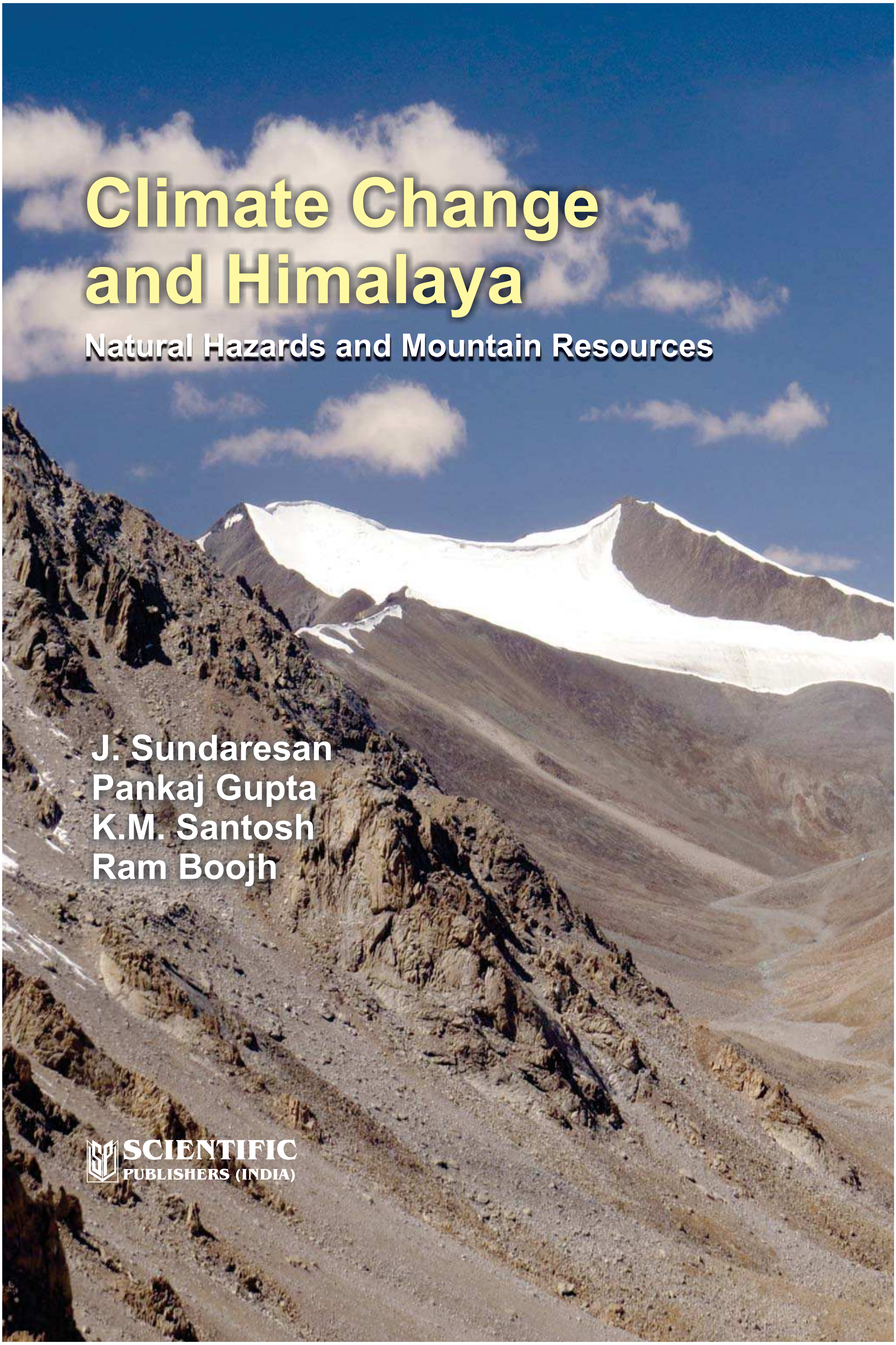

Climate Change and Himalaya

Natural Hazards and Mountain Resources

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SCIENTIFIC PUBLISHERS (INDIA)

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Preface

Cryosphere consists sea ice, glaciers, icecaps, ice sheets, snow cover and frozen grounds. Other than frozen grounds the second highest component of Cryosphere is snow cover. Northern hemisphere has more than 98 % of the global snow cover. Himalaya abode highest segment of snow cover and glaciers other than Polar Regions. Snow has an important role in climate modulations. This is the major source of water and factor to modulate the ecosystem, in Central Asia. Hence snow cover and glaciers are one of the prime resources of mountains. Glaciations begin in Himalaya about 60,000 yr BP. The beginning of glaciations is related to rapid uplift of Himalaya during 0.9 to 0.8 million years. During this period there were slackened monsoons and dry climate in all over the Indian subcontinent. Rapid uplift of Himalaya, climate change and advance of snow cover and glaciations are intermittent phenomena of this region ever since the India plate colloid with the Eurasian Plate. Present book entitled "Climate Change and Himalaya – Natural Hazards and Mountain Resources" consists twenty two chapters. All these chapters are inconsonant on glaciers, geo hydrological hazards and other natural hazards and prime resources of Himalaya.

Geospatial technologies have transformed climate change research. Though field observations consistently recorded changes in climatic processes, remote sensors and satellite observations have become indispensable for global monitoring. Chapter 1, "Spatial distribution of glacier mass balance using remote sensing data in Himalayan region" is a consistent approach to understand glacier mass balance with geospatial tool. Glaciers extent has shown oscillation in the geological past and continues to do so in the present time too. Most conspicuous reason to the current variations is attributed to climate change due to natural cycles and anthropogenic activities. Harsh climate and rugged terrain conditions restrict repetitive monitoring of glaciers at regular interval using conventional methods in the Himalayan region where remote sensing (RS) has played a key role in mapping and monitoring of these resources. One of the major RS applications is the estimation of mass balance using accumulation area ratio (AAR) approach. Basic premise of AAR approach is mapping of snow line on the glaciers from a series of satellite images. This study presents use of satellite images of AWiFS data (receptivity 5 days) of Indian Remote Sensing Satellite (IRS)/Resources sat to estimate AAR and mass balance of glaciers in parts of the Chenab and Ganga basins, and its variability across the Himalayan region. More than 700 glaciers have been monitored in the present analysis and it has been observed that overall all the sub-basins have shown a positive mass balance for the year 2010. Glaciers respond to change in climate in terms of glacier length, mass balance and runoff. The Chapter 2 consists various issues related to the impact of climate change on Himalayan glaciers and melt. Glacier length change, the advance or retreat, is the indirect, delayed, filtered but also enhanced signal to a change in climate, whereas the glacier mass balance, or the change in thickness or volume, is the direct and undelayed response to annual atmospheric conditions. Brief details of the methodologies being used for the impact analysis are presented in the Chapter

"Does the Himalayan glacier study mean for climate change". This chapter infers the need to take up studies at individual glacier in order to explore the impact of global climate change on glaciers.

Fluvial sedimentation in Himalaya begins 31 million years ago. Fission-track dating of detrital zircon and monazite infers the early fluvial deposits in Himalaya. There are a few chapters in this book that had adopted a clay mineral approach to under stand the records of climate change . Garhwal Himalaya is influenced by the Indian Summer Monsoon and partially by westerly. - The studies in Chapter 3 is relied the clay proxies to reconstruct centennial scale climatic changes from AMS dated 3.55 m long lake core from Badanital (Garhwal Himalaya). - Core has almost homogenous sediments. The variation in composition of core highlights six major events into possible six zones. - The climate around the area is more favourable for the last 130 years compared to the past. - Chapter 4 "Estimating glacier changes in the Ravi basin (1972-2006) through remote sensing techniques" is on the decisive role of glacier in the hydrological cycle. - A study of 60 glaciers in the Ravi basin reveals that the glaciers have receded by 16.65 km^2 during the period 1972-2006. Area loss has been 9.8 km^2 in the period of 1972-89, whereas it shows a loss of 6.88 km^2 during 1989-2006 respectively. Ravi basin shows a marked retreat of about 56% in the area range 2-5km^2 comprising the period 1972-2006. Area loss has been highest in the aforesaid category if we compare it with the other area classes. This reflects that glaciers in the area range of 2-5 km^2 are under a bigger threat. The dissolved ion chemistry of Bara Shigri glacier melt water is presented in Chapter 5. - Abundance order of cations and anions follows the trend: $Ca^{2+} > Mg^{2+} > Na^+ > K^+$ and $HCO_3^- > SO_4^{2-} > Cl^- > NO_3^- > PO_4^{3-}$, respectively. The high $(Ca+Mg) / TZ^+$ and (Ca+Mg) / (Na+K) ratios and low $(Na+K) / TZ^+$ ratio show that dissolved ions chemistry of Bara Shigri glacier melt water is controlled by carbonate weathering followed by silicate weathering. Piper plot indicates that alkaline earth metals (Ca+Mg) dominated over alkalis (Na+K), while weak acid (HCO_3) dominated over strong acids (SO_4+Cl). This further confirms that dissolved ions chemistry of study area is mostly controlled by carbonate weathering

Solar radiation is the force of global climate system. Chapter 6 attempts to analyze variations in solar activity and its effect on glacier changes. Different data of Sunspot Numbers, Cosmic Ray Intensity and rate of retreat of Gangotri glacier were compiled and analyzed in this chapter. Different statistical correlations were developed between these parameters. It is observed that there exists a negative correlation between Sunspot Numbers and Cosmic Ray

Intensity and in turn between Cosmic Ray Intensity and Gangotri glacier retreat. Chapter 7 of this book ascribes one of the most sensitive glacier of the Himalaya i.e. Tipra glacier. This glacier showed rapid disturbances on mass, volume area and length further amplify longitudinal and transverse crevasses along with development of supra glacial lakes, ice cave and fluctuation of snout. More recently, it has been documented that whenever glacial mass, volume, area and length reduced sub-alpine (timberline) plants shifted towards permanent snowline. Some specialized plant species resides over glacial surface particularly high energetic and extreme cold resistant. Diversity and distribution of the plants vary and tilting behaviours observed around shrinkage areas due to intersect summit.

The tectonic unrest prevails in Himalaya during the versatile stages of its formations and changes. Many natural hazardous prevails in this region due to consistent tectonic activity. Many catastrophic landslides had developed due to the fragile formations of Himalaya. Chapter 8 of this book is "Climate change and attendant landslide hazards in the Northwest Himalayas". It presents the impact of climate change to hydro-meteorological disasters especially landslides in this region. Continued collision tectonics, high seismicity, high relief expressions and high-energy regime of Northwest Himalayas possesses geo-environmental conditions conducive to major mass wasting phenomenon. Major and minor landslide events have increased in the Himalayan and Trans Himalayan region during last few decades. The frequency of mass wasting activities have increased and transgressed into areas hitherto unknown for such cataclysmic disasters. These events have been influenced by the occurrence of climatic related rainfall /cloudbursts events. Synergy between climate change and mass wasting processes is crucially important in planning a proactive approach to mitigate the hazards and devising adaptation strategies in mountainous environment. During June 2013 Uttarakhand and its neighbour state Himachal Pradesh is rocked by a chain of landslides occurred due to cloudburst, excessive rains and followed by the flash flood and landslides. The Chapter 9 presents the historical perspectives and remedial measures for the above natural calamity. Changes pattern of rainfall due to climate change, human encroachment, over and unsystematic exploitation of natural resources, lack of knowledge – where and how to built sate shelters are the main reasons for such a massive loss of life, property and infrastructure in the natural calamities of Uttrakhand.

Climatic Change and Increasing Geo-hydrological Hazards are conspicuous in Chapter 10 and discuss the major disasters, which rock the Himalaya now and then. Multi-hazard dimension of cloudburst is particularly disastrous when it is experienced in areas near population settlements like villages, towns and cities. Weather related hazards like cloudburst, which were rarely reported, increased in their magnitude, frequency and spreaded more area as well as magnitude over the years, possibly because of the global climatic change. Exploitation of natural resources for the development purposes should also be viewed seriously. Because of un-systematic development for more economic gain with least consideration of natural environmental setup makes these phenomena to act against the humans and their infrastructures more belligerently. In the present study attempt is made for a possible correlation between the extreme phenomena and the consequences vs. development.

Phenotypic plasticity leading to Sympatric speciation in populations of Ephedra in lahaul and Spiti (India) is the content of chapter 11 of this book. It consists contribution of phenotypic plasticity to the phenotypic variation and cause of speciation in *Ephedra* populations. The report of phenotypic plasticity as a major evolutionary force in populations of *Ephedra* via habitat adaptation through the variability of various morphological characters causing sympatric speciation is revealed. Efficient conservation of the populations can only be based on habitat management, to favour the maintenance of micro environmental variation and the resulting strong phenotypic plasticity. Developmental study of two species of a homosporous climbing fern, *Lygodium* is presented in Chapter 12. *Lygodium japonicum* and *Lygodium flexuosum* are the terrestrial climbing ferns belong to family Lygodiaceae. *L. japonicum* is used as an expectorant and in the snakebites while *L. flexuosum* is used in jaundice, rheumatic pain, sprains, scabies, ulcers, eczema and cut wound expectorant, Skin diseases etc. This study infers the events of spore germination, gametophyte growth and differentiation, sex ontogeny and development of sporophytes. Non-food oilseed plant as an alternative resource for biofuel production is discussed in Chapter 13. Specific features of the *Jatropha curcas* plant such as prominent source for the biofuel production, protein concentrates as livestock feed and value-added products that could enhance the economic viability of Jatropha seed oil-based biodiesel production made it a multipurpose plant. Genus *Jatropha* is distributed throughout the tropics and sub-tropics, growing in marginal lands and is a potential biodiesel crop worldwide. Because of all these features, the plant *Jatropha curcas* became the centre of attraction for all the research workers throughout the world in present time. This review focuses some basic aspects of the distribution, diversity, biology, cultivation of *Jatropha* plant and physicochemical properties of crude seed oil and their potential for biodiesel and livestock feed production. It also focuses on pharmaceutical properties of the plant along with some socio-economic and future impacts. Climate Change and Hill Agriculture - A Study of Uttarakhand State of Indian Himalaya is the chapter 14 of this book. This chapter infers that climate change is causative to a decline in traditional crop diversity, agricultural productivity and food security in the mountain areas of Uttarakhand. Mountains are provider of key environmental services such as freshwater, biodiversity conservation and hydropower to more than half of humanity. A rich diversity of traditional crops occurs in Central Himalaya. Over forty species of food grains are grown in traditional agro ecosystems of Central Himalaya. Hill agriculture has never been very productive in Uttarakhand. Migration has been an integral feature of the hill economy. It is felt that in the last decade the further decline in agricultural productivity – for which change in climatic conditions appears to be one of the causes – has been quite detrimental to the interests of the hill farmers.

Climate at Himalayan region requires continuous observations . Cryosphere is a prominent factor in the weather and climate of mountain regions. In chapter 15 analysis of longterm, climate variability for North-Western Himalayan states (Jammu & Kashmir, Himachal Pradesh and Uttarakhand) of the IHR has been carried out for the twentieth century (1901-2000). Analyses indicate significant increasing trends of temperature at different rates in NW Himalaya. Decreasing trends of both maximum and minimum temperature during monsoon season are observed in all three states. Analysis of decadal variations indicates periodicities and episodic variations in temperature as well as precipitation with varying rates. The Chapter 16 is based on discovery of paleoclimatic signatures made by Indus glacier/river on the granites of Ladakh batholiths on the banks of river Indus since 11714 years. These signatures resembles alphabet C. Taphonomical analysis of these C curves in massive Granites show great role of lithology and geomorphology in preservation and understanding the cyclicity of these climate signatures which have been beautifully preserved in the Ladakh Batholith in NW Himalaya. Seeing the paleoclimatic signature in the Batholiths of Ladakh we are presently in the warming maxima times and are curvilinearly moving into the cooling phase finally culminating into ICE age in 2344 years, represented by the lower part of alphabet C. Climate Change and appropriate actions worldwide are discussed in Chapter 17. The year 2011 was the costliest year on record for disasters, with estimated global losses of £234billion (US$380 billion). Losses from extreme weather-related disasters are doubling every 12 years as more people and assets are in harm's way and the effects of climate change bite. Even though a warming trend is global, different areas around the world will experience different specific changes in their climates, which will have unique impacts on local plants, animals and people.

Climate change is the most delicate problem of this century that may require early solutions. Adaptation and mitigation is essential to stop further deterioration of resources and society. The Chapter 18 looks into the implications of two important drivers of the time: urbanization and climate variability. It involves the risk factor to the identified water resources which is subjected to rapid urbanisation around its vicinity and possible climate variability. Climate Smart Disaster Risk Management (CSDRM) approach to integrate disaster risk reduction and climate change adaptation for achieving enhanced efficiency of development efforts are discussed in Chapter 19. CSDRM incorporates climate change resilience into the planning and will identify vulnerabilities of downstream populations and propose "climate smart" livelihood based adaptations derived through integration of climate change adaptation and disaster risk reduction that enables the most vulnerable communities in this fragile region to effectively cope with the impacts of climate change. Landslide and it impact on society is presented in Chapter 20. Narayanbagar landslide is examined as a case study in this chapter.

Incidence of landslides and its destructive efforts can be controlled to a great extent by preventive and protective works at the time of initiation of the landslide.

It is better to build a culture of living in landslide prone areas whilst reducing economically oriented pressure on these lands. - Hence while examining cases of slides both technical and human problems should be borne in mind in providing relief and protection measures.

Earthquakes and related phenomena are recorded in Himalayan region in the early facet of the history. There is continuous underthrusting of Indian plate. It is observed that the underthrusting Indian Plate often get stuck or locked. Periodically larger earthquakes occur when there is unlocking of Indian plate. The Chapter 21 is the "Probabilistic assessment of earthquake recurrence in Northeast India: an appraisal from inverse Gaussian distribution". These articles consists discussion on several physical properties of inverse Gaussian distribution and subsequently examine the suitability of this model in earthquake recurrence interval estimation. A real, homogeneous, and complete earthquake catalog of 20 major events $\left(M \geq 7.0\right)$ from northeast India and its surrounding region (20^0-32^0 N and 87^0-100^0 E) were examined in this chapter. The sample mean recurrence interval, as calculated from this catalog, is 7.82 years. However, this region has not experienced any large magnitude earthquakes during last 18 years (1996-2013). This fact encourages scientists to re-appraise the recurrence interval modeling for this region. This chapter consists a number of cconditional probability curves (hazard curves) generated to examine the seismic vulnerability of the study area. Pattern of rainfall distribution and trend in Srinagar and Banihal stations of Jammu and Kashmir are presented in Chapter 22. Present study analyses the distribution pattern and trend of rainfall in Jammu and Kashmir using various statistical methods. Mann Kendall test has been used to analyze the trend in rainfall distribution. Annual rainfall showed moderate variation ranging from 24 per cent at Srinagar to about 30 per cent in Banihal. Its variation is more prominent in former period of study. Monthly average rainfall showed high fluctuations during study period. Distribution of rainfall in these locations is highly influenced by western disturbances rather than monsoon.

The book "Climate Change and Himalaya – Natural Hazards and Mountain Resources" is the 3rd and final book from the research articles contributed to the "International Conference on Climate Change - Current status and Future perspectives" organised during 28-31st October 2013 (ICCCH). The other books in this series are "Climate Change and Himalayan Informatics" and Climate Change & Himalayan Ecosystem- indicator, Bio & Water Resources". Scientific Publishers (India) had published all these books. The editors are thankful to the consistent efforts of the publishers to keep the quality of the publication and for timely completion of all the three books. Department of Science and Technology(DST,Govt. of India) , Ministry of Earth Sciences (MoES,Govt. of India) and Council of Scientific and Industrial Research (CSIR) had sponsored the conference and the financial support is gratefully acknowledged. All the articles were subjected to extensive review. The peer review of the articles was extensive help to improve the quality of this book. Editors thankfully acknowledge the dedicated work of all the reviewers. The cover photo of this

book is contributed by Dr Pankaj Gupta, CSIR-Central Road Research Institute. Mountain urbanisation and mountain resources are two important aspects discussed in this book. Above two phenomena are extreme important in the perspectives of Climate Change. This book will be highly beneficial to researchers, decision makers and the students who are interested in the studies of mountain urbanisation and mountain resources and will also be beneficial to libraries of universities, colleges, research institutions and personal collections.

J Sundaresan
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Contents

Evolving Climate Resilient Livelihoods through Integration of Climate Change Adaptation and Disaster Risk Mitigation

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Introduction

Hindu Kush-Himalayan (HKH) region is one of the most ecologically sensitive and tectonically fragile areas in the world with an estimated 3 billion people benefitting from the water and other goods and services that originate in these mountains[1] (Map 1). HKH mountain ranges are the regional storehouse of fresh water, and are an integral part of the regional monsoon system which is a lifeline to agriculture, the primary source of livelihood and sustenance to many in the region. HKH is drained by 19 major rivers[3] originating from this system (Map 2). Many of the largest rivers in the HKH region are strongly dependent upon snow and glacial melt for water flow[2] and are trans-boundary in nature. The formation of mountains, the deepening of the valleys by the rivers, and self dynamic processes of rivers accompanied with regional characteristics of temperature and precipitation has led to significant progression of river systems and stream types[3]. For India, recent studies show that cost of water has increased by about 400–500% since 1990 in the Indo-Gangetic Basin of India[2].

HKH region is environmentally stressed and economically underdeveloped and the impacts of growing climatic variability and change in the region are becoming increasingly evident. The region is highly vulnerable to climate change, natural disaster and their environmental and socio-economic risks. Physiographic and climatic characteristics of the region make it prone to a high incidence of both geological and hydro-meteorological hazards[4]. Predicted consequences of climate change and its impacts, frequency and intensity of natural hazards and disasters due to extreme weather events are likely to make the region even more vulnerable. Despite an abundance of natural resources in the region, poverty is rife. HKH countries account for 15 per cent of the world's total migration. Disasters affect lives, homes, and livelihoods of thousands of people in the Himalayan region and damage expensive infrastructure every year. Data suggests that out of total annual disasters in HKH region 14% are due to earthquakes and landslides, 48% are hydrological (i.e. 36% flood, 9% mass movement, 3% drought) whereas 38% are other types of disasters such as storm

Irrigation and Drinking Water

The prolonged periods of drought observed with sudden high intensity rainfall causes a detrimental impact on agriculture as water is unavailable for irrigation. Irrigation in the study area is depended on river water and rain and low rainfall in critical summer months lead to less availability of water for irrigation of summer months. Further with high intensity short duration rain becoming more frequent in the study areas, leading to flash floods which break river banks, destroying crops and property. This causes a repetitive cycle of poverty where the income of the local community is substituted by village members who have migrated out of their ancestral areas moving to urban regions in search of work. These family members support the community who are still living in the Ghaghara River Basin Region.

In order to access water for daily consumption in the study sites, boring wells are being dug further away from the river bank. This is practiced to avoid contamination of drinking water from the flood water. Bore wells for drinking water is dug approximately 300 m away from the river bank, and 100 meters away for irrigation.

Education and Women

Although the local women in the study area contribute to agriculture and allied activities including livestock care, it is seen that the general trend in the area is that women folk in GRB study area have no role in the decision making process but stand as mute spectators to this continuing cycle of disasters and poverty. An effective adaptation plan would have to work to incorporate rights of women and be more gender sensitive to such issues.

As the villages are not electrified, energy for lighting and fuel is met primarily through burning wood causing a major health hazard and also contributing to environmental degradation. Women, especially, are prone to respiratory and allied diseases as they are responsible for daily food work using energy inefficient, open chulhas. Additionally, women are responsible for fuel wood collection and during the monsoons spend hours looking for fuel wood. These hours could be better utilized in pursuit of activities for livelihood Sustenance and enhancement.

Some villages have schools for children where classes can only be conducted during day time due to the villages having no provisions for lighting with kerosene lamps being too expensive for use. The women folk are mostly uneducated, speak the local language *Bhojpuri* and remain inactive outside their homesteads except for when they conduct farm activities.

Biodiversity

The local riparian biodiversity consists of dolphin, otters, gharial, maggars, turtles and more than 15 species of fish which are reportedly in decline. Animals such as wild boars, neelghais and feral cattle were reportedly damaging crops.

Commercial fishing by external agents is a threat to the riverine ecosystem. Wetlands in Sitapur support avifauna. Discharge from local industries, primarily the sugar and paper mills close to the river system has turned the water in the Rapti river an unnatural dark colour which according to village testimonials has caused a decrease in the catch rate from the river. However, the visible effects on river water (BOD) are not seen beyond a few kilometres downstream of the points of pollution. Livestock is of the traditional variety however are healthy. Productivity and yield are poor reflecting the lack of nutrition and poor quality feed for livestock.

Approach and Methodology

As evident from the description of the study area, an integrated approach is the need for the region that not only looks into making the local communities more resilient to changing risks and disasters, but also into integrated natural resources management aspects that are inclusive and sustainable.

Figure 2: Integration of development with climate change adaptation and disaster risk management
Source: Harris, K., Seballos, F., Silva Villanueva, P., and Curmi, P., Changing Climate, Changing Disasters: Pathways Towards Integration (2012) Strengthening Climate Resilience, Brighton, IDS

Link between climate change and disasters is now widely recognised (Box 3 below). Trends in economic and livelihoods related disaster losses are on an upward curve, and the vast majority result from climate-related, hydro-meteorological hazards (IPCC 2007). Due to this reality, there is an urgent need to scale up and adapt disaster management practices to cope with changing needs and realities. Therefore, considering the local conditions of the Ghaghara River Basin using the 'Climate Smart Disaster Risk Management Approach' DRM in this context will be evaluated in order to decrease vulnerabilities to the hazards of flooding, crop damage and poverty and adapt by bettering livelihoods option while considering the varied challenges posed by climate change in the region.

Box 3: Impacts of climate change on disaster risk

Climate Change is …

1.Increasing the frequency and severity of some, but not all, hazards

2. Increasing people's vulnerability and exposure to regularly experienced shocks and stresses

3. Increasing uncertainty and unexpected events

Source: Adapted from Mitchel, T. *et al* (2010)

The CSDRMA incorporates uncertainty in risk calculation and intervention design so that all policy, programmes and allied developmental activities consider the dimension of climate change. Therefore the CSDRM is an integrated social development and disaster risk management approach that aims simultaneously to tackle changing disaster risks, enhance adaptive capacity, address poverty, exposure, vulnerability and their structural causes and promote environmentally sustainable development in a changing climate[6]. CSDRM provides a guide to strategic planning, programme development and policymaking and should be used to assess the effectiveness of existing DRM policies, projects and programmes in the context of a changing climate as well as cross-check DRM interventions and all development activities for their responsiveness to current and future climate variability. This is done by identifying three pillars which relate to progression of vulnerability from root causes to unsafe conditions and are outlined below:

1. Pillar I: Tackle changing disaster risk and uncertainties.
2. Pillar II: Enhance adaptive capacity.
3. Pillar III: Address poverty, vulnerability and their structural causes.

These three pillars of the CSDRM Approach through guiding questions (Annex 2) recognizes the interdependencies and complexities in designing any policy or planning and implementing any programme, project or intervention. These guiding questions are suggestive and assist in holistically addressing vulnerabilities of people and communities. In order to incorporate the primary concerns of each pillar, questions from each could be identified according to the particulars of the individual policy or programme evaluation as relevant and therefore work across the pillars addressing concerns. They show that there is more than one route to CSDRM and that an integrated collaborative effort combining a range of existing institutions and programmes can be used to design project/programme[12]. It is essential to incorporate climate change dimensions into existing disaster risk management frameworks as this would drive the scaling-up of efforts and promote real, constructive collaboration across the different sectors, institutions, and scales. They also demonstrate that institutional independence and proper institutional mandates are vital[12].

Pillar I: Tackle changing disaster risk and uncertainties by highlighting the importance of collaboration between multiple actors/partners/levels. Multiple sources of knowledge are recognised and the importance of increasing access to information by all stakeholders through education, early warning and the media while highlighting measures to understand and address vulnerability and the conditions that create risks. Basically The CSDRM approach treats climate change as a key consideration and attempts to insert climate change into the most critical, climate-sensitive elements in an existing policy or programme.

Pillar II: Enhance adaptive capacity by strengthening the ability of a community or organisation to manage change sustainably by strengthening resilience against poverty. This means that institutions and networks learn and use knowledge and experience and create flexibility in problem solving. Enhancing adaptive capacity is a key strategy for managing increasing uncertainty associated with a changing climate and allows people and organisations to respond to shocks and unexpected events more effectively. The CSDRM approach weaves together many of the characteristics of climate change adaptation and presents these in a practical way in order to enhance ongoing and proposed development opportunities.

Pillar III: Address poverty, vulnerability and their structural causes with regards to identifying the causes of disasters to failures and gaps in development policy and programmes. Therefore, root causes underline the importance of access to power, infrastructure and resources; dynamic pressures, unsafe conditions and hazards all contribute to disaster risk. Additionally, lack of skills and markets and press freedom, coupled with macro forces, such as urbanisation and population growth, contribute to vulnerability.

CSDRM approach requires identification of an entry point through a self assessment exercise which is followed by adopting components of the suggested pathways of integration to plan an integrated project/programme or policy[13]. Strength of the CSDRM approach is its flexibility to adapt to a range of different processes, projects, contexts and stakeholders' needs.

Present study has used the CSDRM Approach to holistically plan for the study area in GRB and have considered our entry point "To Plan" which involves using tools and methods to plan for uncertainty and unexpected events (Refer Annex 2 – the CSDRM Approach). The overall themes suggested by the indicative pathways of the CSDRM Approach are:

- Collaborate
- Assess
- Integrate
- Inform
- Be Flexible
- Challenge

- Empower
- Develop

Considering the specific situation and conditions in the study areas in the GRB, out of the above suggestions an implementable pathway has been selected that are described below:

Recommended Pathways

For the Ghagahra River Basin study area interventions which work across the three pillars of the CSDRM Approach best demonstrate how to interlink development aspects with current and future climate change in order to lower vulnerabilities and increase adaptive capacity through equitable economic systems.

Assess: Periodically assess the effects of climate change on current and future disaster risks and uncertainties

An analysis of data from the study areas reveals that there is no communication between the knowledge hubs that generate data and the farmers who are one of the stakeholders for whom this data is generated for, and would benefit from such inputs. Therefore, any intervention in the GRB should ensure the project should facilitate the collection of weekly weather forecasts and advice and disseminate this information to farmer field schools, agro-service centres and trainers in each village through SMS messaging service. Farmers can use this information to develop coping and adaptive measures to better prepare for and manage the impacts of disasters and climate variability.

With the generation and dissemination of relevant knowledge; farmers are also capable of judging the feasibility and environmental sensitivity of future developments more effectively and mitigate flood risks.

Integrate: Integrate knowledge of changing risks and uncertainties into planning, policy and programme design to reduce the vulnerability and exposure of people's lives and livelihoods

Participatory scenario planning in the project focuses on reducing the physical exposure of farms by strengthening infrastructure (roads, drainage, seed banks) and promoting adaptive agricultural practices. The Participatory Technology Development (PTD) (refer Annex 3) approach could be successfully inserted into any agricultural development project/policy in the region where innovative models of adaptive agriculture for small landholdings that experiment with seasonal and spatial combinations of crops could be grown.

Further, through the participatory approach considering the predictable floods, a spatial management system can be developed and adopted by smallholder farmers. Measures which alter the timings of the conventional cropping cycles to ensure higher returns in the context of a hazard-prone changing climate can be implemented. Measures can range from using short duration cropping varieties, sowing early, to harvest early in order to reduce hazards, growing water resistant crops which can survive in conditions of water logging etc.

Challenge: Promote more socially just and equitable economic system

Policy, programmes and interventions that challenge injustice and exclusion and provide equitable access to sustained livelihoods options such as livestock management should be promoted, as immediately after the floods it is the daily nutrition provided by cattle, other livestock and poultry which has been noted for providing sustenance. The methodology of such interventions should include capacity building and awareness to empower the women using holistic livestock management as a tool to enhance livelihoods options. Empowerment through consultations on the type and need of the intervention (Annex 3) by promoting participatory decision making ensuring that local communities are involved in the policy dialogue and the decisions making process. This will establish linkages across policy-institutions-practice or interventions-people. Such capacity building and information sharing supports marginalised groups to engage in the decision making process that finally has an impact on them.

Empower: Empower communities and local authorities to influence the decisions of national governments, NGOs, international and private sector organisations and to promote accountability and transparency

Majority of the residents of these local communities are poor with no representation of women in the decision making process. Women are especially marginalised even though within the homestead and the farm they are the primary contributors to the labour force. Therefore public consultations and participatory decision making processes on policy, planning and budget proposals have to be identified which carefully consider the marginalised sections of the community and the marginalised community as a whole in local policy development at the Gram Panchayat and block level. One of the crucial inputs into such a process is making available comprehensive information on policies, schemes and programmes that could be leveraged by both local decision makers as well as the community while carrying out participatory planning. An important tool is making information readily available via information sharing networks and capacity building with these sections of the community that supports marginalised groups to engage in influencing decisions that affect them. Implementable measures could be identified and a proper feedback mechanism developed to ensure local communities can contribute to the policy dialogue and the decision-making processes at community level.

Develop: Promote environment sensitive and climate smart development

Considering that GRB region, which has multiple challenges, there is a necessity to take climate change considerations into planning and providing local communities with less carbon intensive livelihood options. Environmentally compatible ‘green’ livelihood options which contribute towards conserving the riverine biodiversity is an imperative for maintaining ecosystem services which the local communities depend and benefit from.

Collaborate: Strengthen collaboration and integration between diverse stakeholders working on disasters, climate and development

In many sections of the GRB region such as the study area, there is a need to identify and bridge the lacunae in the barriers to integration of climate change considerations into the development pathways. For the GRB, collaborations such as establishing strong market linkages between farmers and milk producers to the buyers and other relevant sectors, which fulfil these barriers to integration at the local and district level are required. To reduce hazards from unpredictable climatic conditions partnerships need to be established with the meteorological departments and scientific institutions that lead to improved information sharing and understanding. Further since the impacts of the Ghaghara River are trans-boundary in nature, such collaborations have to include knowledge and information exchange between India and Nepal. Initiating collaborations with the private sector for leveraging clean energy competencies for forming energy efficiency and/or carbon neutral development strategies. Planning and implementation between existing and new partners across sectors and between levels takes place to improve integration across action points.

Inform: Increase access of all stakeholders to information and support services concerning changing disaster risks, uncertainties and broader climate impacts

Common practice in the GRB region during the dry season is to grow crops on the fertile silt laden dry river beds. This becomes entirely water charged in the monsoon flood season with the banks of the Ghaghra River being highly instability. Stream course undergoes acute changes during the flood season eroding large tracts of lands known as *manjhas* leaving the riparian population frequently displaced. Ghaghra stream bed is highly unstable with massive and frequent erosion and deposition of banks therefore farmers should also be well informed of release of flood water and all necessary discharge data from upstream sources (Annex 4). Appropriate and timely early warning systems will function to mitigate the impacts of flooding, flash floods, and droughts that are becoming more frequent in the region due to climate change. Communication strategies have to take into account local perceptions of risk and uncertainty as the farmers using the silt laden dry river beds consider it a resource for farming better crops and therefore to be utilized rather than a potentially dangerous disaster in the making. Access to appropriate climate and weather information, creation of capacity to understand its uncertainty, and the application of it to decisions in ways that reduce their vulnerability and enhance their livelihoods is required. Health and sanitation in the GRB is poor, media and community-led public awareness programmes supporting increased access to information and related support services is required to be developed.

Conclusion

Adaptation efforts should be at the local level and work on conceptual frameworks must be carried out in parallel with practice. CSDRM Approach adopted recommends such a methodology to holistically develop interventions across all levels of governance where links exist between mitigation, adaptation and basic development are fully explored and strengthened. Potentially very diverse implementation activities can build local-level resilience and adaptive capacity especially in regions such as the Himalaya where uncertainties and understandings about the physical and social sciences is great[14].

The way forward to any developmental activity in the GRB must recognise that climate change is a driver for change and innovation across sectors and provides a perspective to meet new challenges and plan in different ways. Recent disaster statistics reveal the alarming trend of increasing losses from natural disasters with land use and climate change the primary cause of this trend. Business-as-usual DRM will fail without a significant shift in how risk calculation and intervention design incorporate climate modelling and associated uncertainty[12]. Nature creates floods and lateral erosion, and man converts it into a hazard. The CSDRM integrates key pillars of action and provides guiding questions to identify gaps and opportunities for new collaborations and an integrated approach in development. Key learning for development in the GRB is that adaptive capacity is central to improving ways of working and will require systematic investment in skills and innovation, rights and access to services, especially to women provide the foundation on which development can be promoted and the nuances of changing risk and uncertainty requires new knowledge that can be blended and brokered in a way that aids effective implementation.

Annex 3

The Participatory Technology Development (PTD) – Organic Basmati Rice Project in India is being conducted in the Ramnagar and Nainital districts of the northern state of Uttarakhand by Intercooperation Social Development India. The PTD concept involves a consultative and interactive process between local communities (farmers) and outside facilitators (researchers, extension workers and other stakeholders) which involves gaining a joint understanding of the main characteristics and changes of that particular agro-ecological system, identifying priority problems, experimenting locally with a variety of options derived both from indigenous knowledge and from formal science, and enhancing farmer's experimental capacities and farmer-to-farmer communication. Therefore, the PTD process is not the conventional top down approach to implementing projects, rather a holistic, consultative approach where the farmer and the funding agency/implementing body has equal stakes in the successful outcomes of the program. The PTD process is one which continuously evolves to incorporate observations and feedback from the field to build upon the knowledge base.

Annex 4

Discharge data recorded by the Irrigation Department is classified and could not be accessed. According to information provided by workers of the department, river discharge abruptly and radically reduces because of closure of the barrage gates during the month of November to abstract water for the 'Rabi' or winter crop. The reduced discharge lasts till mid-March when canal flow is stopped for repairs of the canal system and water released into the river. This is also done to facilitate ritual bathing at different pilgrimage sites all along the course of the Ghaghra on the religious occasion of 'Ram-Navami'', which occurs for ten days in late March/early April. It is conceivable that in case of failure of rains, the barrage gates would be again closed to supply water for the monsoon or Kharif crop.

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Climate Change and Himalaya

Natural Hazards and Mountain Resources

J. Sundaresan, Pankaj Gupta, K.M. Santosh & Ram Boojh

Glaciers and snow cover of Himalaya is the major source of water in Central Asia. Natural calamities and geo hydrological hazards occur in this regime due to rapid uplift of Himalaya and the under thrusting of Indian Plate and other extreme climatic disturbances. The book "Climate Change and Himalaya- Natural hazards and mountain resources" presents the resources of Himalaya along with the potential natural hazards. It consists twenty two chapters from researchers working in different institutions with multi disciplinary approach. More than seven hundred glaciers were monitored and discussed in one of the chapter of this book. Recently, Indian Himalayan Region was rocked by a chain of calamities occurred due to cloudburst , excessive rain fall followed by flash floods and landslides during June 2013. This is one of the initial scientific attempts to understand the above natural calamity. Urbanisation of mountain and sustainable utilisation of mountain resources are discussed in this book. This book will be highly useful to researchers, policy makers, students and is an essential document to libraries of universities, colleges, research institutions and personnel collections.

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