Title: Himalayan Glaciers: Climate Change, Water Resources, and Water Security

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Water is among the most necessary substances of the living beings. Atmosphere is the first source of water from where it generates the hydrological cycle. Water can be found in different forms i.e. solid, liquid and gaseous. The gaseous form depends on the level of evaporation due to temperature from the liquid and solid form of water. It cannot be limited in certain geographical space but depends on the air mass circulation, its direction and temperature change over the ground. However, the liquid and solid states of water have the storage in different forms in various geographical spaces. After the condensation of atmospheric evaporation it results different form of precipitation of water contained in the atmospheric vapor and fall to the earth surface. Snow, rain, slit, hailstone, drizzle are some of the precipitated form of evaporation and convert to solid and liquid form. The precipitated water in the ground stores in different forms like snow, ice, glacial, river, lake, ocean and underground reservoirs. The forms and amount of storages determine by the surface geography. The geographical area with low temperature has accumulation of snow for longer time and it converts to the ice. Similarly, in the warmer area, the rain water immediately flows to downwards with different forms. The water in the form of snow accumulates over time and can make the open surface reservoir. The accumulated snow gradually converts to ice due to the pressure of frequent accumulation and finally forms the glacial. Due to changing thermal condition with it ultimately those glacial start to flow down slope in the form of glacier. Those glaciers are major sources of river water with more or less constant flow level and living being use that water for their survival. On the whole water and its storage system have the direct link with atmospheric temperature. Once the atmospheric temperature rise or falls the water cycle and its storage system goes on change and the sources of water systems might be in vulnerable situation. There is a close linkage between climate change and water resources availability.

For addressing various atmospheric, hydraulic and human lives security nexus in the Hindu Kush-Himalayan (HKH) Region the National Research Council organized a scientific committee from the different organization and individual scientists to describe and analyze the scientific knowledge about the glaciers of the region, their impact on the regional waterscape, and likely impacts of changes in the glaciers on the population of South Asia in 2011. This is a scientific report in the form of book titled **Himalayan Glaciers: Climate Change, Water Resources, and Water Security** prepared by the Scientific Committee of the National Research Council of America and published by the National Academy of Sciences through the National Academic Press, 500 fifth street, NW • Washington, DC 20001 in 2012. This book was retrieved in the digital form available in the open source from http://www.nap.edu/.

The book was intended to seek answers of some specific questions which were mentioned by the Committee Chair, Henry J. Vaux, Jr., in the preface of the book. Those specific questions were:

- How sensitive are the Himalayan glaciers to climate and other environmental factors?
- What are the potential impacts of changes in climate and glaciers on the timing and volume of river flows in the region and what are the likely implications for water supplies and extreme climatic events such as floods?
- What water management systems are in place to help adapt to changes in regional hydrological systems and how might those systems be strengthened?
- What are the main vulnerabilities of downstream populations to changes in water supplies, what are the prospects for conflict and/or cooperation, and what are the implications for national security?

The Committee addressed these questions from several perspectives. However, they have mainly taken the basis of the physical geography of the region, the human geography of the region, and the environmental security of the region. They have also identified additional scientific and data needs as well as possible means of adapting to changes in water security, and drawn a series of conclusions. Based on those major thematic areas the book also divided into five chapters including summary in the top and detail list of references and appendixes in the last section of the book. Before

summary, there are few pages covered for organizational introduction, preface, acknowledgements, and table of contents.

Specific questions were highlighted in the summary section of the book and has been mentioned the summarized version of the findings of each question. At the end, a way forward has been given by addressing major findings as well as for each thematic area. For the quick reading the summary section is enough to draw the major issues of the glacial landscape within the perspectives of climate change, water resources, and water security in the HKH Region.

The introduction chapter starts with the contextualization of the issues. The most common agenda starts by "many glaciers and snowpacks around the world are receding. This recession results from glacial ablation (melt and sublimation) rates that exceed the rates of glacial formation and accretion from precipitation over time." This is what the research has been directed towards the global warming. However, the rate of recession and time vary in different geographical region, location and places. Based on facts the study has been delineated within the glacial landscape of HKH Region i.e. Indus, Ganges and Brahmaputra basins and Interior glaciers of Tibet. From those glaciers, major hydraulic systems of the region originate. World large population in different countries is confined in these river plains. Several conventional social and cultural value systems of the region have been explained. To reach the philosophical route of the research questions vivid aspects of the glaciers and their associated problems in the region is discussed. The thematic area identification and justification of the research agendas have been forwarded. Within the conceptualization section three fundamental units i.e. physical geography of the region, human geography of the region and the environmental security of the region have been clearly identified for the discussion and analysis of the following section.

Chapter two discusses about the physical geography. In this chapter main focus has been given to the context of water supply in the region. In connection with the water supply as the major determining factors for water storages, the link has been established with the glaciers and climate change. The chapter has discussed the glacial geography in a very basic conceptual ground to make understandable to non-geographers and non-glaciologists and gradually given more advance physical geographical interpretation. Within this chapter discussion has been focused on physical properties and its general distribution pattern of glacial field in the various topographical

gradients. However, several empirical examples are cited from HKH Region, without confined only. After the basic understanding about glaciers the discussion has been tried to establish the relationship with meteorological parameters. The section has extensively discussed snow and ice formation and melting behavior changing with the temperature and precipitation. At the end of the chapter, the focus has been given towards the regional climate change analysis based on several current meteorological records, Paleocliamte evidences including tree ring analysis, regional hydrological and cloud-burst events. The chapter has established the linkages between several conventional methods for the prediction of climate change and regional glacial distribution pattern, hydrology and indirect measurement of climate behavior in the past through the present day evidences. It has also been suggested several scientific research questions to be investigated by the researchers in the HKH region. Because glacial fields are located at the difficult geographical landscape and inaccessible for the researchers, therefore, several research questions are left for uncertainty. In such situation application of new scientific methods like remote sensing means to get field based evidences could bring to the certainty level.

Chapter three has discussed human geography. In this chapter the demand side of the water is discussed within the various aspects. The demand has been categorized into three major properties of water i.e. blue water, green water and gray water. All these properties are directly interlinked with the population number, behavior and migration pattern. Therefore, the book has focused the population number and growth in the Region and their water use behavior. They have discussed the variation of demand of water within the human geographical structure of the Region. The demand for blue water is highest in the urban areas which are concentrated in the lower elevation of the region. Because of the influx of the population to the urban centers the demand is rapidly increasing. The book has well discussed about the regional differences of water availability based on the minimum requirement of 17000 cubic meters per person per year as a sufficient level to even less than 5000 cubic meter per person per year as absolute scarcity. The demand for green water is more in the rural inhabited areas where agriculture is their dominant activities. In the region large amount of green water is supplied by the rain water. Therefore, the seasonal variation on receiving rain water is the major factors. It is access in few months of the year and deficit in many months within the annual cycle. The discussion has been concentrated on the use of water in municipals and industries and also

the variation among the rich and poor households. The chapter has further discussed the water use policies, the institutional initiations towards the management at local to the international levels.

Chapter four has discussed risks and vulnerabilities related to natural hazards and provide an overview of water conflicts and political stresses in the Region. The discussion presents environmental change can contribute to violent conflict, especially where there is a history of such conflict and where governance institutions lack capacity or are still in the process of consolidating. It can also threaten political and social stability by creating obstacles to development, undermining public health, causing population displacement, creating problems for traditional livelihood of the people. The discussion emphasizes on many such issues pose potential instabilities in the region. Natural hazard and vulnerability in the mountain areas of the region have been clearly manifested as the major result of the climate change and security systems. While discussed over the natural hazard of the region the detail examination of the activities have been taken from the example of Nepal. Natural disaster mitigation, management and response are the major actions to be tackled amidst the results from the climate change and resource scarcity in the region

Chapter five is the synthesis of the previous chapters along with the summary of the research questions and a way forward. The changing climate stresses on glaciers field and that has caused both supply and demand of water in the region. In this chapter authors have clearly pointed out about the "anticipating future conditions in the HKH Region is hindered by an incomplete understanding of current conditions and of both the extent to which natural feedback mechanisms will generate new equilibria and human systems will adapt to signals of stress and change." Within that contextual ground the book discusses the link of physical geography and human geography. Several uncertainties have been explored based on the integrated knowledge of geography. Enhanced knowledge of interpretation brings the uncertainty within under certainty. Thus, the book suggests for the adapting to changes in climate, hydrology and water availability with the application of new monitoring skills, techniques and scientific innovations.

At the latter section of the book long list of detail references cited in the main text has been given. Those are thematic review and empirical evidences of the explanation. The lists of appendixes are given at the

end of the book. Appendices have covered the list of participants of the workshop, summary of the workshop presentation, glacier measurement methodologies, acronyms, institutional oversight, and biography of the researchers.

On the whole this book has covered the physical geography, human geography, environmental, hazard, risk and security of the Hindu Kush-Himalayan Region within the main title of 'Himalayan Glaciers'. The Himalayas is the water tower provides water resource for almost half of the world population. Glaciers are the living warehouse of the water resources. The climate change is the direct factor causes changes over the physical properties of the glaciers. Because of that the large share of global population could come under the unsecured situation. Within this contextual ground the initial purpose seems to provide the project research report to the Scientific Research Council of America, but it has covered wide range of scientific evidences, facts and figures in a form of book and published by the National Academy of Sciences though National Academic Press. This book is prepared by the highly scientific team and experts and they entirely concentrated in the Himalayas; therefore, this book is one of the best scientific outcomes published by incorporating integrated issues about the HKH Region. This book also provides the importance of geography discipline in the country like Nepal where the geography discipline as a whole is not accounted for the essential subject in academic arena through school to the universities. Although this book was published in 2012 and scientific findings until the year were reviewed and mentioned in the book but it is highly useful for the students, researchers, practitioners and scientists about the Himalayas. It is in open source availability and can be browsed from http://www.nap.edu/.

Krishna Poudel

Professor of Geography
Central Department of Education
Tribhuvan University
Kirtipur, Kathmandu