

Integration of Indigenous knowledge in addressing climate change

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Household survey, focus group discussions, participatory rural appraisal (PRA) tools, viz. trend analyses for temperature, rainfall intensity and farming, pair wise ranking and matrix ranking to get people's perceptions and experiences on climate change in the Pokhara Khola watershed in the Middle-Hills of Nepal. Moreover, local meteorological data was analyzed to see the trend of changes in rainfall and temperature. Analyses of both Indigenous farmers' perceptions and meteorological data showed an increase of temperature with longer summers and warmer and shorter winter during the period of 1982 - 2007. There was a decreasing trend of rainfall over the years in an erratic and unpredictable manner. Water shortage, disease and pest infestation in crops and soil fertility loss are seen as major climate risks and hazards. Marginal and small groups of farmers are more vulnerable with low ability to cope with climate hazards due to lack of familiarity with these conditions. In order to adapt to these adverse conditions (trend of increased temperature and decreased rainfall), people's increasing tendency to apply chemical fertilizer instead of manure and practice less water demanded vegetables farming while decreasing trend of cereal farming was apparent in trend analysis of farming. The conversion of *kharbari* (grass production for roofing thatch and livestock feed) to barren wasteland and grass shortage caused the reduction in production of large livestock. The reduction in number of large livestock (cattle) due to fodder shortage results in less available manure and increased need for fertilizing and pesticide applications against disease, pest attacks and invasive species in crops induced loss of soil fertility for long term. The presence of mosquitoes was seen all year-round except it was only found during summer in the past.

Keywords: Climate risk, Farmers, Livelihood, Soil fertility, Vulnerable, Water shortage, Middle-hills

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Warming in the Himalayas has been much higher than the global average of 0.74⁰C over the last 100 years¹. Recent studies showed that Nepal's temperature is rising at rate of about 0.41⁰C per decade¹ and the mean annual temperature is expected to increase by 2.9⁰C by the middle of the 21ST century². As in other regions of the world, climatic and ecological changes caused by global warming have resulted in an array of negative consequences for people's health, economy and livelihoods in Nepal³. Agriculture – the mainstay of rural food and economy that accounts for about 96% of the total water use in the country – suffers from erratic weather patterns such as heat stress, longer dry seasons and unpredictable rainfall, since 64% of the cultivated area fully depends on monsoon rainfall⁴. Changing climate results in heavy showers which induce flooding, longer wetter, land slides, and invasion of weeds on farmland. During the dry

season, increased evaporation will lead to water scarcity⁵. With reference to climate change at the local scale, therefore, studies conducted in Nepal^{6,7} are of paramount importance. Because, climate change is found to be relatively new challenge of global scale however, at a global scale climate change may have negligible impact rather than local and regional scale. Impact may be severe and substantial at local scale⁷.

Among five physiographic zones of Nepal, the Middle Mountains (200–3000 masl) zone, also known as the “Middle-Hills”, comprises the central belt, which can be characterized as a network of ridges and valleys with less than 5% flat area. It occupies about 30% of Nepal's total land area and hosts about 44% of its human population⁸. About 32% of the country's forests occur in the Middle-Hills. The complementary relationships of crop, livestock and tree components fulfill the livelihood needs of resource-poor farmers and maintain ecological stability is paramount in the

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'Nepalese Hill Farming System'^{9,10}, which offers the greatest ecosystem and species diversity in the Middle-Hills among the five physiographic zones of Nepal¹¹. However, warming in Nepal has been much more pronounced in the Middle-Hills and the high Himalaya than in the Terai and Siwalik regions^{1,12}. Since, the Middle-Hills of Nepal have few livelihood opportunities¹³ and around 80% people are engaged in subsistence hill farming⁴, the population is at particular risk from climate change. Poor, marginalized and disadvantaged people are especially vulnerable to climate change^{13,15}. Land degradation, soil moisture deficits, droughts and possible pest outbreaks will reduce crop productivity and place higher pressure on remaining fertile land. Declining yields due to unfavorable climate and weather extremes will lead to disasters in the form of food insecurity, hunger and shorter life expectancies leading to an overall adverse effect on livelihoods¹⁴. Increased risks and hazards are linked with decreased opportunities and employment at the rural level. Therefore, people are often forced into wage labor and migration to cities and abroad for jobs. In the Middle-Hills, drought and landslides are disrupting the social system and agriculture-dependent livelihoods¹³. Hence, fragile livelihoods and the vulnerability of hill biodiversity have highlighted the necessity for an assessment of local perceptions on climate change with its effects on the farmlands of the Middle-Hills of Nepal. Thus, in order to secure and maintain the area's livelihoods, it is imperative that climate change issues be addressed as a key development concern.

Because of uncertainties associated with regional projections of climate change, the IPCC (Intergovernmental Panel on Climate Change 2007) has attempted to assess the vulnerability of natural and social systems to changes in climate, rather than to provide quantitative predictions of the impacts of climate change at the regional level. Several studies have been carried on understand climate change and its effects with respect to biophysical and social aspects¹⁶. Farmers' experiences and observations of climate change associated with the different risks and effects of changing temperatures, rainfall, and wind patterns can help planners and decision-makers understand aspects of natural phenomena in relation to climate, biodiversity and livelihoods². Therefore, it is important to integrate the "civic science" like farmers' perceptions with "academic science" to

address climate change impacts and the adaptation and development of climate-resilient livelihoods¹⁶. Local perceptions of rainfall variation and temperature increase correlate with previous scientific studies like the IPCC report of 2007.

Climate change vulnerability may depend on sufficient employment opportunities in the risk-prone areas, land-holding size, education level, and family and community size. For example, high class, middle class and low class ethnic people live in the Middle-hills of Nepal. Climate change cannot be divorced from sustainable management as sustainable management may be the most effective way to frame the mitigation question and a crucial dimension of climate change adaptation and impacts¹⁷. Incorporating local knowledge into climate change policies can lead to the development of effective adaptation strategies that are cost-effective, participatory and sustainable¹⁸. Indigenous knowledge should complement, rather than compete with global knowledge systems¹⁹. Therefore, this study aims at exploring climate change scenarios with respect to change in temperature and rainfall trend, determining the climate risks and hazards and articulating impacts on agricultural farming and livelihood and vulnerable groups in the Pokhara Khola watershed in the Middle-Hills of Nepal.

Methodology

The study site

The study site is located about 60 km West of Kathmandu. Geographically, it lies between 27°46'28" N and 27°48'06" N latitude and 84°53'32" E and 84°55'11" E longitude⁴. Pida village of Dhading district is located in the Pokhara Khola watershed in the Central Middle-Hills of Nepal from 400 m in the valley bottom to 800 m on the hill slopes which represents the 'middle mountain farming system' (Fig. 1). There are three distinct seasons: rainy (wet), winter, and hot or humid summer²⁰. Cambisols and Luvisols make up the dominant soils in the study area and the terrain is steeply sloping²¹.

The major land uses in the study area are forestry and agriculture. Forest land covers about 55% of the watershed area and is an integral part of the farming system. Two main cultivation systems are *khet*, which covers about 10%, and *bari* 35% of the watershed area. The *khet* land consists of bounded and leveled terraces, which are generally located near streams away from households. *Bari* land includes *bari*

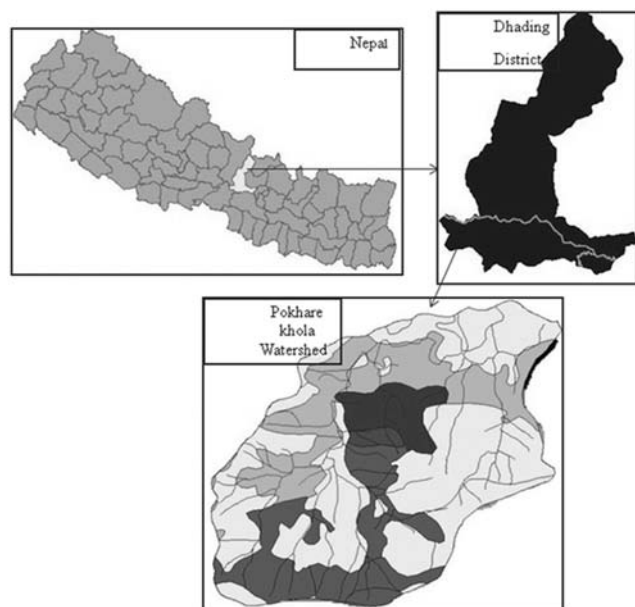


Fig. 1—Location map of Pokhare Khola watershed of Dhading district in the Middle-Hills of Nepal Source: ²⁰Tiwari (2008).

(around the homestead areas) and *pakhabari* (separate plots up to 30 minute walking distance)²¹. This integrated farming system (both *bari* and *khet*) includes trees, crops and livestock, providing both food and a bedding source (tree fodder and grasses) for livestock, compost materials for soil fertility, and fuelwood and timber for household use. Farmers cultivate cereal and vegetables crops in their *bari* and *khet* lands. *Khet* is the most valuable land as it yields two major cereal crops rice (*Oryza sativa*), wheat (*Triticum aestivum* L.), annually with irrigation facility and other crops including maize (*Zea mays* L.), and finger millet [*Eleusine coracana* (L.) Gaertn.] to some extent. *Bari* land consists of outward-sloping, rain fed terraces in which maize and/or millet are mainly grown. The *bari* lands have also been used intensively with several types of seasonal vegetables including cauliflower (*Brassica oleracea* L.), beans (*Phaseolus vulgaris* L.), bitter melon (*Momordica charantia* L.), Pumpkin (*Cucurbita pepo* L.), brinjal or eggplant (*Solanum melongena* L.), etc. for domestic and commercial purposes year-round. *Kharbari* land is set aside for grass production for roofing thatch and livestock feed²².

Research methods

Questionnaire survey

A survey was conducted, stratified by villages at various altitudes (all over 400 m and six at 600 m and

higher). Eight villages in Wards 2 and 3 in the Pokhare Khola watershed were selected, with random sampling of farm households within villages. A total of 148 farm households were selected, from 340 households. The head of the selected households (assumed to be the decision-maker in farming) or their spouse or household members of 40 years and above were interviewed, on the assumption that younger people would have less experience of climate changes and fewer relevant observations. Sample households of each village were selected proportionately according to the number of total households, supplied by Village Development Committee (VDC) offices. Two trained enumerators conducted personal interviews in Nepalese language. Data were collected through survey on climate change, its impacts, regular weather condition and physical changes.

Focus group discussion

The six group discussions were held in six different villages under the minimum guidance of facilitator. Each group varied with 8–10 participants selected based on snow balling techniques and participants who were not considered for survey, form four different farm categories. Two groups were composed of only male; two groups were composed of only female; and another two were composed of both male and female. The purpose of group discussions was to focus on perceptions and experiences of climate change, particularly temperature increase, rainfall patterns and their positive or negative impacts, and utilization and management patterns of crop, trees and livestock to adverse climate.

Participatory rural appraisal (PRA)

Trend analyses, a visual representation of agricultural farming with respect to change in temperature and rainfall were used to determine changes over time (1982 – 2007). Different symbols with big and small size which presented the intensity or increased and decreased amount over time were shown. In identifying climate risks and hazards, pair wise ranking was executed. Comparing each hazard with others and afterwards comparing all hazards to finally sum up their score for each hazard to rank the perceived problems. Matrix ranking was done to identify the degree of vulnerability (difference between impacts and coping ability) among various farm categories.

Secondary information

Meteorological data regarding rainfall and temperature were collected from Dhunibesi station nearest to the study site.

Farm area categorization

Farms were categorized into four groups – marginal, small, medium and large – based on the area of farmland owned (Table 1). The definition of these farm sizes was agreed to by the farmers during the survey.

Results

Local perceptions of climate change scenarios

Weather is an atmospheric condition at the surface timescale from minutes to weeks and has an important impact on agriculture²³. The majority of farmers experienced longer summers, shorter winters and shorter but heavy rainfall with a delay of monsoon breakout, which indicates the changing season. The results revealed that 84% of the farmers perceived that the overall temperature had increased, while around 12% “did not know” and 2.7% perceived the temperature to have remained constant. Almost all (97%) farmers perceived that summer is becoming hotter and 81% of interviewed farmers responded that winter is becoming warmer. Rainfall patterns and distribution were generally perceived to have changed unevenly from 1982 to 2007; about 97% of the respondents observed an unpredictable rainfall

patterns from 1982 to 2007. The farmers’ observations were reflected to some extent in meteorological data of rainfall and temperature patterns (Table 2).

Climate risks and hazards

Water shortagesⁱ due to unusual rain and increased temperature were identified as a key risk (Table 3). The drying up of wells, springs, streams and lakes was found to be severe during dry and hot season. If this trend continues, many biological and human systems dependent on these ecosystems will face grave challenges in the future as a consequence of drought and water shortage. As revealed in the group discussions and interviews, peasants, especially women, were forced to carry out mal-adaptative practices such as using machines to pump water from deeper in the ground, and carrying water from natural springs and ground water sources in order to meet their daily water requirements for household and farming activities. Group discussion and survey revealed that as temperature increases, vector born diseases, pests and invasive species were expected to emerge, spread and encroach on agriculture. Diseases, insects, pest infestation and invasive species emergence in rice, maize, mustard and vegetables mainly tomatoes were second, third and fifth most risks identified by farmers (Table 3). Some peasants reported that livestock, trees [e.g. pest attack in *lichhi* (*Litchi chinensis* Sonn.)] and grasslands were at greatest risk. New diseases were also observed, mainly in goats and chickens. The presence of mosquitoesⁱⁱ was seen year-round, whereas in the past they were only found during summer. People’s perception was that in a few years occurrence of mosquitoes were often cited as an impact of rising temperature, adding the risk of several vector-borne diseases like dengue and malaria, with an increase of mosquitoes and other insects in the hills than the Terai.

Table 1—Household categories based on the area of farm

Farm category	Farm area (Ropani) ^a	Farm area (ha)
Category 1 (Marginal farm)	Equal or less than 5	≤ 0.25
Category 2 (Small farm)	6 to 10	0.26 - 0.5
Category 3 (Medium farm)	11 to 20	0.51 – 1
Category 4 (Large farm)	More than 20	> 1

a. 20 Ropani = 1 ha.

Table 2 —Trend of agricultural farming articulated in scale (low to high: 1 to 5) with respect to change in temperature and rainfall from 1982 to 2007

	1982	1987	1992	1997	2002	2007
Cereal farming	5	4(+0.2 °C, +14.29 mm)	4(-0.2 °C, -3.3 mm)	3(+0.3 °C, +38.02 mm)	3(+0.2 °C, +6.96 mm)	2 (0.0 °C, -27.5 mm)
Vegetable farming	3	4	4	5	5	5
Manure application	5	5	4	4	3	3
Chemical fertilizer application	3	3	4	4	4	5

*Values in parenthesis indicate increase (+) or decrease (-) of temperature and rainfall

Source: Meteorological data (data obtained from Dhunibesi station nearest to the study site)

Table 3—Pair ranking of climate risk and hazards in the study site

No.	Risks and hazards	Pair-ranked points	Position
1	Too and prolonged warm spells	5	6 th
2	Fog	2	7 th
3	Too rain	2	7 th
4	Water shortage	10	1 st
5	Disease	9	2 nd
6	Insects/pests	8	3 rd
7	Flood	1	8 th
8	Soil erosion	2	7 th
9	Soil fertility loss	7	4 th
10	Hail storm	2	7 th
11	Weeds, invasive species	6	5 th

Source: Field data collection (PRA)

Impacts on livelihoods

Over 60% of respondents had sufficient food and surplus food for a year. The rest of the respondents suffered from food insecurity. Some of these had food for 9 months but at least 15% could not manage food for 6 months. There was a strong positive correlation between farm area and food sufficiency (Spearman's $\rho = 0.529$, $n=148$, $p \leq 0.01$), indicating that the larger the farm area, the greater food sufficiency. Farmers with marginal and small farms were more vulnerable to loss of human capital (malnutrition and diseases), natural capital (loss of land fertility, productivity in agriculture, loss of local varieties of crops and fodder shortage) and financial capital (more disasters and lower income) of five livelihood assets. Therefore, these farmers were more susceptible to impacts of climate change with low coping ability in overcoming the risks (Fig. 2).

The difference between impacts and coping ability made people more vulnerable. Vulnerable livelihoods due to climate change impacts will thus leave poor people with fewer of the assets they need to withstand shocks and stresses. In order to adapt to this adverse condition (the trends of increased temperatures and decreased rainfall), an increased trend of farming vegetables demanding less water, decreased cereal farming and increased application of chemical fertilizers instead of manure were apparent in trend analysis of farming (Table 2). Farmers perceived that water shortage and intensity of climate hazards had led to the introduction of improved varieties for their high and faster yielding nature and thus disrupted rain-fed agricultural systems and caused loss of local crop varietiesⁱⁱⁱ. Upreti & Upreti (2002)²⁴ and

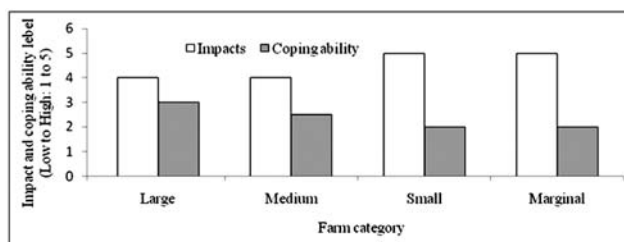


Fig. 2—Degree of vulnerability among farm categories; Source: Field data collection (PRA)

Singh *et al.* (2011)²⁵ also cited loss of agrobiodiversity due to several factors like modern intensive cropping pattern, high population growth, climatic stress, etc. both in Nepal and India, respectively.

Discussion

Farmers' understanding in the study area from long experience with the realities of the local environment was that the climate has changed. Our results are agreement with the study by Gyampoh *et al.* (2007)²⁶ in rural Ghana where farmers' perceptions were corroborated by records of a gradual rise in average temperatures of 1.3°C from the 1961 to 2006. An increase in annual temperature, the hotter summer and warmer winter is consistent with findings of Chapagain *et al.* (2009)²⁷, where local community members of Nepal could understand changes and trends of temperature and rainfall. In general, farmers' thoughts and experiences of this study support the scientific studies⁷ and correlate with the study in Nepal conducted by Shrestha *et al.* (2000)²⁸ where the estimates of rate of temperature increase of 0.41°C per decade based on meteorological data was expected.

Drought and drying of springs/streams was found as a climate risk over the entire Dhading district, from local people's contributions to research conducted by Sagun (2009). Both scientific studies and local perceptions raised the same issue in Nepal in the study by Dahal (2005)¹². Most farmers were found to be abandoning production of potatoes (*Solanum tuberosum*). A similar observation was made in another study in Manang district, Nepal²⁹. The documentation of diseases and insect attack in crops due to climate change in this study is consistent with a study of a range of developing countries^{30,31}. Local people's perceptions regarding emergence of mosquitoes are consistent with studies in both Africa³² and Bangladesh,³³ where people were found to be more vulnerable to a number of climate sensitive

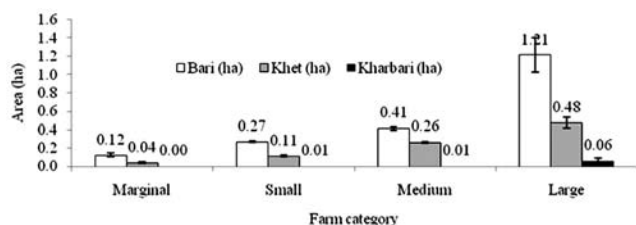


Fig. 3—Mean area of *bari*, *khet* and *kharbari* under different categories of farms. Bars represent \pm SE

diseases including malaria, tuberculosis and diarrhea. Malaria is a frequently cited example, because its prevalence increases in line with the warmer, drier climates that are anticipated with climate change. Under climate change, rising temperatures are changing the geographical distribution of disease vectors which are travelling to new areas and higher altitudes. For example, migration of the malaria-carrying mosquito to higher altitudes will expose large numbers of previously unaffected people to infection in the densely populated East African Highlands³⁴. In this study, people perceived that mosquitoes are nowadays climbing uphill as rising temperature favor the condition, whereas mosquitoes formerly seen in the Terai in Nepal from summer months to round the year.

Moreover, farmers reported that agricultural ecosystems in the study area including *khet*, *bari* and *kharbari* are in critical condition owing to loss of topsoil and consequent loss of soil fertility and reduced groundwater recharge because of accelerating runoff. *Kharbari* is usually used for grass production. This has now been converted to barren wasteland due to prolonged water shortages (Table 3). *Kharbari* areas were basically owned by rich farmers with large farm areas. Other farms with less extensive land resources have also experienced grass and fodder shortages (Fig. 3). Farmers were not allowed to go into the forest to collect fodder and hence livestock production, mainly cattle and buffaloes, has been reduced due to grass, fodder and water shortages, which rich famers were generally able to manage. The reduction in the number of big livestock has resulted in a lack of manure and thus in loss of soil fertility on the one hand (Fig. 4). On the other hand, increased fertilizing and pesticide use against disease, pest attacks and invasive species in crops has induced a decline in land productivity^{iv} for the long term (Tables 2 & 3).

Agriculture was the main occupation of all respondents, although 14% also had secondary jobs

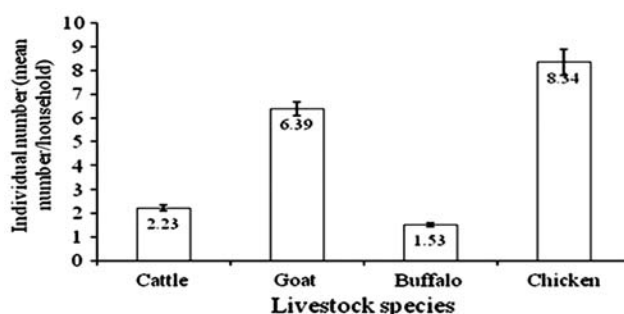


Fig. 4—Status of livestock species (number/household) Bars represent \pm SE Source: Baul *et al.* 2013²²

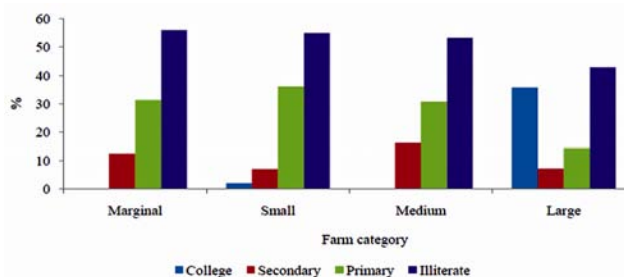


Fig. 5—Distribution of people by education based on farm category

such as driving, carpenter, labor, foreign works, etc. This low number indicates generally low access to alternative livelihood opportunities. Additionally, most of the respondents were illiterate (53%) and had only primary level education (31%), while only 4% and 12% were found to have college and secondary level education. The percentage of illiterate and primary education holders were mostly within marginal, small and medium farmers' categories (Fig. 5). Thus lack of knowledge of poor farmers might be another reason for their lower ability to cope with disasters like food shortages, poor livelihood options and loss of genetic diversity and land fertility. In connection with this, those of the middle class (*Rai*, *Limbo*) and low class ethnic groups (*Daulit*) are in a particularly vulnerable condition.

Conclusion

A study of weather knowledge of farmers of the Middle–Hill region of Nepal revealed a wealth of knowledge they possess. This indigenous knowledge learnt from nature from time immemorial is being applied in understanding climate forecasting and the whole situation and managing their vulnerability to climate change. For example, farmers were found to make appropriate decisions on cropping patterns for

cereal and vegetables crops based on local perceptions of climate conditions.

In sum, the farmers in our study were observing warmer and shorter winters, and more prolonged and hotter summers with increased temperature and decreased rainfall evident from climatic data analysis from 1982 to 2007. There was no permanent trend perceived in rainfall patterns, which were erratic in nature. In general, farmers' observations and experiences of climate parameter changes were supported by corresponding scientific studies.

Water shortages, disease and pest infestations in crops, soil fertility loss and presence of mosquitoes were considered to be the major climate risks and hazards. The conversion of *kharbari* lands to barren wasteland and the resulting grass shortage caused reduction in production of big livestock. The occurrence of heavy rainfall episodes of short duration caused to soil erosion from *bari* and *khet* lands, requiring increased application of fertilizers and pesticides against infestation of insect, pest, weed and disease, and a decreased trend in manure application because of reduced big livestock, thus resulting a long-term decline in land productivity. Marginal and small groups of farmers and women were found to be more vulnerable, with less ability to cope with climate change hazards and fewer livelihood options. The involvement of women in water collection from long distance and livestock grass and fodder collection were notable. Identification of vulnerable groups through this study can provide a platform for researchers and communities to find ways to identify options and opportunities for building resilience of these communities in the face of climate-related adversity.

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