Toward Climate Change and Community-Based Adaptation-Mitigation Strategies in Hill Agriculture

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Abstract

Climate change is being experienced by the hill community in the form of rising temperatures, extreme climatic events, changing rainfall pattern, and frequently occurring drought-like situations. In hills of Uttarakhand, agriculture and animal husbandry are the main occupations, and therefore, food and nutritional security much more depends on favorable climatic conditions. Crop productivity in the hilly areas is getting reduced because of low soil fertility and higher pest and disease infestations. The persistent changes in weather conditions have resulted in overall decrease in the water level in almost all the water sources of the area. The area under irrigation is decreasing gradually due to drying of most of the water bodies for irrigation resulting in low productivity of crops. Rising temperature has led to the shift in forest biodiversity. Pine trees have replaced broad leaf tree species which is posing a major threat to fodder availability and have resulted in increased forest fire incidents. People in hill region have learned to live and survive with risks for thousands of years, but the present rate of climate change is very rapid which demands much attention for the socioeconomic concerns in the area. Women in hills are involved in maintaining and promoting agricultural genetic diversity by selecting, conserving, and propagating seeds. Participatory adaptation strategies with women involved at every stage must be framed as they have rich traditional knowledge and experience with respect to crop adaptation to enhance food security. Drought-resistant crop varieties should be promoted to address drought-like situations and instances of less rain during cropping seasons. Dual-purpose crop varieties which can be grown for grain as well as for fodder could save a lot of time and drudgery of women involved in carrying back-breaking load up and down in hilly terrains. Developmental policies and strategies should be supportive to enhance access and control of

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men and women over natural resources in order to conserve natural resources, alleviate poverty, and ensure that vulnerable groups including women are enabled to cope with the climate change.

Keywords
Climate change • Adaptation • Mitigation • Himalayas

7.1 Introduction

The Indian Himalayas have a critical influence over the climate. It plays an important role in moderating the monsoon and region's rainfall pattern. The perennial snows and vast glaciers are the water towers feeding innumerable rivers, streams, rivulets, and springs throughout the entirety of northern India. The Himalayas are among the youngest mountains in the world and are acutely fragile (Sorkhabi 2007), most threatened ecosystems in the world and susceptible to disaster, including flash floods, cloud bursts, melting snow in the mountains, and droughts and flood in the Tarai (Aryal 2015). Hills and mountains in the northwestern Himalayan (NWH) region are experiencing the consequences of climate change more than any other region (Anthwal et al. 2006); it acts as an indicator of climate change. Here, climate change impacts people ecologically, socially, economically, and also culturally. The climate change is a real threat as it affects water resources including freshwater bodies, agriculture, vegetation and forest, snow cover, and ecological processes such as landslides and floods and has long-term effect on food security and human health (Schmidubher and Tubeillio 2007). Impact of climate change is more pronounced in ecologically fragile mountain areas such as the Himalayas where rapid altitudinal change results in high degree of variation in relief, temperature, rainfall, natural vegetation, water regimes, and other associated phenomena. The climate change is a major and growing challenge in mountain areas where "even small shifts in temperature can jeopardize the fragile balance of natural environments, which are defined by extreme climatic conditions, steep topography, and a wide variety of ecological zones and associated microhabitats with distinct biodiversity" (Kotru et al. 2014).

In Uttarakhand, elevation of the Himalayas ranges from 300 to 3,600 meter (m) spanning the Great, Middle, and sub-Himalayan region. The Great Himalayan region is largely snow-covered peaks and few temporary/seasonal habitations. The Middle Himalayan region has mainly fertile valleys and dense forest cover. The sub-Himalayan regions are Tarai and plain areas which are heavily farmed. Many important reports suggest that due to its unique topography, the Himalayan belt of the country including Uttarakhand is more susceptible to climate change. In Uttarakhand, ~70 % population resides in rural areas and depends mainly on agriculture for livelihood. Out of the total reported area of 53.48 lakh ha, only 7.66 lakh ha (14 %) is under cultivation. In northwestern Himalayan ecosystem, agriculture is mostly rainfed with only 18–20 % area under irrigation. The cropping intensity of Uttarakhand is ~158 % which is higher than the national average (~134 %). Out of the total geographical area of 53,485 km^2, most of the area is under forests (34,651 km^2) and wastelands, thus leaving only 7,488 km^2 of land for cultivation. About half of the total cultivated land is submarginal and 21 % of the landholding is between 0.5 and 1 ha (GOU 2014). In the past few years, Uttarakhand has witnessed a series of extreme climate events, particularly so in 2009, 2010, 2012, and 2013. The flash floods of 2013 inflicted immense loss of human lives, infrastructure, and property, and Rudraprayag, Chamoli, Uttarkashi, Bageshwar, and Pithoragarh districts were worst affected.

The glacial ecosystem has been tremendously affected by climate change and variability. Some of the reported climate-related consequences in the hills of Uttarakhand include receding glaciers and ascending snow line, depleting natural resources, erratic rainfall (leading to flash floods as seen in June 2013 disaster), irregular and less winter rains, advancing cropping seasons, changes in the flowering behavior of plants, shifting of cultivation zones of fruits (the zone has moved by 1,000–2,000 m), less intensity of snow in winters, rise in temperature, drying up of perennial streams, etc.

7.2 Changes in Temperature, Rainfall Pattern, and Snow Cover

The rising of temperature in hills can cause rapid melting of glaciers, consequently impacting the freshwater supply and its quality. The increase in water temperatures leads to changes in physiochemical property of water with increased microbial population and adversely impacts human health. The health of a water body, such as a river, depends upon its ability to effectively self-purify through biodegradation, which is hindered when there is a reduced amount of dissolved oxygen. Consequently, when precipitation events do occur, the contaminants are flushed into water bodies and drinking reservoirs leading to significant health implications (IPCC 2007).

According to a report (GoU 2012), a net increase in temperature in the Himalayan region in the 2030s is forecasted to increase between 1.7 and 2.2 °C (0.6 ± 0.7 °C) with respect to the 1970s. Various studies have reported rapid changes in amount, intensity, frequency, and form of precipitation. The increase in atmospheric aerosol might have begun to affect the monsoon in the Himalayas, offsetting increasing trend in monsoon precipitation that would have been caused by increase in atmospheric greenhouse gases alone (Shrestha et al. 2000). In the hilly region of India, people are increasingly getting overwhelmed with liquid precipitation rather than solid precipitation that were earlier received in the form of snow (Rautela and Karki 2015). This is perceived to be responsible for reduced snowfall duration in the region. As a result the entire region is suffering from scarcity of water. This trend of increasing temperature has affected rainfall pattern and its distribution across the world particularly over the Indian monsoon by modulating atmospheric moisture content (Singh and Kumar 1997; Goswami et al. 2006; Rajeevan et al. 2006, 2008; Singh et al. 2008; Pattanaik and Rajeevan 2010).

Rainfall has become more erratic and intense for the last 10–15 years. It has been observed that intense rainfall has instigated various disastrous events, most commonly landslides, flash floods, etc. Climate change-related hazards such as drought and flood create stress on rural livelihoods by reducing existing livelihood options and by creating volatility and unpredictability in streams of livelihood benefits (Agarwal and Perrin 2008; Conway and Schipper 2011).

In the Himalayan region, snow cover is highly sensitive to climate change. In many studies snowfall is found to have decreased in amount, as well as changed in timing over the past 20–25 years in NWH region. Himalayan glaciers are melting faster due to rising temperature. A significant rise of 1.6 °C from 1901 to 2002 has been reported in the northwestern Himalayas (Bhutiyani et al. 2007). The seasonal mean and maximum and minimum winter temperatures from 1985 to 2008 also have increased over the Himalayas (Shekhar et al. 2010). The study also reported changes in the seasonal snowfall pattern in the western Himalayas from 1989 to 2007 witnessing a decreasing trend in the winter snowfall. Despite the complexity of observations and the lack of on-site measurements, an overall pattern of warming has been apparent, with evidence of receding glacier and snow cover decrease recorded in the Himalayan region (Armstrong 2010; Kang et al. 2010; Bamber 2012; Bolch et al. 2012).

More specifically, snowfall events are thought to oscillate in two important ways, firstly reduction in the intensity and quantity of snowfall and secondly change in the timing of snowfall. Reduced snowfall results in less snow in glaciers and reduced stream flow. The shorter period of snowfall prevents the snow from turning into hard ice crystals which are liable to melt when summer arrives (Shiva and Bhatt 2009). As reported by Dobhal et al. (2004), Gangotri glacier – the source of the Ganga – is receding at 20–23 miles/year. Milam glacier is receding at 30 m/year and Dokriani is retreating at 15–20 m/year. The receding of glaciers has accelerated with global warming. Some of the most overwhelming effects of glacial meltdown occur in the form of sudden overflow of glacial lakes and glacial lake outburst floods (GLOFs). According to the Intergovernmental Panel on Climate Change (IPCC), "glaciers in the Himalayas are receding faster than in any other part of the world and if the present rate continues, the likelihood of their disappearing by the year 2035 and perhaps sooner is very high if the earth keeps getting warmer at the current rate." According to the IPCC report, the total area of glaciers in the Himalayas will shrink from 1,930,051 to 38,000 mile^2 by 2035. There is a sharp decrease in overall precipitation especially during winters. Less snow results in less moisture for growing crops. This has led a huge impact on agriculture and horticulture.

7.3 Impact of Climate Change on Mountain Agriculture

Agriculture is dependent on appropriate amalgamation of weather and associated factors and is thus highly susceptible to climate variability. A slight change in these factors can have a severe impact on the crop yield. Eighty-five percent of the population of Uttarakhand is directly or indirectly dependent on agriculture for its sustenance and income. Any reduction in production or productivity of crops adversely impacts the food security and the ultimate source of income of these farm families. The quality and productivity of land have been declining over the years. Due to highly erratic rainfall pattern and lowering of level of water streams, farmers are gradually leaving cultivation of some crops like paddy cultivation. Frequent floods and severe rains have led to washing away of fertile land (Satendra 2003; Meena et al. 2013, Meena et al. 2015a; Singh et al. 2014; Kumar et al. 2015; Ghosh et al. 2016). Based on different studies and consultations held by Uttarakhand Centre on Climate Change, Uttarakhand State Action Plan for Climate Change (2012) has reported the main trends of climate change as overall less and more erratic rainfall, increasing atmospheric temperatures, increased frequency of intense rainfall events, less or absent winter rains, overall decreased water availability, warmer and shorter winter, etc.

Temperature, precipitation, and their associated seasonal patterns are determining components of agricultural production. Rising atmospheric temperature as a result of climate change adversely affects crop production. The area under irrigation has gradually decreased due to lack of sufficient water for irrigation resulting in low crop production. Erratic, unpredictable, insufficient rainfall when needed has led to drastic reduction in cultivation of rice (both irrigated and nonirrigated) and other crops such as wheat, cauliflower, potatoes, etc. In addition, untimely hailstorms also damage crops. Winter rains are crucial for soil moisture but this too has become highly erratic (Meena et al. 2015c, d, e; Verma et al. 2015a).

In hills, snow is critical for the maintenance of proper level of soil moisture. This has positive ramification on crops such as wheat, barley, etc. Underground seepage has suffered hugely. Drizzle has become now very uncommon, which was particularly effective as it resulted in water seepage and improved soil moisture. Fog is also more frequent in comparison to earlier years adversely affecting wheat, barley, lentils, and even vegetable production. In some areas of hills, farmers have significantly deviated from their traditional crop calendar. Overall seasonal precipitation determines the crop yield over large areas, but stress and dry spells threaten productivity, even a few hours at critical growth stages (Huntingford et al. 2005). The excessive destruction by wild animals especially wild boars and even monkeys is also one of the reasons why people have switched over to other crops and fruit cultivation and left their land barren. Some environmentalists relate the animal menace as one of the ill effects of climate change. Forest structure is changing at a fast rate where broad-leaved oak forests are rapidly converting into chir pine forests or scrubs. There are many examples where an oak forest has completely converted into pine forest within ~20 years. This rapidly changing forest structure has led to habitat destruction and threat to wildlife. Due to scarcity of food in the forest areas, many wild animals encroach into nearby residential areas and agricultural land for survival. As a result wild animal menace has become a burning issue. A preliminary survey reveals that 30–70 % damage to the agricultural crops is done by displaced wild animals. Due to monkey menace, farmers of many villages have stopped cultivating vegetables and other crops. Monkeys, boars, and leopards have become commonly sighted animals in the villages of Kumaon and Garhwal region of Uttarakhand.

Climate change has also affected insect population in the region. Being poikilotherms, the behavior, distribution, development, survival, and reproduction of insects get influenced by temperature (Yamamura and Kiritani 1998; Petzoldt and Seaman 2010). The major factors of climate change like elevated CO_2 level, rising temperature, and deficient soil moisture therefore affect population dynamics of insect pests and thus significantly enhance the extent of crop yield losses (Reddy 2013).

Reduced insect population has affected seed dispersal, thereby affecting production of cash crops like potato, rye, sesame, amaranth, and kidney bean. Orchards are also affected adversely by climate change. In most of the areas in Uttarakhand due to low and erratic rains, trees could not bear fruits in time. Those villagers with traditional knowledge and agricultural scientists identify changes in crop productions and productivity with rapid changes in climatic conditions that have been witnessed in the hilly regions of Uttarakhand. The phenological responses of plants, particularly the early flowering in plants and crops, are considered to be prominent biological indicators of climate change (Parmesan and Yohe 2003). Dormancy of plants is broken early due to reduced winter periods which are reflected in the form of early flowering. As a result most of the plants flower at the time when weather conditions are unfavorable for their growth and survival. Hailstorms which are common during the period of flowering also result in major crop loss. Blooming which takes place even before local pollinators are active results in less fruiting and thus low productivity. Early flowering in almost all agricultural, horticultural, and forest tree species is reported to be a common observation, particularly in *Rubus* spp., *Malus domestica*, and *Rhododendron arboreum* (Rautela and Karki 2015) (Table 7.1).

The agriculture and climate change work in a vicious circle, from the agricultural practices reducing the sustainability of forest as an ecosystem, stabilizing climate, and contributing to the climate change, which in turn increases the vulnerability of agricultural practices and production. Increase in temperature and erratic rainfall directly affects the agriculture production and food supply. Insufficient rain and increased temperature cause drought-like situations, whereas intense and erratic rain for short period reduces groundwater recharge by accelerating runoff and causes flash floods. Such situations induce negative effects in the agriculture (Malla 2008) (Figs. 7.1 and 7.2).

Table 7.1 Impacts of climate change on agriculture

Temperature-related changes
Extended frost-free periods
High average winter temperature
Fewer extreme cold temperatures in winter
Higher night temperature both in summer and winter
Increased temperature variability
Rainfall-related changes
More variability of summer precipitation
More intense rainfall results in more runoff
Higher absolute humidity
Other climate-related changes
Low wind speeds
Enlarged tropospheric ozone
Excessive loss of soil carbon
Faster plant growth and maturity
More growth of weeds and vines
Under elevated atmospheric CO_2
Weeds migrate northward and are less sensitive to herbicides/weedicides

Source: Sharma and Dobriyal (2014)

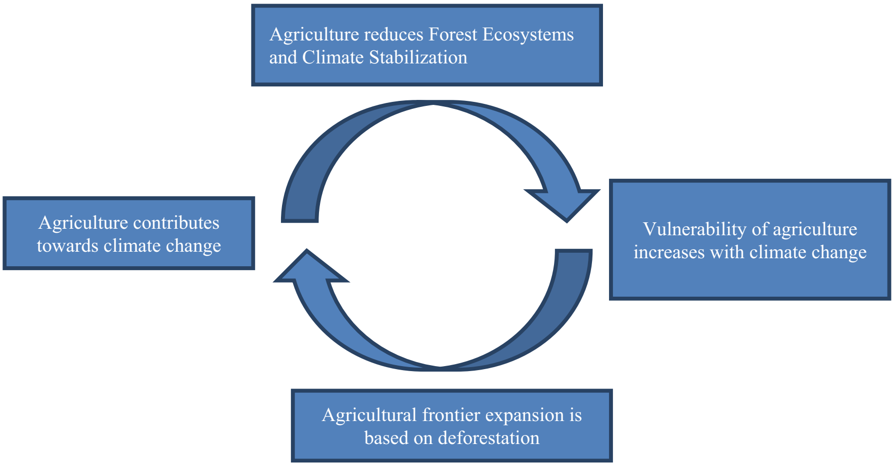

Fig. 7.1 Vicious circle of agriculture and climate change

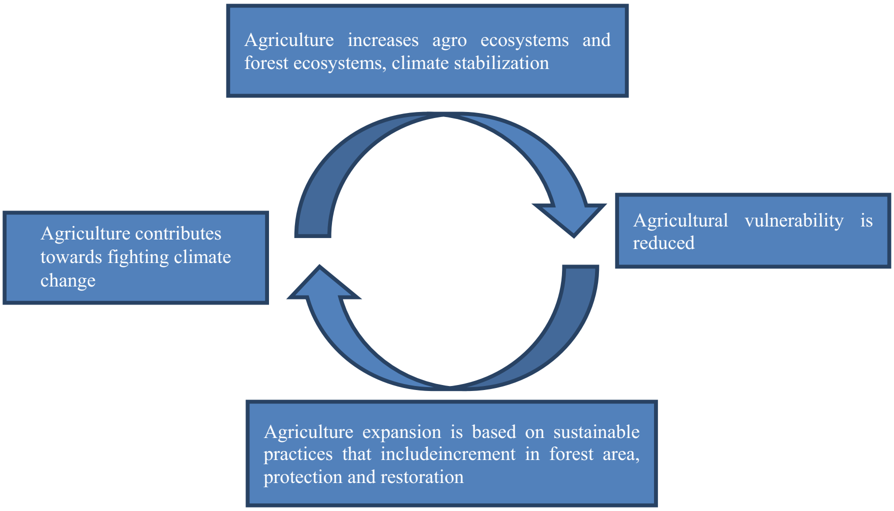

Fig. 7.2 Virtuous circle of agriculture and climate change (Adopted and modified from Rodas 2015)

7.4 Impact of Climate Change on Forest Resources

In the Himalayan region, majority of population is directly dependent on agriculture and forest resources for their livelihood. Any change in structure, composition, and distribution of forests has severe consequences on communities and their livelihood which depends on these forests. In hills, people are dependent on forests for fuelwood, grass, and other biomass. Due to changes in weather pattern, broad-leaved species, a highly nutritious source of fodder, are gradually disappearing from the forest. Some studies suggest that the forest ecosystem can be seriously impacted by further climate change. Even a rise of 1–2 °C in global temperature will result in changes in species compositions, productivity, and biodiversity (Climate Change 2001; Ravindranath et al. 2006). Uttarakhand contains rich floral diversity. Important tree species are distributed across different latitudinal zones, i.e., the sub-Himalayan, Lesser Himalayan, and Great Himalayan. Prominent trees of sub-Himalayan zone include sal (*Shorea robusta*), khair (*Acacia catechu*), and sheesham (*Dalbergia sissoo*). Most important tree species in Lesser Himalayan zone are chir or pine (*Pinus roxburghii*), oak (*Quercus leucotrichophora*), rhododendron (*Rhododendron arboreum*), and alders (*Alnus nepalensis*). Similarly, firs (*Abies alba*), bhojpatra or birch (*Betula utilis*), stunted rhododendron (*Rhododendron campanulatum*), and junipers (*Juniperus* spp.) are the prominent species at the Great Himalayan zone from where alpine meadows start. Alpine meadows, which start from ~3,000 m, are homes of valuable herbs and flower species. Many studies reported that floral wealth of alpine meadows is also at decline.

Rawat (2013) reported that the hill community perceives that climate change affects the phonological events like early flowering and less fruiting in trees. The maximum effects can be seen on *Quercus leucotrichophora*, *Rhododendron arboreum*, *Rubus ellipticus*, *Pyrus communis*, etc. Phenological changes occur due to irregular and erratic rainfall, less snowfall, increasing temperature, and decreasing moisture content in soils. As a result of these climatic conditions, plants have changed their new leaf formation time and flowering and fruiting time, which is now 15–20 days ahead as compared to the timings 10–15 years ago. These studies have reported that in the Himalayan region forests around the villages have depleted and degraded due to road construction activities, cutting of trees for fuelwood, loss of vegetation due to glacial action and other natural disasters, frequent forest fires, overgrazing by animals, and decreased regeneration rates of trees in the forest area.

Deforestation has also increased the physical and social vulnerability in hilly areas; ~65 % of the total land in the state comes under the forest. However, satellite imageries point toward a huge reduction in the actual forest cover. The communities traditionally preserved forests in the Himalayan region as it provides safety against many hazards, e.g., flash floods, slides, avalanche, and rock falls (Gupta and Nair 2012; Verma et al. 2015b; Meena et al. 2016). The degradation of forests in the mid-slopes of the Himalayan region has reduced the availability of fodder and leaf litter, with serious implication on livestock. Fuelwood is still the primary source of energy for cooking in most of the villages in hills. Fuelwood collection which is primarily being done by women has become more burdensome. In hills, dependence on forest resources generally increases during drought-like conditions or other natural calamities (Rautela and Karki 2015; Meena et al. 2015b). Changes in oak forest cover and climate change have adverse impact on the availability of wild species of mushroom, i.e., *Morchella esculenta*.

Forest resources which also include fruits, roots, leaves, mushrooms, and medicinal plants are traditionally collected from forests by people of higher hills. In the last few years, collection of high-value *Ophiocordyceps sinensis*, colloquially known as caterpillar fungus (kira jari or yarsagumba), has become a major source of income inducing people of high hills to visit high altitudes during its harvest season. It appears in the high altitude in the month of May or June with the melting of the snow (Rautela and Karki 2015). From the many studies reported, income from this activity is quite enough for many families of the area to sustain all through the year. According to the people of high hills, due to decrease in growth of the caterpillar fungus, its collection is decreasing every year. It is feared that in years to come it may become an extinct fungus.

7.5 Impact of Climate Change on Food Security

The climate and weather condition of hills determines food security of the hill communities, who depend primarily on agriculture and animal husbandry for their subsistence. Traditional millets have been replaced with rice and wheat (Rawat

2013). The practice of consuming vegetables and other food items which are wild in nature is also disappearing because of declining mixed forests. It is generally difficult to find wild varieties in pine or mono-species forest. This has reduced nutrition, variety, and taste in food, particularly of women and poor as they are frequent visitors to the forests. Traditional grains and vegetables have almost disappeared from the diet of new generation. The inclination to grow and consume at least a bit of healthy traditional food every season is still evident among women, particularly older women, even in areas where cash crops are popularly practiced. In hills, people are now becoming more and more dependent on the market to buy food such as vegetables, lentils, and even grains. Consumption of milk and milk products has gone down due to the decline in animal population primarily by reduced availability of fodder and grass from the forest.

Bees and butterflies are considered to be indicators of climate change and are used for predicting various environmental variations. Their specific survival-related ecological requirement that includes temperature, humidity, food plants, and egg-laying habitats makes them most susceptible to climate change. Reduced nectar availability due to dry spells, drought-like conditions, and phenological changes is perceived to be responsible for their reduced population (Forister and Shapiro 2003; Rakosy and Schmitt 2011). These changes have adversely affected the food security of people with reduced availability of varied, safe, tasty, culturally acceptable, and nutritious food for all, particularly women and other vulnerable sectors. This has had a negative impact on the health of both humans and livestock.

7.6 Impact of Climate Change on Livestock

The population of domesticated animals has also become less dense. As a result of forest degradation, availability of grass and fodder has gone down. Replacement of traditional crops with cash crops has resulted in reduction in the availability of fodder. With the reduced number of livestock, the availability of cow dung for farm yard manure has also reduced considerably and has negatively impacted the quality of soil and production. According to Houghton et al. changes in atmospheric temperature, humidity, wind speed, and other climate factors influence livestock performance like growth, milk production, wool production, and reproduction. Other findings of Singh et al. (2012) examined perceived climate change impacts and adaptation strategies to sustain livestock production adopted by livestock in NWH. Majority of the respondents of NW Himalayas perceived that climate change has adversely affected productive and reproductive performance of livestock. Other changes include increased incidence of livestock diseases and parasitic infestation and decreased availability of feed, fodder resources, and water.

7.7 Climate Change and Gender Issues

In hills, women play a major and crucial role in agricultural economy. They have rich and diversified knowledge as well as skill acquired through managing natural resources, livestock care, and agriculture-based livelihood and practice indigenous ways of maintaining good health. Women have contributed a great deal in maintaining and promoting agricultural genetic diversity (Shiva 2015). Due to natural calamities in the past 5 years, women experienced extended workload and physical and mental exertion. The unpredictability in seasons and rainfall is affecting water availability, soil moisture, forest regeneration, and eventually food production. With limited access to resources and almost negligible participation in decision-making processes at household and community levels, women will be most seriously affected by reduced food and nutritional security (PANAP 2011).

Women collect fuel and fodder from forest which along with other household responsibility put them under mental and physical exertions. Unusual events and extreme conditions enhanced pressure on them along with increasing risks and vulnerability. As compared to other parts of the country, women in hills are more vulnerable to nutritional problems. Difficult living conditions in hills such as fragmented fields, steep slopes, and women's continuous toil in the fields for 14–15 h consistently, coupled with household chores, make their workload overwhelming. Various studies show that women perceive that work involved in cash crops is much greater compared to traditional crops, and this has increased women's workload many times over. Most of the women in hills suffer from lower back pain due to carrying heavy loads over long distances; they also suffer from various skin problems due to long exposure to sun. Due to the use of agrochemicals, women are exposed to several health hazards and gynecological infection. In case of rice transplantation, arthritis and intestinal and parasitic infections may take place due to long hours of work in mud and water (Pandey 2001).

Increased temperature due to climate change is leading to an increase in weed infestation, and as weeding is essentially a women's task, it has added workload of women farmers. Since women's role and responsibilities are closely associated with natural resource management and farming, women will be the worst sufferer of climatic variabilities. Women's limited access and control over these resources increase their vulnerability to climate change and hinder their adaptation capacity. Already marginalized women bear the brunt of increasing food insecurity.

7.8 Adaptation and Mitigation Strategies Toward Climate Change

Adaptation generally refers to the actions that help in better coping with the changing conditions. Adaptation strategies are constantly renewed through learning by doing, experimenting with new ideas, and knowledge-making processes that allow hill communities to adjust and modify their actions with changing climatic conditions. Those living in the rural and hill areas are well aware about the changes taking place in their surrounding due to climate change. The most common phenomena as a result of climate change are varying temperatures, frequent and longer drought periods, erratic rainfall, untimely flowering in some plant species, slowly disappearing natural resources, and occurrence of new diseases. Hill communities are somehow adapting to these changes with the resources available to them. However, presently they lack information, services, technologies, assets, mobility, and the ability to make choices and decisions (Joshi and Bhardwaj 2015; Chulu 2015).

In some areas of hills, farmers have already started taking adaptation measures which include replacing grain crops with vegetables (Gum et al. 2009). These crops give higher production than grain crops even in smaller areas with less resources and labor. This also provides them with much needed cash and nutrition. Production of off-season vegetables together with cash crops can be a strategy toward ensuring sustainable livelihood. With increasing temperature and shortened and less harsh winters, farmers of hill areas can start planting crops early. According to a study, genetic and species diversity in field has been maintained in Johar, Byans, and Niti valley areas through mixed cropping system of Barahanja, meaning 12 grains. In this system, 12 different crops are grown together which ensure favorable conditions for each other and thus improve crop productivity. This practice provides them protection against the entire crop failure and is an effective instrument of food security (Rautela and Karki 2015). The traditional varieties or traditional knowledge system (TKS) of millet when grown along with other modern crops provide for contingency when conditions are unfavorable. Buck wheat, for example, is one of the shortest duration crops that takes only 4–5 weeks from sowing to flowering and thus suppresses weed infestation and prevents soil erosion. The crop at the same time has multiple usages as it is used as vegetable and is also an important source of cattle feed (Rautela and Karki 2015).

In hills, women manage the conservation of seeds. Their traditional knowledge on this aspect is very strong. This knowledge is crucial for adapting to climatic variability and environmental changes. In the Himalayan mountain region, 80–90 % seed requirements of crops are met through traditional seed management and exchange systems, where the role of women is very important. Women are custodians of traditional knowledge related to seed conservation and maintain a diverse genetic pool of this valuable resource through in-situ conservation (Dhakal and Leduc 2010).

In order to meet fodder and fuelwood requirement, planting fodder trees/plants along the boundaries of the terraced fields can be promoted. Studies conducted for about a decade at ICAR-VPKAS, Almora, have revealed that introduction of improved grasses and legumes like pangola (*Digitaria eriantha*), giant star (*Cynodon plectostachyus*), *Panicum coloratum*, *Panicum repens*, and *Setaria kazungula* is a promising technology for the improvement of grassland and other forage production systems (Bisht et al. 1999). The climatic conditions in hills are also favorable for growing medicinal plants that can fetch high prices and have a large and ready market. People of Niti area in Uttarakhand are cultivating jambu faran (*Allium stracheyi Baker*), kala jeera (*Carum persicum*), and sea buckthorn

(*Hippophae rhamnoides*) at many places and earning their livelihood (Rautela and Karki 2015).

This is an irony of the hills that despite of plenty of water sources and adequate rainfall, there exists acute shortage of water not only for raising the crops but also for drinking. This is mainly due to rains getting confined within 3–4 months and several dry spells. In order to cope with this situation, efforts must be made for developing rainwater conservation mechanism along with sprinklers and drip irrigation systems (especially for horticultural crops) for the efficient use of available water. There are several more options available which should be taken up vigorously in order to address the water crisis. These include the repair of *naula* (traditional wells), construction of infiltration tanks and recharging of natural water springs, and plantation of broad-leaved tree species that enhance water retention property of the soil and strengthen slope stability (Acharya 2012). Community water tanks should also be constructed to reduce drudgery of walking long distances to collect water. Forests have significant emission removal capability which can further be enhanced by operational major afforestation and reforestation initiatives like the National Mission for a Green India besides continued strengthening of the present protection regime of forests (Kishwan et al. 2009; Yadav 2013).

Women constitute the largest percentage of the hill population and are invariably affected the most by these changes. But their experiences, perceptions, and viewpoints rarely are heard in various decision-making platforms, both locally and globally, in relation to mitigation and adaptation strategies. The different challenges faced by women and men need to be recognized, and it is crucial that gender perspectives are introduced in adaptation and mitigation strategies. This perspective will prove to be very effective in reducing the impact of climate-induced changes and in enhancing food security (Nelson 2011).

Studies on climate change need to be *multidimensional* as people's lives are affected by various factors such as access to natural resources, globalization, poverty, climate change, etc. Since these factors are closely interwoven, an *integrated approach* is imperative when designing adaptation and mitigation strategies in agriculture, forestry, health, and livelihoods. Assessment of the effects of global climate change on agriculture might help to deal with the farming system and to enhance agricultural production (Table 7.2).

7.9 Conclusions and Future Prospective

Hill regions are more susceptible to climate change events. Natural resources are depleting with the change in seasonal pattern and climate variables. Climate change-induced changes in the region include receding glaciers, erratic rainfall, less and irregular winter rainfall, reduction in snowfall in winter, raised temperature, drying up of perennial streams, etc. The major impact of climate change is presently being perceived on the agricultural sector that accommodates highest proportion of the workforce of the hilly areas. These changes have resulted in fluctuations in the flowering behavior of plants, shifting of cultivation zones of

Table 7.2 Impact of climate change on livelihood and proposed mitigation mechanism

Climatic changes	Impact on livelihood systems	Coping and adaptation mechanism	Potential future risks
Decrease in rainfall and change in rainfall timing	Reduced agricultural productivity and agro-biodiversity	Growing cash crops; change in timing of sowing of crops	Increasing livelihood and food security
Longer dry spells	Drying up of water sources; less flow in springs and streams	Traditional system of water sharing, change in time of sowing of crops	Scarcity of water for drinking and agriculture, adverse effect on workload of women
Warmer winters, lee snow, and more precipitation in the form of rain instead of snow	Increased incidences of crop infestation, weed crop failure	Increased use of insecticides, pesticides, and weedicides	Increasing livelihood and food security
Better survival of wild animals due to deceased snowfall and less harsh winters	Increased incidences of animal attack on agriculture	No coping mechanism	Huge crop loss, low agricultural productivity, and more migration

various agricultural crops, and advancing cropping seasons, and many species of flora and fauna are pushed toward the verge of extinction. These changes have brought disruption in social and economic life of hill communities and enhanced their vulnerability against the climate change.

Women in hill regions are particularly vulnerable to climatic variability due to their limited adaptive capacities that arise from already prevailing social inequalities and ascribed social and economic roles. Women play a significant role in maintaining household chores and in managing natural resources. Women are repositories of indigenous knowledge which contributes toward survival of the community and toward their own adaptation in extreme climatic conditions. In climatic stress conditions, they are forced to turn toward creating indigenous innovations which are cost-effective and less time consuming. However, their role is hardly ever recognized while framing developmental and environmental policies and strategies. Women and men have different ascribed roles in the society, face different challenges, and demonstrate different reactions and methods for coping. These issues should be addressed in research, development, disaster preparedness, and adaptation and mitigation strategies. Climate change affects men and women differently according to their respective vulnerability and adaptation capacities. Therefore, all aspects related to climate change (i.e., mitigation, adaptation, policy development, decision-making) must consider gender perspective and ensure that men and women are able to adapt these climatic variabilities. Although women have low capacity to adapt, the share of the adaptation burden falls disproportionately on them. This makes the consideration of the impact of climate change on gender most imperative. Gender-blind adaptation strategies are very harmful as they may increase already existing inequalities.

The major concerns of the hill communities are their dependence on subsistence farming, forests, and rainfall. The strategies need to be developed to decrease their reliance on these factors which will increase their resilience to climate change impact. It is high time for policy formulators, political leaders, and administrators to put climate change at the center stage of development strategies as it has become a crosscutting issue. Multidisciplinary groups are required to be formed for developing climate change mitigation and adaptation strategies.

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