Change Adaptation Socioecol. Syst. 2015; 2: 8–25 DE GRUYTER OPEN

Research Article Open Access

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Climate Change and Rural Out-migration in Himalaya

DOI 10.1515/cass-2015-0002
received November 10, 2014; accepted March 30, 2015

Abstract: This paper examines linkages between climate change and rural out-migration in Himalaya. Subsistence agriculture constitutes the main source of food and rural livelihoods in the region although the availability of arable land is severely limited and crop productivity is low. The constraints of the subsistence economy compel a large proportion of the adult male population to out-migrate from the mountain region in search of livelihoods and employment. Changing climatic conditions have stressed Himalayan agricultural and livelihood systems through higher mean annual temperatures and melting of glaciers and snow, altered precipitation patterns and hydrological disruptions, and more frequent and severe extreme weather events. The amount of rainfall events and number of rainy days has declined respectively by 52% and 34% during the last ten years and the incidence of high intensity rainfall and droughts have increased. These changes have disrupted the hydrological systems and reduced the availability of water resulting in frequent crop failures, declines in irrigation potential (25%), decreased agricultural productivity (26%), and loss of rural livelihoods (34%) in traditional rural sectors. These pressures have contributed to increasing trends of rural out-migration, specifically an overall increase of 2536% between 2001 and 2013. The increasing trend of out-migration among male youth has affected the quality of life of rural women through feminization of mountain agriculture and resource development processes.

Keywords: Rainfall variability; extreme weather events; decline in agricultural productivity; loss of rural livelihoods; feminization of agriculture; climate change

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1 Introduction

Mountain regions encompass nearly 24% of the total land surface of the Earth [1] and are home to approximately 12% of the world's population with an additional 14% of the global population living in their foothills and adjoining lowlands [2]. Approximately half of the world's population inhabiting the large river basins located far away from mountains depends on mountain headwaters for the supply of freshwater [3]. Mountains comprise sources of a variety of ecosystem services which sustain livelihoods and economies of large populations. Mountains retain the largest proportion of the world's forests, a feature consisting of global biodiversity hot spots and pools of genetic resources which regulates and modifies climatic conditions and contributes towards mitigating global warming through carbon sinks [4]. However, mountains are highly important from the view point of environmental sensitivity, inaccessibility, marginality, and poverty [5]. Mountains include some of the most fragile ecosystems on the planet [4] as they are highly sensitive to changes caused by natural and anthropogenic factors [6-8]. Subsistence agriculture, animal husbandry, and income generation through small scale trade, and wage and casual labour constitute the main sources of livelihoods in mountain communities [9]. The Food and Agricultural Organization (FAO) of United Nations has identified more than 75% of the land surface of the world's mountain regions as unsuitable or marginally suitable for practicing agriculture [2,10,11]. The proportion of poor and vulnerable people increases with elevation [2]. There is evidence that poverty inequality between mountain people and those living in other areas is increasing [4]. Approximately 271 million people in Asia and Latin America, accounting for nearly 40% of the mountain population in developing and transition countries, have been estimated to be highly vulnerable to food insecurity [2,12].

Mountain regions have often traditionally been characterized by unsustainable resource exploitation by their inhabitants. However, in recent years understanding of problems facing mountain regions and approaches to their development has increased [4]. This has contributed to a deepening anxiety over the depletion of natural resources and the disruption of mountain ecosystem services. As a result, the significance of mountain socio-ecological systems was acknowledged for the first time on a global scale in Agenda 21 of the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro, Brazil, in 1992 [13]. Currently, mountain ecosystems as well as mountain communities are particularly threatened by the ongoing processes of global environmental change, population dynamics, economic globalization, and the resultant exploitation of mountain resources [14]. In recent years, a variety of changes have emerged in the traditional resource use structure in high mountain areas, particularly in developing and underdeveloped regions of the world. These are mainly in response to the changing global economic order, transforming political systems, rapid urban growth, increased demographic pressures and a resultant increased demand and exploitation of natural resources. As a result, mountain regions of the world are passing through a process of rapid environmental, socio-economic and cultural transformation and exploitation and depletion of their natural resources leading to ecological imbalances and socio-economic impacts both in upland and lowland areas [15,7].

Climate change is acting as an additional stressor which can multiply existing development deficits. It may also reverse socio-economic development in mountain regions particularly in underdeveloped and developing countries [16]. Further, these impacts are likely to undermine the inherent capacity of indigenous mountain communities to respond and adapt to changing environmental conditions including those associated with climate change [2,12]. The main objective of this study was to assess the impacts of changing climatic conditions, particularly rainfall variability, on rural out-migration through the examination of linkages between changes in rainfall patterns, extreme weather events, availability of water resources, food productivity, livelihood opportunities and rural out-migration. Examination of these parameters is undertaken through an empirical study of Ramgad Catchment located in Uttarakhand Himalaya, India.

2 Himalaya: Marginalization and Vulnerability

Himalaya contains the most extensive and high altitude areas on the planet, and the largest areas covered by glaciers and permafrost outside the polar regions [4]. The mighty glaciers, snow and forests constitute headwaters of some of the largest trans-boundary basins on the planet. They sustain 1.3 billion people in South and East Asia dependent primarily on subsistence agriculture [4]. Tectonically active, Himalaya is densely populated and inhibited by some the poorest and marginalized people on one of the planet's most fragile ecosystems [9]. The mountain range is a geographically, geologically and culturally unique landscape that provides a variety of environmental services for hundreds of millions of people both up-stream and down-stream [17,18]. Due to constraints of terrain and climate in Himalaya, subsistence agriculture constitutes the main source of rural livelihoods; the availability of arable land is severely limited and agricultural productivity is low [4]. A high dependency on natural resources and increasing marginalisation are important factors contributing to poverty, food and livelihood insecurity and poor community health in Himalaya which are further increasing the vulnerability of local communities to the long-term impacts of global environmental changes [2]. Due to limitations of the subsistence economy, a large proportion of the adult male population out-migrates from the region in search of new livelihoods [19,4].

In the recent past, a variety of changes have emerged in traditional resource utilization patterns in response to population growth, an increased demand for natural resources, economic globalization, urbanization, and climate change in Himalaya [4,20]. These changes have exerted sharply accentuated pressures on local subsistence economies through impacts on land, water, biodiversity and forest resources. As a result, conventional production systems have collapsed increasing community vulnerability to livelihood impacts, food insecurity and increased risks from natural disasters [9]. Economic globalisation has increased the vulnerability of mountain communities to environmental risks through exploitation of natural resources even in remote and inaccessible areas. This seems to have further strengthened wealth imbalances between highlands and lowlands [21,2]. Moreover, changing climatic conditions have stressed the Himalayan ecosystem through higher mean annual temperatures and melting of glaciers and snow, altered precipitation patterns, and more frequent and extreme weather events which are likely to intensify the impacts of other natural as well as socio-economic drivers of change [22,23,1]. This has increased male out-migration and consequently increased hardships of rural women and deteriorated their quality of life [24].

3 Research Methodology

3.1 The Study Area

Ramgad Catchment, situated in the Lesser Himalayan ranges of the Himalayan State of Uttarakhand, India, was the area of study for this investigation (Figure 1). The catchment encompasses a geographical area of nearly 75.8 km^2 between 1025 m and 2346 m in altitude. Ramgad is the one of the principal tributaries of the Kosi River in its mountainous part. The catchment is characterized by a diversified terrain and a geomorphic landscape with varying magnitudes of slopes, a variety of soils, natural vegetation, hydrological regimes, and climatic patterns. The total population of the headwater in 2013 was 22,085 persons inhabiting 24 revenue villages – administrative units of rural areas with defined borders. Cultivation, horticulture, tourism and grazing are extended over large areas and are leading to the exploitation of natural resources, land use intensification, and depletion of mountain ecosystem services. The study area was divided into three micro-watersheds employing stream ordering techniques. These micro-watersheds comprised lower level geographical units for analysis and mapping completed in this study. This exercise was carried out using topographical maps printed on 1:50,000 scales published by Survey of India. The three micro-watersheds of the Ramgad Watershed are: Upper Ramgad Micro-watershed (28.88 km^2); Middle Ramgad Micro-watershed (26.53 km^2); and (iii) Lower Ramgad Watershed (20.39 km^2).

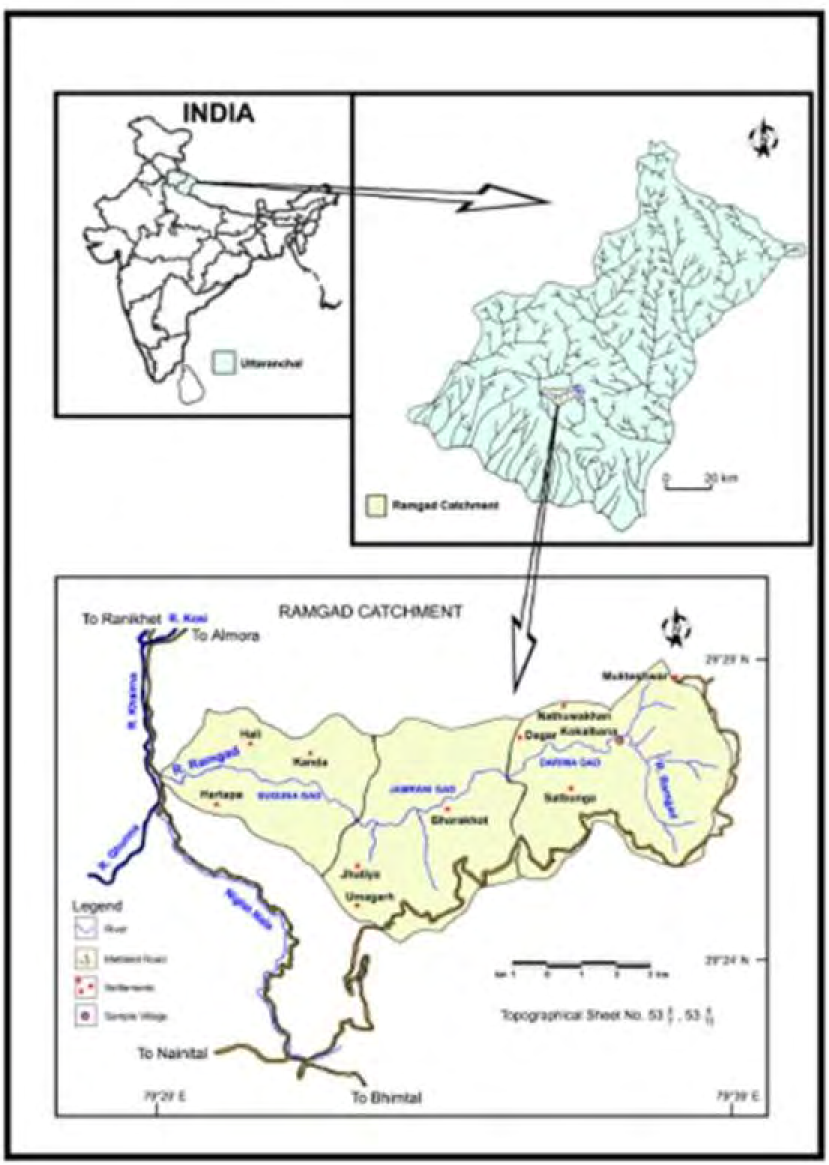

Figure 1: Location map of the study area.

3.2 Materials and Methods

The methods of this study included: (a) observation and monitoring of rainfall variability and extreme weather events; (b) analysis of land use, and appraisal of land, water and forest resources; and (c) interpretation of inter-linkages among: (i) rainfall variability and extreme weather events, (ii) availability of water, (iii) food and livelihood security, and (iv) trends of rural out-migration. The information and data required for the study were generated and collected from various primary and secondary sources. The primary information was generated through intensive field investigations to map, observe, monitor, and conduct socio-economic surveys. The secondary methods included the examination of high resolution satellite data, Survey of India (SOI) topographical maps of the area at scale 1:50,000, forest maps, cadastral maps and a review of available published and un-published literature including government reports. Panchromatic (PAN) and Linear Imaging Self Scanner (LISS-3) merged data (5.8 m resolution) of the Indian Remote Sensing Satellite 1D (IRS-1D) and Cartosat-2 (1 m resolution) data were used for the survey and mapping of land use and the appraisal of land, water, and forest resource dynamics. Digital interpretation techniques supported by intensive ground truth collection and intensive reconnaissance surveys were used to analyze the remote sensing data.

The data pertaining to the number of rainy days, amount of rainfall, and extreme weather events were collected from local meteorological stations operated by various government agencies. Water resources were assessed through long-term monitoring of water discharge in springs and streams and by analyzing their environmental status. The annual average flow was considered for the interpretation of water discharge in streams and springs. The environmental status of water resources (streams and springs) was also determined by interviewing elderly people in each of the villages of the study region. Information on the impacts of climate change and extreme weather events on water availability and local agricultural, food and livelihood systems was generated through household surveys conducted in all 24 villages within the catchment. The information pertaining to trends of rural out-migration and its causes was collected through household surveys and the village population register. The sample size for the household surveys constituted 33% or 725 of the total households (2197 total households) and was composed of select women headed households (25%), households below the poverty line (as classified by the Government of Uttarakhand State) (40%), households solely dependent on agriculture (15%) and families dependent on agriculture and other means of income (20%) from each of the 24 villages of the catchment. The sample size from the 3 micro-watersheds of Ramgad was in proportion to the number of households. Out of the total 725 households surveyed, 340, 249 and 136 were from Upper, Middle and Lower Ramgad micro-watersheds respectively.

4 Results and Discussion

4.1 Climate Change Trends in Himalaya

Himalaya has shown consistent trends in overall warming over the past 100 years; temperature rise in mountains has been faster than in plains [25,26]. A number of studies indicated that the increase in temperature in Himalaya has been much higher than the global average of 0.74°C over the last 100 years [23,26]. Himalaya has experienced warming of between 0.15°C – 0.6°C per decade during the last three decades with an average temperature increase of 0.6°C per decade between 1977 and 2000 [27]. The most significant impact of climate change is the remarkable retreat of Himalyan glaciers over the past century. The rate of retreat of the Gangotri – the largest Himalayan glacier– has been three times faster than the rate at which it melted during the preceding 200 years [28,29,23,30]. In the Nepalese Himalaya, a large number of glaciers are receding rapidly [31,32,33]. The study indicated that 6% of glaciers in the headwaters of Tamor and Dudh Koshi basins in Nepal Himalaya have decreased during 1970 - 2000 [27]. These observed changes in the cryosphere are transforming the hydrological regimes of the Himalayan headwaters and disrupting drainage systems all across the basins. Consequently, the regime of water resources in Himalaya is likely to change rapidly with respect to discharge, volumes, and availability [3,7,34,35].

Himalaya constitutes headwaters of some of the planet's largest trans-boundary basins that sustain one-fourth of the global population that depend primarily on subsistence agriculture in Pakistan, India, Nepal, Bhutan, China and Bangladesh. Climate change has stressed hydrological regimes of Himalayan headwaters through higher mean annual temperatures, melting of glaciers, and altered precipitation patterns causing a substantial decrease in water availability. It is most likely that Himalaya and its lowland face a catastrophic water scarcity by the 2050s resulting from climate change, population growth, and the subsequent increase in water demand [36,8]. This may increase the vulnerability of 1.7 billion people living in South Asia to water and food insecurity [29]. This will have enormous regional implications for fundamental human development goals ranging from poverty alleviation to environmental sustainability, climate change adaptation, and ultimately human security [37]. Climate change is threatening sustainable development in the mountains, particularly poverty alleviation and livelihood improvement programmes. Critical resources such as agricultural lands and crops and the storage of food and seeds are under increasingly threatened by climate change triggered natural risks particularly in developing countries. Mountain communities are expected to face more severe impacts in the future due to the likelihood of more and more frequent occurrences of extreme events, and this will increase risks to their economies. The long-term impacts of climate change may thus further widen existing socio-economic inequalities between highland and lowland communities [8].

The Himalayan mountain ecosystem is highly vulnerable to a variety of natural hazards and disasters which are now being triggered by rapidly changing climatic conditions. Global warming is likely to intensify the hydrological cycle of the Himalayan watersheds, and consequently change the frequency, intensity and severity of floods and droughts in mountains and their lowlands [40]. Recent catastrophic disasters in Western Himalaya clearly indicate that high intensity precipitation is triggering flash floods, slope failures and landslides in mountainous terrains having severe impacts on the natural and socio-economic sustainability of fragile mountain ecosystems. The most dangerous natural disasters in high mountains are associated with the direct consequences of changes in the cryosphere. These changes in the cryosphere have led to the formation of a large number of glacial lakes in Himalaya, and many of these high altitude lakes are potentially dangerous. The resulting Glacial Lake Out Flows (GLOFs) can cause catastrophic flooding in lowlands affecting human lives, property, forests, agricultural land, crops and infrastructure [41,42]. The long-term impacts of climate change are expected to exacerbate the impacts of other drivers of change in these fragile and densely populated mountains. However, the exact impacts of climate change on mountain ecosystems, and the inter-linkages with other drivers of global change are yet to be investigated and are not properly understood [4].

4.2 Rainfall Variability

As in other parts of Himalaya, the distribution of rainfall in Ramgad Catchment mainly depends upon altitude, slope-aspect, and alignment of mountain ridges. Physiographic diversity and altitudinal variations play important roles in determining the quantity of rainfall at different locations. Higher amounts of rainfall are recorded along south facing slopes which are first to come into contact with monsoon winds. It has been observed that the amount of rainfall increases up to an altitude of 2100 m, but a rapid decrease in rainfall is recorded above this height since increasing altitude reduces the supply of moisture from the ground to the air [43]. In Ramgad Catchment the average annual rainfall is 90 mm with mean monthly rainfall ranging between 11 mm in the month of November and 230 mm in the month of August. The rainfall pattern is governed by the south-west monsoon, and nearly 80% of the total annual rainfall occurs during the monsoon season, normally between June 15 and September 15. The largest proportion of rainfall flows out the catchment through overland flow. The observed pattern of annual rainfall and the trend of annual rainy days are presented in Tables 1 and 2 respectively. Total annual rainfall has shown a consistently declining trend from 2001 to 2013 except in the years 2004 (2200 mm), 2008 (2970 mm) and 2010 (3500 mm) when the entire region experienced abnormally high rainfall during the monsoon season. The amount of total yearly rainfall in Ramgad Watershed declined from 2400 mm to 1155 mm for an overall decrease of nearly 52% between 2001 and 2013. This indicates that, on average, the amount of annual rainfall has been decreasing continuously in the region for the last 13 years with a few exceptions (Tables 1 and 2).

4.3 Rainy Days

In addition to the quantity of rainfall, the period over which the rainfall is distributed is critically important for the availability and temporal distribution of the water resources and their potential use. As mentioned above, most of the rainfall occurs in a short period mainly between June and September. The annual distribution of rainy days determines the availability of water and the level of groundwater recharge. The overall distribution of rainy days in Ramgad Watershed from 2001 to 2013 is presented in Table 2. In general there has been a progressive decline in the number of rainy days in the region during that period. The number of annual rainy days has declined from an average of 85 days to nearly 56 days with a few exceptions from 2001 to 2013 for an overall decline of 34% during the last 13 years. During this period the lowest number of rainy days was recorded in 2008 and 2013 when rainfall occurred respectively on only 55

Table 1: Observed rainfall variability and extreme weather events.

Years	Total Annual Rainfall (in mm)	Annual Number of Rainy Days	Days of High Intensity Rainfall
2001	2400	85	04
2002	2125	93	04
2003	2010	89	03
2004	2200	71	07
2005	1915	65	09
2006	1870	67	11
2007	1700	62	14
2008	2970	55	15
2009	1635	56	14
2010	3570	62	17
2011	1610	56	21
2012	1605	57	25
2013	1155	56	07
Average	2134	67	12

Source: Meteorological Station, Muktshwer, Nainital, Uttarakhand.

Table 2: Pattern of annual rainy days in Ramgad watershed during 2001 – 2013.

Months	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
January	5	6	7	3	0	1	3	2	1	1	0	2	2
February	3	6	7	4	6	5	4	1	4	3	3	1	2
March	5	7	0	5	2	3	5	0	4	5	6	5	4
April	0	3	6	3	3	5	1	0	1	3	1	2	3
May	4	7	12	3	2	6	3	8	5	7	4	4	3
June	13	7	10	6	7	12	6	11	10	13	12	13	12
July	22	22	16	14	12	8	12	16	13	16	15	14	12
August	17	19	20	20	20	10	15	10	11	7	7	6	7
September	13	16	11	12	11	6	9	3	7	6	6	6	7
October	2	0	0	0	2	6	4	4	0	1	2	3	4
November	1	0	0	0	0	2	0	0	0	0	0	0	0
December	0	0	0	1	0	3	0	0	0	0	0	1	0
Total	85	93	89	71	65	67	62	55	56	62	56	57	56

Source: Meteorological Station, Muktshwer, Nainital, Uttarakhand.

and 56 days (Table 2). During 2003 and 2009, the number of rainy days fluctuated between 65 and 56, respectively, whereas in 2010 the number of rainy days increased to 62 which devastated the entire region with high intensity rainfall and flash floods several times during the peak monsoon month of September. These observations make it clear that due to a considerably smaller number of rainy days per year the duration of sunshine would be very high resulting in high radiation and high-energy intake from the sun in the region. This in turn would increase the rate of evaporation during dry season and cause high evapotranspiration during the monsoon. It has not been possible to calculate the energy and water budgets for the watershed due to a lack of meteorological information. However, assuming medium rainfall and high radiation in the catchment, it is likely that the overall water budget in the region is trending downward.

5 Trends in Extreme Weather Events and Natural Hazard Risks

As in other parts of Himalaya, the observed changes in precipitation patterns have increased the frequency, severity and the intensity of extreme weather events, particularly the hydrological extremes in the region. The frequency of high intensity rainfall has increased from 4 days in 2001 to as many as 25 days in 2012 during peak monsoon months in the region. However, an abrupt decline in the incidence of high intensity rainfall was recorded in 2013 over previous years (Table 1). The increased incidence of high intensity rainfall is resulting in hydrological disruptions, flash floods and slope instability and thus triggering landslides in the catchment. Tectonically active and environmentally sensitive, the watershed is highly vulnerable to these changes in precipitation patterns and consequently susceptible to hydrological disruptions which have increased the severity and frequency of landslides. Increasing incidents of slope failure and landslides are not only devastating productive agricultural land and disrupting conventional irrigation systems, but are also damaging road networks which constitute the only means of food-supply across the remote mountains.

The natural as well as socio-economic sustainability of the fragile Himalayan mountains is being disrupted by increased instances and severity of flash floods and landslides. The Ramgad Watershed was devastated by an average of 25 flash floods and 46 landslides every year during the last 13 years (Table 3). The constant decline in annual rainfall and the decrease in the number of rainy days have also created and intensified drought conditions across the watershed as an average of 13 villages in the region faced drought during 2001 -2013 (Table 3). Taken together, these extremes have been responsible for an increasing incidence of crop failure in approximately 11 villages each year undermining the disaster resilience of rural socio-ecological systems (Table 3). Water related natural disasters took nearly 550 human lives and several hundred livestock, damaging 255 houses, a road transportation network of 110.36 km, 74 km of irrigation canals, and 75 ha of productive agricultural land in Ramgad Watershed during 2001 - 2013 (Table 4).

Climate related natural disasters not only devastated nearly 75 ha of productive agricultural land and decreased agricultural production by 18%, but also increased the food insecurity both in terms of availability and access to food for local people. Food imports were reduced by up to 25% of the regular intake due to prolonged disruption of road transport in the region during last 13 years (Table 4). Therefore extreme weather events consistent with climate change adversely affected the livelihoods and food security of a large, mainly poor, proportion of the population in the region. Long-term impacts of these changes are likely to increase the vulnerability of regional populations to food insecurity through a substantial decrease in production and access to food. With a few exceptions, the number of households affected by extreme weather events increased between 2001 and 2013 distressing 680 families in the study area during the period. Out of the total number of households affected by hydrological disasters the proportion of families with agriculture as the only means of livelihood was the highest (59%). This suggests that greater livelihood options could reduce vulnerability to

Table 3: Incidences of droughts, flash floods, landslides and crop failure.

Years	Incidences of Droughts (villages)	Incidences of Flash Floods	Occurrence of Landslides	Incidences of Crop Failures (villages)
2001	02	21	14	02
2002	00	11	11	00
2003	01	11	27	00
2004	05	09	31	06
2005	09	10	35	11
2006	09	17	55	10
2007	11	24	55	10
2008	17	27	61	15
2009	21	35	65	17
2010	27	47	77	17
2011	31	55	75	21
2012	30	57	77	20
2013	05	07	21	11
Average	13	25	46	11

Source: Nainital Sub Division Office of District Nainital, Uttarakhand, India.

Table 4: Loss of agricultural land, irrigation channels, road network, food production food import due to extreme weather events during 2001-2013.

Years	Loss of Agricultural Land (ha)	Irrigation Channels Disrupted (m)	Decline in Agricultural Production (%)	Road Network Damaged (km)	Food Import Decreased (%)
2001	**03.66**	**7.10**	**11**	**3.40**	15
2002	03.50	7.00	14	3.47	17
2003	03.79	7.70	14	3.53	17
2004	04.25	6.90	07	3.02	12
2005	04.80	6.90	08	3.00	11
2006	04.75	7.11	17	3.70	19
2007	04.90	7.50	16	4.15	23
2008	05.00	8.00	18	4.30	17
2009	06.10	8.25	21	4.77	21
2010	07.55	9.80	25	5.57	37
2011	07.25	9.65	25	27.11	35
2012	07.37	8.80	25	21.75	35
2013	11.57	15.65	39	45.79	67
Total	74.49	110.36	18.46	133.56	25

Source: Nainital Sub Division Office of District Nainital, Uttarakhand, India and field surveys.

natural risks. A comparison of data presented in Tables 1 and 3 indicates that, in general, the higher the amount of rainfall, the greater the number of flash floods and landslides. However, the frequency of high intensity rainfall has more direct impact on the occurrences of both flash floods and landslides in the region (Table 1 and 3). It was observed during field surveys that Upper Ramgad Micro-watershed (being located at the highest elevation and along steep surface gradient) is highly vulnerable to flash floods as well as to landslides; the highest number of these two hazards occurred in the micro-watershed during the last 13 years.

6 Hydrological Disruptions and the Depletion of Water Resources

Ramgad catchment is situated in the rain-fed Lesser Himalayan ranges and rainfall is the most important form of precipitation in the region. Rainfall thus constitutes the basis of the surface, sub-surface and ground water regimes in the region. As a result, streams and springs constitute the principal sources of water in the catchment. The observed changes in rainfall patterns over the last 13 years have disrupted the hydrological system of the watershed and contributed significantly towards depletion of water resources in the region. The hydrological imbalances have been observed in the forms of: (i) decline in groundwater reserve, (ii) drying of natural springs and decline in water-flow, (iii) decrease in the water discharge into streams, and (iv) drying of streams [30]. Recent hydrological investigations carried out in Kumaon Himalaya revealed that the average groundwater storage level in the region was nearly 12% instead of the recommended norm of at least 31% [30]. Field surveys suggest that out of a total of 169 natural springs, 47 have completely dried during the last 25-30 years (Table 5). The average annual water discharge into streams in the region has also been reduced considerably during this time period [20]. The interpretation of satellite data and field surveys indicates that the heads of perennial streams have declined by several metres and dried by about 1.7 km (in 6 villages), 2.5 km (in 5 villages) and 2.9 km (in 13 villages) during the last 30 years. The average water-fetching distances in the watershed vary from a minimum of 0.5 km to a maximum of 2.5 km in water scarce villages during summer. Out of a total of 24 villages in Ramgad Watershed, 20 villages (83%) have been identified as facing great water scarcity for drinking, irrigation and sanitation (Table 6). The 20 villages are not homogenously distributed across Ramgad Watershed. Upper Ramgad Micro-watershed, located mostly at higher elevation and in up-slope areas, has the largest number of villages (11) facing water scarcity, followed by Lower Ramgad (5) and Middle Ramgad Micro-watershed (4).

Table 5: Environmental status natural springs in Ramgad watershed.

Microwatershed	Total Area (km^2)	Perennial Spring	Dried Perennial Spring	Seasonal Spring	Dried Seasonal Spring
Lower Ramgad	20.39	10	03	17	07
Middle Ramgad	2.653	13	03	24	08
Upper Ramgad	28.88	44	11	61	15
Ramgad Catchment	75.80	67	17	102	30

Source: field monitoring by authors.

Table 6: Microwatershed-wise water scarcity in Ramgad catchment.

Microwatershed	Total Area (Km^2)	Total Villages	No. of Villages Under Water Scarcity	% of Total Villages
Lower Ramgad	20.39	6	05	83
Middle Ramgad	26.53	5	04	80
Upper Ramgad	28.88	13	11	85
Ramgad Catchment	75.80	24	20	83

Source: village surveys conducted by authors.

7 Reduced Irrigation Potential

Out of the total cultivated land of Ramgad Watershed (24.24 km^2) only 4% is irrigated. As in the case of domestic water supply, streams and natural springs constitute the sources of water for irrigation. The irrigated land is mainly confined to valley floors and other low-lying areas where a regular supply of water is available year round. The increasing rainfall variability has adversely impacted irrigation potential during the last 13 years mainly owing to reduced groundwater recharge and depletion of springs and streams. The results of this study indicated that the irrigated area in the watershed has declined between 14% and 30% in all three micro-watersheds of the region due to reduced availability of water and the resultant increase in water stress between 2001 and 2013. This brought an overall decrease of about 25% in irrigated agriculture in the watershed during last 13 years (Table 7). This is concerning because 77% of the population is solely dependent on agriculture for its food and livelihood.

8 Impacts on Agricultural Productivity

Climate change and the depletion of water resources have not only decreased local food production, but have also reduced community food purchasing power rendering the entire region highly vulnerable to food insecurity (Figures 2 and 3). A decrease in rainfall and the number of rainy days, increasing frequency of extreme weather events, depletion of water resources and the resultant loss of irrigation potential have stressed the agricultural and food systems of the region [44,45]. As a result, agricultural production has declined from 583 kg/ha/year in 2001 to 430 kg/ha/year in 2013 during the period (Table 8). With population growth and the decline in agricultural production, per capita food productivity has shown a continuously decreasing trend over the last 13 years. As a result, the different micro-watersheds in the catchment face food deficits of between 72% and 80% with annual average deficits of 67% as per the food requirement norms of India's National Institute of Nutrition (NIN) (Table 9). Out of the total population (22,085 persons) of Ramgad Watershed, 13,570 (nearly 62%) distributed in 1302 households (65% of households) have been identified as food insecure (having neither enough local food production nor adequate purchasing power to buy food from markets). Marginal and small farmers and landless households with marginal or small incomes constitute the highly food insecure segment of the region's rural population. The study revealed that most of the food insecure households in the region are not able to obtain enough food. In order to cope with the situation they have had to reduce the consumption (from 30% to 45%) of a variety of essential but expensive food commodities such as rice, pulses, and sugar.

Table 7: The village-wise status of irrigated agricultural land.

Microwatersheds	Village Name	Total Irrigated Area (ha)		Change During 2001-2013	
		2001	2013	ha	%
Lower Ramgad	Hali	24.00	21.00	-3.00	-13.00
	Hartapa	-	-	-	-
	Thowa	-	-	-	-
	Kanda	-	-	-	-
	Suguna	12.00	7.00	-5.00	-42.00
	Picchaltanda	12.00	6.00	-6.00	-50.00
	Total	48.00	34.00	-14.00	-29.00
Middle Ramgad	Jhutiya	12.00	8.00	-4.00	-33.00
	Umagarh	-	-	-	-
	Bhorakhot	-	-	-	-
	Nokana	13.20	10.50	-2.70	-20.00
	Lushgani	12.00	7.50	-4.50	-38.00
	Total	37.20	26.00	-11.20	-30.00
Upper Ramgad	Satbunga	2.40	2.10	-0.30	-13.00
	Nathuwakhan	12.00	11.30	-0.70	-6.00
	Dagar	-	-	-	-
	Maura	-	-	-	-
	Garhgaon	-	-	-	-
	Galla	12.00	11.00	-1.00	-8.00
	Supi	-	-	-	-
	Lodh	12.00	8.75	-3.25	-27.00
	Khaprad	-	-	-	-
	Budebana	-	-	-	-
	Kokalbana	-	-	-	-
	Darima	-	-	-	-
	Sunkia	-	-	-	-
	Total	38.40	33.15	-5.25	-14.00
Ramgad Watershed Total		123.60	93.15	-30.45	-25.00

Source: village surveys conducted by authors.

9 Impacts on Rural Livelihoods

The Upper Ramgad Micro-watershed located in the up-slope areas with improved road connectivity has the highest population (11,070 persons) in Ramgad Watershed. Middle Ramgad Micro-watershed, located in the mid-slopes with traditional agriculture being the main occupation, has fewer inhabitants (6,456 persons) than Upper Ramgad. Lower Ramgad Micro-watershed has the lowest population (4,559 persons) as it is characterized by narrow valleys, steep slopes and poor road connectivity. However, there are no significant socio-economic and cultural differences in the populations inhabiting the three micro-watersheds, except the level of poverty and sex-ratio. In Upper Ramgad the proportion of female population is higher and, besides agriculture, smaller proportions of the population are engaged in horticulture (11%) and road side small business enterprises (7%) such as tea shops, tailoring outlets, and similar homespun forms of cottage industry. Nevertheless, the trend of male out-migration is higher in Upper Ramgad as these rural activities cannot provide viable means of livelihood to rural populations. Subsistence agriculture constitutes the main source of rural livelihood in all three micro-watersheds of the Ramgad Watershed region. A large proportion of the population, particularly the poor, marginalized and landless, depend on traditional agricultural livelihoods, such as agricultural labour, making agricultural implements and processing minor agricultural products. The proportion of the population engaged in these traditional sources of livelihood in Lower, Middle and Upper Ramgad micro-watersheds are 15%, 27% and 39% respectively.

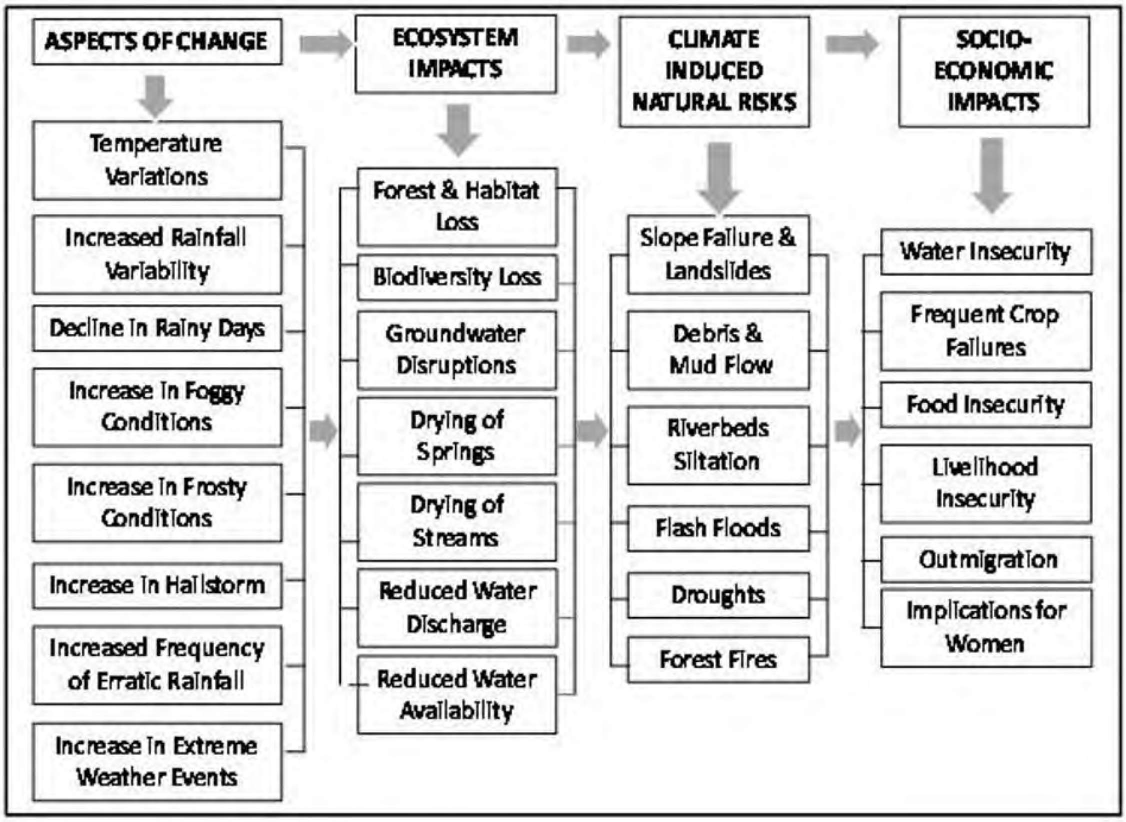

Figure 2: Climate change impacts in Ramgad Watershed.

Bottlenecks	Community Response (%)
Irratic and Reduced Rainfall	91
Reduced Water for Irrigation	20
Labour Scarcity	03
lack of Improved Seeds	03
Lack of Extension Services	01
Lack of Fertilizer	02

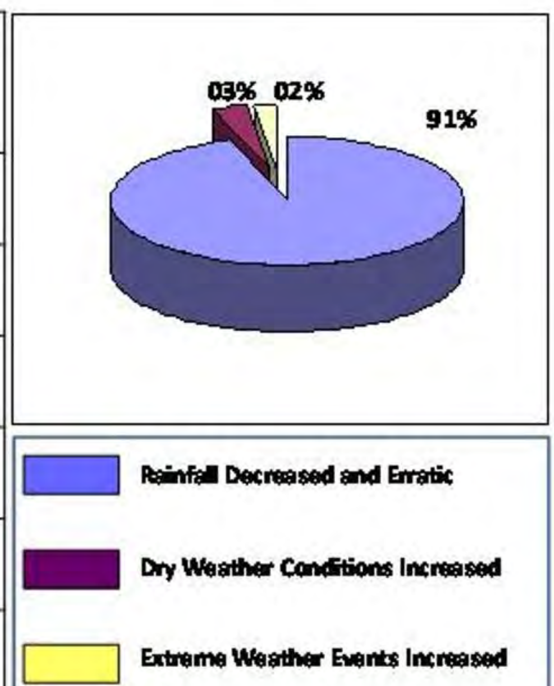

Figure 3: Community perception of climate change and constraints to sustained agricultural production in Ramgad catchment.

Table 8: The status of agricultural productivity in Ramgad watershed.

Micro-watersheds	Number of Villages	Agricultural Production (Kg/Ha/Year)		Decline in Agricultural Production	
		2001	2013	(Kg/Ha)	%
Lower Ramgad	06	755	566	189	25
Middle Ramgad	05	591	396	195	33
Upper Ramgad	13	404	327	77	19
Ramgad Watershed	24	583	430	154	26

Source: field surveys conducted by authors.

Table 9: Food production, demand and deficit situations in Ramgad watershed.

Micro-watersheds	Number of Villages	Total Population	Food Production (Tonnes/Year)	Food Demand (Tonnes/Year)	Food Deficit	
					Tonnes/ Year	%
Lower Ramgad	6	4559	195	932	737	80.0
Middle Ramgad	5	6456	255	1178	923	78.0
Upper Ramgad	13	11070	575	2020	1445	72.0
Ramgad Watershed	24	22085	1025	4130	3105	77.0

Source: field surveys conducted by authors.

A huge proportion of the rural population, particularly landless, marginalized and poor people, depends on agricultural labour, village based processing of agricultural and livestock products, making agricultural tools and traditional handcraft items and the collection of minor forest products including medicinal plants. The livelihood and employment opportunities in these traditional sectors primarily depend on agricultural and livestock productivity and the availability of local natural resources, mainly forests and biodiversity. But, due to massive depletion of forest resources and the consequent loss of biodiversity, employment opportunities in this traditional sector have decreased. The rapidly changing climatic conditions, particularly the reduced annual rainfall and the number of rainy days, the increased incidence of high intensity rainfall, flash floods and landslides, drying of water sources and declining irrigation potential have destabilized traditional agricultural and food systems and reduced the productivity of forests and livestock while depleting biodiversity in the region [24]. As a result, livelihoods in these traditional rural sectors have declined considerably during the last 13 years. In 2001, 6,747 persons were engaged in traditional sectors, such as agricultural labour, livestock, minor forest products, rural handicrafts and agricultural tool making in the watershed, whereas in 2013 this number was reduced to 4,437 persons thus decreasing overall livelihood opportunities by 34% in these conventional rural sectors (Table 10).

10 Rural Out-migration Trends

For millennia, mountain communities have developed mechanisms to adapt to changing environmental conditions [46,47,4]. Across the mountain regions of the world, migration of male youth is an important response mechanism to constraints of subsistence economies and changing environmental conditions [48]. On one hand, labour migration improves economic conditions and ensures food security in terms of remittance while on the other hand, it has inadvertently created a gap in mountain societies where women are burdened with extra responsibilities [48,49,50]. Between 1991 and 2000, the level of adult male out-migration in the mountainous regions of South Asian exceeded 40% [51]. The depletion of productive human resources from mountains has serious implications not only for economic development, but also for the enrichment of socio-cultural life in the region [19].

In Himalaya, due to constraints of subsistence agricultural economies, a large proportion of the rural male youth population traditionally out-migrates from the region in search of new livelihood options. The remittances sent back by the migrated population to their families residing in the mountains constitutes the principal source of cash income and food purchasing power for the majority of the rural population in the region. The study revealed that during the last 30 years, the region has experienced

Table 10: Loss of rural livelihood opportunities in Ramgad watershed.

Micro-watersheds	Number of Villages	Total Population	Persons Engaged In Traditional Livelihood Sectors (in 2001)	Persons Engaged In Traditional Livelihood Sectors (in 2003)	Total Decline in Rural Livelihood (2001-2013)	% Decline in Rural Livelihood (2001-2013)
Lower Ramgad	6	4559	1215	775	440	36.0
Middle Ramgad	5	6456	1977	1147	830	42.0
Upper Ramgad	13	11070	3555	2515	1040	29.0
Ramgad Watershed	24	22085	6747	4437	2310	34.0

Source: household surveys conducted by authors.

high population growth despite prevailing trends of rural out-migration. This growth threatens the development potential of the traditional subsistence agriculture-livestock systems due to the depletion of natural resources and consequent loss of ecosystem services in the region over past decades. The subsistence agricultural economy, with its high cropping intensity and low productivity, has not been able to adapt to the increasing population and has experienced increased rural out-migration. Moreover, rapidly changing climatic conditions have stressed the Himalayan agricultural system through higher mean annual temperatures, altered precipitation patterns, and more frequent and extreme weather events which are increasing the vulnerability of rural communities to food and livelihood insecurity. Consequently, agricultural productivity is declining and livelihood opportunities in traditional sectors are decreasing. People are engaged in agriculture under very difficult conditions as the availability of arable land is severely limited (less than 0.2 ha/person), agricultural productivity is low, and there are no other viable means of livelihood in the region. This has led to more intense cropping (168% increase from 2001-2013) but lower productivity which is characteristic of distressed land husbandry [19].

This study indicates that climate change has increased trends of rural out- migration in the entire region. An increasing incidence of extreme weather events and resultant crop failures have been the most important reason for out-migration in the watershed (Figure 4). The migration is of both a temporary and permanent nature, and migrants include both educated and uneducated youths, particularly males (Tables 11 and 12). In 2001 only 701 people out-migrated from the region, whereas the number of out-migrants in 2013 was 2425 for an overall increase of 41% (Tables 11 and 12). Out of the total number of people leaving between 2001 and 2013 32% migrated on a permanent basis whereas 68% migrated temporarily with their families and eventually returned to the watershed (Table 12). The interpretation of primary data revealed that poverty, a decline in agricultural productivity, the loss of livelihood opportunities and an increasing incidence of natural hazards were the most important causes of the increasing trends of out-migration (Figure 4). Most of the migrant population was educated, skilled, and trained in various professions (Table 12). The increasing trend of rural out-migration has great impact on community planning, sustainable resource development, disaster risk reduction programmes and climate change adaptation in the region.

Increasing out-migration among male youths has not only affected the quality of life of rural women through feminization of mountain agriculture and the resource development process, but has also eroded the rich traditional knowledge which rural communities have developed through their long experimentation with nature and changing natural conditions [52]. Consequently, Himalayan women have often been designated as ‘primary resource developers’. As a result, the burden of living under difficult mountain-conditions falls mainly on women who have to bear the drudgery of scrounging for primary natural resources including fuel-wood and fodder from shrinking forests and water from increasingly long distances. They must also undertake agricultural activities (e.g., tending to livestock) and caring for children, and aged family members [19]. The study revealed that 75% of adult women and 35% of girls in of the Ramgad Catchment have to bear the major responsibility of carrying potable water from increasingly long distances which consumes a lot of physical energy and time. Dwindling water resources have increased the hardships of rural women by increasing the water fetching distances. There is also a severe shortage of adult male labour to work in agriculture and other sectors of the rural economy which further acts as a drag on agricultural productivity and retards the process of socio-economic development in the mountains. The cumulative impact of

Drivers of Rural Outmigration	Community Response (%)
Poverty	37
Lack of Livelihood Opporunities	27
Decline in Agricultural Productivity	21
Extreme Weather Events and Natural Disasters	11
Landless and Marginalized	02
Lack of Services and Facilitirs	01

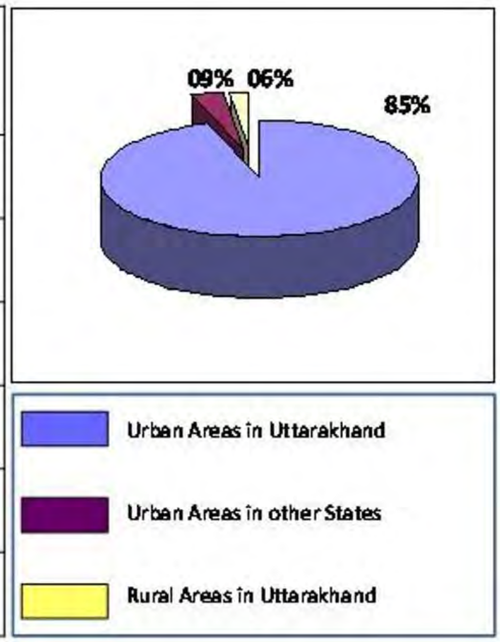

Figure 4: Compelling factors of rural out-migration.

Table 11: Trends of rural outmigration in Ramgad watershed.

Years	Total Migrants
2001	701
2002	795
2003	1007
2004	1105
2005	1121
2006	1155
2007	1191
2008	1195
2009	1291
2010	2111
2011	2185
2012	2197
2013	2425
Total	18479

Source: household surveys conducted by authors.

Table 12: Nature and educational level of migrants in Ramgad watershed.

Micro-watersheds	Total Migrants	Permanent Migrants	Temporary Migrants	Educated Migrants	Uneducated Migrants
Upper Ramgad	7571	37.00	63.00	75.21	24.79
Middle Ramgad	6251	21.55	78.45	81.55	18.45
Lower Ramgad	4657	37.11	62.89	77.59	22.41
Total	18479	32.00	68.00	78.00	22.00

Source: household surveys conducted by authors.

these physical, socio-economic and cultural constraints occurring in the mountains is grinding poverty, hardship, constant fear of insecurity, a feeling of helplessness, and complete dependence on outside help. The environment thus created is not conducive for attaining the goals of sustainable mountain development [53].

Women experience these changes differently and disproportionately and respond to them in varying ways because of socially constructed gender relations and the environmental sensitivities of mountain ecosystems [54]. They make use of their traditional knowledge and experiences in natural resource management and of adapting agricultural and food systems to multiple drivers of environmental change including climate change, globalization, out-migration, and land-use changes in mountain environments. This helps women become important agents of sustainable mountain development [8,9]. However, this also increases the vulnerability of women to the impacts of climate change due to skewed power relations and inequitable cultural and social norms. Consequently they are often exposed to increased risks associated with environmental changes [4]. These risks include further marginalization and exclusion from decision-making processes and less access to resources for survival. Strikingly, women generally have far less access to and control over the natural resources they manage and conserve [48].

11 Options for Sustainable Development

Climate change has increased the vulnerability of Himalayan communities and accelerated the ongoing process of environmental degradation. These changes result not only in the decline of agricultural productivity, but also in loss of traditional livelihoods, sources of rural livelihoods, and a weakening of traditional adaptation practices. Nevertheless, agriculture remains an important economic activity in Himalaya, and thus will constitute one of the core components of a climate change adaptation strategy in the region in the future. This is primarily because agriculture is an important economic activity and fundamental source of livelihoods in local rural communities. But it is also integral part of the culture, history and traditions of the people, and an invaluable source of traditional ecological knowledge required for adapting to climate change. In addition, the region has some highly productive and agriculturally prosperous valleys and mid-slopes which still have the potential of contributing towards food and livelihood security. Varying agro-climatic zones from valleys to higher elevations can also be utilized for growing a variety of crops and producing seasonal as well as off-season agricultural products.

Agro-climatic diversity from productive valleys to higher elevations can be utilized for the diversification of agriculture, horticulture, floriculture, dairying, and forestry to improve the productivity of the entire mountain crop and livestock system. In order to attain this, the mountain agriculture system should be considered as one of the integral components of an overall, integrated and adaptive Himalayan development framework. Mountain agriculture activities therefore need to be integrated with ongoing poverty eradication programmes, food and livelihood improvement strategies, rural employment schemes as well as with ecological restoration and climate change adaptation mechanisms in the region. Further, the integration of different sectors of the Himalayan economy with local agricultural production systems combined with a greater flow of credit to rural areas and increased investment in mountain agricultural enterprises will help make Himalayan agriculture economically viable and ecologically sound.

Himalaya is endowed with areas of scenic beauty including forests, glaciers, lakes, waterfalls, and alpine landscapes. Its variety of wildlife presents an endless scope for the promotion of tourism integrated with environmental conservation and socio-economic development. Tourism, can be adopted to support sustainable development in the region, not only for economic growth and the employment of an educated and professional workforce, but also to generate a viable means of improving the livelihoods of the poor, women and uneducated and unskilled people in rural areas. Tourism supports the conservation of nature and natural resources through multi-stakeholder involvement and participation. Furthermore, tourism is a less resource and more labour intensive, non-consumptive, and environmentally conducive industry. As such, it is one of the most appropriate strategies for adapting to climate change and other environmental changes in mountain ecosystems. As discussed earlier, the creation of livelihood options for off-farm income generation through the development of traditional sectors of the rural economy, such as agriculture and animal husbandry, are limited in Himalaya. Furthermore, global environmental changes have increased the vulnerability of mountain ecosystems and communities by accelerating the ongoing process of environmental degradation, and the depletion of natural resources and the consequent unsustainability of traditional livelihoods and food systems. Conventional adaptation practices and mechanisms to respond to environmental changes are losing their efficacy and there is an urgent need for new response strategies to cope with these unprecedented changes. By capitalizing upon both the socio-cultural and biophysical strengths of the mountain landscape, tourism would contribute significantly towards securing viable alternative livelihood opportunities, particularly for the poor and marginalized in mountain communities. However, in order to make tourism an ecologically conducive, economically viable, and pro-poor livelihood adaptation strategy it needs to be linked with local agricultural and food systems.

12 Conclusion

Himalaya is experiencing rapid and sweeping changes in the pattern of rainfall which is increasing the frequency and severity of extreme weather events. The amount of rainfall, as well as the number of rainy days are declining and the incidence of high intensity rainfall events and droughts have increased. These changes have disrupted regimes of rain-fed hydrological watersheds, and consequently reduced available waters, increased instances of crop failures, decreased irrigation potential and diminished livelihood opportunities in traditional agricultural sectors. The emerging risks of food and livelihood insecurity have accelerated the process of out-migration of rural male youth in the region. The increasing trend of out-migration has affected the overall quality of rural life by increasing the responsibilities, hardship and workload of rural women. At the same time women do not enjoy equitable access to development resources and opportunities or decision making processes.

This study clearly indicated that the conventional land based economic sectors, specifically the crop-animal husbandry combination, are not capable of generating adequate surplus to meet the needs of a growing population through adequate livelihoods above a subsistence level in Himalaya. This is particularly the case with ongoing land use intensification, the resultant depletion of natural resources and the impending threat of changing climatic conditions. Nevertheless, the enormous value of large forest areas with waterbodies and high altitude pastures characterized by charismatic landscapes, natural splendor, a variety of flora and fauna, enthralling wilderness and rich biodiversity has so far not been linked to the improvement of rural livelihoods. The situation therefore calls for looking beyond the traditional agricultural system and to the generation of rural employment opportunities in off-farm and non-traditional sectors, particularly through development of village based ecological tourism, value chain development and linking production systems with other sectors of the economy from local to global levels. This further underlines the need for restoration of ecosystem services through sustainable utilization and conservation of critical natural resources, particularly, land, water, forests, and biodiversity. Priority should also be placed on reducing the vulnerability of mountain communities to climate change through the development of sustainable livelihoods.

Acknowledgements: The authors are thankful to the local people of Ramgad Watershed and officials of different government agencies who extended every possible support and cooperation as and when required during the field surveys.

Conflict of interest statement: The authors declare that they have no competing interests.

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