Climate Change and Himalaya
Natural Hazards and Mountain Resources

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Foreword

Himalayan mountain system has a prominent role in shaping the climate and environment of South Asia. The region as a whole is one of the most fragile and vulnerable ecosystems in the world. This vast mountain system with a geographical area of about 591,000 km^2 representing 18% area of the country, is also an important part of the global climate system. Indian Himalayan system, particularly the northeastern region is recognized as a global biodiversity hotspot. It has been recognized that any perturbation or change in the system will have considerable implications on the global climate system as a whole. During the past 9.5 to 8 million years, the rapid growing Himalaya (Greater Himalaya) caused barriers and disrupted the flow of west to east air current. This had developed low pressure region in North India and attracted summer winds from Indian Ocean that contribute copious seasonal monsoon rainfall in this region. During the rapid uplift of Himalayan region cooler conditions contributing to develop glacier and Cryosphere came into existence in Himalaya. Glaciers and monsoon had contributed many perennial rivers and other water resources. This resulted in Himalaya becoming the food basket and lifeline of South Asia.

I am glad to note that the book "Climate Change and Himalaya – Natural Hazards and Mountain Resources" vividly discusses various issues related to climate change and natural hazards of Himalaya and is a timely one owing to recent natural disaster in Uttarakhand which has affected the life and livelihood of millions of the people besides loss to life and property. This is the first scientific publication soon after the June 2013 tragedy analysing the cause of the disaster. There have been many glacial cycles in Himalaya during the past. The present period is the interglacial warm period. Extreme climatic events may occur during interglacial warm period. Glacial retreat and unusual melting of glaciers may develop geo-hydrological Hazards in the Himalayan region and its hinterlands. The Indian Himalayan Region (IHR) has suffered the worst such geo hydrologic hazards during June 2013. Cloud burst and excessive rains caused havoc in Uttarakhand and its neighbouring State Himachal Pradesh during the above disaster which was as a result of a chain of landslides followed by the flash floods.

The book has in total 22 chapters on various aspects of Himalayan glaciers natural hazards and other resources of Himalaya. Climate change that caused the uplift of Himalaya during many million years ago and the accelerated global warming and its impact on Himalayan glaciers and other resources have been scientifically discussed in the book. The book also provides information on re-constructed climate changes in Garhwal Himalaya through core data. Application of geo informatics as a tool to understand the glaciers and glacier melting along with Satellite data have been discussed in various chapters.

The book is a result of interdisciplinary studies on the impact of climate change in Himalayan ecosystem. Indicators of climate change with regional perspectives are part of this study. Paleoclimatic signatures made by Indus glacier/river on the granites of Ladakh batholiths on the banks of river Indus are discussed in detail in this book. Climate Change and its impact in Himalaya require early solutions. Climate change inclusive planning is the essential approach for the same. Climate Change adaptations and new pathways for future needs are presented with cross sectoral thinking in many chapters.

I warmly welcome this publication and congratulate its editors Dr J Sundaresan, Head, Climate Change Informatics, CSIR-NISCAIR, Dr Pankaj Gupta, Principal scientist, CSIR-Central Road Research Institute, Dr K M Santosh, Faculty, School of Marine Sciences, Cochin University of Science & Technology (CUSAT) and my colleague Dr Ram Boojh, Programme Officer, Natural Sciences, UNESCO New Delhi for bringing out such an important publication of contemporary interest. I hope and believe that this publication will receive due attention from researchers, policy and decision makers, field level functionaries and all those interested in Himalayan ecology and sustainable development.

Shigeru AOYAGI
Director and UNESCO Representative to Bhutan, India, Maldives and Sri Lanka
UNESCO Office in New Delhi

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 $(M \geq 7.0)$ 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.

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