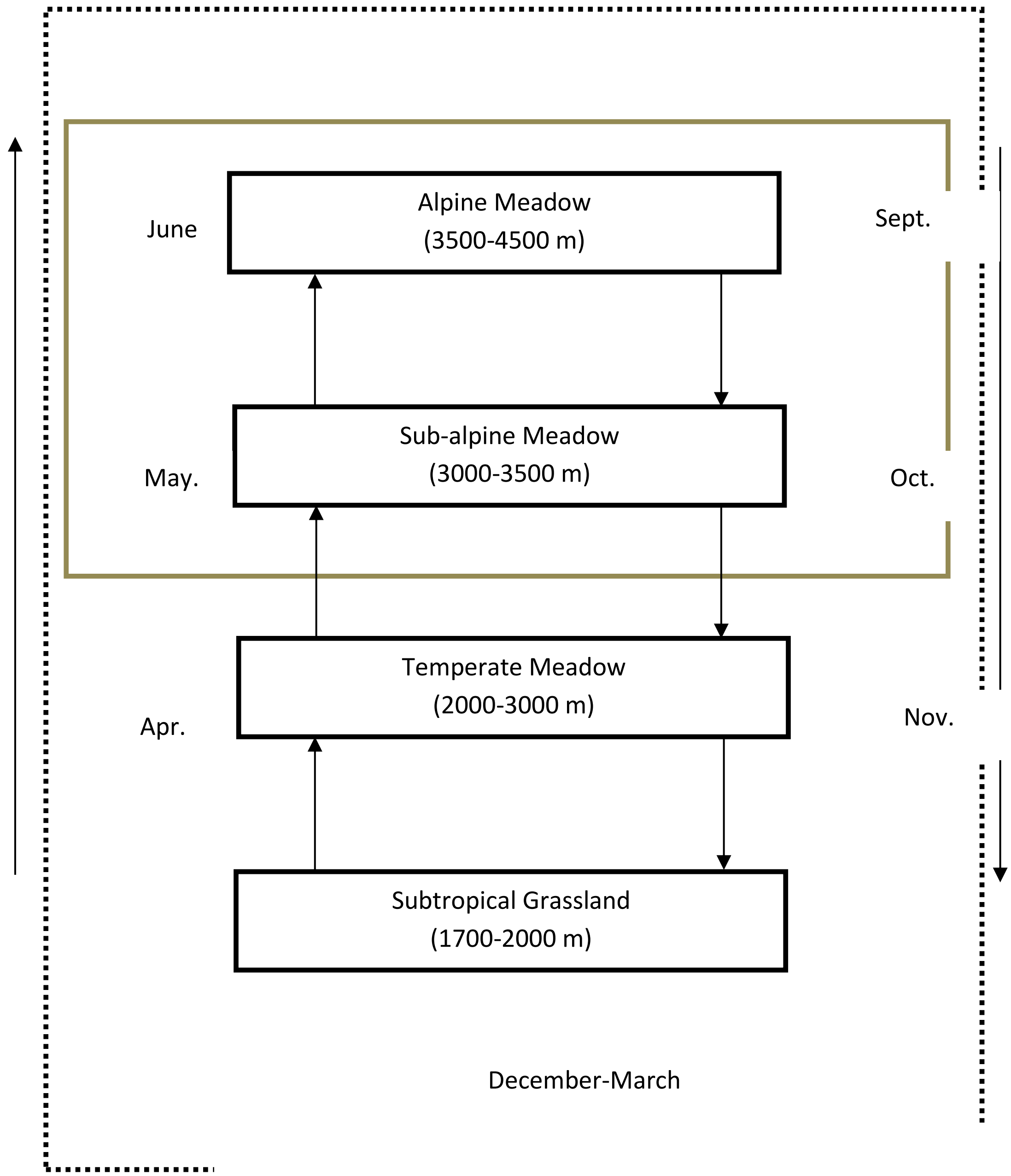

Figure 4. Typical transhumant herder's movement of Lho.

Climatic data and land-use change analysis

a) Temperature

The analysis of overall trends of mean annual maximum, minimum, and average temperature from 1985 to 2017 showed an increment of 0.085°C, 0.038°C, and 0.062°C respectively (Figure 5). This showed the general hotness and decreased coldness of the area. The temperature of the study area is on an increasing trend which supported the evidence of climate change in the study site.

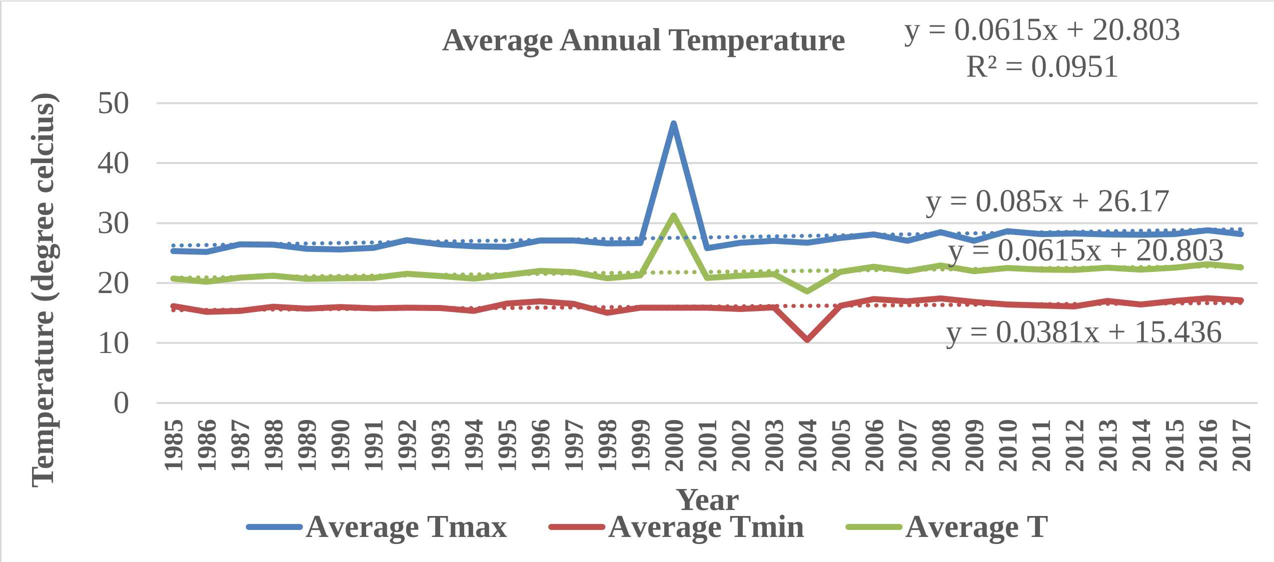

Figure 5. The trend of temperature from 1985-2017 A.D.

b) Precipitation/ Rainfall

An analysis of 32 years' average annual rainfall data showed that the mean annual rainfall of the study area was lowest (driest, drought-prone) in 1998 with only 60.675 mm of average monthly rainfall whereas 1995 was the wettest year with 198.957 mm of average rainfall per month. Recently in the year 2017, the rainfall was increased from 2016 by 0.233 mm of average monthly rainfall. Figure 6, shows the average monthly rainfall trend from 1985 to 2017, which was decreased by 0.26 mm (Table 4). It shows that there are ups and downs in rainfall patterns. The station has a negative trend of rainfall patterns.

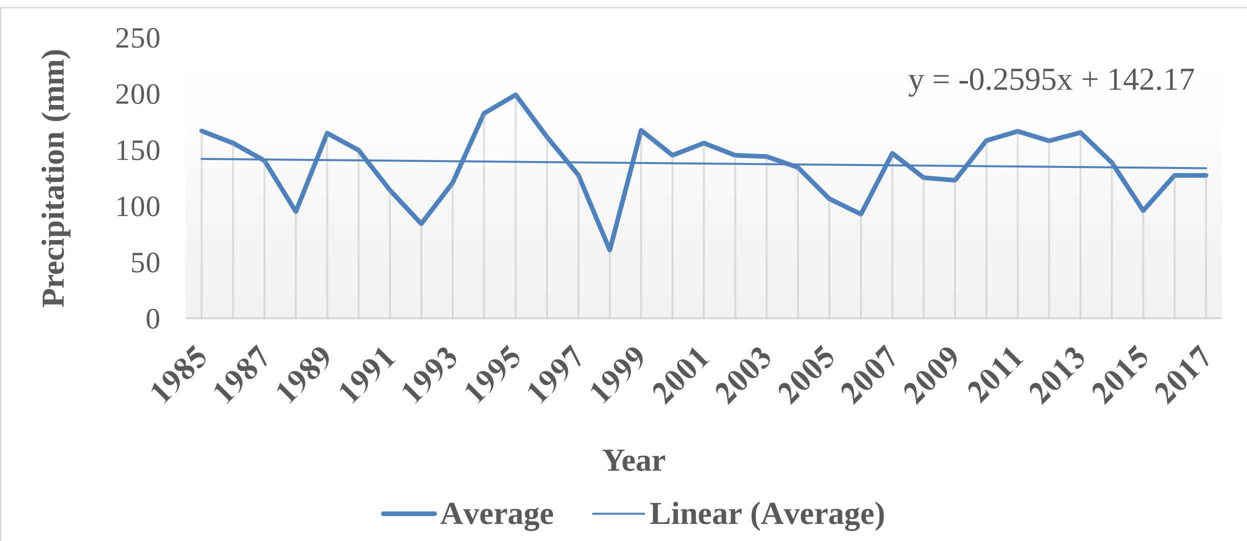

Figure 6. Rainfall trend from 1985-2017 A.D.

Table 4. Results of rainfall and temperature variability of the station.

Station	Variability in rainfall	Variability in temperature
Gorkha	Falling at 0.26 mm per year	Rising at 0.062°C per year

General understanding of climate change by herders

Out of the total respondents, only 37% are clear about the term climate change. The majority were unclear and unaware of the term climate change (Figure 7).

a) Perception on temperature variability

Most of the respondents had the opinion that summer temperature is increasing than before (75%). Similarly, they had the opinion that winter temperature (60%), melting rate of snow (85%) and the number of hotter days (72%) all are in an increasing trend (Table 5). Furthermore, long-term temperature data also support the local people's perception (Figure 5). The climatic data also shows a slight increase in mean annual temperature.

b) Perception on rainfall variability

Herders were likely to experience erratic rainfall. They had the opinion that total rainfall in monsoon, total rainfall in winter, snowfall amount, and number of snowfall days all are in decreasing trend which is 58%, 65%, 79%, and 72% respectively (Table 6). This might be the result of changing climate. Furthermore, long-term precipitation data also support the local people's perception (Figure 6).

c) Adaptation strategies by herders

Different adaptation strategies perceived by 39 herders were adopted differently which are significant at $p<0.01$. The seasonal movement of livestock (mean rank = 1.63) was the most significant adaptation strategy practiced by them. Similarly, diversification of income sources (mean rank = 2.3) and grazing resources (mean rank = 3.26) were also major adaptation strategies adopted by them. Livestock insurance (mean rank = 6.22) was ranked as the least prioritized adaptation strategy (Table 7).

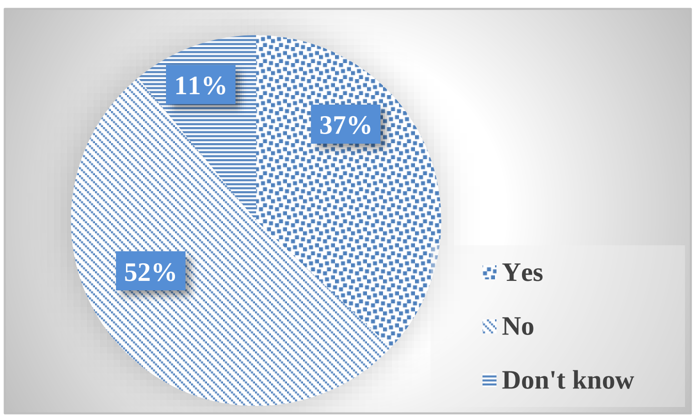

Figure 7. Herder's knowledge on climate change.

Table 5. Perceptions on temperature variability.

Temperature Variability	Increased (%)	Same as before (%)	Decreased (%)
Summer Temperature	75	8	17
Winter Temperature	60	18	22
Melting of snow	85	9	6
Number of hotter days	72	10	18

Table 6. Perceptions on rainfall variability.

Rainfall Variability	Increased (%)	Same as before (%)	Decreased (%)
Total Rainfall in monsoon	28	14	58
Total Rainfall in Winter	19	16	65
Snowfall Amount	2	19	79
Number of snow days	6	22	72

Table 7. Ranking of adaptation strategies.

S. N	Adaptation Strategies	Mean Rank
1	Seasonal Movement of Livestock	1.63
2	Reserve some grazing and grasses	5.34
3	Store grass, hey, crop, residue, and grain	4.11
4	Change in Variety of Livestock	5.11
5	Diversification in family income source	2.32
6	Diversification in grazing resource	3.26
7	Livestock Insurance	6.22

Normalized Difference Vegetation Index (NDVI)

Although, there are several vegetation indices, one of the most used is the NDVI which shows the presence or absence of vegetation. The NDVI map of the study site was prepared for the years 1995 and 2015 A.D. after downloading images (Figure 8). This showed that there is a change in vegetation cover during this period which is increased by 6.48 km^2 (Figure 9).

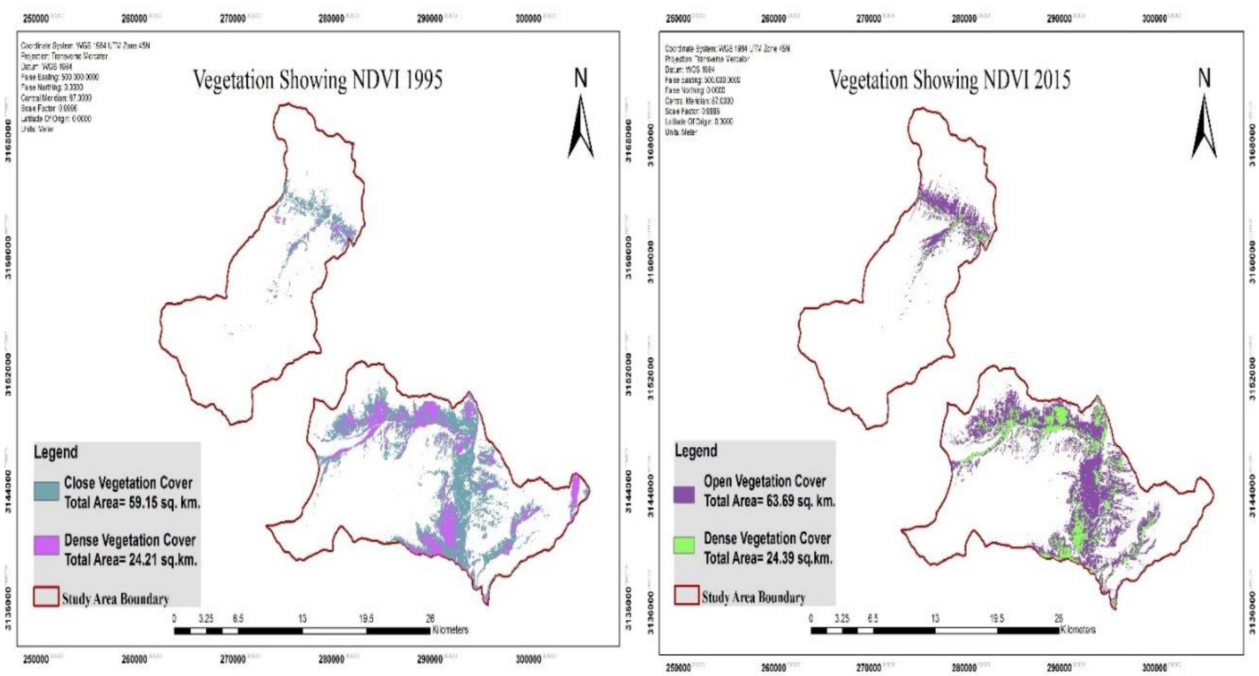

Figure 8.a) NDVI map of study site 1995 A.D. **b)** NDVI map of study site 2015 A.D.

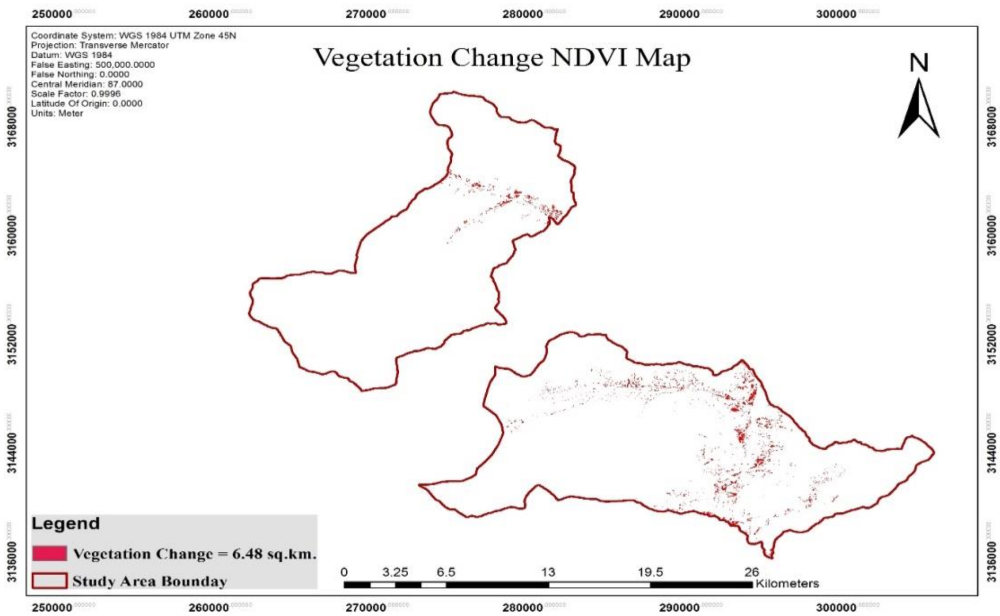

Figure 9. Vegetation cover change between 1995 and 2015 A.D.

Normalized Difference Snow Index (NDSI)

NDSI shows the presence or absence of snow cover which is important for weather and hydrological forecasting. The NDSI map of the study site was prepared for the years 1995 and 2015 A.D (Figure 10). This showed that there is a decrease in snow cover during this period which is 16.55 km^2 (Figure 11). This implies that a rise in temperature shown by climatic data analysis might be responsible for decreasing snow cover which in instance supports climate change. The study also reveals that the transhumant herders are moving to higher altitudes than before.

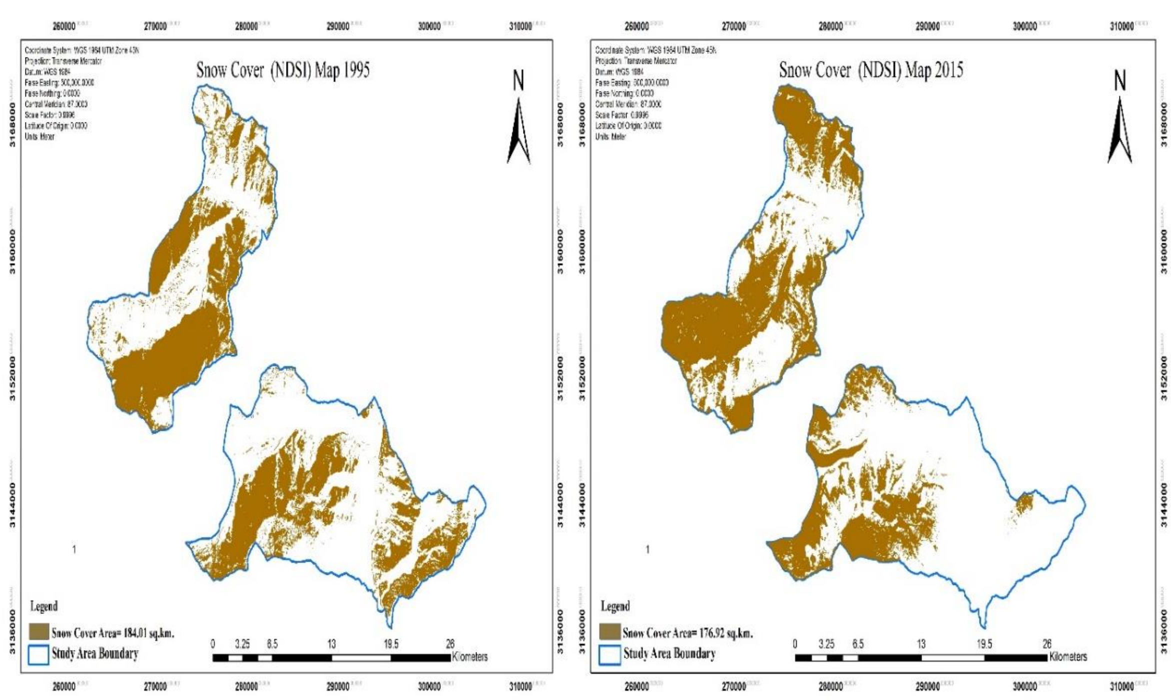

Figure 10. a) NDSI map of study site in 1995 A.D. **b)** NDSI map of study site in 2015 A.D.

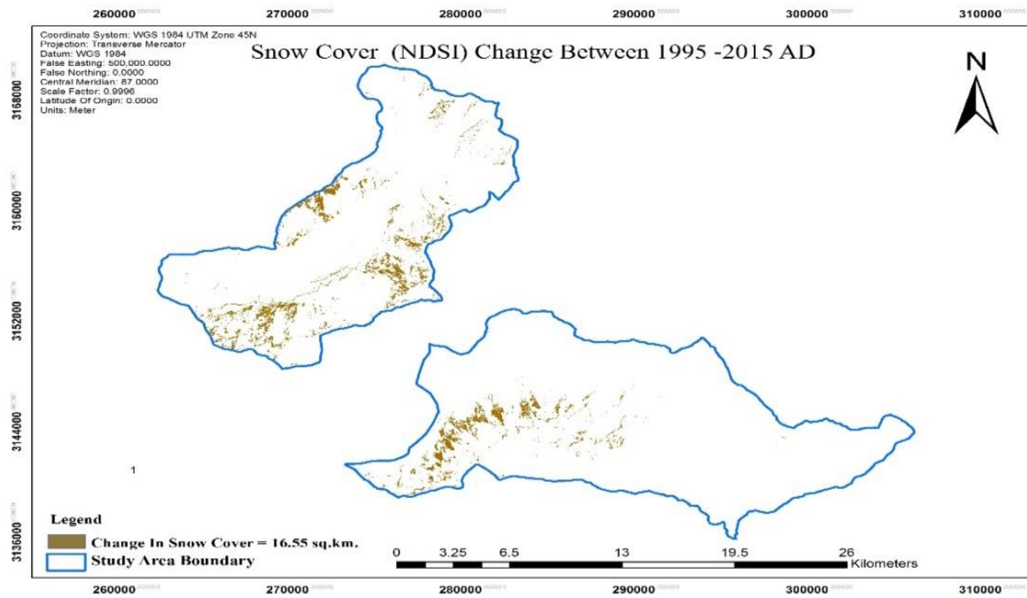

Figure 11. Snow cover changed between 1995 to 2015 A.D.

Discussion

In the study area, an analysis of mean annual temperature showed an increasing pattern by 0.062^{0}C which is in line with the finding of Rayamajhi and Manandhar (2020) and, the report of DHM (2015). Warming is more pronounced in the high-altitude regions as compared to the low lands (NAPA, 2010; Shrestha and Aryal, 2011). Meanwhile, precipitation was erratic and decreased at a rate of 0.26 mm per annum, which is supported by other studies in the Himalayan region (Tiwari *et al.*, 2010; NAPA, 2010). These patterns of temperature and precipitation were also perceived by the transhumant herders, similar to the study of Gentle and Maraseni (2012). However, most of the respondents were unknown about climate change and trends which might be illiteracy (literacy=29%) and poor economic conditions in such remote areas. This change in the climatic variables could seriously affect marginalized communities such as those dependent on transhumance (Macchi, 2011) because the herders have little access to modern facilities, markets, health services, and alternative means of production. Furthermore, transhumance herding is sensitive to the timing of rainfall and grass production, agricultural seasons, persistence and melting of snow in rangelands, and availability of water near grazing areas which could be highly affected by climate change.

The NDVI and NDSI are linked to climatic factors and are the function of temperature and precipitation (Ning *et al*., 2015; Pei *et al.,* 2019). The increase in NDVI might be the result of different parameters such as migration of people and involvement of NTNC in the conservation of natural resources. The rising temperature causes snow to melt in the early spring and changes the runoff timings/volume (Butt and Iqbal, 2009). Shrinking areas of snow cover and retreating glaciers (NAPA, 2010) and a decline in water availability (Tiwari *et al.*, 2010) also supported the result of this study.

Herders were found to graze their livestock nearby residence from December to March and moved to higher altitudes from April to August while returning down during September. Similar seasonal movements of herders were reported by other studies (Namgay *et al*., 2013; Rayamajhi and Manandhar, 2020) as adaptation strategies to climate change. These movements were primarily for searching forage, adjusting temperature, and seeking water availability (Aryal *et al.,* 2014). Mixed herding also helped to reduce vulnerabilities to climate change (Altieri and Nicholls 2017; Megersa *et al*., 2014a), increasing food diversity and security (Megersa *et al*., 2014b), efficient utilization of grazing resources available at different locations and altitudes because all grazing areas are not equally accessible to all livestock types.

Conclusion

This study found an alteration in precipitation pattern and an increase in temperature based on the meteorological data and perception of herders. An analysis of overall trends of temperature showed an increment in its mean annual, maximum, and minimum value within 32 years period. While average annual rainfall data was found to decrease by 0.26 mm. The NDVI and NDSI map was prepared that showed a remarkable increase in vegetation cover (by 6.48 km^2) and a decline in the snow cover (by 16.55 km^2). Seasonal movement of herder was basically for searching forage availability followed by adjusting the temperature. Impacts such as decreasing pasture resources and increasing drought events affecting agricultural production were perceived by the herders as results of an increase in temperature and a decline in rainfall. Various coping strategies were found adopted by the herders for overcoming the impacts of climate change. On top of that, there is a significant association between the seasonal movement of livestock and climate change based on herder's perception. To overcome climate change, their response differed significantly in the case of diversification in income sources and diversification of grazing resources. This study documents the perception of transhumant herders in response to changing climate and provides a way out for designing the adaptation and subsistence strategies for sustaining the people, pasture, and livestock of the mountainous region.

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References

Altieri, M.A. and C.I. Nicholls 2017. The adaptation and mitigation potential of traditional agriculture in a changing climate. *Climatic Change*, ***140***(1): 33-45. DOI: https://doi.org/10.1007/s10584-013-0909-y

Aryal, S. 2015. The socio-ecological impacts of structural changes in the transhumance system of the mountainous area of Nepal (Doctoral dissertation, University of Southern Queensland).

Aryal, A and A. Subedi 2011. The conservation and potential habitat of the Himalayan Musk Deer (Moschus chrysogaster) in the protected areas of Nepal. *International Journal of Conservation Science*, ***2***(a): 127-141.

Aryal, S., T.N. Maraseni and G. Cockfield 2014. Sustainability of transhumance grazing systems under socio-economic threats in Langtang, Nepal. *Journal of Mountain Science*, ***11***(4): 1023-1034.

Aryal, S., S.K. Ghimire, Y.R. Dhakal, N.P. Gaire and S. Bhandari 2017. Perceptions of agro-pastoralists towards the change in temperature and precipitation in the trans-Himalayan regions of Nepal. *Banko Janakari*, ***27***(1): 21-30.

Bhusal, P., M.R. Banjade and N.S. Paudel 2018. Pastoralism in crisis: Mounting challenges in herding system in high altitude region of Nepal. *Journal of Forest and Livelihood*, ***16***(1): 56-70. DOI: https://doi.org/10.3126/jfl.v16i1.22882

Butt, M.J. and M.F. Iqbal 2009. Impact of climate variability on snow cover: a case study of northern Pakistan. *Pakistan Journal of Meteorology*, ***5***(10): 53-63.

Carleton, T.A. and S.M. Hsiang 2016. Social and economic impacts of climate. *Science*, ***353***(6304).

Chaudhary, P. and K.S. Bawa 2011. Local perceptions of climate change validated by scientific evidence in the Himalayas. *Biology Letters*, ***7***(5): 767-770.

DHM. 2015. *Draft Report: Study of climate and climatic variation over Nepal*. Department of

Hydrology and Meteorology (DHM), Kathmandu, Nepal.

Gentle, P. and T.N. Maraseni 2012. Climate change, poverty and livelihoods: adaptation practices by rural mountain communities in Nepal. *Environmental Science & Policy*, ***21***: 24-34. DOI: https://doi.org/10.1016/j.envsci.2012.03.007.

Godde, C.M., R.B. Boone, A.J. Ash, K. Waha, L.L. Sloat, P.K. Thornton and M. Herrero 2020. Global rangeland production systems and livelihoods at threat under climate change and variability. *Environmental Research letter*, 15.

Jodha, N.S. 2000. Poverty alleviation and sustainable development in mountain areas: Role of highland-lowland links in the context of rapid globalization. In *Growth, poverty alleviation, and sustainable resource management in the mountain areas of South Asia* (Eds. M. Banskota, T. S. Papola and J. Richter). Deutsche Stiftung fur international Entwicklung: Feldafing. pp 541-570.

Kilroy, G. 2015. A review of the biophysical impacts of climate change in three hotspot regions in Africa and Asia. *Reg Environ Change*, ***15***: 771-782.

Kimaro, E.G., S.M. Mor and J.L.M.L. Toribio 2018. Climate change perception and impacts on cattle production in pastoral communities of northern Tanzania. *Pastoralism: Research, Policy and Practice*.

Macchi, M. 2011. *Framework for community-based climate vulnerability and capacity assessment in mountain areas*. International Centre for Integrated Mountain Development (ICIMOD).

Megersa, B., A. Markemann, A. Angassa, and A.V. Zárate 2014a. The role of livestock diversification in ensuring household food security under a changing climate in Borana, Ethiopia. *Food Security*, ***6***(1): 15-28. DOI: https://doi.org/10.1007/s12571-013-0314-4

Megersa, B., A, Markemann, A. Angassa, J.O. Ogutu, H.P. Piepho,and A.V. Zárate 2014b. Livestock diversification: an adaptive strategy to climate and rangeland ecosystem changes in southern Ethiopia. *Human Ecology*, ***42***(4): 509-520. DOI: https://doi.org/10.1007/s10745-014-9668-2

Miller, M.H. 1986. Financial innovation: The last twenty years and the next. *Journal of Financial and Quantitative Analysis*, ***21***(4): 459-471.

Namgay, K., J. Millar, R. Black and T. Samdup, T 2013. Transhumant agro-pastoralism in Bhutan: Exploring contemporary practices and socio-cultural traditions. *Pastoralism: Research, Policy and Practice*, ***3***(1): 1-26. DOI: https://doi.org/10.1186/2041-7136-3-13

NAPA. 2010. *National Adaptation Programme of Action (NAPA)*. Ministry of Environment, Government of Nepal, Kathmandu.

Ning, T., W. Liu, W. Lin, and X. Song 2015. NDVI variation and its responses to climate change on the northern Loess Plateau of China from 1998 to 2012. *Advances in Meteorology*, 2015. DOI: https://doi.org/10.1155/2015/725427

Pei, Z., S. Fang, W. Yang, L, Wang, M. Wu, Q. Zhang, W. Han and D.N. Khoi 2019. The relationship between NDVI and climate factors at different monthly time scale: A case study of grasslands in inner Mongolia, China (1982-2015). *Sustainability*, ***11***: 7243.

Rayamajhi, N. and B. Manandhar 2020. Impact of climate change and adaptation measures on transhumance herding system in Gatlang, Rasuwa. *Air, Soil and Water Research*, 13, 1178622120951173. DOI: https://doi.org/10.1177/1178622120951173

Shi, J., V.H.M. Visschers and M. Siegrist 2015. Public perception of climate change: the importance of knowledge and cultural wordviews. *Risk Analysis*, ***35***(12): 2183-2201.

Shrestha, A.B. and R. Aryal 2011. Climate change in Nepal and its impact on Himalayan glaciers. *Regional environmental change*, ***11***(1): 65-77. DOI: https://doi.org/10.1007/s10113-010-0174-9

Tiwari, K.R., K.D. Awasthi, M.K. Balla and B.K. Sitaula 2010. Local people's perception on climate change, its impact and adaptation practices in Himalaya to Terai regions of Nepal.https://digitalrepository.unm.edu/nsc_research/48?utm_source=digitalrepository.unm.edu%2Fnsc_research%2F48&utm_medium=PDF&utm_campaign=PDFCoverPages

Tiwari, K.R., B.K. Sitaula, R.M. Bajracharya, N. Raut, P. Bhusal and M. Sengel 2020. Vulnerability of Pastoralism: A case study from the High Mountains of Nepal. *Sustainability*, ***12***, 2737.