

Local perceptions and adaptation of indigenous communities to climate change: Evidences from High Mountain Pangri valley of Indian Himalayas

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The present study was undertaken with aim to understand the perceptions of indigenous communities about climate change pattern and its local impacts on climate variables, seasons, agriculture, biodiversity and adaptive strategies in geographical and technological-isolated *Pangri* valley situated in Chamba district, Himachal Pradesh. Randomly selected 120 respondents were interviewed and their perceptions were recorded on pre-designed questionnaire. The climate change impacts are experienced in the form of decreased snowfall (98.3%), temperature rise (97.5%), late onset of monsoon (90.8%), decreased rainfall (76.7%), reduced snow-melted water availability (86.7%) and increased drought incidences (85.8%) of over the years. Further, these climatic changes affecting agriculture through early shifts in crop season (80.8%), shorter growing season (91.7%), introduction of fruit and vegetable crops (90.8%), increased incidence of insect-pest (81.2%) and diseases (84.2%) and thereby decline in crop yield (70%). However, majority of the respondents undertaken adaptive strategies such as crop diversification, traditional mixed-cropping, mixed farming, crop rotation and agro-forestry/agro-horticulture systems to cope with climate change but they are either little or unaware of modern farming practices such as snow water/glacier runoff harvesting, agro advisory services, mulching and zero tillage as adaptation strategies.

Keywords: Adaptation, High mountain, Indian Himalayas, Indigenous communities, Pangri valley, *Pangwals* and *Bhots* tribes

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Mountain ecosystems are sensitive and characterized by vast eco-biodiversity, ecological fragility, geomorphological instability and socio-economic backwardness¹⁻³. Climate change viewed as a global threat with varied local impacts. Climate change-induced impacts are manifested in the form of temperature rise, unpredictable rainfall, decreased precipitation, glacier melting, prolonged summer period, short winter period, drought and changes in seasonal cycle, and are unparalleled across the mountain region^{2,4}. These impacts are occurring at earliest, fastest and greatest in high altitude mountain areas than lower parts of the world⁵⁻⁷. High mountain ecosystems have 'high risk' and 'low resilience' due to inherent constraints such as steepness, limited arable land, short crop season, unfavorable biophysical conditions, poor farm productivity, depleting natural resource base, poor infrastructure, landslides, economic marginality, agro-technological isolation

and high dependency on agricultural activities⁸⁻⁹. Global temperature rise of 1.5°C projected to increase temperature in high altitude Hindu Kush Himalayas by 2.0-2.3°C than 2.0°C, an upper threshold limit agreed in Paris agreement of the United Nations Framework Convention on Climate Change^{10,11}. Such temperature rise would multiply the existing vulnerabilities and brings several irreversible changes in ecosystem and environment, turn these areas from 'biodiversity hotspot' to 'climate-induced-vulnerability hotspot'. Climate change impacts are commonly negative than positive on ecosystem, biodiversity, water resources, agriculture production, farm productivity, socio-economy and livelihood, depending on location in the region^{2,9,12-13}.

Himalayan region is usually labelled as a *white spot* or *data scant region* due to insufficient data on natural resources^{1,14}. Also, climate is little studied or poorly-understood due to sparsely located meteorological observatories, less effectiveness of remote sensing data due to presence of cloud cover

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and high spatio-temporal micro-climate variability in high mountain areas^{6,14-15}. Thus, climate change predictions, extrapolations or downscaling of climate products to local level are likely to be relatively less-accurate at local scale than regional and global scales¹⁶⁻¹⁷. Thus, this poses challenges for mountain natural resource developmental planning particularly agricultural land use planning, where farming communities are highly sensitive to climatic aberrations¹⁸⁻²⁰.

Local communities are well known for their close interaction and better understanding of local environment²⁰ and act as *watchkeeper* for any changes in surrounding ecosystems over the period. Their climatic perceptions reflect local issues and response, which are relatively accurate and important for decision making, devising appropriate developmental policies and adaptive capacities to reduce climate-associated risks at local scales^{7, 20-24}. Local communities evolved and sustained their indigenous knowledge and practices for sustainable management of natural resources in high risk environments²⁵. Most climate change studies focused on long-term trends of climate variables than their actual impact on local levels¹⁷. Previous studies were carried out to understand climate change, its impacts and local measures adopted to mitigate climate change impacts^{2,20,24,26-28}, but insufficient studies are reported from remote, high altitude Himalayas. In addition, effective climate smart strategies requires knowledge of the problems, communities responses and existing technological options^{7,12,23,29-30}. Agriculture technologies have the potential for poverty reduction³¹, but little or unexplored in high altitude Himalayas due to various reasons.

Therefore, study was carried out to understand the indigenous communities perceptions on climate change, its impact on local climate variables; climate associated

extreme events, seasonal changes, agriculture, biodiversity and existing strategies adopted by farming communities in poorly gauged high mountain Pangi valley located in Chamba district of Himachal Pradesh, India. This will overcome the high altitude observational gaps and provide local evidences for better understanding of climate change, its impact and provide valuable input to scientists, land use planners and local authority's for evidence based dynamic adaptation planning at local scales³², by integrating traditional and modern knowledge of farming. Study will also support the India's climate change policies and adaptation action plan, and prioritization of resources allocation towards vulnerable area in the Himalayan region.

Materials and methods

Description of study area

The study was carried out in the Pangi Valley (32° 48' 42" N to 33° 12' 31" N latitude and 76° 13' 58" E to 76° 47' 01" E longitude with elevation ranged from 2000 to 6500 m amsl) hidden between the Pir Panjal and Zaskar ranges of the Western Himalayas. The valley falls in North western portion of Chamba district, surrounded by Lahul & Spiti district of Himachal Pradesh in South and East, and Jammu and Kashmir in its northern parts (Fig. 1). The total geographical area (TGA) of 1600.52 sq km. spread over 106 rural (60 inhabited) villages across the valley. Out of the TGA, approx. 2% area is under agriculture, which supports livelihood of 18,868 populations. The sparsely populous valley has population density of 11.78 per sq. km³³. Pangi is a highly tribal populated (90%) valley, mainly composed of *Pangwals* and *Bhots* tribes, which are not exposed to outside cultural changes³⁴⁻³⁵, due to geographical isolation and remoteness.

Pangi is a under-developed valley with about 70% of total population depends on traditional subsistence agriculture and livestock rearing. The valley is rich in agro-biodiversity per unit cultivated area. The crops grown in the valley are wheat, barely (naked), *fulanu/bharesh* (buckwheat spp.), pea, maize, potato, *cheena* (Proso millet), French bean, *bhabari* (Amaranthus), apple, plum, cole crops and so on. The farm animals are *Churi* (crossbred female offspring of local cow and yak), *chur* (crossbred male offspring of local cow and yak), *desi* cow, jersey cow, sheep, goat, donkey and jackass. Poultry birds are also raised for family consumption requirement. Farmers uses *chur* for tillage (2-3) operations in traditional natural zero budgeting farming. Apart from agro-biodiversity, valley is home to various natural flora (such as walnut, *thangi* (hazelnut), pine, chilgoza pine, peeling-birch, deodar, *bedhah*, wild apricot, wild apple, poplar, bracken fern, grasses, *gucchi* (edible mushroom), kalazeera (*Carum bulbocastanum*), *tilla* or patish (*Aconitum heterohyllum*), Himalyan yew, etc.) and fauna (snow leopard, ibex, Himalayan thar, brown bear, black bear, musk deer, *chukar*, *monal*, cheer pheasants, Himalayan western tragopan, snow peacock, Himalayan woodpecker, butterflies, bees, etc.)³⁴⁻³⁶. Due to biodiversity richness, valley is referred as Important Plant Area³⁶ and a potential site for “agriculture heritage status”.

Agriculture dependency also indirectly indicates the dependency on climate, therefore, any change in climate, would have serious impacts on agriculture and livelihood due to limited growing season and grazing activities as the area remains snow-covered for 4-6 months³⁵. The valley receives little monsoon rainfall and decreasing snowfall likely to reduce water availability for drinking and irrigation purposes, where half of the cultivated area is under irrigation³³. With growing emphasis on development and conservation of natural resources in higher Himalayas necessitates scientific database, which is presently lacking in the region.

Field survey, respondent selection, data collection and analysis

The climatic perceptions and responses were collected during Land Resource Inventory field work carried out in the different villages of Pangi valley from August to October, 2016. Simple random sampling method was employed for data collection. The selected respondents involved farmers, agriculture officials and other peoples, who partially engaged in

agriculture. The respondents of age ≥ 30 yrs were chosen for interviews because they have enough experience than younger respondents (< 30 yrs)¹⁹, for comparison of climatic perceptions between two period of 1985-2000 (Period-I) and 2000-2015 (Period-II). The perceptions were collected from randomly selected 120 respondents (perception observation density =1 per 157 population) from 40 villages (1-10 respondents from each village depending on population) of the valley. They were informed about nature of work prior to data recording²⁴. Climatic perceptions were collected through questionnaire survey as used in the other studies^{19-20,28,37}. The questionnaire dealt with indigenous communities climate change perceptions on climate variables, its effects on extreme events (drought, landslide, avalanches, etc.), seasonal changes, agricultural production systems, biodiversity and adopted coping measures. While considering the questionnaire, some of the proxy-indicators were intentionally kept so that the reality of climatic changes can be captured through perceptions. The climatic parameters were



Fig. 1 — Location map of Pangi valley, Chamba district, Himachal Pradesh.

validated through proxy indicators, as meteorological database of Pangi valley is unavailable, and published literatures. Collected perceptions of indigenous communities were analyzed using frequency statistics and presented in per cent of total responses³⁸⁻³⁹.

Results and discussion

Communities perceptions on climate change

Most of the respondents perceived climate change through various associated changes experienced during the period 2000-2015 compared to 1985-2000 period. More than 90% of the respondents in the valley had perceived climate change in the form of decreased snowfall (98.3%), temperature rise (97.5%) and late onset of monsoon (91%) over the past period (Fig. 2). The respondents expounded that snowfall of 5-15 ft (1.5-4.5 m) was a regular phenomenon before 2000 in the peak months of snowfall (*i.e.* January-March) but now it reduced to 2-8 ft (0.5 -2.4 m), depending up on the elevation in the valley. A respondent from Shunn village in the valley reported that snowfall in February-March now is similar to that of earlier snowfall in November-December. Majority of the respondents believed that rainfall is decreasing (76.7%) over the years. More than half of the respondents viewed that long dry spell (60%), more intense rainfall (59.2), decreased number of cloudy days (57.5%) and stronger wind (55.8%) as result of climatic change. About 32.5% and 28% of the respondents said that snowfall timing delayed and early withdrawal of monsoon, respectively. Respondents believed that climatic events became unpredictable over the years. These perceived changes, are strong indicators of climate change in the high altitude Himalayas, as corroborated with the previous findings of changes in meteorological variables such as temperature, precipitation (rainfall +snowfall)

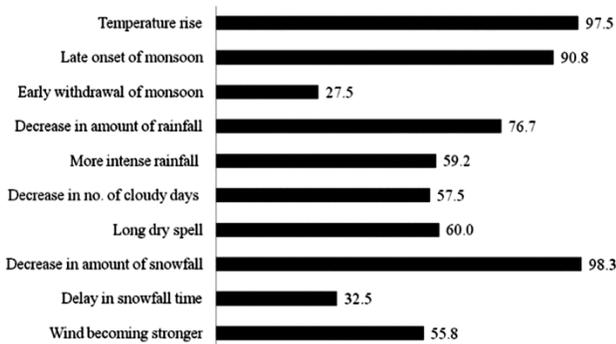


Fig. 2 — Climatic perceptions (%) of indigenous communities on climate variables in the Pangi valley (n=120).

patterns and magnitude, wind velocity and cloud covers in the Chamba tehsil as well as other parts of Himalayan region^{1-2,20,38,40-44}.

Communities perceptions on climate change-induced extreme events and seasonal changes

Among the seasons, the respondents opined that summer season (95.8%) and winter season (82.5%) are getting hotter (Fig. 3). Moreover, 91.7% of the respondents believed that winter period is reducing while about 72.5% respondents said that summer period becomes longer than previous years. The decreased snowfall and increased temperature led to reduced winter period and longer summer over the studied period. Previous studies also reported similar findings on seasonal patterns^{2,4,20,45}. About 85.8% of the respondents said that drought incidence has increased over the period due to decreased and uncertain precipitation (rainfall+snowfall) pattern and temperature rise. The respondents observed decreased flow of snow-melted water/glacier runoff (86.7%) and avalanches (80.8%) in the valley. The decreased snowfall led to decrease incidence of avalanches during winter season, decrease in snow-melted water/glacier runoff and subsequently water flows in natural springs and *nalas*. As a result of this, “adequate or deficient” water situations occurring in some parts of year in the high mountain Himalayan region and will have adverse effects on water availability for drinking, irrigation and hydro-electricity generation purposes in the mountain as well as plain areas. Similar findings on drought incidence and reduced water flows were also reported in the previous studies from different parts of Himalayas^{2,9,20,40,45}. About 45% of respondents believed that landslides have decreased over the years and rests of them were disagreed with any changes occurrence of this event. This might be due to

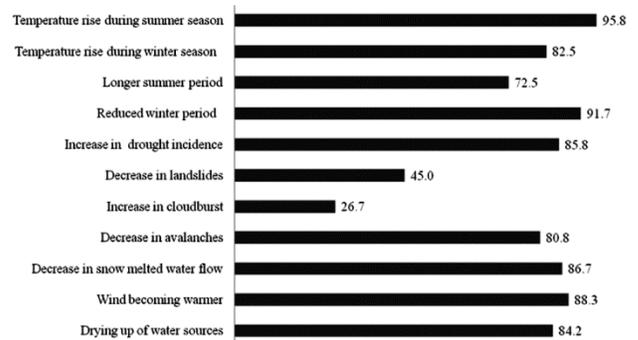


Fig. 3 — Climatic perceptions (%) of indigenous communities on season and extreme events in the Pangi valley (n=120).

decreased rainfall, reduced snowfall and its fast disappearance led to decrease in moisture content in soil. In addition to this, intense rainfall and steep slope provide short residence time for water percolation and, hence less-favorable condition for initiation of landslides. Further, more than one-fourth of the respondents were of opinion that number of cloudburst had increased while others decline the occurrence of phenomena. This might be due to the fact that such climate extreme events rarely occur⁴⁶.

Climatic perceptions on agricultural production systems

The perceptions of indigenous communities on agri-production systems (changes in cropping season, flowering time, length of growing season, crop maturity, occurrence of insect-pest and diseases in crops, introduction of new crops, crop yield and its variability over the years) to changing climate are visible in the last 15 years (Fig. 4). All the respondents (99.2%) admitted that organic pea is emerging as an off-season cash crop grown in high altitude sub-valleys such as *Sural* and *Hundan Bhattori*. This is supported by earlier observations that recently farmers started pea cultivation at high altitude valley of Himachal Pradesh^{2,35}. About 90.8% of the respondent's reported introduction of new fruit and vegetables crops. Cultivation of apple and *meetha tilla* (*Chaerophyllum villosum*), is increasing in the parts of valley, which were earlier found in wild variant. The valley also witnessed change in crops and their acreage from traditional staple crops (barley, wheat, pulses, millets) to high value cash crops (such as pea, apple, potato, patish, cole crops, tomato) in some parts of valley. The temperature rise and decreased snowfall changed unsuitable or marginal suitable area into moderately to very suitable area for cultivation of temperate/cool season crops. Similar findings were reported in previous studies of the Indian Himalayas^{2,9,47}. About 91.7% of the respondent believed decrease in length of growing season (LGS), while 80.8% respondents expounded early shifts in cropping season. Earlier crops were sown in the last week of April to first week of May, but now sowing time advanced, by 15-25 days, to end of March to mid-April, depending on the elevation in the valley. Nearly three-fourth of the respondents observed changes in flowering time of crops and about 83.3% of the respondents reported early crops maturity than previously. Temperatures rise led to

advancement of crops sowing results in early crop maturity by 15-30 days. A farmer from *Hundan Bhattori* village reported early harvesting of newly introduced pea crop by 20-30 days, which was earlier harvested in the middle of September month. Change in crop phenology may be the result of higher temperature and shortage of moisture, which led to early flowering, forced maturity, reduced growth period and grain yield^{2,4,20,48-50}. The incidences of insect-pest (81.7%) and diseases (84.2%) have increased over the years especially woolly aphid, scab, wilt in newly introduced crops such as apple and potato. About 51% of the respondents believed that new crop pests and diseases are seen in the last 15 years. A farmer from Kufa village reported appearance of new pest and disease in apple such as woolly aphid, scab and premature fallen of apple flowers. Changes in local conditions such as temperature and moisture regimes, led to occurrence and proliferation of insect-pests and diseases^{9, 20, 48}. Majority of respondents viewed that increased temporal variability of crop yield (80%) while 70% of the respondents believed that crop yield decreased over the years. About 79.2% of the respondent reported small fruit size and deformed fruit in the newly introduced crops. The reasons cited by respondents for yield decline were decreased and uncertain rainfall, shortage of moisture/irrigation water availability, decline in soil fertility and occurrence of insect-pests and disease. Such changes brought adverse effects on yield, quality of the produce and will further degrade the fragile natural resources and socio-economic conditions of mountain communities. Similar observations were also reported from India and elsewhere^{9,20,41-42,51-52}. The area under fruits, vegetables and medicinal crops are picking up,

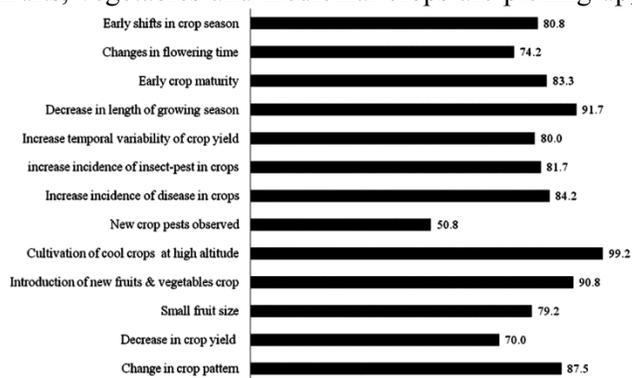


Fig. 4 — Perceptions (%) of indigenous communities on climate induced changes in agricultural production system in the Pangri valley (n=120).

hence, brought opportunities to enhance farmer income in the valley. The cultivation of high value medicinal trees/crops such as *Taxus baccata* (Himalyan Yew) needs to be promoted for improvement of farmer’s income in the valley³⁶. Similarly, previous study from the relatively agriculturally advanced Lahul valley reported the change in crop productivity and increase in farmers income². The full economic benefits could be realized, if modern agro-technologies adopted in whole package of practices with integration of local wisdoms to suit the local conditions. In addition to this, early onset and prolonged summer season and reduced winter period provides a window period of 1-2 months for cultivation of short duration crops/grasses, if the timely and adequate irrigation water availability is ensured.

Climatic perceptions of respondents about change in biodiversity and ecosystem health

Bioindicators are natural living organisms or species, highly sensitive to climatic and biogeographic changes, used as quick indicator to monitor the status of biodiversity, habitat quality, ecosystem and environmental health⁵³⁻⁵⁴. They respond quickly to the altered environment by shifting population density, habitat, behavior and physiology⁵⁴⁻⁵⁶.

In this study, change in population of bees, butterflies, mosquitoes, birds migration, birds diversity, wild bear and monkey are used as bio-indicator^{20,57-58}. About 81.7% of the respondents perceived decrease in appearance of wild bear population in cultivated and inhabited area (Fig. 5). More than three-fourth of respondents believed that honey bees population has decreased over the years. More than half of the respondents noted decrease in butterfly population. Majority of respondents said that increased appearance of mosquito (72.5%) observed in the valley. Such

decrease in honeybees, butter flies and increased appearance of mosquitoes population might be the result of climate change. About 72.5% respondents reported early migration of bird species (72.5%) while 48.3% respondents replied that there was decrease in birds population particularly of vulture, *chakor*, pigeon, monal and crow. A farmer from Takwas village reported that bird species staying period is increasing as they are coming early and returning late to their native habitat. The reason could be climate change, developmental activities such as blasting, use of drugs for animal diseases and use of agro-chemicals in apple cultivation. About 40% of the respondents believed that monkey population is increasing in the cultivated and inhabited area of the valley and seen as growing menace for crops cultivation in the valley. Previous studies also reported change and movement of some insects, birds and animals species in the Himalayan region^{2,4,19-20,59-60}.

Validations of climatic perceptions through proxy-indicators

Perception studies are useful to mimic the local conditions, if due care is taken. The errors were minimized through random sampling, validation⁵⁹, good perception observation density (1 per 157 population) and proxy-indicators. In this study, wind warming, drying of water resources and change in crop pattern were used as proxy-indicators for changes in temperature, water resources and agriculture, respectively (Fig. 3 and Fig. 4). Perceptions on wind warming (88.3%) were closely perceived to average of temperature rise perceptions on summer and winter seasons (89.2%) than annual temperature rise (97.5%). Perceptions on drying up of water resources (84.2%) are closely related to decrease in snow melted water flow (86.7%). The climatic change impacts on drying up of water resources are also evidenced by average of perceptions on decrease in snowfall (98.3%) and rainfall amount (76.7%), which results in 87.5%. Perceptions on crop pattern (87.5%) are related to introductions of new fruits and vegetable crops (90.8%). However, there was perception variations among the communities, with proxy indicators to related indicators, were ranged between 1-14%. These variations might be due to variations in geographic conditions and elevation location.

Existing adaptation strategies to cope with climate change

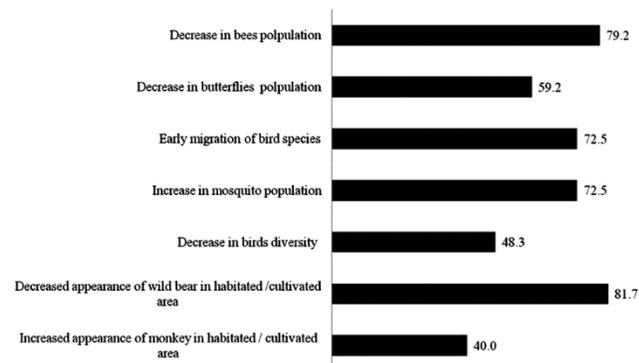


Fig. 5 — Climatic perceptions (%) of indigenous communities on biodiversity and ecosystem health in the Pangri valley (n=120).

To cope with climate change, indigenous communities adopted strategies such as crop diversification, mixed cropping, mixed farming, crop rotation, agroforestry/ agro-horticulture and improved varieties to build resilience against climate change (Fig. 6). About 96.7% respondents have diversified their crop on their land holding to meet parts of their own food requirement and maximization of farm produce. About 94.2% of respondents adopted 2-3 yrs crop rotation, which was earlier adopted as yearly rotation to maintain soil fertility. About 83.3% of the respondents have adopted traditional mixed cropping in form of maize and frenchbean, potato and amaranthus, pea and potato. About 79.2% of the respondents practicing mixed farming (crops, animals) as the adaptive strategies to reduce climatic risks. Recently, some farmers reported rearing of Jersey cow/improve variety in the valley. About 70% of the respondents adopted improved varieties/ seedlings in newly introduce crops as adaptation strategies. However, improved varieties are adapted to lesser extent in other crops. About 56.7% of the respondents were using farm yard manure (FYM), farm animal urine and wood ash as indigenous traditional knowledge (ITK) for maintaining soil fertility and other agricultural purposes. A farmer from Saach village reported decrease in FYM application due to decline in animal population. The low percentage of FYM use might be due to movement of animals to high altitude alpine grasslands (locally known as *adhwari*) for summer grazing, which makes difficult to bring such bulky materials to cultivated area. The climate change and overgrazing, results in degradation of grazing land, low grass production, shift in grazing area and ultimately degradation of land resources through high soil erosion, otherwise grasses act as soil binder³⁸. About two-third of respondents adopted traditional agroforestry, agro-horticulture systems for reducing soil erosion, regulation of field microclimate, maximizing output per unit area and to meet the fodder requirement of animals. Previous studies reported similar traditional farming practices as coping measures^{20,61-63}. However, more than 83% of the respondents did not adopted snow water/glacier runoff harvesting. Similarly, about 61% and 49% of the respondents were unaware about the mulching and zero tillage practice, respectively. Zero tillage and mulching are well known climate smart strategies which reduce soil erosion, conserve soil moisture and

moderate soil thermal conditions^{20, 64}. In the valley, farmers are carrying 2-3 tillage operations by *chur*. Further, About 5% of respondents were aware of agro advisory services such as Kisan Call Centre for reducing the risk of climate change.

Increasing water scarcity for drinking and irrigation purposes could be overcome by water conservation technique like artificial glaciers or glacier grafting as adopted in Ladakh region of high altitude cold desert⁶⁵⁻⁶⁷. Agro-production risks could be reduced through reorientation or transformation of farming techniques by better integration of traditional and modern farming suit to local conditions⁶⁴. The uncertain climatic condition requires dynamic farming practices such as soil and water conservation techniques, development of multiple stress tolerant varieties, timely access of agriculture inputs, communities seed and fodder banks, integrated pest management, adoption of improved management in agro forestry/agro horticulture (integration of cash crops/improved varieties, fruit, fodder trees and medicinal crops) needs to be adopted. In this valley, livestock is important component of mixed farming, so there is a need of scientific livestock rearing through improved animal breeds and feeding strategies. This will reduce the livestock grazing density, promote stall feeding and improve livestock productivity. New opportunities created by climate change such as growing period and prospect of new crops (vegetable seed production, cultivation of off season vegetables, medicinal crops and nuts) requires creation and expansion of necessary infrastructure such as road, irrigation, processing of farm products,

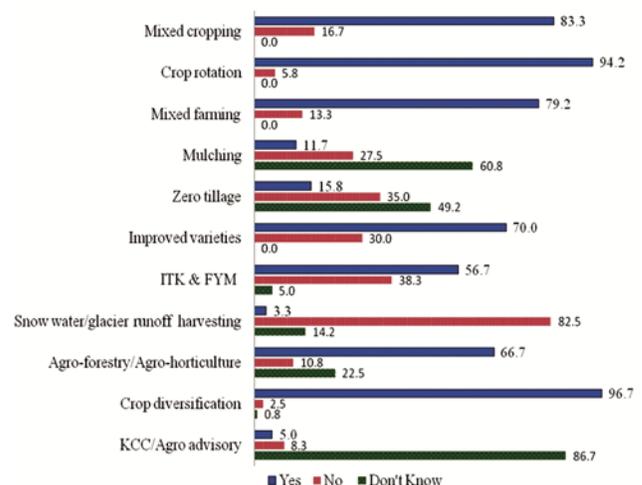


Fig. 6 — Perceptions (%) of indigenous communities on adaptation strategies in the Pangri valley (n=120).

eco-labeling of products, crop/animal insurance and market access. In addition, awareness and capacity building of the indigenous communities should be considered for conservation and management of natural resources⁶⁸.

Conclusions and policy implications

The study established that climate change impacts are visible on traditional subsistence farming, which is under increased biotic and abiotic stresses in the high mountain Himalayan valley. The indigenous communities have limited climate adaptive capacity and preparedness such as crop diversification, crop rotation, mixed cropping, agroforestry/agro-horticulture and mixed farming. Economic backwardness and poor knowledge of modern climate-smart strategies such as zero tillage, snow water/ glacier runoff harvesting, mulching and agro advisory services makes the situation more alarming. The cost effective and environmentally friendly traditional measures need to be reoriented through integration of modern farming techniques suit to local-conditions. Further, new opportunities and challenges brought by climate change require timely access of agri-inputs, creation and expansion of infrastructures (irrigation and road), soil and water conservation measures, crop/animal insurance, eco-labeling of farm products and market access to realize the full economic benefit. In addition, scientific livestock rearing should be taken into consideration during developmental planning so that erosion of biodiversity and natural resource could be minimized in fragile high mountain areas. Further, awareness and capacity building of indigenous communities should also be taken on priority.

This study will be helpful to support government agencies in evidence-based decision making and dynamic climate smart farm planning in Pangri valley and other parts of Indian Himalayas.

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