

Climate change, biodiversity and livelihoods in Indian Himalaya

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Abstract

Conservation of biodiversity and avoidance of negative impacts of climate change are the perhaps most critical challenges faced by all sections of the society. The patterns and processes related to climate change and biodiversity are so complex that corrective measures are often taken with an imperfect scientific knowledge base. This article draws on the scope of indigenous knowledge in mitigation and adaptation to climate change, with special reference to central region of Indian Himalaya.

1. Introduction

With adoption of Convention on Biological Diversity and United Nations Framework Convention on Climate Change, global warming and biodiversity depletion figure as the most as the critical challenges for sustainable development worldwide. As the current phase of climate change has been progressing parallelly with a whole range of ecological-socio-economic-cultural-technological changes, with significant interactions between them, it is difficult to precisely segregate the effects of climate change on ecosystem structure and function and livelihoods. This article deals with some dimensions of climate change-biodiversity-livelihoods relationships in the central region of Indian Himalaya, a region distinguished globally for its rich biodiversity and far-reaching climatic and hydrological immense environmental services.

2. Climate change -trends and perceptions

2.1. *Scientific perceptions*

While unprecedented rate of global warming in recent times is conclusively established, scientific capacity to predict future climate scenarios is limited, with projected warming rates reported in the range of 1.0 to 5.8 °C on a global scale (IPCC, 2001) and 0.4 to 2.0 °C in India (Hingane et al., 1985; Parish and Funnell, 1999) largely because of an upward trend in maximum temperature (Rupa Kumar et al., 1994). Kavi Kumar and Parikh (2001) considered likely warming by 2 °C in temperature together with a 7% increase in precipitation as the 'best guess'. Climate change projections may vary depending on the analytical tools used for making predictions. A trend of warming in the 20th century in Himalaya unraveled by mathematical modeling and trend analysis of long-term climate data is not supported by the tree ring width data (Yadav et al., 1997). Future climate scenarios in higher Himalayas constructed by the Oregon State University model radically differ from those by Goddard Institute Space Studies model (Brazel and Marcus, 1991). Nesting of high resolution local/regional models within the low resolution global models can improve precision of predictions. While monsoon rainfall has been considered trendless over a long period of time by many workers, Rupa Kumar et al. (1992) concluded a decline in rainfall by 6-8% per hundred years over the north-eastern but an increase by 10-12% per 100 over the western part of the country. Prediction of sporadic extreme climate events is much more difficult compared to changes in climate on annual or seasonal scale. An uncertainty in the projected rates of climate change implies an uncertainty of the predictions about its consequences or the outcomes of the mitigation or adaptation measures identified based on an imperfect knowledge. Enhancement of scientific knowledge must be an integral component of all climate

change programmes (Steffen et al., 2002). Farmers' perceptions about climate change can provide useful insights for adaptation and vulnerability to such a change.

2.2. Farmers' perceptions

Farmers are concerned more with the impacts of and adaptation to climate change rather than the nature and degree of climate change. Reconstruction of the past by farmers will always be limited to variables which are traditionally quantified, and to a time scale within the range of human memory (Showers, 1996). Farmers can hide or providing inaccurate information (Omiti et al., 1999) and careful cross-checking of responses is required. One can ask farmer to identify climate change or to list changes in their surroundings first and then to identify the causal factors. Majority of Himalayan farmers accept climate change but are unable to measure its rate. They conclude warming based on a trend of a decline: (i) in area and duration of snow around snow peaks and (ii) in time and energy put in to clear pathways during snowfall period.

By 'good climate year' farmers mean sporadic low rainfall events during March-May, peak monsoon rainfall during July-August, moderate rainfall/heavy snowfall during December-January and absence of cloud burst events, with highest degree of uncertainty attached to the onset of monsoon and time of abnormally high rainfall events. Thus, farmers attach more importance to precipitation than temperature. Farmers feel a trend of decrease in frequency of occurrence of good climate years, with increasing frequency and intensity of abnormally high precipitation events in at elevations > 1500 m, low precipitation events in 500-1500 m zone and both kinds of abnormalities in the foot hill zone. People believe drought, excessive rainfall/flood, hail storm and cloud burst events as unpredictable and unavoidable events in the hands of supernatural powers.

Prayers and rituals devoted for favorable climates, though undoubtedly superstitious, seem to have fostered evolution of ecosystem management practices and institutions enabling minimal possible damage due to and fast recovery following catastrophic events. Farmers consider climate change a factor not as crucial as other factors in determining spatio-temporal dynamics of ecosystems and livelihoods, suggesting the need of integrating climate change issues with the livelihood issues (Table 1).

3. Climate and agrobiodiversity

Cropping patterns in the Himalaya are built around two seasons: the monsoon/rainy season and the winter season. With a belief of occurrence of absolute crop failure due to bad climate only in one cropping season in a year, farmers tend to stock staple food required for a period of 6 months. Over the last 50 years, farmers could recall complete failure of both crops only in 1966-67 in a few high elevation villages. People coped such a situation by consuming wild staple food like dried fruits of *Pyrus pashia* and *Aesculus indica* and by selling non-timber forest products and by earning wages in far off places. However, policy of supplying a quota of staple food at subsidized price since 1970s have drawn farmers' attention away from local production based food security system (Semwal et al., 2004; Singh et al., 2008). Even though sowing of winter crops has been delayed by about a month due to late winter precipitation in recent years, harvesting time seem to be unchanged possibly because of warming.

Farmers view two major risks to crops: the risks arising from (a) uncertainty of monsoon rainfall and (b) cultivating distant fields that demand huge labor and time spent in travel/transport. Maintenance of a heterogeneous village landscape is a reflection of indigenous ways of risk management: the rainfed crop agroecosystem is characterized by

both climatic and distance related risks, rainfed agroforestry systems by only climatic risks, the irrigated crop system by only distance related risk and the homegarden system by neither of the two risks (Singh et al., 2008). Within an agroecosystem type, farmers cope climatic risks by growing crops/cultivars based on indigenous knowledge on their responses to different ecological conditions ((Bardsley, 2003). After the first monsoon showers in April/May, Muatha and Bhagan cultivars of barnyard millet and Jhalarya and Chauras cultivars of fingermillet are sown in a few fields. If monsoon commences by mid-June, maize is sown in about 50% of the remaining fields. If maize growth is normal till 20-25 days after sowing, soybean is intercropped between maize rows and Mungerikwad cultivar of fingermillet is sown in the remaining vacant fields. If the crop growth is poor during first month after sowing, maize fields are ploughed afresh and sown with Mungerikwad cultivar of fingermillet. If monsoon does not commence by mid-June, all cultivars of barnyard millet and fingermillet are sown, covering almost equal areas (Figure 1). Jhaidu and Khimanand ki Ghodi are local rice cultivars able to withstand hail storms while Rekher or Syal Satti and Misri and Thangya varieties of wheat can survive heavy snow fall occurs during early stages of crop growth.

Farmers classify crops in three groups based on their responses to various stresses/risks together with their economic values : (a) economically more-valuable crops with poor performance under extreme rainfall regimes, low soil fertility levels and weed abundance including maize, soybean, paddy, wheat, lentil, potato, buckwheat, amaranths and green vegetable, (b) economically less-valuable crops with ability to perform under unfavorable climatic conditions, low soil fertility levels and weed abundance including fingermillet, barnyard millet and barley, and (c) economically more-valuable crops with

ability to perform under unfavorable climatic conditions, soil stresses and weed abundance including sesame, cowpea, black pea (*Pisum arvense*), horsegram and pigeon pea. Though many of farmers' perceptions about crop-environment relations are substantiated by scientific evidences (Maikhuri et al., 1996; Singh et al., 1997; Sherchan et al., 1999; Pilbeam et al., 2000; Singh et al., 2008), there is a need of undertaking long term comprehensive programs for validation and enhancement of local knowledge system. A traditional crop like *Panicum miliaceum* is unique in that its maturity time is as short as two months but is not viewed as a delicious food. Increasing the area under this crop following bad climate seasons is a common way of achieving food sufficiency. Farmers apply higher levels of inputs available in limited quantities to the perceived low risk agroecosystems as compared to the more risky ones (Carter and Murwira, 1995).

Conversion of rainfed to irrigated farming reduces the risks of climatic uncertainty and improves productivity (Bhatnagar et al., 1996; Maikhuri et al., 1997) but has not progressed much for two reasons. First, farmers face a shortage of manure (due to scarcity of forest resources) required for performance of irrigated crops and are unable to afford the chemical fertilizers. Second, labor productivity from the irrigated crop system is lower than other traditional land uses like homegardens. Highly productive indigenous irrigated farming systems do exist in situations where rainfed crops fail to survive (e.g., cold desert) or when population pressure exceeds the carrying capacity of rainfed agriculture or when farmers do not have any source of income other than irrigated crops (Rao and Saxena, 1994; Chandrasekhar et al., 2007).

A trend of replacement of traditional staple food/fodder crops by cash crops is progressing fast since last couple of decades partly because of a socio-cultural

transformation from subsistence to market economy often supported by development programmes enabling availability of food and modern agricultural inputs at subsidized rates and government supported marketing system (Singh et al., 1997; Semwal et al., 2004). Farmlands in the Himalaya are heavily dependent on forests for manure and livestock feed. The ongoing changes in cropping patterns are such that manure input rates have increased along with an increase in soil erosion rates but fodder production from farmland has decreased, which in turn has increased the threats to forest ecosystem functions as a result of higher intensities of litter removal and grazing in forests (Sen et al., 1997; Maikhuri et al., 2000). The tendency for maximisation of income has marginalised the traditional values attached to crop-environment compatibility, social integrity achieved through exchange of complementary crop products and farmers' selection/conservation of crop genetic diversity. Over time, many local communities have gained some understanding about the market risks and uncertainties and have been found to grow cash crops to an extent that their traditional food security system is least disturbed (Maikhuri et al., 2000; Semwal et al., 2004).

As biological potential of traditional crops/cultivars is poorly understood, their loss is not in the interest of the scientific and wider community too. Traditional farmers had selected and conserved a wide variety of crops and cultivars to cope up with the risks, uncertainties and extremes of monsoon and huge micro-edaphic variability in the mountains. Pests and diseases are common in warm-cold regions but not in extreme cold arid region, indicating a possibility of higher risks of damaging agents in warmer climate. Farmer selected cultivars/crops may reduce such future risks.

4. Forest biodiversity-agrobiodiversity-climate change linkages

Theoretically, plants may respond to climate change in four possible ways: (a) phenotypic plasticity enabling species survival, with alterations in eco-physiological processes, in the changed climate, (b) evolutionary adaptation to new climate, (c) emigration to favorable habitats and (d) extinction (Bawa and Dayanandan, 1998; Saxena and Purohit, 1993). Indicators of warming reported by people indicate phenotypic plasticity: shifting of flowering time of *Rhododendron arboreum* from February/March to January/February and of fruit ripening time of *Prunus cerasoides* from February to January. Farmers observed an increase in dominance of *Bauhinia vahlii* twining around *Pinus roxburghii* trees and attributed this change to reduction in fire frequency arising from shortening of hot-dry period. Indeed, people's observations are confined to biologically conspicuous species and the ones affecting their livelihoods.

Forests provide fodder and manure, protection of crops from wildlife and downslope processes and drinking water (through recharge of springs, the source of drinking water), the various forms of environmental services directly to local inhabitants from natural forests, apart from the services, such as regional hydrological balance, soil and biodiversity conservation and carbon sequestration, to the benefit of the global community. Climate change raises a question of uncertainty about these services in future. Forest resource use regimes, which do not pose any threat to both global and local benefits from forest ecosystems, have neither been worked out in scientific terms nor in the indigenous knowledge system. A religious belief that natural hazards/catastrophic events follow if timber trade is adopted as a means of livelihood and agricultural land use is expanded for economic development together with socio-cultural norms allowing sale of non-timber forest products only by economically weaker families and forest resource

uses in groups of families, with utilization-regeneration regimes decided by the community, are the elements of social capital favoring forest conservation. People value forests most for availability of inputs required for sustaining agricultural production, health and the insurance it provides from the uncertainties of environmental extremes (Singh et al., 2008).

5. Climate change mitigation and adaptation: strategic actions

As a rich biodiversity base would provide a greater variety of adaptations to changing climatic conditions, effective ways and means of biodiversity conservation are urgently needed.

5.1. Protected area management

Protected areas will be able to achieve their stipulated goal only when conservation actions are coupled with development of local communities. A number of recent studies do not support the assumption of protected area planners that traditional resource systems (e.g., tourism, low input crop/livestock husbandry) agriculture were not 'efficient' (Maikhuri et al., 2000; Semwal et al., 2004; Chandrasekhara et., 2007; Singh et al., 2008). Larger soil organic carbons stocks and biodiversity in traditional homegardens (Singh et al., 2008) do not support the common contention of a viewing forest land use more efficient than farming in terms of carbon sequestration. Rarity of many economic species is often attributed to over-exploitation, though it may also be related to climate change. Traditional resource uses need to be scientifically evaluated and conservation strategy should be built on the indigenous knowledge completed/supplemented by scientific knowledge and institutional support.

5.2. Conservation of traditional crop diversity

As biological potential of traditional crops/cultivars is poorly understood, their loss is not in the interest of the wider community. A realization of negative consequences of high yielding varieties, viz., dependency on external agencies for seeds, fertilizers, irrigation and pesticides, drastic yield losses under unfavourable climatic conditions and low input management and lower fodder production compared to traditional varieties, in recent years has rejuvenated local efforts towards agrobiodiversity conservation in Hanval valley of Tihri Garhwal. Such efforts must be followed with scientific analysis of crop/cultivar-environment relationships.

5.3. Water management

Global warming will aggravate water stress, a factor often limiting crop yields and life quality. The traditional systems centered on minimum inputs for water purification, storage and canalization, minimal interference with natural hydrological processes, and minimal risks of damages likely from high rainfall events were, by and large, abandoned when water supply was treated as a government service to the people. With experiences of the large scale failure of the new system over the last few decades (Rao and Saxena, 1994), innovations in water technology and management sectors that can be sustained in the likely global warming scenarios are needed.

5.4. Improvement in traditional agroforestry tree management

Traditional farmers usually lop all branches of farm trees during winters when fodder/fuelwood are scarce in forests. Retention of 25% of branches together with an increase in tree density in farmland will enhance carbon sequestration in farm lands without any decline in crop yields (Semwal et al., 2002).

5.6. Improvement in traditional soil fertility management

As agriculture is dependent on forests for manure and fodder, reduction in intensity of biomass removal from forests without any threat to agroecosystem functions is crucial for forest conservation. Application of oak residue based manure enables crop yields 15% higher compared to pine residue based manure partly because of higher rates of nitrogen mineralization coupled with better synchronization of nutrient release and crop uptake in the former (Rao et al., 2003).

5.7. Rehabilitation of degraded lands

Out of 59 million ha of land land constituting the total geographical area of Indian Himalaya, 21 million ha are degraded forest lands. Coupling of local concerns with global concerns is crucial for success of any ecorestoration programme. Introduction of ‘nurse species’ or ‘keystone species’ would be the most desired treatment in degraded lands but knowledge of such species is meager. Yet, there is a scope of developing rehabilitation strategies built on indigenous knowledge supplemented/complemented with the scientific knowledge (Maikhuri et al., 1997, 2000 ; Rao et al., 1999, 2003).

Acknowledgements

Some data and observations presented here are drawn from the work carried out in projects supported by the Winrock International, Delhi and TSBF Institute of CIAT, Nairobi.

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Table 1. Climate change attributes s drawn from anlaysis of people's perceptions in Indian central Himalayan region

Kind of change	Evidence	Response
Decline in snowfall/rainfall	<ul style="list-style-type: none"> <input type="checkbox"/> Decline in snow-covered area around clearly visible peaks <input type="checkbox"/> Decrease in depth and persistence of snow around settlements in higher altitudes <input type="checkbox"/> Decline in apple yield as it needs proper chilling during winters for proper fruit yield 	<ul style="list-style-type: none"> <input type="checkbox"/> Decline in transhumant practices as poor winter follow poor fodder quality as well as quantity <input type="checkbox"/> Replacement of apple by annual cash crops like chilly and cabbage under rainfed conditions in conditions in lower altitude
Decline in rainfall during March-May	<ul style="list-style-type: none"> <input type="checkbox"/> Adverse impacts in terms of decline in yield of Kharif crops due to large scale mortality and/or poor growth in the initial stage of crop growth 	<ul style="list-style-type: none"> <input type="checkbox"/> Abandonment of crops e.g., Panicum miliaceum in March. This crop matures over a period of 3 months and is affected if rainfall is delayed. <input type="checkbox"/> Casual management of traditional staple food crops in dry season <input type="checkbox"/> Replacement of Amaranthus paniculatus by crops like potato, search of off-farm employment opportunities <input type="checkbox"/> innovation of new agricultural practices characterized by productivity and stress tolerant cash crops, e.g. chickpea
High rainfall during August/September instead of the normal peak in July/August	<ul style="list-style-type: none"> <input type="checkbox"/> Damage to rainy season crops when they are close to maturity <input type="checkbox"/> Huge landslides blocking roads during August-September 	<ul style="list-style-type: none"> <input type="checkbox"/> Search for off-farm employment opportunities
Winter precipitation in January/February instead of December/January and decline in intensity of snow fall	<ul style="list-style-type: none"> <input type="checkbox"/> Delayed ploughing/sowing of wheat, barley, naked barley and mustard – earlier it used to be done in November but now in December <input type="checkbox"/> high yielding variety of wheat and green pea which did not perform well earlier, can perform well at higher altitudes <input type="checkbox"/> Decline in barley and wheat yields but in black pea (black does not need as much soil moisture as wheat and barley) 	<ul style="list-style-type: none"> <input type="checkbox"/> Replacement of traditional cultivars of wheat and barley <input type="checkbox"/> replacement of barley by green pea
Increase in instances of cloud burst	Heavy losses of life and property due heavy downpour over a short period of time	Re-establishment of dwellings

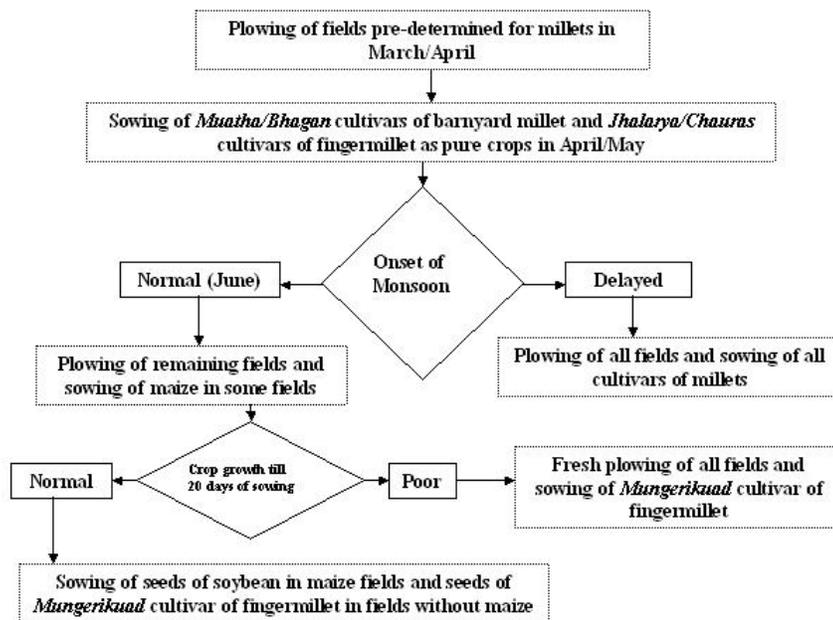


Figure 1. Farmers' decision making on cropping pattern during rainy season in rainfed agroforestry system (based on Singh et al., 2008).