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Changes in the monsoon pattern and its impact on water resources in the Himalayas: community responses and adaptation

Prakash C. Tiwari & Bhagwati Joshi

Abstract

The Indian monsoon has shown sweeping changes over the last 20 years disrupting the hydrological system and decreasing water availability in Himalaya. The number of rainy days and the amount of rainfall has declined. Consequently, the groundwater recharge has been reduced and water discharge in streams and springs has diminished by 35%, decreasing irrigation potential (15%), declining agricultural productivity (25%) and undermining food and livelihood security. Local people are responding to these changes through replenishing water sources, water conserving forestry and horticultural practices, cultivating drought resistant crops, rainwater-harvesting, altering cropping pattern, adjusting crop rotation and relocating agriculture using traditional knowledge.

Keywords: subsistence agriculture, response strategies, Kumaon Himalaya, empirical studies, indigenous knowledge, adaptive water management

1 Introduction

In Himalaya, both the nature of terrain and climate impose severe limitations on the scale of resource productivity as well as on the efficiency of infrastructural facilities. As a result, biomass based subsistence agriculture constitutes the main source of rural food supply and livelihood for more than 75% of the population even though the availability of arable land is severely limited and agricultural production is considerably low in the region. During the recent past, a variety of changes has emerged in the traditional agricultural practices mainly in response to population growth and resultant increased demand of natural resources, such as, land, food, fodder, fuel wood etc. As a result, the critical natural resources, such as land, forests, pastures etc. have depleted steadily and significantly leading to their conversion into degraded, waste and non-productive lands in the region. These land use changes have unprecedented adverse impact on basic ecosystem services, particularly water, biomass and soil-nutrients, and consequently, the region recorded a considerable decline in agricultural productivity during the last 25–30 years (Tiwari & Joshi 2011).

Moreover, climate change has stressed the traditional agro-ecosystem through higher mean annual temperatures and melting of glaciers and snow, altered precipitation patterns and hydrological disruptions, and more frequent and extreme weather events in Himalaya. Consequently, the regime of water resources is likely to change fast with respect to discharge, volume and availability in Himalaya (Bandyopadhyay & Sharma 2002). Besides, changing Indian monsoon pattern is causing large rain-

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fall variability reducing number of rainy days, decreasing rainfall and causing severe drought in Himalaya (Chaulagain 2006; UNFCCC 2007). This is disrupting the hydrological regime of Himalayan watersheds through reduced groundwater recharge and drying of natural springs and thus impairing basic ecological services, particularly drinking and irrigation water and undermining livelihood and food securities in large parts of Asia dependent on subsistence agriculture (Singh & Bengtsson 2005). These environmental changes could cause respectively 25%, 15%, 21% and 20% decline in drinking and irrigation water, hydropower, and agricultural productivity in Himalaya and adjoining plains which could bring 9–13% loss of Gross Domestic Product in India by 2100 (Cline 2007; Aase et al. 2009). It is therefore highly imperative to improve the understanding of the impacts of climate change in the Himalayan ecosystems, and identify potential response strategies in various natural resources sectors. Since water is the most critical resource to climate change, it is necessary to analyse the dynamics of glaciers and precipitation pattern, and to interpret consequent hydrological responses and to evolve adaptive, integrated and community oriented water management frameworks in order to enhance adaptive capacity of natural and social system to long term impact of climate change (UNDP 2006).

2 Objective and methods

The main objective of the paper is to analyze the variability in rainfall pattern, assess its impact on agricultural productivity and food security, and to interpret indigenous adaptation measures and traditional coping mechanism to changing climatic conditions with a case study of Kosi Headwater in Kumaon Himalaya, India. Detailed information with respect to precipitation pattern, water discharge in springs and streams was collected through long-term hydro-meteorological monitoring and observations. The of analysis agricultural land use pattern and resource utilization structure have been carried out through the interpretation of high resolution satellite data and field survey and mapping techniques, and employing community based resource appraisal and management tools. Necessary data and information pertaining to irrigation potential and agricultural productivity have been collected through conducting comprehensive socio-economic surveys using exclusively designed schedules and questionnaires, and from various secondary sources. In order to ascertain and analyze community adaptation mechanism, empirical studies have been carried out to document practices, approaches and methods evolved and used by indigenous communities to adapt their agricultural resource utilization pattern and food systems to changing climatic conditions.

3 The study area

The study has been carried out in Upper Kosi Catchment which encompasses a geographical area of 107.94 km^2 between 1,425–2,650 m above mean sea level (m. s. l.), in the Lesser Himalayan ranges of district Almora which put together with twelve

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other districts constitutes the newly carved Himalayan state of Uttarakhand in India. The total population of the region is 16,080 persons in 62 villages. Subsistence Agriculture with animal husbandry as its natural ally constitutes the main source of livelihood. More than 75% of the population depends on subsistence agriculture although the availability of arable land is severely limited and productivity is low. More than 90% operational land holdings are of less than one hectare and the availability cultivated land per capita is merely 0.17 ha which results in low food productivity as well as low economic viability of agriculture in the region.

4 Traditional livelihood and food system

As in other parts of Himalaya, due to constraints of terrain and climate more than 75% of the population of the region is dependent on traditional biomass based (forest based) subsistence agriculture for its food and livelihood. However, crop farming is not economically viable in most areas of the region due to several geo-environmental constraints and resultant poor agricultural productivity. The availability of arable land is considerable low, the size of land holdings is very small, and consequently, the intensity of cropping (i. e., number of crops grown in an agricultural year) is as high as 150%. In order to preserve soil fertility level and productivity of land under sustained cropping, in such an agro-ecosystem, there must be a net transfer of energy from the forests to arable land. This flow of energy from forest to cultivated land, in the Himalayan agro-ecosystem is mediated through livestock, which is usually in the form of fodder of stall-fed cattle whose manure and labour is applied to the cultivated land. Forest, livestock and arable land are the three basic components of the Himalayan agro-ecosystem, in which forests are pivotal to the maintenance of crop production levels. On an average, one unit of agronomic production in the region involves nine units of energy from the surrounding forest ecosystem (Singh et al. 1984). During the period, the region registered nearly 83% population growth despite increasing out-migration. As a result, both the availability of per capita cultivated land and yield declined. Expansion of cultivation on marginal and sub-marginal land and abandonment of less productive land continuously decreased food productivity in the region. Rapid land use changes and resultant deforestation not only decreased the supply of biomass to cultivated land but also reduced ground water recharge and declined agricultural productivity. The variability of rainfall observed both in terms of declining the amount of rainfall as well as rainy days affected adversely the food productivity in the region. The region also suffered a massive loss of agro-biodiversity in terms of reduction of a large number of variety of staple food-crops, particularly, rice, wheat, pulses mainly due to changes in food habits, and socio-economic and environmental transformations. The economic recession and the resultant decline in income and hike in food prices made the region highly food insecure. Food insecurity increased both in absolute and relative terms with increase in population and decline in productivity and income level.

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5 Changes in rainfall pattern and its impact water resources

The interpretation of hydro-meteorological data (collected from local meteorological stations for the period between 1980 and 2010) brought out clearly the fact that the number of annual rainy days per year have declined from an average of 60 days to less than 50 days with a few exceptions. Consequently, the amount of annual rainfall had decreased from average 140 cm to approximately 115 cm during the last 20 years. The rapidly changing land use pattern and the resultant decrease in forest area and decreasing annual rainfall have disrupted the hydrological regime of the entire catchment, and this has unprecedented adverse impact on the water resources of the region (Ives 1985, 1989). The water resources of the catchment are diminishing and depleting fast mainly due to reduced ground water recharge (Valdiya & Bartarya 1991; Tiwari 2000; Tiwari & Joshi 2005, 2011). The studies carried out in the region revealed that the amount of surface runoff from cultivated and barren lands is much higher compared to the amount of runoff from other categories of land, particularly, forests and areas under horticulture (Tiwari 1995, 2000, 2008, 2010; Tiwari & Joshi 2009). These hydrological imbalances are clearly discernible in (i) long-term decreasing trend of stream discharge, (ii) diminishing discharge and drying of springs, and (iii) biotic impact on surface run-off flow system and channel network capacity (Tiwari & Joshi 2005).

As a result, the water discharge in streams and springs has diminished drastically which is clearly indicated by the observed trends of water discharge of river Kosi – the main river of the catchment. The river showed a continuously declining water discharge between 2000 and 2008 except in the year 2007, and a stream-length of approximately 736 km (in 107.94 km^2) comprising mainly first order tributary streams of Kosi River has completely dried during the last 20 years. River Kosi is considered as the lifeline of the region as not only most of the productive arable land is constituted by polycyclic flat terraces situated on both sides of the river, but also the majority of the drinking water supply and irrigation schemes take water from the Kosi. Further, it was investigated that nearly 34% and 11% natural springs have gone dry and become seasonal respectively primarily due to decreasing trend of rainfall and declining groundwater recharge, in the catchment. As a result, as many as 61% villages have been facing great scarcity of water. In these villages this water scarcity situation turns into severe water crisis during the summer and dry winter months. These hydrological disruptions have shown their direct adverse impact on the irrigation potential that has decreased considerably during the last three decades mainly owing to reduced ground water recharge and drying of springs and streams. The irrigation potential has been analyzed in terms of the declined area under irrigation due to non-availability of adequate water in the irrigation system. Although, only 12% of the total cultivated land is irrigated in the region, yet the catchment has lost 25% of this irrigated area due to non-availability of water during the last 30 years. The decrease in irrigated area ranges between 14% and 21% in different villages of the catchment.

The loss of basic ecosystem services, particularly, water has unprecedented adverse impact on the agricultural productivity in the entire region which has declined

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by nearly 25%, while per capita food productivity has shown a continuously decreasing trend during the last 30 years. As a result, the different settlements in the catchment are facing a food deficit between 22% and 88%. Similarly, the fodder and fuel wood deficit situations have respectively shown an overall increase of 20% and 27%. The observed decrease in fodder supplies have great adverse impact on livestock health and their productivity which is further worsening the situation of nutrient supplies to rural population, particularly the children which are already malnourished and deficient in nutrients, and thus affecting the overall health of rural population in the region.

6 Community responses and adaptation

It has been observed that indigenous communities inhabiting remote high Himalayan mountains for several thousand years had foreseen changing climatic conditions, such as changes in temperature and precipitation pattern, shift in monsoon, increase in the frequency and severity of extreme weather events etc. and visualized their probable impacts on their subsistence agriculture through their traditional ecological knowledge and experiences much earlier than the climate change and their potential impacts were accepted by scientific community. Only 15% of the total cultivated land situated mainly in the low lying valley floor is irrigated in the catchment. Whereas, the remaining 85% agricultural land is never irrigated due to non-availability of water, and the crop production in this un-irrigated land completely depends on rainfall. The food productivity in the region therefore mainly depends on the seasonal distribution as well as on the amount of rainfall. The local people have realized that water is the most important input in subsistence agricultural system, and it is highly susceptible to climate change. As observed in the preceding sections both the amount of rainfall and the number of rainy days has declined decreasing irrigation potential as well as agricultural productivity in the region.

In order to maintain local food and livelihood security under changing climatic conditions, local communities have evolved and implemented several schemes for regeneration and conservation of depleting water resources using their indigenous knowledge and traditional water management system and institutionalizing water resources. Besides, in order to improve agricultural changing precipitation pattern and depleting water resources people have adopted several measures based on their traditional experience and knowledge. These adaptation practices include, altering traditional cropping pattern, adjusting crop rotation, cultivating abandoned land and relocating agriculture. It was investigated that: (i) communities in 27% of the villages have replenished dwindling water sources through water conserving forestry and horticultural practices around natural springs and streams, (ii) 25% of the villages managed scarce water through rainwater harvesting schemes through community participation. It was also observed that: (i) nearly, of the 19% families cultivated less water requiring and drought resistant food as well as cash crops, such as, finger millets and maize, (ii) 21% of the households altered traditional cropping pattern and adjusted crop rotation, (iii) 11% of the households cultivated abandoned land,

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(vi) 27% of the families relocated their agriculture. The study revealed that: (i) 7% of the families have abandoned their agriculture land due to declining productivity, and switched over to secondary and tertiary economic activities, (ii) 5% of the families out-migrated the region, and (ii) 11% of the households has decreased the consumption of certain food crops, such as rice and pulses which are quite low in productivity mainly due to decreased rainfall and declined irrigation potential. Since, these practices and methods are the outcome of community experimentation with local natural conditions for several thousand years; they have proved highly effective in enhancing the resilience and adaptive capacity of both natural and social system to long term impacts of climate change and improving livelihood and food security at local level.

7 Community based water sector adaptation plan

However, it was observed that traditional adaptation mechanism would not be able to reduce the vulnerability of poor and marginalized communities to food security in view of long term impacts of climate change on water resources in the region. In order to enhance the efficiency and resilience of traditional water sector adaptation measures an adaptive, comprehensive and community oriented action plan for management and governence of water resources was formulated at village level. The proposed water adaptation plan primarily focuses on the regeneration, protection and replenishing of water resources using local traditional knowledge and strengthening traditional community water management system and active participation and involvement of local people. Attempts have been made to institutionalize water resources through reviving and strengthening existing participatory mechanism and building grass root institutions in each of the 62 villages of Upper Kosi Catchment. Water Resource Management Committees (WRMC) with ensured participation of women and youth were constituted in all the villages. The proposed water sector adaptation framework makes provisions for: (i) development of 85 'Spring Sanctuaries' around the springs and sources of streams by planting water conserving trees (Valdiya & Bartarya 1991; Tiwari 1995), (ii) conservation of water by constructing 57 mud ponds, (iii) building of 35 check dams on the streams for checking run-off, (iv) treatment of 25 first order stream-catchments through afforestation, (v) conservation of 255 hactare of forests through reforestation, protection and regulated resource utilization, and (vi) rehabilitation and development of 105 ha of waste and degraded lands through plantation of energy and fodder species, horticulture and cultivation of tea and medicinal plants.

8 Conclusions

Himalaya being tectonically alive, ecologically fragile, economically underdeveloped and densely populated is highly vulnerable to long term impacts of climate change. The changes in precipitation pattern and resultant diminishing stream flow, the dry-

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ing of springs and the decreased irrigation potential have disrupted hydrological system and stressed available water resources in Himalaya. Consequently, agricultural productivity has declined steadily and significantly undermining livelihood and food security of a large proportion of rural population consisting mainly poor and marginalized communities. The local communities have evolved and experimented with several kinds of coping practices and measures to adapt their livelihood and food systems to changing precipitation pattern and depleting water resources using their indigenous knowledge. However, it was observed that traditional adaptation mechanism would not be able to reduce the vulnerability of local communities in view of long term impacts of climate change. In view of this, an adaptive, integrated and community based water management framework has been evolved to enhance the efficiency and resilience of traditional water sector adaptation system through regeneration, protection and replenishing of water resources using local traditional knowledge and active participation and involvement of local people.

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Digitale Literatur/Digital Literature

Zeitschrift/Journal: IGF-Forschungsberichte (Instituts für Interdisziplinäre Gebirgsforschung [IGF]) (Institute of Mountain Research)

Jahr/Year: 2011

Band/Volume: 4

Autor(en)/Author(s): Tiwari Prakash C., Joshi Bhagwati

Artikel/Article: Changes in the monsoon pattern and its impact on water resources in the Himalayas: community responses and adaptation 155-162