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Climate change adaptation in the western-Himalayas: Household level perspectives on impacts and barriers

Rajiv Pandey, Praveen Kumar, Kelli M. Archie, Ajay K. Gupta, P.K.. Joshi, Donatella Valente, Irene Petrosillo

Highlights

• This study assesses climate change adaptation of Himalayan communities with focus to role of information and communication.

•This paper assesses the barriers of climate change information for adaptation planning and action.

•Traditional knowledge is the key for developing strategies for rural communities suitable to cope climate change impacts.

•Additional information is needed to match the high priority community needs with viable adaptation strategies.

•Adaptation plans must be integrated for enabling sustainable development through the efficient use of information.

Abstract

A vast amount of knowledge and experience on coping with climatic variability and extreme weather events exists within local communities, and indigenous coping strategies are important elements of successful adaptation plans. Traditional knowledge can help to provide efficient, appropriate and time-tested ways of responding to climate change especially in far-flung communities. However, little is known about how traditional coping strategies translate into adaptation to long-term changes, and to what degree they prevent

pro-active, transformational responses to climate change. This paper assesses the use of climate related information for communities in the Himalayan foothills of rural India, and reports on the barriers to adaptation planning and actions. Surveys have been carried out to analyze the current practices and the role of information in planning for climate change adaptation in the rural areas of the Nainital region of India located in Western Himalaya. Respondents perceive the local climate change, the intensity of change, and the negative impacts on the community and landscape. Decreases in water quantity and changes in precipitation patterns are among the major concerns for respondents, however, communities have begun to use traditional knowledge and historical climate information for developing strategies suitable to cope with impacts of climate change. Going forward, additional information is needed to match the high priority community needs with viable adaptation strategies. Lack of money, lack of access to information, and lack of awareness or understanding are considered the three largest hurdles besides low priority for adaptation, recognized by community members as barriers to adaptation planning and actions. Adaptation plans must be integrated into both top-down and bottom-up approaches to plan for enabling sustainable development and the efficient use of information for adaptation. Finally, traditional knowledge seems to be useful not only in contrasting climate change impacts, but also in recovering several ecosystem services that work all together for enanching the quality of life of villagers at local scale.

Keyword: Communication; Coping strategy; Information barrier; Resilience; Traditional knowledge

1. Introduction

Mountain areas of the world cover 24% of the global land surface (UNEP-WCMC, 2002) and host roughly 12% of the global human population (Huddleston and Ataman, 2003). Mountain areas are repositories of biological and cultural diversity and provide vital ecosystem services, such as the provisioning of food and wood, natural hazard protection, habitat diversity and cultural services (Körner and Ohsawa, 2005) to both local communities and those in the surrounding lowlands (Grêt-Regamey et al., 2012). However, mountain environments are fragile, and people living in mountainous areas are exposed to environmental stressors as well as human stressors (Nogues-Bravo et al., 2007, Macchi, 2010). These stressors are interconnected and, together with the geographical isolation, increase the existing pressure on water, land, and other natural resources and services, which can have serious consequences for mountain resident livelihoods. Although the impacts of climate change act equally on developed and on developing countries, on the rich populations as well as on those indigent, however, underdeveloped and poor nations are

more vulnerable (Adger et al., 2003). Climate change impacts intensify the stress on the system with wide ranging effects on the environment, biodiversity, and socioeconomic conditions (Beniston, 2003). Consequently, these new conditions together with the increased human pressure on natural systems may limit mountain resident's inherent capacity to cope and adapt to changes (Macchi, 2010). However, little knowledge exists about the impacts of climate change on the livelihoods of mountain communities, and their capacity to adapt to climatic variability and change (Macchi, 2011), except at very coarse spatial and temporal scale (Fagre et al., 2003).

In a socio-ecological system the adaptive capacity can be the adaptation process through which societies make themselves better able to cope with actual or expected climate stimuli or their effects (McCarthy et al., 2001, IPCC, 2001b). The accurate analysis of the adaptation process requires to focus on the local scale, where the evaluation of local responses at the individual or household level can provide evidences for expected future conditions, and allows for appropriate adaptation policy responses (Adger and Vincent, 2005, Smit and Wandel, 2006).

However, lack of information has repeatedly been identified as a barrier to climate change adaptation planning and implementation (Crabbe and Robin, 2006, Mukheibir and Ziervogel, 2007, Tribbia and Moser, 2008, Lowe et al., 2009, Carter and Culp, 2010, Foster et al., 2011, Archie et al., 2012). Therefore, the possibility to have access to relevant information is an extremely valuable resource, and communities that have access to this kind of information can successfully carry out an adaptation process (Cruce, 2007). Although not always available or accessible, good quality information from multiple sectors (climate, hydrology, agriculture, forest and socioeconomics) are needed both to assess the impacts of and the vulnerability to climate change and to work out on adaptation strategies (Fischer et al., 2002, Schroter et al., 2005). Successful adaptation will entail adjustments and changes at every level, through local-scale actions that will provide the most effective protection for communities and individuals, especially in areas with marginalized or natural resource dependent populations.

Lack of information is not the only barrier to action (Archie et al., 2012), because other constraints such as lack of funding, competing priorities, and lack of public support and understanding are all hurdles that often have to be overcome (Shackleton et al., 2015). Therefore, there is the need to make climate information more accurate, accessible and useful considering the importance of these information to support adaptation and to manage climate risk especially in rural areas (Roncoli et al., 2002, Ziervogel et al., 2005, Hansen et al., 2009). A significant barrier to adaptation is not only the presence of gaps in knowledge (Klein et al., 2014) (or knowledge deficits) related to the impacts of climate change,

adaptation options, and uncertainty, but also the significant obstacles to have access, integrate and mobilize knowledge (Adger et al., 2007, Klein et al., 2014). Science, information, knowledge and learning are necessary factors for adaptation planning and implementation (Klein et al., 2014, Ford and King, 2015).

This paper intends to fill a research gap related to the role of information to adapt to climate change. This is carried out by providing both the theoretical context to understand the relationship between traditional coping strategies and adaptation, as well as some practical needs of vulnerable households in the Himalaya that can be in common with other mountainous regions. In order to address this issue, the current study focuses on the perspectives of residents of rural mountain communities in the Indian Himalaya. In particular, the aim of this paper is to address the role of traditional knowledge and adaptation strategies in countering the ill-effects of the climate change, and to analyze whether sufficient information exist to enable residents to adapt.

1.1. The overview on Himalaya

The Himalaya, one of the largest mountain systems in the world, lies in one of the poorest regions in the world (Hunzai et al., 2011), and it is a physically and biologically complex and diversified mountain system. The mountains are characterized by high biodiversity, undulating physical settings, varied climatic regimes, and diversified social and cultural peculiarities. Unique historical, linguistic, political, cultural (religions, house styles, livelihoods farming methods), structural, ecological, and psychological dimensions define distinctly the region and its people (Dahal, 2008). The Himalayan region, a fragile area susceptible to multiple hazards such as earthquakes, landslides, droughts, wildfires, cloudbursts, is facing a multitude of undesirable changes across both biophysical and social realms many resulting from climate change (Jing and Leduc, 2010). It is expected that the net increase in temperature in the region will be between 1.7 °C and 2.2 °C by 2030 over 1970s levels (INCCA, 2010), however, increase in incidence and intensity of extreme events has been observed during the last few years (UAPCC, 2012). These changes pose serious threats to water resources, biodiversity, agriculture, human health, and food security (Chaudhary and Bawa, 2011), integral components of a good quality of life (MEA, 2005). People of the region lack access to basic facilities, services and institutions, and have higher dependency ratios on natural resources (Hunzai et al., 2011). Thus, the geography and socio-economic settings of the Himalaya make the region highly vulnerable to risk factors such as climate change, population growth, and globalization (Gerlitz et al., 2014). A risk-based approach could help to clarify the underlying relationships between the actual adaptation

behavior, the awareness of climate change-related phenomena, and local people beliefs in future climate change (Li et al., 2017).

In the context of climate change, vulnerability is the degree to which a system is susceptible to, and unable to cope with adverse effects of climate change, including climate variability and extreme events (IPCC, 2001a). Climate change will pose additional impacts on the social and natural resources under the current social and physical settings of Himalaya, making the region more vulnerable (IPCC, 2007). Therefore, the impacts of climate change and the ongoing adaptation strategies can exacerbate a precarious situation for the Himalayan communities, already vulnerable to a multitude of environmental risks. Specific knowledge and data on human wellbeing in the Himalaya is limited, however, the continued effects of climate change need immediate understanding of local scale vulnerability. Therefore, it is important to understand how households and communities currently deal with change and to analyze whether or not these strategies will be beneficial in the future.

The knowledge of preferences and of the social prospects of the local community encourages the development of environmental decision-making process more informed (and therefore most reliable) and qualitatively more valid (Davies et al., 2015). The management policies must be inspired to the social perspectives in order to be considered adaptive. So that, in the future these policies should combine human welfare with the enhancement of ecosystem services. In this way, it is essential to manage ecosystems and to create future economies that foster both sustainable ecosystem services supply use and the promotion of human well-being (Reyers et al., 2009). In particular, the investigation of perception is fundamental for understanding adaptation and transformation vulnerability state. This because in the decision-making processes it is fundamental the way how people perceive the risks of climate change that it is the basis of their resulting adaptive capacity (Coelho, 2004). Their perceptions of the risks linked to climate change bear heavily the decisions about their everyday actions and how to adapt their behavior (Menapace et al., 2015).

Human perception of the environment shapes and is shaped by human knowledge of the environment, and involves interpretation of events or information; therefore, any landscape consists of two basic elements, the biophysical components of an area affected by human activities and analyzed through “objective” analysis, and the perception and the value assigned to the environment by people, evaluated through “subjective” analysis (Petrosillo et al., 2007, Petrosillo et al., 2013). However, researchers have been carried out to evaluate the perception of household or community about different aspects of the climate change, but in a very disaggregate manner. In this research context, Tse-ring et al. (2010) and Chaudhary and Bawa (2011) have examined perception of changes in climate

and consequences of such changes for biodiversity and agriculture, through household interviews in Himalaya. Vulnerability related to climate change has also been assessed in Himalaya considering different targets, such as the community (Pandey and Jha, 2012); water (Pandey et al., 2015); socio-ecological systems (Pandey et al., 2016a, Pandey et al., 2016b); and multidimensional livelihood vulnerability (Gerlitz et al., 2016). The adaptation based on vulnerability to climate change has also been assessed by Pandey et al., 2016a, Pandey et al., 2016b, and Pandey (2016). However, very few researches have been carried out with the aim to analyze in detail the local responses and the role of information to adapt to climate change in this region.

2. Study area

The study area is represented by the rural area of the Nainital district of Uttarakhand, India (Fig. 1). This area covers roughly 3860 km^2 of land in the outer ranges of the mid Himalayas and it is situated near 29.38°N Latitude and 79.45°E longitude. According to the 2011 census, the population of the Nainital district was 955,128 individuals with a population density of 225 people per square kilometer, however, the population density in the study area is much lower than the average of the Nainital district, presenting a relatively high literacy rate of about 85%, and with the same number of men and women. Topographically, the study area is characterized by undulating hills and rugged mountains with varied elevation ranging from 500 m to 2300 m above sea level. Major forest tree species are chir pine (*Pinus roxburghii*), deodar (*Cedrus deodara*), moru oak (*Quercus floribunda*), bamboo, banj (*Quercus leucotricophora)*, sal (*Shorea robusta*), and silver fir (*Abies alba* Mill.). Most of the villages are remotely located and lack basic infrastructure in terms of road connectivity, transportation, markets, schools, banks and hospital facilities.

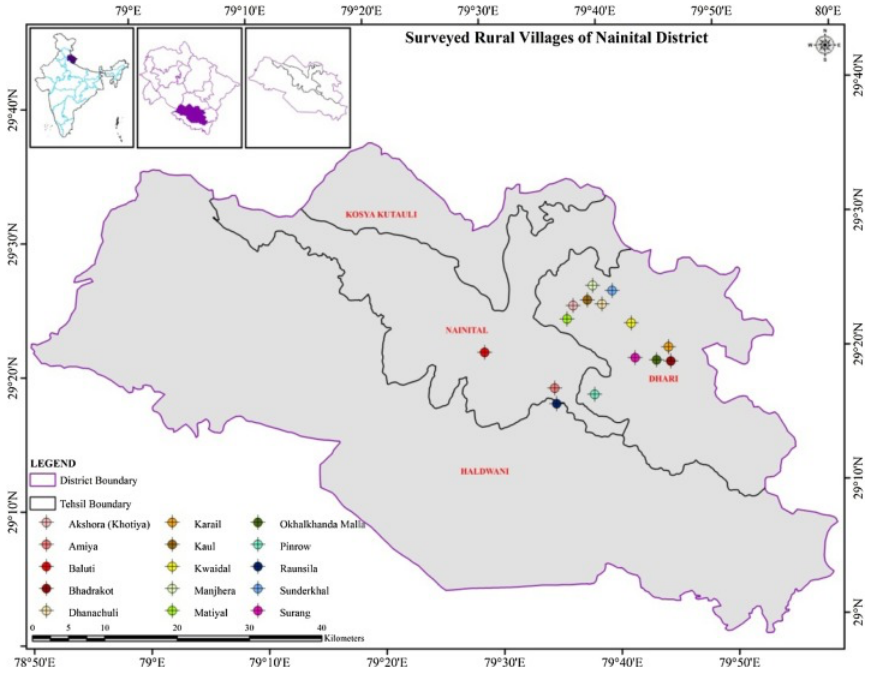

Fig. 1. Surveyed rural villages of the Nainital district, Uttarakhand.

Despite a distinct lack of irrigation, agriculture is the primary livelihood for residents of this region followed by wage labour activities such as road construction, forest work and market help. Villagers raise cattle for milk for self-consumption and use their manure as fertilizer. Village residents are dependent on forest resources for fuel, fodder, fruits and meat. Farming, which is largely rain fed, is mainly terrace based with major crops being rice (*Oryza sativa*), wheat (*Triticum* spp.), maize (*Zea mays*), mandua (*Eleusine coracana*), and barley (*Hordeum vulgare*). The major vegetables grown are potatoes (*Solanum tuberosum*), cabbage (*Brassica oleracea*), and pea (*Pisum sativum*). Organic fertilizers (a mixture of dung and pine needles) are generally used for increasing farm production. Major tree species for agroforestry in the region are banj oak (*Quercus leucotricophora*), chir (*Pinus roxburghii*), padam (*Prunus cerasoides*), kweral (*Bauhinia varigata*), kakhad (*Pistacia integerrima*), and bhimal (*Grewia optiva* L.). Trees planted near farms provide firewood, fodder and timber for farmers, as there is a ban on wild tree felling in the region.
This research includes residents from 15 different villages, considering that roughly half of the villages are accessible by motorable metalled road (Amiya, Baluti, Karail, Matiyal, Okhalkhanda Malla, Pinrow, Raunsila, and Surang), while the others can only be reached via path (Akshora, Bhadrakot Dhanachuli, Kaul, Kwaidal, Manjhera, and Sunderkhal). Most of the households in the study area are involved in agriculture as cultivators or agricultural labourers. Although people still practice subsistence farming in various villages, many farmers have started cash crop farming using hybrid seeds, fertilizers, and pesticides. The main cultivated cash crops are wheat, potato, cabbage, and pea. The local panchayat or

village government is in charge of the community forest, but the village forests in this region differ in volume, species composition, quality, and density. In Sunderkhal, Manjhera, Kaul, Kwaidal, Amiya and Raunsila, the village forests are quite dense and largely comprised of broad leaf species. In contrast, Baluti, Matiyal, Dhanachuli and Pinrow, Karail, Akshora, and Surang villages have mostly pine forests. Villagers obtain fuel wood, fodder, leaves and twigs for composting from the nearby forests.

3. Materials and methods

In order to obtain data about the role of information for adaptation planning in Himalayan mountain communities, a paper-based survey, based on previous research on similar topics (Tribbia and Moser, 2008, Theoharides et al., 2009, Archie et al., 2012), has been carried out. The questionnaire has been tested in the Kehri village of the Dehradun District in India to ensure questions have been worded clearly, potential responses could cover common themes, and the topics could be relevant to the proper audience. The questionnaire was also fine tuned further in the study region. Free responses have been solicited for open-ended questions, and have been later categorized using a comprehensive and predefined list unknown for respondents in order to avoid possible bias. The questionnaire (Appendix A in Supplementary material) is composed of a total of 30 questions including open-ended, Likert scale, check-all and close-ended questions, and it is divided in four parts focused on: the geographical information about the village, the socio-demographic profile of household, questions on how climate change affects community household decision making and, finally, people information needs to take decisions. Therefore, respondents were asked questions on a variety of subjects such as: the types of climate impact they have already experienced, how they have responded to changes, what types of information they currently use and/or need, and what barriers exist to adaptation planning and actions.

A participatory rural appraisal (PRA) approach (Macchi, 2011) has been used for ascertaining quality household level data. To ensure the sample did not exclude households with low levels of literacy, researchers allowed for oral responses in addition to written ones. As befitting the local customs, most of the survey respondents were considered the head-of-household who was well acquainted with the prevailing mechanisms and livelihood options. For the study area, ninety households have been chosen at random from 15 different villages situated between 600 m and 2200 m above sea level in the Nainital district of northern India (Fig. 1). Villages in this region contain between 40 and 80 households, and the survey has covered approximately 10% of the households from each village. Respondent households have an average of 6 residents. Although situated at different altitudes, these villages have similar challenges, are remotely located, practice similar types of cultivation, have few

employment opportunities, and high forest dependency. Researcher visits to the villages prior to data collection have shown little if any differentiation in household socio-economic status, confirmed also by village residents, therefore, respondent households were numbered and have been chosen using a random number table.

4. Results and discussion

4.1. Household characteristics

In this region, men are typically the spokesperson for the family, so that male people represent 78% of the surveyed respondents. The maximum and minimum age of household respondents is 85 and 24 years old respectively with a mean age of 53. Overall, the female to male ratio in the composition of households is nearly equal (0.92). The number of people living in each household varies dramatically from 2 to 26 with a mean family size of 5.25. There is a markedly low level of education among interviewed households in the study area, and nearly half of the household members is either illiterate (13.3%) or has only completed primary school (32.2%) with only a small number having completed at least a bachelor's degree (11.1%). Women have significantly lower levels of education than men. Low levels of educational attainment in this region are due to poor local educational facilities and a lack of importance placed on formal education by older generations.

In this region, the economic status can be assessed by analyzing the type of house in which a family resides within a village. Three general types of housing exist in the villages surveyed in this research: pakka, semi-pakka and kaccha. Pakka houses are made entirely of brick and concrete and denote the highest level of economic status. Semi-pakka houses are made in the same fashion as pakka except that they lack a solid surface roof. Semi-pakka houses denote less economic status than the former but more than kaccha houses, which are made of mud and wood. The proportions of pakka, semi-pakka, and kaccha houses are, respectively, 57%, 29% and 14%. Most families interviewed do not have modern means of transport (only 21% own a motorized vehicle), so they have to walk for several kilometers to reach any destination outside their village. Resources obtained from community forests are extremely important. The all households gather wood for fuel, however slightly over a quarter of respondent households occasionally make use of liquid propane gas (LPG) for cooking. Only one household in this sample used bio-gas as cooking energy.

Generally, households in this area depend on more than one profession for their subsistence. Sixty six percent of the respondent households practice agriculture as their primary profession, followed by service employment (18%), self-employment (9%), and wage labour (5%). Agriculture is, generally, rain fed and very little agricultural infrastructure exists in

this region with a mere 6% of agriculture currently under irrigation. Sixty-four percent of agricultural land is farmed without irrigation and 30% is uncultivated. Nearly all the surveyed households use organic manure made of compost, dung, leaves, and twigs from local forests for increasing the production of crops, but 78% use also chemical fertilizers. The proportional distribution of livestock is 40% cows, 24% goats, 13% oxen, 15% buffaloes, and 8% other animals with an average of 2.8 livestock per household.

4.2. Challenges faced by the mountain communities

To better understand villager perceptions of climate change within the context of other challenges they currently face, respondents were asked to rank the potential socio-economic and ecological challenges currently faced by their community. Ninety one percent of respondents choose economic issues as the top socio-economic challenge followed by 81% who choose disturbance in social cohesion, and only 31% choose population pressure. Changes in precipitation, temperature and water quantity and quality are considered to be the most challenging ecological issues with respectively 100%, 86%, and 57% of the responses (Fig. 2). To gauge the relative importance of the challenges reported by the respondents, they were asked to rate the severity of the challenges that they chose. In the case of ecological challenges, 79% of respondents report change in precipitation, and 55% report water quantity and quality as very severe challenge. In contrast, for socio-economic challenges, only 51% and 31% of respondents report economic issues and population pressure as very severe challenges. On average, respondents consider challenges to be only slightly problematic with no responses of severe or very severe (Fig. 3).

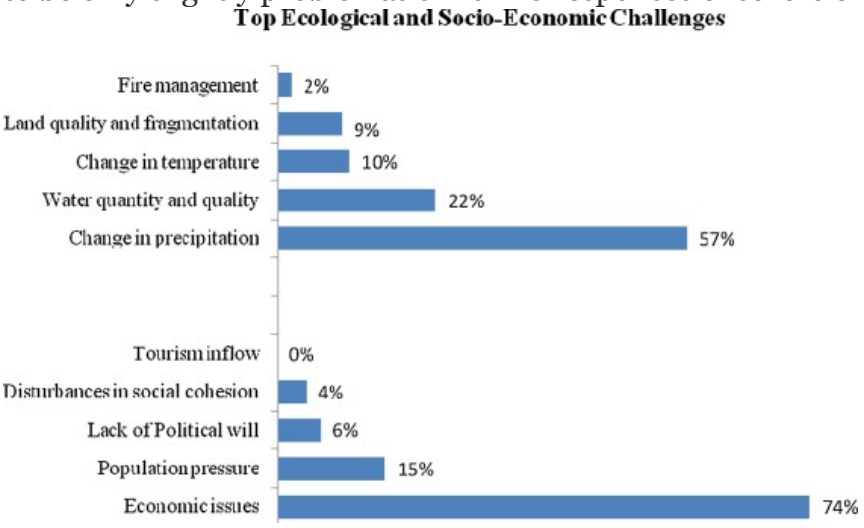

Fig. 2. Ecological and Socio-economic challenges for local communities. Graph shows the percent of respondents who consider each choice to be the top challenge in each category.

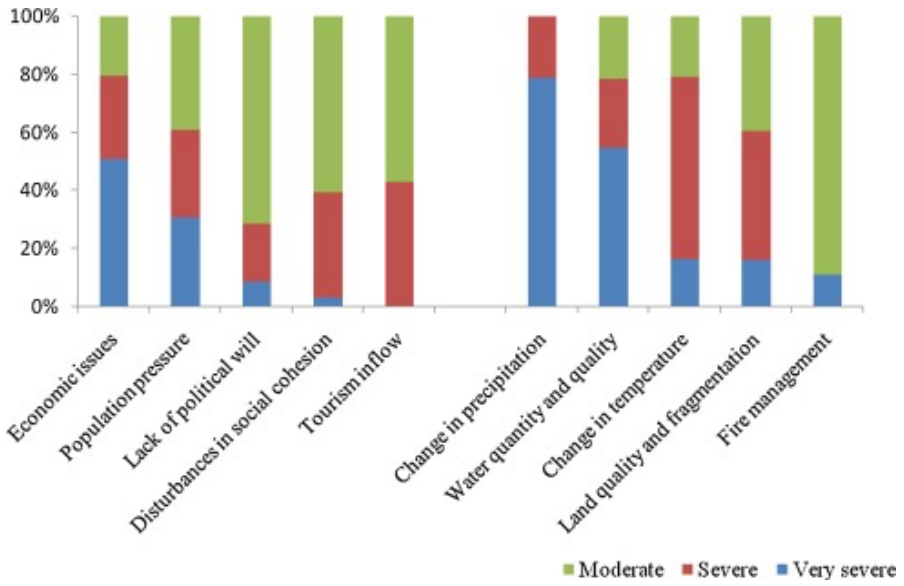

Fig. 3. Relative importance of Socio-economic and Ecological challenges for local communities. Graph shows the percent of respondents for each choice of the different challenge.

4.3. Community perceptions of climate change

Respondents in this study consider climate change as it relates to local and regional changes in weather patterns and conditions, and do not necessarily refer specifically to the broad concept of global and anthropogenic climate change. Although respondents may not necessarily understand the complex connections between human activity and climate change, their responses show that they are generally aware of the problem and they have at least a broad understanding of the causes and implications. The villagers are aware that changes in temperature and rainfall that are taking place in the region can be attributable to deforestation and vehicular pollution. Eighty nine percent of respondents agree that climate change is real and it is already happening now, with another 11% responding that climate change is probably happening but the impacts will be seen in the near future. In addition, 85% of respondents consider climate change to be either a serious or very serious problem, with the remaining 14% reporting that it is a somewhat serious problem. Surprisingly, the collective attitudes about the urgency of the climate change problem stand in stark contrast to the lack of severity assigned to the top challenges mentioned previously.

4.3.1. Local impacts of climate change

To assess perceptions of local vulnerability to climate change, respondents were first asked to rate the likelihood of 12 potential impacts of climate change on their community. Respondents were also asked to rate each option on a scale from very low possibility to high possibility, including options for do not expect to change and don't know. Five of the

presented potential consequences: negative impacts on local wildlife, negative impacts on local forest ecosystems, increased local air temperatures, less frequent local rainfall and decreases in local water quantity or quality were considered by at least 90% of respondents to be at least moderately likely as a result of climate change (Fig. 4). The two potential positive impacts of climate change on wildlife and local forest have been selected by a very low percentage of respondents, therefore impacts from climate change are generally considered to be negative.

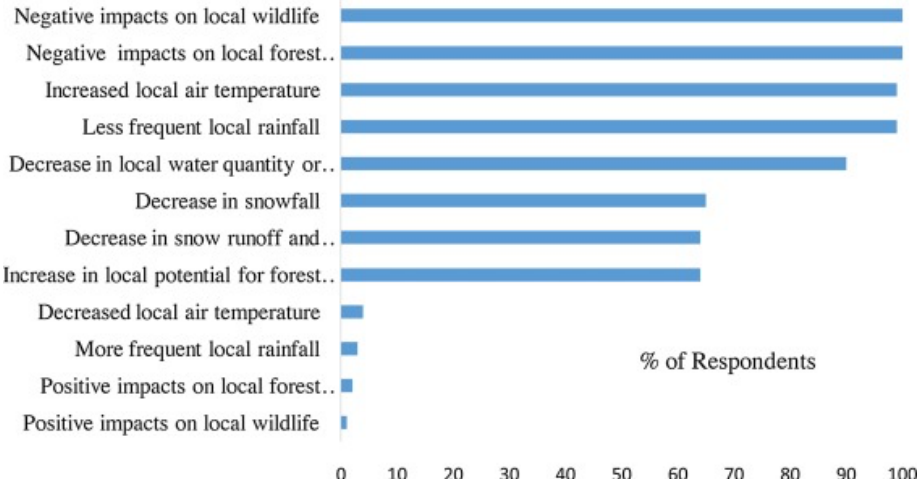

Fig. 4. Likelihood of potential impacts from climate change on local communities as reported by respondents. Bars show the percent of respondents who consider the option to be at least moderately likely.

The impact of climate change on local forest ecosystem is quite evident, with effects on forest deliverables (fuelwood and fodder – provisioning ecosystem services) that result reduced and on the regulation of local micro-climate (regulating ecosystem services). On the other side, the negative impact on local wildlife can be attributable to changes in their habitat and loss of food. Water for crop irrigation as well as for potable purposes is considered as a scare resource. The change in precipitation has tremendously affected the crop productivity and also the water availability in the springs, resulted into low availability of water to residents for day-to-day purposes. The increase of forest fire is also a serious concern, as it changes local micro-climate, reduces forest productivity and affects wildlife habitats' availability.

4.3.2. Changes in precipitation and temperature

The complex topography of the Himalayan region has led to an abundance of micro-climates; thus this region will experience the same effects of climate change (Pandey, 2016). Because large-scale data collection often lacks the detail necessary to facilitate local response to changes (Chaudhary and Bawa, 2011), the research is specifically focused on the local perceptions of changes in climatic conditions. Eighty percent of respondents report recent shifts in precipitation patterns in terms of duration, frequency and timing.

Nowadays, monsoon rains are slightly displaced in irregular pattern in the period beyond mid-August. Rainfall intensity (the amount of rain falling at one time) has reportedly increased in recent years but storm frequency and duration has decreased. Respondents collectively agree that winters have become drier and slightly more than half of respondents (59%) report that the volume of snowfall has decreased over the past 20–25 years. According to respondents, snowfalls that generally interest the area at least two or three times during the winter, are completely absent in some recent years, as well as it is evident the reduction of perennial snow.

Eighty-five percent of respondents report increased average local temperatures and increased occurrence of extreme temperatures during the most recent years. Temperature changes have been experienced year-round and respondents report that winters are shorter and less severe than previously. In the past, winter conditions began in October and continued through March, while in recent years, winter conditions have been relegated to a shorter period of November–February. Respondents report that rising winter temperatures and changes in precipitation patterns have led to a decrease in water availability in the summer as streams dry up early in the season and are not consistently replenished by rainfall. Respondents from each of the involved villages report that changes in precipitation patterns and forest degradation have resulted in low groundwater recharge; which has reduced water levels in local springs. The small stone structures that house these springs, called nalas, are important cultural and spiritual buildings. Thus the drying of the springs has community impacts beyond just diminished access to water.

Statistical data and studies corroborate reports of both precipitation and temperature changes in this region. The annual mean temperature in the Nainital region has increased by 0.21 °C over the last 15 years (IMD, 2015) and annual average precipitation in this area has declined significantly during the past two decades (Mishra, 2014).

4.3.3. Agriculture and land degradation

According to 74% of respondents the productivity of agricultural land has been declining in recent years, and 60% believe that recent fluctuations in weather, including the unpredictability of precipitation, have had the major negative impacts on agriculture. The productivity of total food grains in the state has fallen from 1.79 m in 2009–10 to 1.63 m in 2014–15, leading to 8.79% decrease (MoAFW, 2015). However, other potential causes of agriculture decline are unrelated to climate. Research in this region has shown that application of chemical fertilizers and pesticides initially increases yields but has diminishing returns over time (Chhetri, 2015). Respondents also report that the application of chemicals has resulted in a decrease in soil moisture, which is compounded by changes in

precipitation patterns. Faulty road construction in the fragile region makes the region vulnerable to landslides, and continuous soil erosion contributes to a loss of fertile soil. Thus, both anthropogenic and climatic factors seem to be responsible for the reduction in agriculture productivity leading some residents to gradually abandon agriculture. As a consequence of declining agricultural conditions this region has seen increases in emigration, given the reduced food availability. Migration from the district was 206,772 persons (Census of India, 2001), and the current data on migration is not available for Census 2011, moreover, the respondents were reported higher migration due to complexities in livelihood. In some villages, at least 50% of the land is now lying barren due to migration, as observed during data collection and confirmed by villagers.

Residents who have stayed and continued to cultivate their farmland have begun to make changes in their cropping patterns. Erratic, unpredictable, and often insufficient rainfall has led to drastic reductions in the cultivation of certain crops such as wheat, cabbage, potatoes, and peas. Cultivated land has also been at increased risk of destruction by wild animals such as wild boars and monkeys, prompting residents to switch to alternative vegetable crops or fruit cultivation, or in some instances to leave their land barren. The pattern of human-wildlife conflicts leads not only to a reduction in crop productivity but also reduces the opportunities for adaptation against other stressors such as climate change.

In addition to the impacts on agricultural land, residents report that forests have also been suffered under changing climatic conditions. Ninety eight percent of respondents believe that forests are among the most important natural resources in Uttarakhand as they are central to the agricultural economy. Residents of this region are dependent on forests for fuel wood, grass and other biomass. Because of recent changes in weather patterns, broad-leaved species, a highly nutritious source of fodder, are gradually disappearing from the forest. Because of changes in precipitation patterns, moisture availability is either insufficient or not timely to allow for proper germination. Respondents report that chir (pine) forests thrive in the drier soil, but forest fires, even in mixed forests, have become more frequent during recent times.

4.4. Adaptation planning and barriers to planning

Given the high isolation of the study area and the low level of education, it is interesting to analyze the adaptation strategies put in place by the residents. In this context, respondents were first asked whether or not their household has developed strategies or plans to deal with the potential impacts of climate change. Overall, 48% of respondents report that their household is not currently planning for adaptation to climate change, 4% report that their household is currently developing adaptation plans, and 47% reported that adaptation

strategies are currently being carried out (Fig. 5). The obvious split between responses of either action or non-action with few reports of planning suggests that potential responses are likely to be immediate and do not require long periods of planning. In other words, once a family becomes aware of a problem or a change, they quickly take action to face it. In other words, they activate a sort of traditional coping response.

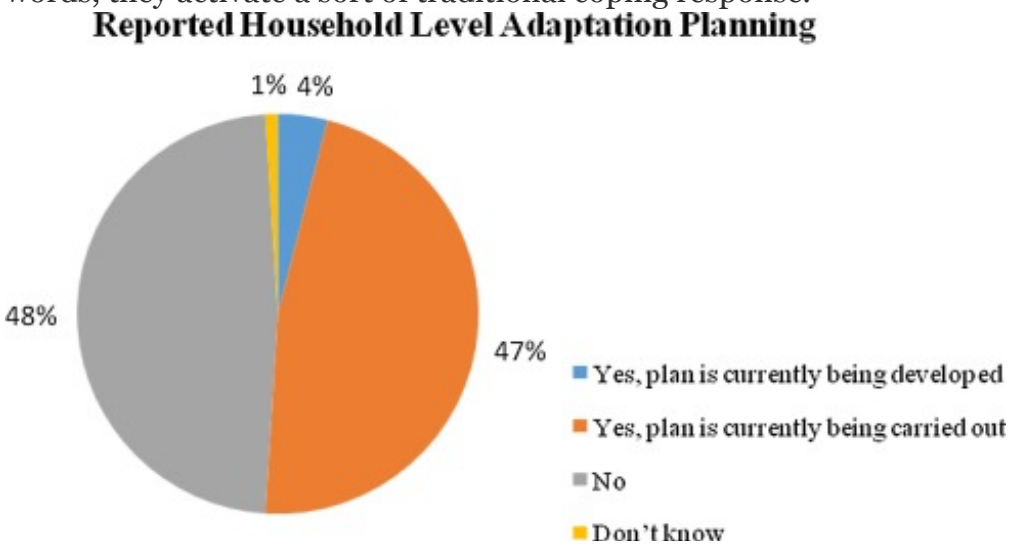

Fig. 5. Current adaptation planning at the household level as reported by mountain community survey respondents.

Individually, some of the households have adapted to climate change by modifying the cultivation strategies either through shifting the cultivation time and using fertilizers and insecticides. Others have started using other cooking fuel as well as cultivating high yielding crop varieties. They have also improved the water consumption to address water scarcity either by conserving the water point, i.e. springs, or by appropriately using water besides reducing the volume of livestock rearing (a potential agent for water consumption). On the other side, the lack of adaptation plan reported by many households can be primarily due to the availability of resources at least for basic subsistence, besides many other barriers such as lack of information about climate, and accessibility of climate resilient technologies. A previous research on similar topics has shown that decisions regarding adaptation can be contagious (Archie, 2013), so that it is interesting to analyze whether decisions by the government and in nearby communities would have an effect on the decisions made about adaptation in the communities surveyed in this research. Seventy-six percent of respondents report that decisions made by government either frequently or sometimes affect planning and decision making in their community, while only 20% report that government decisions do not affect local decision making (Fig. 6). Eighty-eight percent of respondents report that decisions made in nearby communities either frequently or sometimes affect planning and decision making in their community, with a mere 12% reporting that decisions made in nearby communities do not affect their local decisions (Fig. 6). Thus, decisions made outside

of the community can strongly influence local decision-making, and adaptation responses could spread rapidly once implemented in one area.

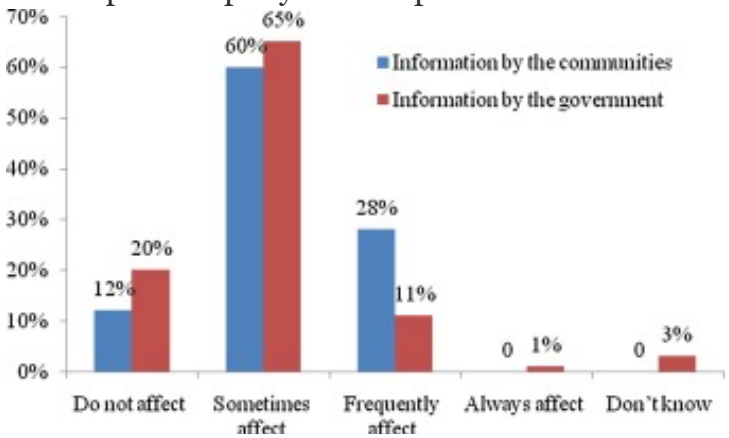

Fig. 6. Effect of decisions made by government and surrounding communities on household level decision making.

Respondents were also asked what, if any, changes their community has or will make in response to climate change. The three most common responses are represented by: (1) increased forest protection, (2) structural buildings reinforcement, and (3) use of alternative energy (Fig. 7).

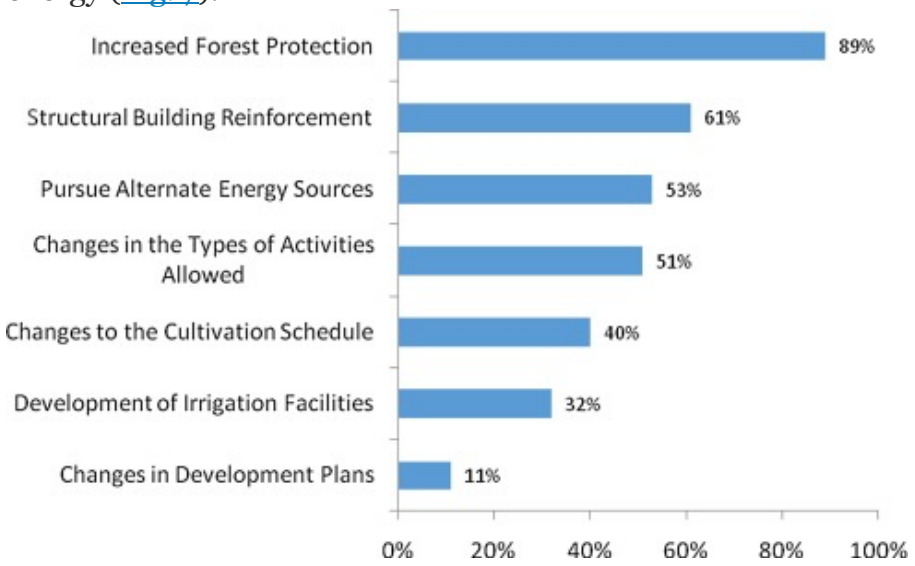

Fig. 7. Changes in community or household management plans in response the climate change (by percent of respondents choosing each option).

In order to understand what factors community members consider to be barriers to adaptation planning and actions, we asked respondents to rate some potential issues as a big hurdle, a small hurdle, or not a hurdle. Overall, lack of money, lack of access to information, and lack of awareness or understanding have been considered the three largest hurdles besides low priority for adaptation (Fig. 8).

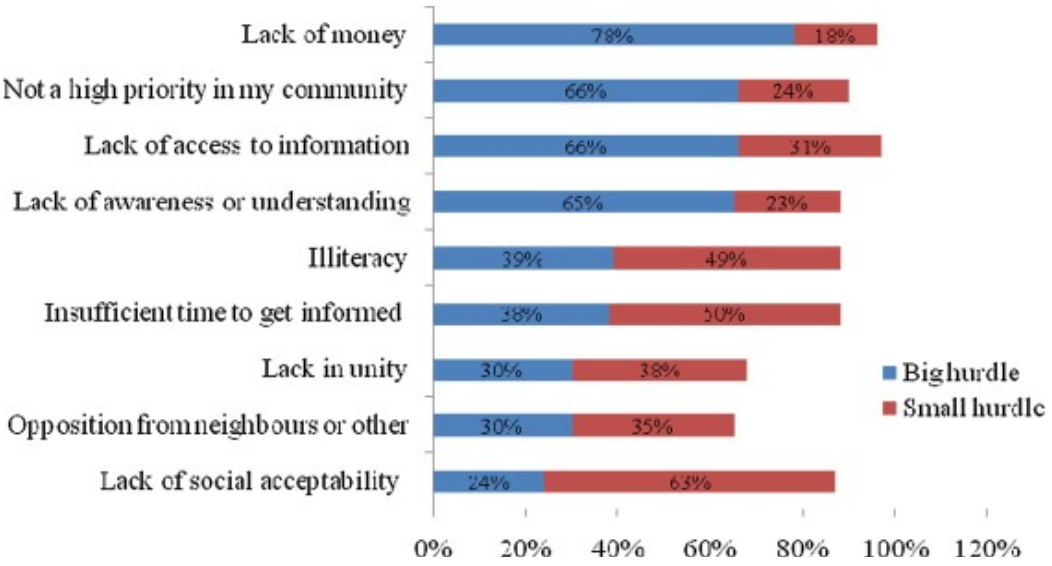

Fig. 8. Hurdles to the implementation of adaptation plans as reported by respondents.

Respondents were asked about what kind of data and information they typically consult in regards to both their daily responsibilities and in planning activities for the future. Traditional knowledge is identified as source of information for adaptation by 96% of households. Weather forecasts by concerned government authority are identified by 41% as a mean of adaptation planning and strategies at household level.

Respondents were also asked about the sources they typically consult to obtain the data and information they use in their work by identifying seven different sources and with the following options to be chosen: do not use in my work (0), rarely (1), occasionally (2), frequently (3), or all the time (4) (Fig. 9). Some sources are used more widely than others and the choice of source differs for respondents from different regions. Village elders and audio-visual systems are the most commonly accessed source of information and more than 90% villagers rely on them. Nearly 80% of villagers obtain information from newspapers and villagers of nearby areas, while government officials and reports, and teachers are rarely consulted as source of information (Fig. 9).

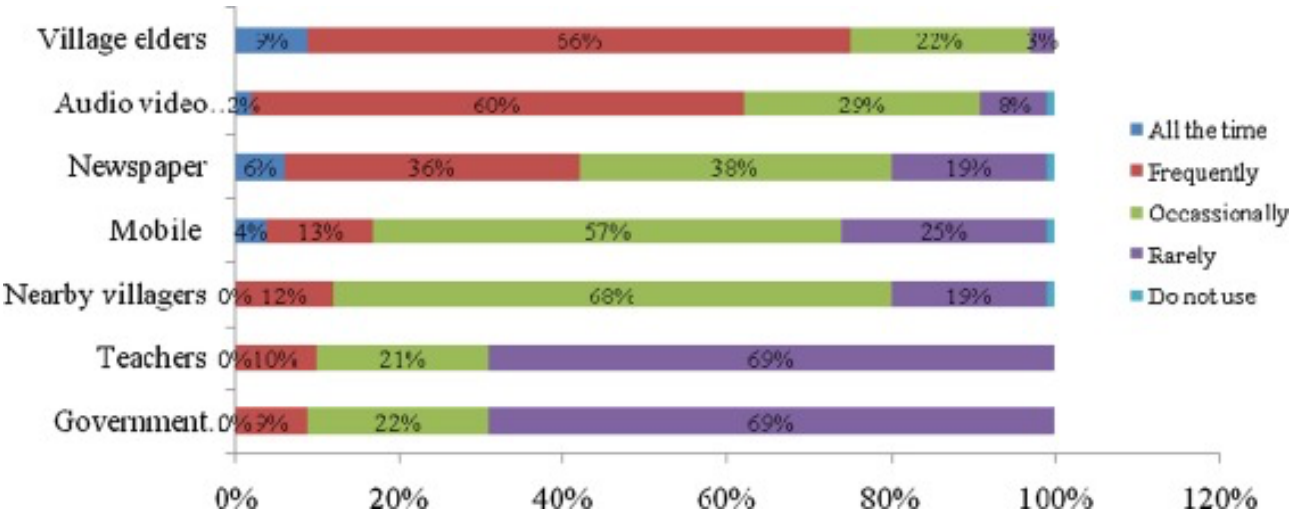

Fig. 9. Sources of information for adaptation mechanism. The graph shows the percent of respondents who access information via these sources either frequently or all the time.

Since previous studies suggest that lack of information at some relevant scales can be a major barrier to adaptation (for details: Broad and Agrawala, 2000, Letson et al., 2001, Broad et al., 2002, Jagtap et al., 2002; Patt and Gwata, 2002, Leetmaa, 2003, Rayner et al., 2005, Archie et al., 2012, Archie et al., 2014), respondents were asked about the most useful scale of information to plan for adaptation to climate change. Ninety eight percent of respondents report that information at local scale is the most useful for community in planning for adaptation to climate change, while nobody consider useful the national scale. In addition, 84% of respondents report that a lack of information at local scale can prevent them from planning for adaptation, while 16% report that even if they plan in the absence of the information at the appropriate scale, these plans are very coarse.

The household chores and function differs among the members of household. Woman has major responsibility within household as well as also assisting for cultivation, livestock rearing, and forest collection. During general discussion, the villagers have revealed a different level of awareness about climate change adaptation that can be correlated with their functions and role they play in the context of family welfare. Women face mainly challenges related to climate change such as: water shortage, forest depletion, livestock rearing, and cultivation. Since women responsibilities are more focused on family welfare in the area, they are more concerned about climate change, and the adaptive capacity (resilience) of their family. However, lack of sufficient information flow and their access to women besides low engagement in household decision making are critical components for subsistence livelihood adaptation among the farmers.

5. Conclusions

Respondents report that the local climate is changing with net negative impacts on the community and the ecosystem. Decreases in water quantity, and changes in precipitation patterns were among the major concerns for respondents, but communities are making use of traditional knowledge and historical climate information for developing strategies to cope with impacts of climate change. The uncertainty in the weather is a valid topic for increasing the resilience of the communities and making ecosystems adaptable to unpredictable change (Tompkins and Adger, 2004). Climate variability and changes have more and strong impact on the natural resources such as forest, agriculture lands, and water especially in the fragile ecosystems of mountains.

The high exposure to climate risks and the urgent need to reduce both current and future community vulnerability to these risks are essentially required for sustainable livelihood. Information can act as a major instrument for addressing the criticality of climate change by providing information on adaptation strategies and planning at household level and, thus, reducing the vulnerability of an exposed system. This research has highlighted the role of additional information to match the high priority community needs; viable adaptation strategies and adaptation plans need to be integrated into both top-down and bottom-up approaches for planning to enable sustainable development and the efficient use of information for adaptation (Fig. 10).

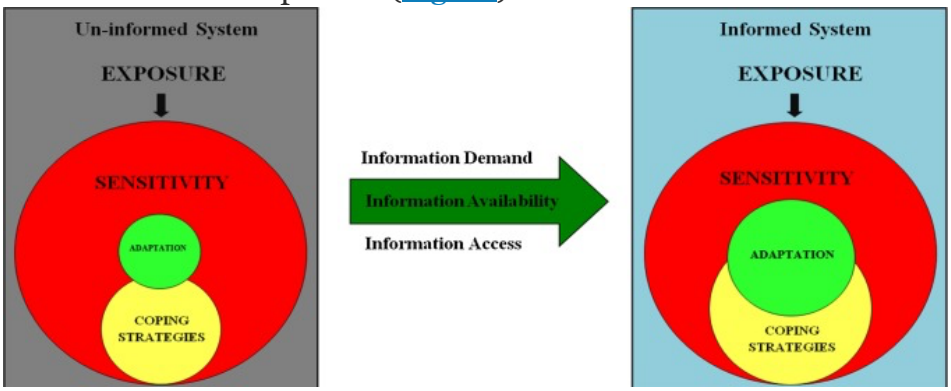

Fig. 10. Increased potential for adaptation planning when information plays a key role in planning.

Although information at the local scale is considered by respondents to be the most useful in planning for adaptation to climate change at the household and community level, climate information at local scale are difficult to be obtained due to the lack of meteorological stations. However, planning under uncertainty is not uncommon both at local and national scale, but in vulnerable areas with limited resources, researches can facilitate and forward the risk by improving the managing capability of both the policy makers and villagers. To face up to the problem of data gaps, it is necessary a more widespread and long-term monitoring of flora and fauna, tracking of glacial ice volumes, an approach on local

landscape and trans-boundary to biodiversity conservation, open data exchange, and cooperation between all countries in the Greater Himalayas (Sarkar, 2007).

Available and reliable information provide new ways and ideas suitable for adaptation planning. Coping strategies and adaptation tends to increase with the intensification of the information flow regarding the various household livelihood strategies. Traditional knowledge is one of the major sources of information, which can be used in planning adaptation in response to climate change at household level. Improving the flow of usable scientific information could facilitate the spread of adaptation in the region, but traditional knowledge will continue to play an important role. In the absence of additional input from policy makers and the scientific community, well-known and locally employed coping strategies are the most used, such as rain-water harvesting system, use of alternate source of energy, using traditional practices in the agriculture field and shifting of cropping pattern. A common understanding of climate change needs to be expanded through regional and local-scale research, so that strategies for mitigation and adaptation to climate change can be identified and implemented. The challenges can only be addressed through increased collaboration between and incorporation of local knowledge, scientific research and policy-making (Xu et al., 2009). The use of different methods and levels of input results indifferent, complementary types of insights and detail needed for balanced and informed decision-making (Van Oort et al., 2015). Moreover, collective actions about the urgency of the climate change problem would lead to better addressing the risk of the climate change and the challenges faced by the locals. Therefore, it would be desired that policy perspective must revolve around household development with flavor of incorporating the traditional knowledge for adapting to the changes. As highlighted in this study, the traditional knowledge is very useful not only in contrasting climate change effects, but also in recovering several ecosystem services that work all together for enanching the quality of life of villagers at local scale. Ecosystem services are absolutely necessary for livelihoods in many regions, especially in rural areas such as the Himalayas, where people for sustenance and the income are strongly dependent by forest production and agriculture (Van Oort et al., 2015). Key informant discussions with district level authorities revealed that local knowledge and values of ecosystem services are rarely incorporated in local development planning. However, local participation, input and definition of ecosystem services use is critical to understand which of them are relevant for livelihoods, sustenance, and well-being, and generates engagement to support sustainable change (Van Oort et al., 2015).

Indigenous, local, and traditional knowledge systems and practices, including holistic views of the relationship between human communities and the environment, are an important resource in adapting to climate change (Tse-ring et al., 2010, Chaudhary and Bawa, 2011).

Natural resource dependent communities, have a long history of adapting to highly variable and changing social and ecological conditions (Pandey et al., 2016a, Pandey et al., 2016b). Integration of traditional knowledge and scientific information would increase both the quantity and effectiveness of adaptation. This study and others on related topics (Fussel, 2007, Archie, 2013, Gerlitz et al., 2014) have highlighted the contagiousness of adaptation. This suggests that provision of tools and information that facilitate adaptation in even a small number of households could prompt the uptake of beneficial practices around the entire region.

In conclusion, the policy for the adaptation to climate change should be based on equitable, effective, efficient and legitimate action harmonious with wider sustainability (Burton et al., 2002, Adger et al., 2005a). For adaptation, equity in outcome means identifying who gains and who loses from any impact/adaptation policy. Often, many current adaptation actions reinforce existing inequalities and underline vulnerabilities (Adger et al., 2003, Adger et al., 2005b). However, there are no universal rules for procedures that guarantee the legitimacy of policy responses because cultural expectations and interpretations define what is or is not legitimate (Brown et al., 2002), as highlighted by the findings of this research where respondents identify increased forest protection, structural reinforcement for buildings, and the use of alternative energy as possible policy priority for the adaptation to climate change.

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