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People's Perception to Climate Change in Remote Himalayan Mountains and Rainfall Variability in the Kailash Sacred Landscape-India

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Abstract

Climate change is a gradual on-going phenomenon which has been hastened by anthropogenic activities. With the rise in temperature it is observed that the usual rainfall pattern changes. Absolute analysis of climate variables (in the present case rainfall) for developing an understanding of climatic patterns is required to strengthen the link between the rural livelihood and vulnerability reduction. The study analyzed the historical rainfall data for hundred years and survey based perception of people. The findings are a clear indication of change in rainfall pattern for the districts of Kumaun region and for district Pithoragarh of Uttarakhand and its impacts associated with the sectors of agriculture and various services that will affect the rural population dwelling in the fragile mountains.

Keywords: Climate change; Erratic behavior; Vulnerability; Resilient; Adaptive capacity

Introduction

Mountains fall among the class of most fragile environments on planet Earth. They are rich repositories of biodiversity and water and providers of ecosystem goods and services on which downstream and lowland communities, both regional and global, rely [1-3]. Mountains inhabit some of the world's most threatened and endemic species, as well as to the poorest people, who are highly reliant on their biological resources [4,5]. As a result, these mountains are biodiversity rich, often with sharp transitions (ecotones) in vegetation sequences and equally rapid changes from vegetation and soil to snow and ice5. Himalayas, the water tower of Asia is the source of ten rivers [6,7]. Climate change poses a threat to the livelihood of people who directly depend on freshwater from these mountains; it will make water availability more uncertain, both in time and space. While overall trends are difficult to decipher, there are clear indications that the frequency and magnitude of high intensity rainfall events are increasing [8] with negative implications for infiltration and groundwater recharge, and also for long-term soil moisture and water accessibility for plants. The timing and Length of the monsoon period also seems to be changing [9,10]. These early signs are likely to have profound effects on agricultural and natural ecosystems, also on the availability of water for household use, industry, and energy, thereby affecting considerably on people's livelihoods and wellbeing. Assessment of the vulnerability and the socio-economic impacts would result in better adaptation and policy making. This would reduce the negative impacts of climate change on inhabitants of this area. In the past, due to geographical complexities the Himalayas have been data deficient therefore mountain planning perspective has not been as prominent as it should have been. However, in recent years, it has received attention to address issues associated with vulnerability and the impacts of climate change. Before the prominent effects of climate change, humans had a fair idea of the crop flowering and the tree fruiting pattern. However, to keep a pace with the changing climate and adjusting in the 'survival of the fittest' concept by Darwin the flowering and fruiting patterns have either become premature or delayed than their usual times. The farmer community, the direct dealers of the risk associated with climate change is affected the most whereas indirectly everyone gets affected. The study finds the change in rainfall pattern in last hundred years and the impacts on communities who sustain on and in the mountains.

Study Area

Lying in the lap of Himalayan mountains district Pithoragarh acquires a unique location of the Kailash Sacred Landscape at 29°35'1N and 80°12'34E. It is one of the six districts of the Kumaun region of Uttarakhand State (Figure1a). The topography varies considerably from ~250 m amsl in valleys to above 6000m in Trans Himalayan region, making this landscape heterogeneous on account of climatic variations. A survey regarding impacts associated with climate change was conducted in twelve villages of Pithoragarh district in Uttarakhand, India. The following villages were surveyed: Chhanapandey, Chhehra, Dharapani, Gaudiyagaon, Pitrauta, Ratwari, Hureti, Majhera, Kante. Figure 2 shows the study area map.

Methodology

This study has several scales ranging from individuals to landscapes. Semi-structured questionnaire survey was adopted through views and awareness of the people with respect to climate change impacts. The questionnaire consisted of 20 different questions. Three options were provided to the respondents as "Yes" (have experiences/observed), "No" (haven't experienced/ observed), and "Don't know". The study was conducted in twelve villages/hamlets located in Pithoragarh district.

Historical Rainfall Data (monthly precipitation, area averaged rainfall for a district; from 1901-2001) was obtained from Climate Research Unit (CRU) TS2.1 dataset available through Indian Water Portal. This data was further analyzed to know the rhythm of annual/ seasonal rainfall over a period of 100 years and extreme events (wet

and dry years) in the last century. The wet and dry years were calculated using standardized anomaly.

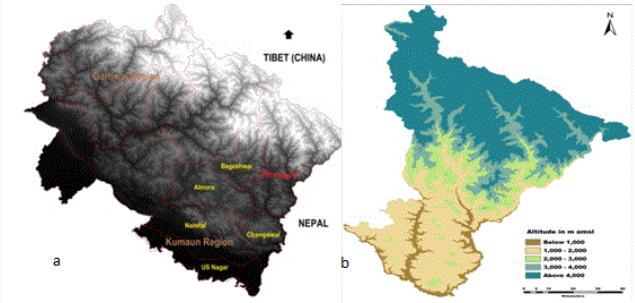

Figure 1: DEM of Kumaun region Uttarakhand ,India (a);DEM of District Pithoragarh Uttarakhand, India(b).

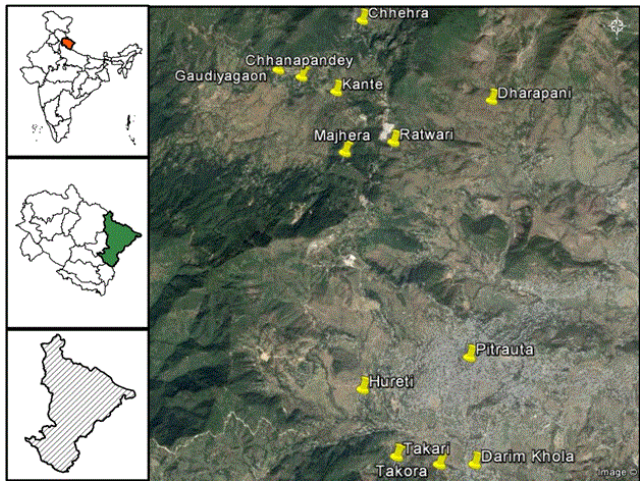

Figure 2: Study Area Map.

Result

Inter-annual and spatial variability of rainfall during last century (1901-2000) in the Kumaun region of the state

Rainfall received by districts of Kumaun region in the last century indicates that during first four decades of last century total rainfall has a tendency to increase following by a decrease in remaining next three decades (Figure 3). Total rainfall increased in the following decade (1970-1980) whereas continuously decreasing afterward till the end of century. Total annual rainfall also increases depending on their spatial locations of different districts. A correlation is apparent between increasing amount of total rainfall and spatial distance from plains of India to inner Himalayan mountains (US Nagar< Nainital< Almora< Bageshwar< Pithoragarh; Champawat being a newly carved out district from Pithoragarh behaves in a similar fashion as parental district).

Inter-annual variability during last century (1901-2000) in district Pithoragarh

Following the decadal trends, annual variability of total rainfall received by District Pithoragarh during different phases of last century indicates an increasing trend since the beginning of century up to the year 1935 (Figure 4.a), and then further decreasing in the following years (Figure 4b and 4c). Hence, total precipitation per year in the form of rains is decreasing over the years in district Pithoragarh. This may influence the total water budget of system and quantum of flow in rivers, which is also apparent by decreased flow of water in various rain-fed streams and rivers of the state.

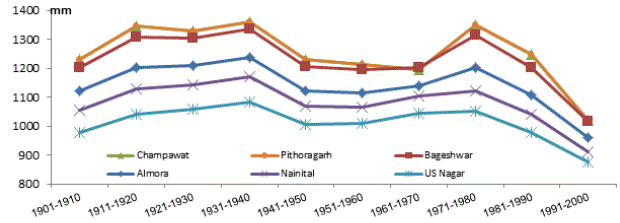

Figure 3: Decadal variation (average) in total annual rainfall of different districts of Kumaun region.

Intra-annual variability during Last Century (1901-2000) in District Pithoragarh

Prevailing monsoonal climate of the north-India determines receipt of maximum rainfall during the rainy season distributed in the months of June, July, August & September. In district Pithoragarh 77.4% (average of 100 years) of the total rainfall in a year was observed during a typical rainy season (Figure 5.a). But due to climatic perturbations this peak shifts in various months affecting various rain fall dependent agricultural operations (crop field preparation, sowing of seeds, irrigation, etc.) and other rural activities. Shift of maximum rainfall (typically received in the month of July) has also been experienced (Figure 5.b). During rainy season, maximum rainfall of July has a tendency to occur in the following month (i.e., August, 39%) or further delay (i.e., September, 10%). Only five times.

No pattern was observed for frequency of occurrence of these events over a time series of 100 years (e.g., maximum in August occurred 19 times in first half of the century than 20 times in later half). Maximum rainfall in the month of June (advancement during rainy season) has been reduced in later half of the century which was more frequent in first half of the century, however delayed peak (maximum rainfall) was more frequent (60% events) in latter than the former half of the century (40% events).

Maximum rainfall of July advanced to previous month i.e., June, the first month of the rainy season. People inhabiting in the higher Himalayas have observed significant changes in the timing of rains, intensity, and erratic behavior [11].

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Erratic behavior of rainfall during monsoonal months in the last Century (1901-2000)

In northern India, summer monsoon commences from June and extends till September. Typical pattern (Figure 5.a) observed is as follows - maximum in July followed by August then September, and lest in June. Analysis of deviation from this pattern of total rainfall in the months of rainy season indicates the following:

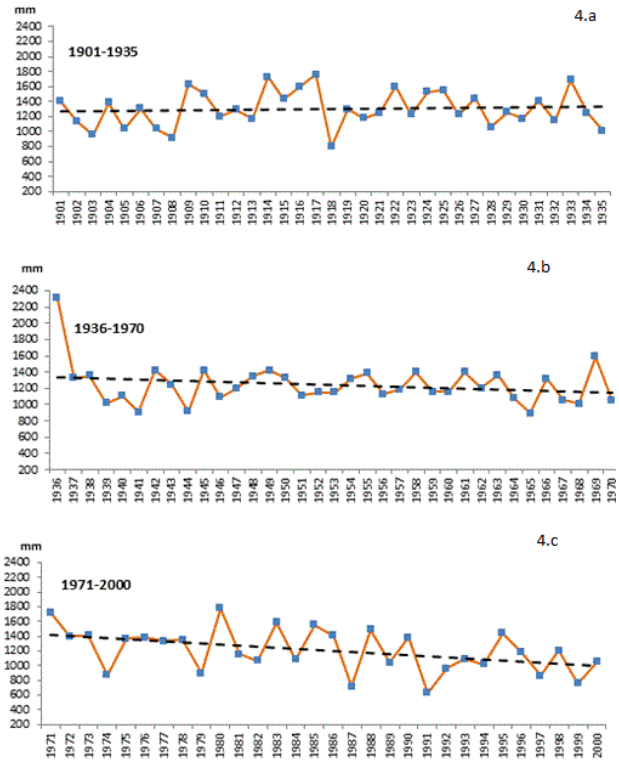

Figure 4: Total Annual Rainfall (trend by dashed line) in district Pithoragarh during the last century.

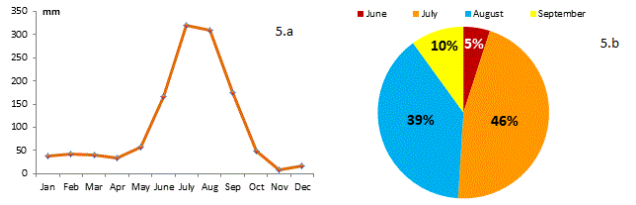

Figure 5: Rainfall Patterns in district Pithoragarh;Typical rainfall pattern of a year in (monthly average of 100 years)(5.a); Highest rainfall in monsoonal months of last century(5.b).

Frequency of receiving more rains (not the case of maximum rainfall) in June than the month of July has increased in the last 30 years of the century i.e., after 1970 while the same number of events were distributed over previous 70 years (x Jun-July, Figure 6; Less frequent earlier, more frequent now). In the majority of years (43 in number) of last century month of August received more rainfall than the peak month of July (+July-Aug, Figure 6). A very clear frequency of exceeding total rainfall of September over the month of August was observed in the latter half of the century (62% of the total events) than the former half (Aug-Sep, Figure 6), however, a reverse trend was observed while comparing the total rainfall received in June (first month of monsoon) than August (second highest rainfall receiver of the monsoon period) (Jun-Aug, Figure 6). Unusual receiving of rains in the month of June over the month of September (Jun-Sep, Figure 6) was also observed in several years of the last century which is usually less than the amount of rainfall received in the month of September (Figure 5a). Per cent frequency of this event was increased (30% of total event) in the last 30 years of the century (after 1970). Unusual receiving of total rainfall in the month of September was also observed exceeding over peak month of rainy season i.e., July (Jul-Sep, Figure 6). This frequency is prominent in last 30 years of the century, as evident by occurrence of 45% events in these 30 years. A complex shift of monsoonal months is apparent where tendency of having more rainfall in the month of September (36 times) than the months of August and July is frequent in recent years, particularly after 1970.

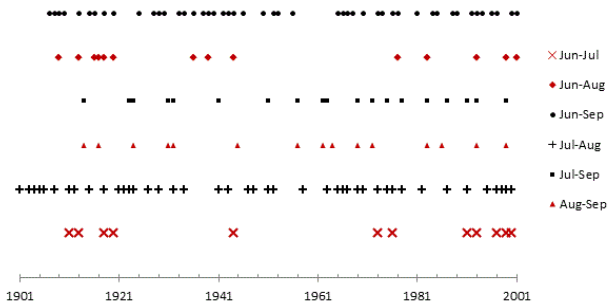

Figure 6: Disruption in a typical rainfall pattern over the last century.

Discussion

The region is particularly vulnerable to climate change due to its ecological fragility and economic marginality. The present analysis implies that the frequency of unusual events or erratic behavior in rains have gained pace after 1970. The unusual patterns have greatly affected the lives of people living there through climate induced disasters and events of extremes. Reasons are multi-faceted, some of the major ones being Greenhouse gases (GHG) emissions, air pollution, land use conversion, deforestation, and land degradation, that are slowly creeping into mountain regions [12]. Also the probable hydrological impacts of increase in atmospheric concentration of greenhouse gases is the increase in the extent and magnitude of floods [13-15]. GHG change the energy balance of the atmosphere and lead to atmospheric warming, which increases the water-holding capacity of the atmosphere, which in turn, potentially changes the amounts of perceptible water. The resultant warming also changes the form of precipitation (more rain and less snow), changes the timing of snowmelt [16-18] which is a deviation from the usual precipitation pattern.

Rising temperatures will strongly influence plant reproduction, timing of leaf flush and flowering, and activities of flower-visiting animals in monsoonal Asia [19]. Changes in precipitation pattern have both direct impacts and indirect impacts on the livelihood of rural

communities. Heavy rainfall on one hand can cause flooding, crop rots, pest outbreak, landslides, soil erosion, loss of healthy micro flora that supports crop growth, disturbed agri-ecosystems whereas on the other hand no rainfall or lesser amount of rainfall can cause the vice versa effects like drought, no germination of crops etc. Both negatively influence the crop systems and the livelihood of communities. Effective human adaptation to climate change includes the establishment of adaptive capacity: knowledge and governance and the adaptation itself (i.e., changes in behavior and livelihood practices to meet new conditions) [20]. Climate-change-induced risks at the rate and scale projected in the Greater Himalayas, however, cannot be eliminated by a natural process of gradual adaptation.

Socio-Economic Impacts of climate induced extreme events

Rural landscape of the mountains is more sensitive about the variations in climate (inter- or intra-annual variability) due to great dependence on natural resources for livelihood, thus making rural societies more vulnerable than the urban populace, and exposed to climate induced disasters those have severe dent on the life of the inhabitants. Marginalized communities and rural people with natural resource-based livelihood have been considered as potential victims of the threats posed by various climatic parameters. In recent years, natural disasters in the district Pithoragarh have a toll of 127 human since 2007, 21 persons still missing, and 99 persons were injured. Livelihood hit back was loss of (i) domestic animals (livestock 5841 & goats 162), and (ii) agricultural land (120.5 ha). Among all the districts of Kumaun region severity of damage to buildings was maximum for district Pithoragarh. More than 52% of the buildings were severely/completely damaged in last 8 years in the district. Such accidents indicate that human habitation is prone to events induced by climate change, particularly precipitation. Impacts of precipitation, particularly rainfall, on various sectors related to rural livelihoods are summarized in Table 1.

S.no	Sector & Variable	Risk Factor	Likely Impacts
	Agriculture	Dependence on Rain	
	Less Rains	Rain-fed crop fields	Less Production in drought years
	Excess Rains	Small or big Landslide	Overall reduction in production due to Loss of cropland Damage to crops
1	Shift in Rains	Crop sowing/Maturity	Decrease in productivity
	Horticulture	Extreme Events	
	Hail Strom	Flowering/Fruiting	Damage to fruits and quality
2	Shift in Rains	Fruit ripening	Low quality/Less production
	Livestock	Extreme Events	
	Excess Rains	Animals	Loss of Heads due to Flood & Landslide
		Disease	Expenditure & Mortality
3		Grazing Lands	Accidents due to slippery path
	Services	Water Flow	
	Excess Rains		No operation due to heavy Silt
		Water Mill	Partial or complete damage due to flood
		Road & Path	Partial or full damage leading to disruption in supply chain
4	Less Rains	Water Mill	No operation in lean period

Table 1: Vulnerability to precipitation dependent livelihood in rural areas of Uttarakhand State.

People Perception with respect to associated impacts

The questionnaire based survey led to certain findings (Figure 7). The people of rural Uttarakhand rely on natural source of water vernacularly called 'Naule-Dhara'. 64.9% respondents believe that 'Naule-Dhara' is drying up. The reason they stated were due to drier summers and winters, reduced precipitation. Soaring population has exerted a lot of pressure on the natural source of water; the untimely rains have led to reduced production of crops which has an indirect impact on water sources too.

49.0% of respondents have observed changed in the time of anthesis and fruit ripening 35.5% out of the 48% people said the anthesis now occurred earlier 10.63% out of the 48% people observed delayed anthesis. The reason could be warmer temperature for delayed flowering.

Advanced spring phenology damages flowers and tender young leaves, which has negative impacts on plant growth and fruit development.

58.5% of the respondents changed the time of sowing and harvesting. 17.73% sow and harvest their fields early while 24.82% have shifted to delayed sowing and harvesting.

57.1% of the respondents have observed the emergence of new insects. They described it as the 'kala-keeda' which was found near the root of rice plants and destroys the entire crop, heavily affecting the productivity. People have observed the emergence of red ants which they said did not exist earlier. They believe red ants emerged as a result of warmer temperature nowadays. Mosquitoes were also observed. Respondents stated that mosquitoes might have been carried from plains to the hills. The respondents inhabiting near the drains had observed mosquitoes than those inhabiting in cleaner and hygienic areas. Climate influences the survival and spread of insects and pathogens directly [21].

57.1% of the respondents believe that there is an increase in attack of wild animals. The reason being, human populations are clearing away the forests for building and agriculture purpose, the natural habitat of the wild animals is being lost in the process of deforestation and habitat fragmentation. Wild animals due to the disturbed ecosystem move towards the villages in search of food or when they sense harm for their life. Attacks by boars, monkeys and leopard are a common observation villagers said.

48.2% respondents stated that there are new animals are being observed, however none of the respondent was able to define the characteristic of the new animal spotted.

20.9% respondents felt that there are ill effects of the changing temperature on health whereas majority of the respondents i.e., 74.5% did not believe that there are any changes on health because of the changing temperature.

Naula can be described as man-made water storage. Naturally moist areas are dug up and large rocks are placed at the base of the depression. Water gradually exudes from its natural source, gets filtered through the rocks and accumulates as clean water. Naulas are covered with a roof to protect it from contamination. However, it is not covered with a lid in order to keep the water cool and clean.

Dhara in hindi means spring which unlike naula keeps flowing and the water is not stored. Many of the respondents said that there is a decrease in production for many crops like *Oryza sativa* rice, *Triticum aestivum* wheat, Zea mays (makka), *Hordeum vulgare* barley (jau), *Sorghum bicolour* sorghum (jowar), *Panicum miliaceum* barnyard millet (madhua), *Brassica juncea* mustard (sarson), *Lens culinaris* red lentils (masoor dal),*Glycine max* L. Merri. black soybean (bhat dal), *Vigna mungo* L. black gram lentils (urad dal), *Raphanus sativus* L. radish (muli). The respondents also observed a reduction in fruit yield for various fruits like *Citrus reticulata* mandarin orange (malta), mountain banana (pahari kela), orange (narangi), *Prunus domestica* plum (aloo-bukhara), *Juglans regia* L. walnut (akhrot), *Prunus armeniaca* L. apricot (khumani), *Prunus persica* peach (aadu). However, a handful of respondents believed that there has been an increase in the yields of narangi, malta and aadu.

A couple of respondents said that there is a decrease in fruit size as compared to earlier fruit size which was larger. The reduction in fruit size has been reported in case of some Citrus fruits by Hutton and Landsberg in 2000. Pest infestation after scarcity of water seems to be another huge issue that is responsible for lesser yield. White colored pest in cereals, black insect in paddy, termites, red insects infesting peach, grasshoppers, leafhoppers were few of the culprits. Another keen observation of a few villagers was a reduced population of honey bees and butterflies which are prime pollinators for many crop species.

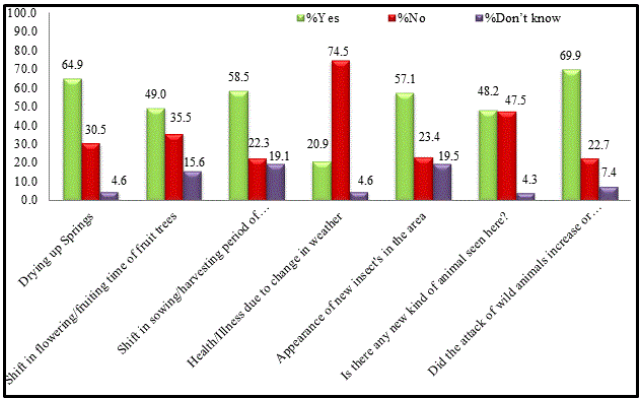

Figure 7: Associated Impacts (Responses to questionnaire).

Padam vriksh (*Prunus cerasoides*) holds a religious significance to the local people and this plant no more grows there. Since the water sources are drying up due to anthropogenic pressure government has installed various hand pumps for the ease of water extraction. Variation in seasons was also a common observation by the elder people of the village. They stated that the winter monsoons have disappeared altogether which has a direct impact on rain-fed crops they believe. Earlier onset of winters, increase in intensity of drier winters, lighter snowfall intensity, increase in temperature were commonly observed.

Future Prospects

While rural inhabitants reap the best of natural resources effectiveness of resource utilization is associated with a cost; cost of being vulnerable to the impacts of climate change. A framework for analyzing social vulnerability is required for Kailash Sacred Landscape to play an effective role (i) by decreasing socio-economic impacts related to rural livelihood, and (ii) to develop resilience in rural communities for climate extremes. The present analysis indicates that the frequency of unusual events or erratic behavior in rains have gained pace after 1970. The unusual patterns have greatly affected the lives of people living there through climate induced disasters and events of extremes. The consequences of which have come to the notice of rural inhabitants. Identification of pests and their necessary biological control will enhance the crop production. The rural communities dwelling in these mountains have developed some cope-up mechanism based on their traditional knowledge, the practices still fall short. Need of the hour is to analyze in depth the impacts of climate change and to design various institutional mechanisms those will reduce the likely impacts and will contribute in well-being of rural people in the landscape. Mere analysis will not provide resilience to the local communities rather identifying the sensitivities and acting according to it is required to build stronger systems. People must act now to reduce future negative consequences [7]. Simple traditional methods like rain water harvesting in every house with the help of government subsidized rates, establishment of poly-houses for non-seasonal crops, group discussions with farmers on farming practices that helps increase the yield with less requirement of water, sensitizing the local population about climate change and what can be done to mitigate the after effects are a few suggestion which would help strengthen the life of dwellers. The problems of people living in such

remote areas appear to be the tip of the iceberg, if analyzed thoroughly it is a chaotic mesh of networks where they are dealing with migration, crop failure, struggle for basic needs, isolation from rest of the world all of which has a direct link to financial instability. The consequences of climate change though drastic would affect everyone on this planet but the first ones to be devastated would be the farmer community because of highly uncertain occupation of farming. Once the base of the trophic level is disrupted, the entire pyramid falls.

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