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Lecture Notes

Mountains:
Definition, Classification, Significance, Marginality, Vulnerability, Environmental Changes and Sustainable Development

Authors:

Professor Prakash C. Tiwari
Department of Geography
Kumaun University
Nainital-263 002, Uttarakhand, India
and
Dr. Bhagwati Joshi
Department of Geography
Government Post Graduate College [Kumaun University]
Rudrapur 263153 Uttarakhand, India

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Definition of Mountains

Mountains constitute very significant phenomena on the earth's land surface with varying altitudinal ranges and heterogeneity of landscape and terrain characteristics and diversity ecosystems. Food and Agricultural Organization (FAO 2008) of the United Nations has defined mountains as areas with high altitudes and characteristic topography, and all the areas above 2500 m elevation have been included under mountains. Further, the areas having altitude between 300 m and 2500 m can also be categorized as mountain regions if they are marked with steep slopes or wide range of elevation in a small spatial unit (FAO 2002). However, highland plateaus having elevation below 2500 m that lack surface slope and/or local elevation rate are therefore not included under mountains. United Nations Environment Programme – World Conservation Monitoring Centre (UNEP-WCMC) characterized mountain area as a land mass with slope and elevation which includes both mountains and hills. Mountains can be characterized by their altitudinal progression across different climatic and vegetation zones, physiographic characteristics and landforms types. "Mountains include all areas of a marked relief with significant ecological differences and slopes which are susceptible to natural hazards and human activities

Mountains and Hills

However, in several cases mountains are separated from hills on the basis of their higher elevations, steeper slopes and lower temperatures. Food and Agricultural Organization (FAO) of the United Nations has defined mountains as areas with high altitudes and characteristic topography, and all the areas above 2500 m elevation have been included under mountains. Further, the areas having altitude between 300 m and 2500 m can also be categorized as mountain regions if they are marked with steep slopes or wide range of elevation in a small spatial unit (FAO 2002). However, highland plateaus having elevation below 2500 m that lack surface slope and/or local elevation rate are therefore not included under mountains. But, the hills marked with low altitudes but exhibiting difficult terrain conditions have been classified as mountains (FAO

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Figure 1: The Great Himalayan Mountains

Figure 2: The Great Himalayan Mountains

Types of Mountains

The UNEP-WCMC classified world mountains into six categories ranging from Class – 1 to Class – 6 mountains taking into account elevation from the mean sea level and surface slope. The elevations higher than 2500 m from the mean sea level have been categorized as mountain areas irrespective of the magnitude of slope and topographic characteristics (Table 1 and Figure 3). The Class – 1 mountains are those areas which are situated in an altitudinal range of 300 m and 1000 m with a Local Elevation Range (LER) of 300 m of 5 km (i.e., characterized with 5^0 slope); , Class – 2 Mountains have an elevation from 1000 m to 1500 m with slope equal to or more than 5^0 or a Local Elevation Range 300 m of 5 km; Class – 3 Mountains should be located between the altitude of 1500 m and 2500 with a surface slope equal to and above 2^0; Class – 4 mountains area with elevation between 2500 and 3500; Class – 5 with altitudinal range between 3500 m and 4500 m; and Class – 6 mountains should have altitude above 4500 m. It is interesting to observe that this classification of mountain does not consider regions below the altitude of 2 500 m, high plateaus and large intermountain valleys as mountain areas, despite their showing several features of mountain ecology and being interconnected with mountain ecosystems. However, areas located just at altitude of 300 m above mean sea level but marked with more than 2^0 of slope have been classified as mountain areas from Class – 1 to Class – 3 Mountains (Table 1).

Distribution of Mountains

As per the UNEP-WCMC classification of world mountains' nearly 29 million km^2 area which accounts for about 22% of the total geographical land surface of the world is under different types of mountains. The maximum proportion of World Mountains (22 million km^2) is located in in developing countries and only a small proportion (5 million km^2) is situated in transition countries (Figure 3 and Table 1). The Asia and the Pacific region of the developing world shares 28%, developed countries 23% and countries in transition have 18% of the world's mountains. The sub-regions of developing and transition countries in which the mountain regions are extend over more than 1 million km^2 include East Asia, the Commonwealth of Independent States (CIS), South America, the Near East, Southeast Asia and Oceania, South Asia and East Africa, and mountains in these sub-regions account for approximately 90% of the total mountain areas of the developing and transition countries (Figure 3 and Table 1). However, Huddleston et al. (2003) has classified those countries as mountainous where one-third of their population was living in mountain areas

and/or in which mountainous terrain encompass more than one-third of the total geographical area.

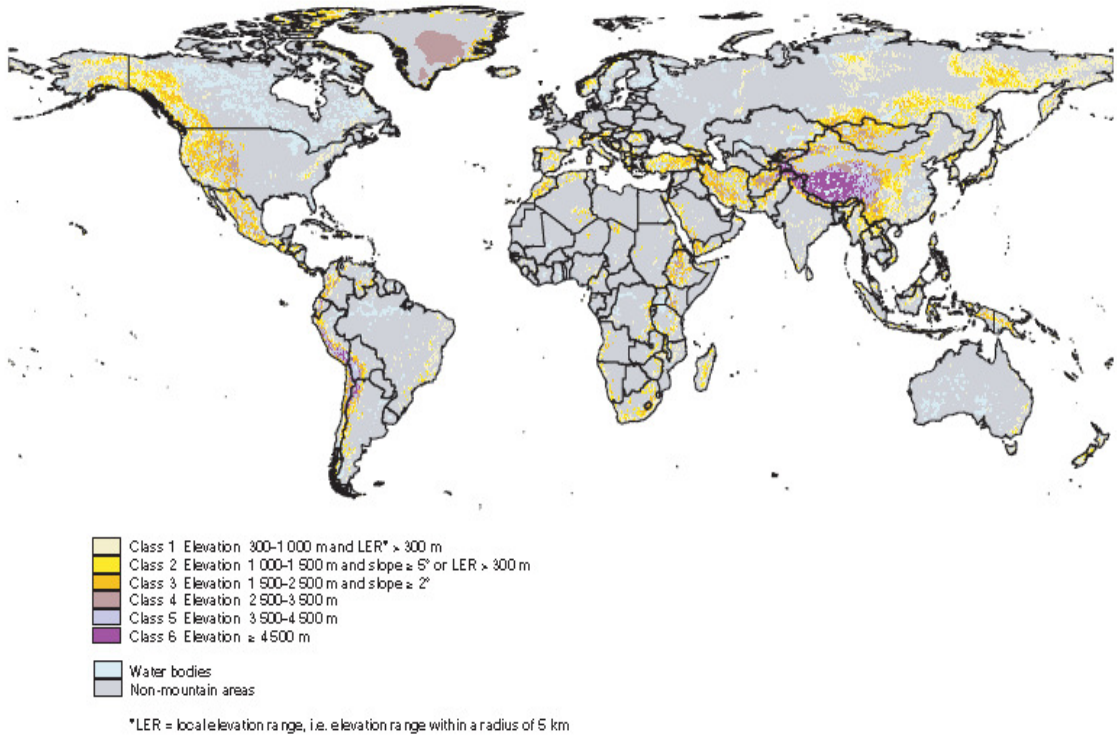

Figure 3: Distribution of Mountains

Table 1: Distribution of Mountains

Sub Region	Mountain Area Category-wise (in thousand km^2)						
	Class – 1	Class – 2	Class – 3	Class – 4	Class – 5	Class – 6	Total
Asia & Pacific	2 731	1 151	1 219	759	853	1 581	8 294
Latin America & Caribbean	1 412	730	812	443	585	155	4 136
Near East & North America	857	752	798	223	37	13	2 681
Sub Saharan Africa	921	668	438	94	5	--	2 125
Total Developing Countries	5921	3301	3268	1518	1479	1748	17237
Total Transition Countries	3353	1129	546	156	93	27	5305
Total Developed Countries	3263	1573	1296	698	12	--	6842
Total World	12538	6003	5110	2372	1585	1776	29384

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However, taking into the proportion of total geographical area the sub-regions in developing and transition countries, East Asia, North America (Mexico), Central America, Southeast Asia and Oceania and the Near East respectively account for 50%, 45%, 41%, 35% and 34% areas of the respective sub-region. Interestingly, 80% of the world's mountains have altitude 2500 m and almost 50% mountains regions have elevation below 1000 m. The high mountains in the planet extend across the Himalaya, Andes mountain ranges and in Tibetan plateau. Geologically, the Himalaya, Andes, Alps and Rockies are considered as the youngest and tectonically active mountain ranges of the world, and owing to their high elevation, steep slope and geo-tectonic instability these mountains are characterized with high environmental fragility as well as socio-economic vulnerability.

Nearly 90% of the mountain population live in developing or transition countries (Huddleston et al. 2003); 50% in the Asia-Pacific region and one-third live in China. About 30% of total world's mountain population lives in urban centres even though during the recent years the mountain regions of heavily populated developing countries have been experiencing rapid urban growth (Hassan et al. 2005). Out of the total population living in the mountain regions more than 50% live below 1000 m, and over 70% live below 1 500 m, whereas less than 10% global mountain population live in the mountain area located above 2500 m (Huddleston et al. 2003). However, the distribution of population living in mountain areas varies remarkably from one region to another (Table 2). The Hindu Kush Himalayan (HKH) mountains ranges extending across the countries of Bhutan, Nepal, Afghanistan, India, Pakistan, the Tibetan Plateau

and the Andes Mountains in Bolivia, northern Chile, Ecuador, Peru are virtually the only mountain regions which are inhibited by humans above an elevation of 4500 m even though the population living in these high mountains account for

merely less than 1% of total global mountain population (Huddleston et al. 2003).

Significance of Mountains

Mountain regions which encompass nearly 24% of the total land surface of the earth (UNEP-WCMC 2002) and constitute home for approximately 12% of the world's population (Huddleston et al. 2003) in addition to nearly 14% global population living in their foothills and adjoining lowlands are highly critical from the view point of marginality, environmental sensitivity, climate change, constraints of terrain, geographical inaccessibility and less infrastructural development (Meybeck et al. 2001). Mountain headwaters provide freshwater to approximately half of the world population inhabiting the large river basins located far away from mountains (Viviroli et al. 2007).

The largest trans-boundary river systems of the planet have their origin in high mountains (Figure 4, 5 and 6). Mountains have still the largest proportion of world's forests which not only constitute global biodiversity hot spots and the pool of genetic resources, but they also regulate and modify climatic conditions and contribute towards mitigating global warming through serving as carbon sinks (ICIMOD 2010). Mountain agriculture and farming systems constitute the principal source of food and livelihood for about half a billion population.

The indigenous communities inhabiting mountain regions since time immemorial have evolved diversity of cultures that comprise traditional knowledge, resource development and environmental conservation practices, agricultural and food systems, adaptation and coping mechanism, languages, customs, traditions, costumes, conventions and rituals which have immense relevance and practical significance in environmental restoration, climate change adaptation and ensuring sustained resource productivity in mountain ecosystems.

Figure 4: Mountain and Water

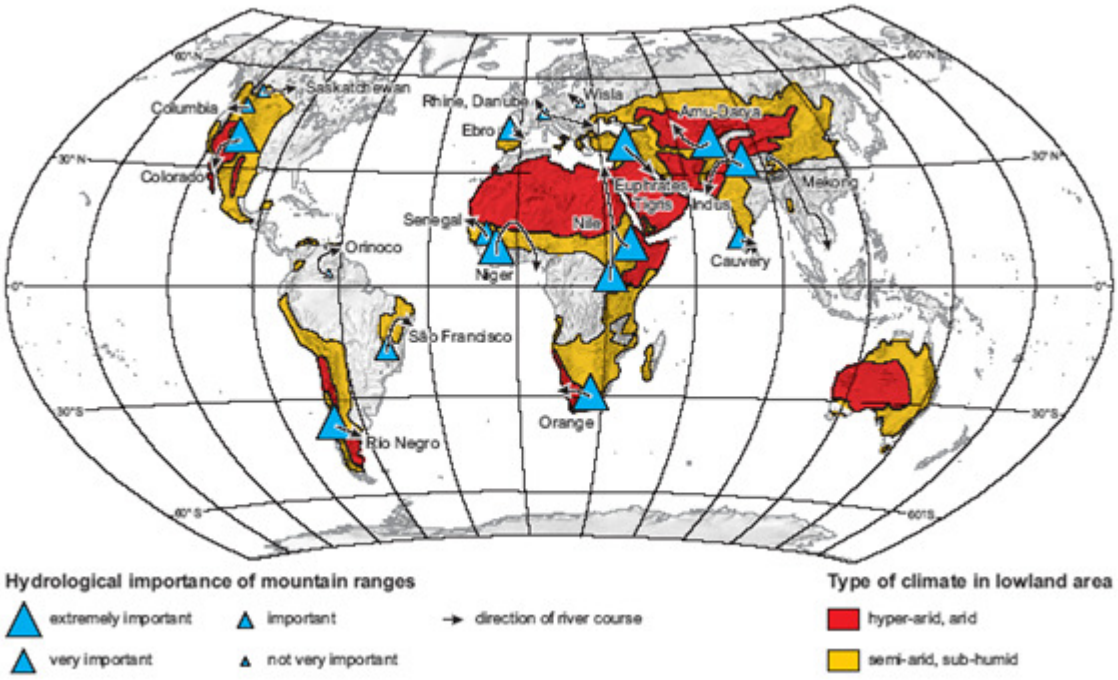

Figure 5: Hydrological Significance of Mountains

Figure 6: Mountain Constitute Source of Freshwater for Large Population

Mountain Ecosystem Services

Mountains constitute the sources of a variety of ecosystems services, including water, biodiversity, soils, natural beauty, recreational opportunities, wilderness and cultural diversity which sustains the livelihood and economy of large population both in mountains and their vast lowlands. The Millennium Ecosystem Assessment (MA) was carried out between 2001 and 2005 to assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to improve the conservation and sustainable utilization of ecosystems and their contributions to human well-being (Millennium Ecosystem Assessment 2005a). MA defines ecosystem as a dynamic complex of biotic components of nature that include plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit, and also as 'the benefits people obtain from ecosystems' (MA) (Millennium Ecosystem Assessment 2005). The MA deals with the full range of relatively undisturbed ecosystems, such as natural forests and landscapes with mixed patterns of human use, and also ecosystems intensively managed and modified by humans, such as agricultural land and urban areas. Ecosystems are natural assets that provide a wide range of services and products that sustain humanity across the planet (Millennium Ecosystem Assessment 2005).

Mountains support many different ecosystems and provide key resources and services for human sustenance far away from mountains as most of the goods and services provided by mountains have their origin in the headwaters, the beneficiaries of these services are mostly in the lowlands (Beniston 2005) (Table 2 and Figure 7). Highland and lowland ecosystems are thus highly interactive and inter-dependent in terms of ecology and economy as well as in social and political perspectives. The mountain population have contributed significantly to the conservation and protection of these ecosystem goods and services with their indigenous knowledge and traditional resource management practices. In view of this, mountain people need to be given some tangible incentives and adequate compensation for their most sincere efforts towards supporting the sustainability of large lowland population. The goods and services provided by mountain ecosystems can be divided into the following three primary categories (Hassan et al. 2005; UNEP-WCMC 2002)):

(i) *Supporting Services* which maintain the essential natural conditions for all forms of life on the earth and are intangible and do not have an explicit market value. These services mainly include soil formation, photosynthesis, and nutrient cycling. (ii) *Provisioning Services* that provide means of livelihoods and the economy by supplying various natural resources and products, such as, food, water, timber, and fibre. Undoubtedly, the most important good provided by mountain ecosystem is water, and therefore mountains are often known as 'water towers' for the world (Viviroli 2007; UNEP-WCMC 2002) (Table 2 and Figure 7). Mountains slopes and valleys have the capacity to store a large amount of fresh-water in the forms of glaciers, snow, and ice; as well as in the forms of groundwater and lakes. Almost all the principal rivers of the world besides many a large number of others have their sources in mountains (Messerli and Ives 1997). It has been observed that more than half of the total geographical area of world's mountains is highly crucial for supplying fresh-water to large population inhabiting the lowlands. The freshwater of Hindu Kush Himalayan (HKH) mountain ranges is used by more than 200 million people living in the region and by 1.3 billion people living in the ten downstream river basins of South and East Asia (Viviroli et al. 2007).

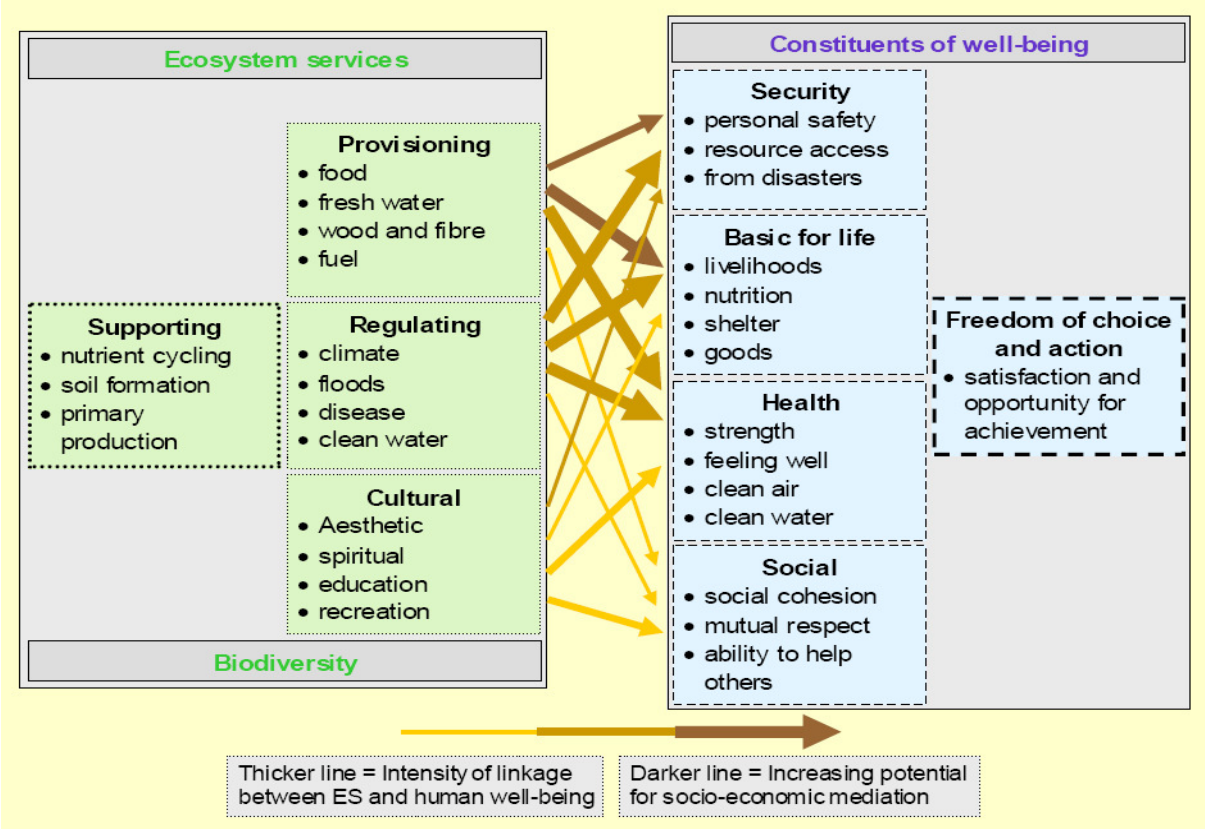

Figure 7: Mountain Ecosystem Services

Besides water, mountains are endowed with high biological and agricultural diversity that includes variety of food and fibre crops and medicinal plants (UNEP-WCMC 2002). (iii) *Regulating Services* regulate climate, flood and, disease, maintain water quality and recycle wastes. Mountain play vital role in maintaining and supporting a healthy and safe environment and climatic conditions for the survival of human being as well as for other living organism. Mountains contribute significantly in maintaining the hydrological cycle through purification and retention of rainwater in the forms of groundwater, ice, and snow, as well as in lakes and streams. Mountain ecosystems play important role in atmospheric circulation and climate regulation and act as pool for the storage carbon and soil nutrients.

Table 2: Mountain Ecosystem Services

Mountain Type		Ecosystem Services								
		Down Stream Safety	Fresh water	Energy	Grazing	Crops	Fuel Wood	Timber	Medicinal	Recreation
Alpine	Terrestrial	+++	+++	+++	++	●	●	●	+++	++
	Aquatic	●	+++	+++	●	●	●	●	●	+
Montane	Terrestrial	+++	+++	+++	+++	+++	++	++	+++	++
	Aquatic	●	+++	+++	●	+	●	●	●	++
Hills and Plateau	Terrestrial	+	+	+	+++	●	++	++	+	+++
	Aquatic	●	+	+	●	++	●	●	●	+
Legend: +++ = Very Important, ++ = Important, + = Relevant & ● = Not Relevant										

The mountain slopes consisting of nearly 28% of the world's forests provide mechanical support to landscape and hence protect fragile slopes against land degradation and slope instability (IPCC 2007a, b). (iv) *Cultural Services* that provide opportunities for recreation and education and spiritual and aesthetic inspiration (World Resource Institute 2005) (Table 3). The mountain regions are exhibited by cultural and ethnological diversity including spiritual traits and rich traditional ecological knowledge which besides strengthening the adaptive capacity of mountain communities to global change also provide fascinating attractions to a variety of visitors (Bernbaum 1997).

During the last 50 years human interventions have transformed natural ecosystems more rapidly and extensively than in any comparable period of time in human history on the earth. This was primarily to fulfill rapidly growing demands of natural resources, such as, arable land, food, fresh water, timber, grazing areas and energy which resulted into a considerable and largely irreversible loss of biodiversity and ecosystem services on the earth. Although these changes in the natural system have contributed significantly towards betterment of the quality of human life, but they also caused rapid exploitation of natural resources, substantial loss of ecosystem services and imbalanced economic growth in many parts of the planet.

The depletion of natural resources and continued disruption and loss of ecosystem services may affect adversely the process of attaining the Millennium Development Goals MDGs) (Millennium Ecosystem Assessment 2005). The challenge of restoration of ecosystem services and conservation of environment while meeting increasing demands of natural resources would require significant changes in policy plans and decision making processes from local to international levels. There are a number of possibilities and opportunities that may be used to restore certain types of ecosystem goods and services in such a way that they provide positive synergies with other ecosystem services (Millennium Ecosystem Assessment 2005).

Marginality and Vulnerability of Mountains and their Inhabitants

Marginality of the Mountain Regions of the World

Mountain regions which encompass nearly 24% of the total land surface of the earth and constitute home for approximately 12% of the world's population (http://www.fao.org/3/a-y4558e.pdf) in addition to nearly 14% global population living in their foothills and adjoining lowlands are highly critical from the view point of marginality, environmental sensitivity, climate change, constraints of terrain, geographical inaccessibility and less infrastructural development (http://www.fao.org/3/a-y4558e.pdf). Mountains constitute the sources of a variety of ecosystems services, including water, biodiversity, soils, natural beauty, recreational opportunities, wilderness and cultural diversity which sustains the livelihood and economy of large proportion of population both in mountains and their vast lowlands. Mountain headwaters provide freshwater to approximately 70% of the world population inhabiting the large river basins located far away from mountains (http://www.fao.org/documents/card/en/c/CA5561EN).

The largest trans-boundary river systems of the planet have their origin in high mountains, and mountains have still the largest proportion of world's forests which not only constitute global biodiversity hot spots and the pool of genetic resources, but they also regulate and modify climatic conditions and contribute towards mitigating global warming through serving as carbon sinks (*lib.icimod.org).* Mountain agriculture and farming systems constitute the principal source of food and livelihood for about half a billion population. The indigenous communities inhabiting mountain regions since time immemorial have evolved diversity of cultures that comprise traditional knowledge, resource development and environmental conservation practices, agricultural and food systems, adaptation and coping mechanism, languages, customs, traditions, costumes, conventions and rituals which have immense relevance and practical significance in environmental restoration, climate change adaptation and ensuring sustained resource productivity in mountain ecosystems (*lib.icimod.org).*

But, mountains have long been marginalized from the view point of sustainable development of their resources and inhabitants. However, our understanding about the problems of mountain regions and approach to their development has

undergone drastic changes, during the recent years**.** Currently, mountain ecosystems as well as mountain communities are particularly threatened by the ongoing processes of environmental global change, population dynamics and globalizing economy and resultant exploitation of mountain resources.

During the recent years, a variety of changes have emerged in the traditional resource use structure in high mountain areas, particularly in developing and underdeveloped regions of the world mainly in response to changing global economic order, transforming political systems, rapid urban growth, increased demographic pressure and resultant increased demand and exploitation of natural resources**.** As a result, mountain regions of the world are passing through a process of rapid environmental, socio-economic and cultural transformation and exploitation and depletion of their natural resources leading to ecological imbalances and economic un-sustainability both in upland and lowland areas (*lib.icimod.org).*

Moreover, the changing climatic conditions have already stressed mountain ecosystems through higher mean annual temperatures and melting of glaciers and snow, altered precipitation patterns and hydrological disruptions, and more frequent and extreme weather events. In this context, climate change acts as an additional stress which can multiply existing development deficits and may also reverse the process of socio-economic development in mountain regions particularly in poor and developing countries (*www.asia-pacific.undp.org › dam › rbap › docs › human_development).*

Mountain people, who have contributed the least to global greenhouse gas (GHG) emissions, and helped significantly in mitigating climate change through promoting carbon sequestration by preserving the largest proportion of forests on the planet are likely to be the worst affected by long-term impacts of climate change (*lib.icimod.org).* Further, these changes are likely to undermine the inherent capacity of indigenous mountain communities to respond and adapt to changing environmental conditions including climate change. Besides, the recent food crisis followed by global economic recession has adversely affected the food and livelihood security of mountain communities because of their subsistence economies, constraints of terrain and climate and resultant physical isolation and low productivity, vulnerability to natural risks, poor infrastructure, limited access to markets, higher cost of production, and poor employment and livelihood opportunities. It has been estimated that a large proportion of food insecure population now live in mountain regions of the world (http://www.fao.org/3/a-y4558e.pdf).

It is therefore high time that national as well as international policy and decision making agencies and organizations must realize the significance of mountain ecosystems is sustaining world population, and evolve framework for the sustainable development of mountain regions and well being of their inhabitants (*www.fao.org› iym).* The world community should come forward to compensate mountain people for the value of the ecosystem services provided by the mountain regions, and facilitate them in the protection of their fragile environment and conservation of natural resources and take benefit from emerging opportunities of globalization. This particularly imperative in the context of the United Nations Framework Convention on Climate Change (UNFCCC] for providing monetary benefits to mountain inhabitants for their contribution towards mitigating climate change through conservation of forests. The developed countries should line up to act as important resource centers for capacity building of developing countries by providing knowledge, technology, and expertise to mountain regions.

A marginal entity or an area in any context, is referred to the one that counts the least in the mainstream situation. This may apply to the natural system and its carrying capacity; and productivity, availability, efficiency of and access to natural resources and their utilization and governance system as well as to human community and it's social, economic and political systems. The basic factors contributing to such a status of any area and community are remoteness, inaccessibility, constraints of terrain, complexities of climate, sensitive flora and fauna, and geodynamic instability. The factors of marginality also include isolation, fragility and resultant low productivity and carrying capacity of natural resources, and series of human constraints [social, economic and political] that prevents community participation and active involvement in the mainstream patterns of activities and development process, and political decision making processes. The voices of people inhibiting such regions are often unheard and un-represented.

Since, mountain regions are characterized by the above-mentioned specificities and attributes they present the most appropriate example of marginal areas. The mountain regions being marginal areas as against the other geographical areas, such as plains share the above-mentioned attributes of marginal entities, and suffer the consequences of such status in different ways in their overall socio-economic and political developmental process. A large proportion of mountain regions of the world, particularly in developing and less developed countries are still poor and underdeveloped due mainly to their marginality, and this makes

them sensitive to the impacts of global environmental change, particularly climate change and climate change induced natural disasters.

Vulnerability of Mountains

Vulnerability is the magnitude to which people, assets, resources and resource utilization systems, infrastructure, services, socio-ecological systems, and livelihood are susceptible to adverse natural and socio-economic conditions and changes caused by natural and made process. The Intergovernmental Panel on Climate Change (IPCC 2014) (https://unfccc.int/topics/science/workstreams/cooperation-with-the-ipcc/the-fifth-assessment-report-of-the-ipcc) defines vulnerability as the propensity or predisposition to be adversely affected, which in other words, refers to people's sensitivity to adverse impacts and their capacity to cope with these. In the mountain regions, socio-economic, cultural and political factors, among many others, shape community vulnerability to the effects of global environmental change. These conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of possible risks (https://www.unisdr.org/we/inform/terminology).

The marginality and the resultant constraints to resource-productivity, livelihood and food security, socio-economic underdevelopment and poverty make mountains some of the most vulnerable ecosystems on the planet. In the mountains of developing and poor countries, community access to resources and poverty are key factors contributing to their vulnerability to environmental change. The poor households have less resources for adaptation measures, moving them towards dangerous tipping points, such as hunger and loss of livelihoods. In general, poverty is most prevalent and more persistent in remote mountainous areas. The higher poverty levels are partly the result of lower access to basic facilities, restricted and very poor access to markets and urban centres, small and decreasing landholdings and more dependents within a household. Limited access to economic services and power restricts not only developmental opportunities, but also political representation and empowerment. Isolation and distance from markets and services and inaccessibility therefore exacerbates poverty in the mountains, and thereby increases vulnerability to and costs of adaption to climate change (Figures 8, 9, 10 and 11). For example, transport costs can be prohibitive for improving and developing adapting infrastructure in remote mountain areas.

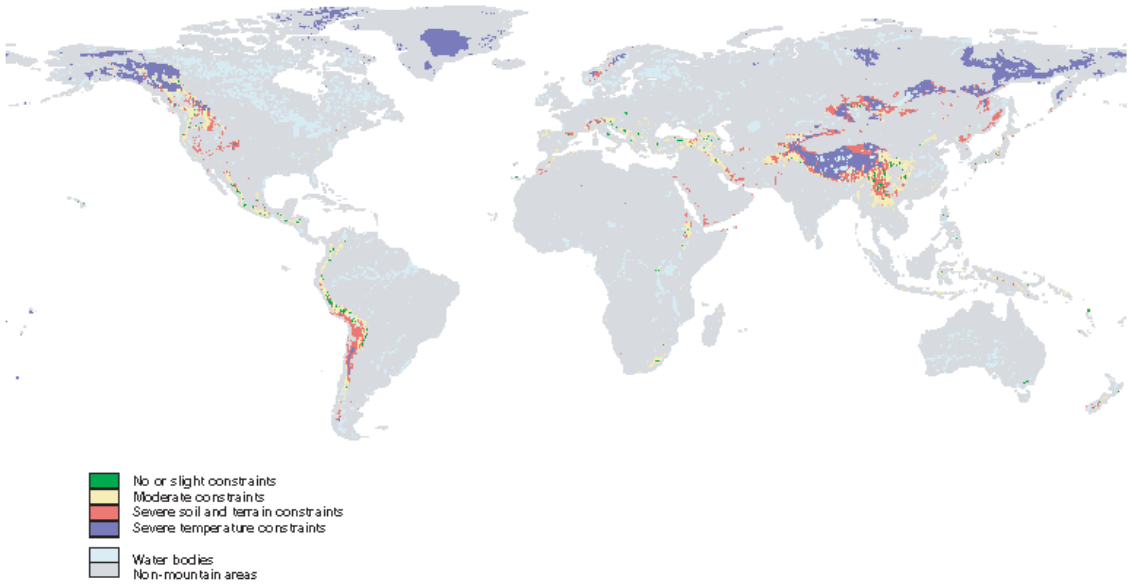

Figure 8: Geo-environmental Constraints in Mountains

The size of farm landholdings in mountainous areas are generally smaller than in the plains and is more fragmented, making food production more time-consuming and labour intensive. Moreover, during the recent years, the issues such as population growth, deforestation, land degradation, climate change and the resultant disruption of mountain ecosystem services have reduced the average landholdings in densely populated mountains, such as Himalaya and Andes. In the Himalayan mountains in Nepal the average size of landholdings reduced by almost 19% during 2001-2011 (*cbs.gov.np › image › data › Publication › Nepal in Figures English 2014).* This results in low productivity levels of agricultural resources and more vulnerability of local communities to environmental changes, particularly to climate change in mountain regions. More than 52% of the world's undernourished people live in the eight countries of Hindu Kush Himalaya. Mountain communities are especially vulnerable to food and nutrition insecurity due to extreme climatic conditions, constraints of terrains, poor soils, short growing seasons and low temperatures. Food and Agricultural Organization of the United Nations (FAO) observed in 2015that the proportion of food insecure population in developing countries was approximately 13%, whereas it was as much as 39% in the mountain regions (http://www.fao.org/3/a-y4558e.pdf).

Figure 9: Compact Rural Settlement in Himalaya Reflect the Constraints of Mountain

Mountain regions are highly sensitive to a variety of changes caused by natural processes as well as by anthropogenic interventions. The driving forces of mountain people's vulnerability include mainly geo-environmental constraints, socio-economic and political marginalisation and high dependency on natural resources resulting into unbalanced poverty levels, low agricultural productivity, food and livelihood insecurity and increased vulnerability to environmental changes. The population living in mountain regions of developing and less developed countries primarily depends on subsistence agriculture and livestock rearing for its food and livelihood even-though the availability of arable land is severely limited and crop productivity is poor. As a result, the mountain ecosystems and their inhabitants are highly vulnerable to the long-term impacts of global environmental change particularly in developing and poor countries of the world. Although mountain areas are rich in natural resources, such as biodiversity, water and scenic beauty, but they often presents several challenges because of their subsistence economy, fragile environment, physical isolation, inadequate access to markets and inputs, low resource productivity and resultant vulnerability to risks of a variety of natural hazards and disasters.

Figure 10: Women are Primary Resource Developers in Mountains

As a result, the mountain ecosystems and their inhabitants are highly vulnerable to the long-term impacts of global environmental changes particularly in developing and poor countries of the world. Mountain regions, particularly in developing countries are largely inhibited by poor people. The mountain communities are subject to prevailing poverty and lower levels of socio-economic development than those in their adjoining lowland areas in developing countries. The main drivers of mountain poverty include fragility of ecosystems; remoteness; poor accessibility and marginalisation of mountain communities from the mainstream; lack of equity in terms of access to basic facilities such as health care, education, and physical infrastructure, as well as to markets, political marginalization; lack of employment opportunities; and proneness to natural disasters. Food and Agricultural Organization (FAO) of the United Nations (UN) observed that the proportion of poor and vulnerable people increases with elevation, and the ongoing process of globalisation seems to have further strengthened poverty imbalances between highlands and lowlands (http://www.fao.org/3/a-y4558e.pdf).

Figure 11: Impact of Constraints on Mountain

Out of the total of 245 million mountain rural population identified as vulnerable food insecurity as much as 87% live below 2500 m above mean sea level which constitute the most densely populated transact of mountains specifically in Asia and Latin America. Although in higher mountains regions the number of vulnerable rural population is comparatively small, but that accounts for nearly 70% of the population living in high mountains above 2500 m. Furthermore, due to very limited and no access to primary health-care and sanitation facilities and increasing food insecurity and nutrition deficiencies the maternal and infant mortality rates have been observed very high in mountain regions, particularly in developing and underdeveloped countries. High dependency on natural resources and increasing marginalisation are some of the important factors for prevailing poverty, food and livelihood insecurity, poor community health, in high mountains of developing and less developed countries which are further increasing their vulnerability to long-term impacts of global environmental change.

Global Environmental Change and Mountains - Challenges and Opportunities

Drivers of Global Environment Change in Mountains

Mountains are highly critical from the view point of marginality, environmental sensitivity, constraints of terrain, inaccessibility and climate change (http://www.fao.org/3/a-y4558e.pdf). But, mountains have long been marginalized from the view point of sustainable development of their resources and inhabitants.

However, we are experiencing an emergence of responsiveness of the ecological significance of mountain systems and their environmental significance for the sustainability of global community, particularly after the United Nations Conference on Sustainable Development – the Rios Earth Summit in 1992 (UN). As a result, our understanding about the dilemmas of mountain ecosystems and approach to their development has undergone drastic changes, during the last two decades.

Currently, mountain ecosystems as well as mountain communities are particularly threatened by the ongoing processes of global environmental change. During the recent years, a variety of changes have emerged in the traditional resource use structure in high mountain areas, particularly in developing and underdeveloped regions mainly in response to economic globalization, increased demographic pressure and rapid urban growth.

As a result, mountain regions of the world are passing through a process of rapid environmental, socio-economic and cultural transformation and exploitation and depletion of their natural resources leading to ecological un-sustainability both in upland and lowland areas. Moreover, the changing climatic conditions have already stressed mountain ecosystems through higher mean annual temperatures, altered precipitation patterns and frequent extreme weather events (lib.icimod.org).

The global change is referred to the changes caused by both natural and anthropogenic processes and encompass, among other factors, climate change, land use cover change, industrialisation, urbanisation, and changes in atmospheric chemistry. The global environmental changes affecting mountain ecosystems fall into two groups: (i) systemic changes that operate at a global scale (such as climate change) and cumulative changes caused by processes at a

local scale but that are globally pervasive (such as land use cover change)(https://www.researchgate.net/publication/241288109_Global_Change_and_Mountain_Regions).

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As a result, mountain regions of the world are passing through a process of rapid environmental, socio-economic and cultural transformation and exploitation and depletion of their natural resources leading to ecological imbalances and economic un-sustainability both in upland and lowland areas**.**

Moreover, the changing climatic conditions have already stressed mountain ecosystems through higher mean annual temperatures and melting of glaciers and snow, altered precipitation patterns and hydrological disruptions, and more frequent and extreme weather events.

In this context, climate change acts as an additional stress which can multiply existing development deficits and may also reverse the process of socio-economic development in mountain regions particularly in underdeveloped and developing countries (http://www.unep-wcmc.org/mountains/mountainwatchreport). Further, these changes are likely to undermine the inherent capacity of indigenous mountain communities to respond and adapt to changing environmental conditions including climate change. Besides, the recent food crisis followed by global economic recession has adversely affected the food and livelihood security of mountain communities because of their subsistence economies, constraints of terrain and climate and resultant physical isolation and low productivity, vulnerability to natural risks, poor infrastructure, limited access to markets, higher cost of production, and poor employment and livelihood opportunities. It has been estimated that a large proportion of food insecure population now live in

mountain regions of the world (http://www.fao.org/documents/card/en/c/CA5561EN).

The climate change has long-term impacts on ecosystem services both in mountains and their downstream, and even more severe effect on the socio-economic landscape including agriculture, population structure and its dynamics, as well as on the marginalization of peripheral mountain communities (*https://www.millenniumassessment.org›documents› document.766.aspx.pdf).* Mountains consisting a vast repository of a variety of ecosystem services and goods constitute one of the most fragile environments on the planet and they are considered as being highly sensitive to global change. People living in mountain areas are exposed to a series of environmental and non-environmental stressors which are interconnected and have serious implications on the livelihood and quality of life of mountain communities. These stressors include population growth and processes of socio-economic development which are linked to increasing demand of goods and services and globalisation that leads to depletion of natural resources, such as, land, water, forests, minerals and biodiversity (http://lib.icimod.org/record/26882/files/attachment_708.pdf).

Currently, mountain ecosystems are changing more rapidly than at any time in human history on the earth. The long-term impacts of changes caused by deleterious anthropogenic interventions, such as intensification of land use and overexploitation of natural resources are much more deleterious for mountain communities than the affects of natural processes, such as volcanic and seismic events, landslides, and flooding that devastate large parts of mountain ecosystems every year (http://lib.icimod.org/record/26882/files/attachment_708.pdf). Currently, mountain ecosystems and their inhabitants are exposed to a variety of drivers of change including globalisation; economic policies; and increasing pressure on land and mountain resources due to economic growth and changes in population and lifestyle (http://lib.icimod.org/record/26882/files/attachment_708.pdf).The major drivers of global change on world's mountain mainly include climate change, population dynamics, economic globalization, land use change, urbanization (https://www.millenniumassessment.org›documents› document.766.aspx.pdf).

Climate Change: Impacts and Adaptation

The mountains across the world have shown consistent trends in overall warming during past 100 years and the temperature rise in mountains is faster than in plains. However, the exact impacts of climate change on mountain ecosystems, and the interlink-ages with other drivers of global change are yet to be investigated and properly understood (*lib.icimod.org › record › files › attachment_634).* The mountain regions across the world have experienced the effects of global warming which are resulting into the retreat of glaciers, decrease in permafrost, changes in the seasonality of runoff, upward shifts of the vegetation line, and changes in the biodiversity of alpine lakes and streams (Figure 12). The long-term impacts of these changes are not only of direct relevance to the high mountains, but they will have serious implications for downstream regions. The rise in temperature in mountain regions has affected mountain environments and ecological processes across the globe.

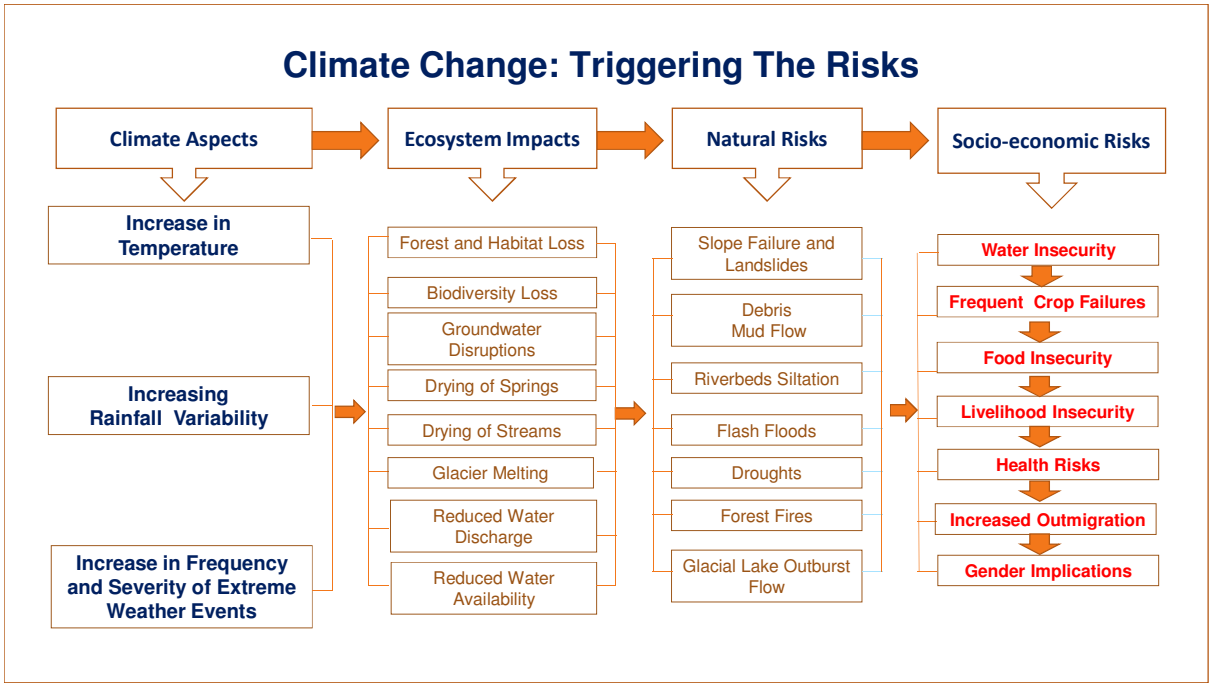

Figure 12: Climate Change and Impacts in Himalaya

Mountain ecosystems are expected to react very sharply to climate change, with both natural and social systems being influenced all over the world. The climate change has shown it's most remarkable and significant impact on the glaciers which are retreating fast since the last century (*https://www.ipcc.ch › site › assets › uploads › 2018/03 › ar4_wg2_full_report).* The trend of glaciers melting is global and rapid which may lead to the de-glaciation of large parts of many mountain ranges in the world in the next decades (UNEP WGMS 2002). The Alps has experienced an intensified retreat of Alpine glaciers during the

previous century. The Alpine glaciers have reduced by nearly 22% between 1850 and 2000. The volume of glaciers in Canadian Rockies has decreased a minimum of 25% during the last century. In the world's highest and largest mountain system – Himalayas, the rate of retreat of glaciers has been relatively faster than the world average and they are thinning at the magnitude of 0.3-1 m/year, and the rate of retreat of the Gangotri – the largest glacier of Himalaya – has been three times higher than the rate at which it melted during the preceding 200 years (http://www.grid.unep.ch/glaciers).

As much as more than 82% glaciers in western China have receded during the last half century. Further, the area under glaciers in Tibetan Plateau has decreased by about 11.5% over the last 40 years. Similar trends in the responses of glaciers and snow-packed areas have been observed in South African mountains where about 85% of the total ice volume of the plateau glaciers of Mount Kilimanjaro in Africa vanished between 1912 and 2000 (lib.icimod.org › record › files › attachment_634).

In general, the de-glaciation is accelerating in mountains, and consequently, that most snow and ice caps across the world are shrinking at alarming rates. In North American mountains, it was observed that a large number of glaciers were continuously retreating and thinning, and the unconsolidated and unstable sediment is exposed and mobilized into rivers, which causes aggradation in downstream. As a result, the rate of sedimentation in most of the river-beds has increased from 7–13 cm up to 1.8 m per decade leading to more frequent catastrophic shifts in the courses of river channels (*www.fao.org › fileadmin › user_upload › mountain_partnership › docs).*

The glaciers have been found retreating in all Andean countries over the last three decades with the complete disappearance of a large number of glaciers. The average rate of retreat of glaciers in Cordillera Blanca of Peru has been observed to be 26% between 1970 and 2003, in Ecuador 27% during 1997 – 2006, 87% reduction in the Mérida Cordillera in Venezuela in the last 50 years, and 2% to 5% annual decrease in glaciers in Colombia over the last 10 years.

The annual rate of contribution to sea-level rise from the Patagonian ice-fields has doubled during 2000 – 2005 in comparison to 1975 – 2000. The area of small glaciers has reduced by 50% in the Argentinean Tierra del Fuego. The Northern Patagonian Ice Field in South America lost nearly 140 km² of its snow covered area during1942 and 2001 (*www.fao.org › fileadmin › docs › ANDES FINAL Andes_report_eng_final).*

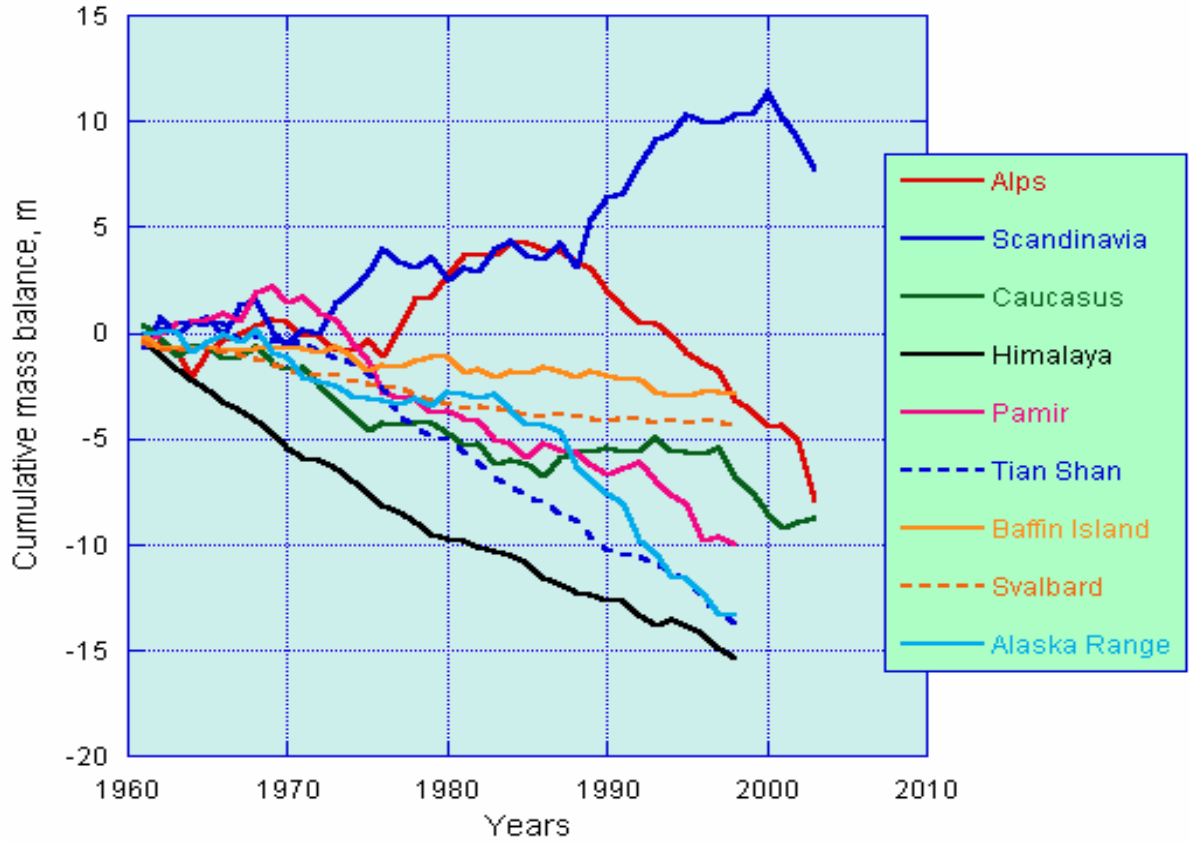

Figure 13: The Trends of Glacier Retreat in Different Mountain Regions of the World

These observed changes in the cryosphere are transforming the hydrological regimes of mountain headwaters and disrupting drainage systems all across the basins. Consequently, regime of water resources in mountain headwaters is likely to change rapidly, with respect to discharge, volumes and availability.

The impacts of retreating glaciers on river-flows expected to be greater, in small, more highly glaciated headwaters. It is most likely that most of the mountain regions and their lowlands face a catastrophic water scarcity by the 2050s resulting from population growth, climatic change, and the increase of water demand.

The continued melting of glaciers, snow and ice cover will adversely affect the supply of water leading to severe water crisis and potential conflicts in large part of the world. Himalaya, for example, constitutes headwaters of some of the largest trans-boundary basins of planet (e.g. Amu Darya, Brahmaputra, Ganges, Indus, Irrawaddy, Mekong, Salween, Tarim, Yangtze and Yellow River Basins) that sustain one-fourth global population dependent primarily on subsistence agriculture in Pakistan, India, Nepal, Bhutan, China and Bangladesh.

Climate change has stressed hydrological regimes of Himalayan headwaters through higher mean annual temperatures, melting of glaciers and altered precipitation patterns causing substantial decrease in water availability. This may increase proportion of health, food and livelihood insecure population in South Asia which includes some of the poorest people of the world with access to less than 5% of planet's freshwater resources.

This will have enormous regional implications for fundamental human endeavours ranging from poverty alleviation to environmental sustainability and climate change adaptation, and even to human security. However, in view of the complexity of inter-linkages between the climatic and non-climatic drivers influencing the mountain freshwater resources and very high improbability regarding changes in precipitation patterns it is extremely difficult to project future changes in mountain freshwater ecosystems.

Mountain ecosystems sustain about 25% of the terrestrial biodiversity, and support approximately half of the biodiversity hotspots of the planet. Furthermore, nearly 28% of geographical area of world's terrestrial protected areas is in the mountains. Nonetheless, mountain biological species are adapted to specific altitudinal zones and microclimatic conditions; hence they are highly sensitive to climate variability.

The observed trends of changes in temperature are expected to push the vegetation belts upward in higher elevations and the geographical ranges of species may advance northward in the northern hemisphere changing the species composition of communities. The advancing unfolding, blossoming, and ripening in the leaves and fruit of wild plants; and of hibernation, migration, and breeding of wildlife have been observed in mountain regions. The climate change also increases the risk of extinction for species with narrow geographic or climatic distributions and also disruption of existing communities (lib.icimod.org › record › files › attachment_634).

There is widespread agreement that climate change is increasing the frequency and magnitude of extreme weather events and causes severe natural hazards and disasters. Mountain ecosystems are highly vulnerable to a variety of natural hazards and disasters which now being triggered by rapidly changing climatic conditions.

The changes in temperature and precipitation pattern and melting of glaciers and snow alter the frequencies, distribution and magnitudes of natural hazards and disasters in mountains. Mountains are typically exposed to a variety of

natural hazards and their multiple impacts, and the incidences and magnitude of hazards and extreme events, such as, floods, windstorms, and droughts, cloud bursts, flash-floods will increase with increasing temperature and changes in precipitation pattern. The likely impacts of climate change has been shown in Table 3.

Table 3: Expected Climate Change Impacts in the Andean Mountains

Country	Expected Climate Change Impacts
Argentina	▪ Less snowfall in mountains (affecting hydroelectric production, and water availability for irrigation). ▪ Reduction in rainfall in mountains (trends recorded since last century) ▪ Warming of 1° C (greater demand for water in agriculture due to greater evapo-transpiration
Bolivia	▪ Greater concentration of rainfall with less days of rain and more intense flooding ▪ Greater frequency of frost ▪ Greater frequency of hail (destruction of crops) ▪ Longer periods without rain (greater need for irrigation, reduction in hydroelectric energy) ▪ Retreat of glaciers
Chile	▪ Decrease in rainfall from north to centre of country (reduced agricultural yields), and increases on altiplano and further south (increase in suitable climate for grasslands and yields) ▪ Decrease in frosts, milder spring temperatures (improve conditions for temperate fruit growing), but colder winter temperatures.
Colombia	▪ Transition from semi-humid to semi-arid climate in mountain regions
Ecuador	▪ Reduction in rainfall (affecting hydroelectric production), conversion to grasslands in some agriculture regions ▪ Reduction in glacier areas
Peru	▪ Increase in rainfall north, central mountains, decrease in rainfall further south ▪ Increase in temperature in all mountain regions ▪ Drastic reduction in areas of glaciers, or disappearance (affecting tourism)
Venezuela	▪ Increase in areas with less than four months of rain per year. ▪ Relocation of tourism to higher elevations

The global warming is to intensify the hydrological cycle in mountain watersheds changing the frequency, intensity and severity of floods and droughts in mountains as well as in their lowlands. The high intensity precipitation could trigger flash floods, slope failure and landslides in mountainous terrain having severe impacts on the natural and socio-economic sustainability of fragile mountain ecosystems especially in the tropics and at higher latitudes where an increase in overall precipitation is expected.

In high mountains, it is likely that food insecurity could increase more sharp with climate change, and the community health conditions, particularly the sensitive segment of society, such as the old people, infants and children, pregnant women, and the chronically sick may further deteriorate.

The declining rainfall and decreasing number of rainy days and the reduced availability of water and increasing incidences and severity of natural disasters may result in crop failure spread of crop and livestock pests and vector-borne diseases to higher elevations with rising temperatures.

This may further undermine the sustainability and wellbeing of mountain communities in poor regions. Moreover, the traditional livestock rearing and pastoral practices are becoming increasingly vulnerable due to population growth and the resultant land use intensifications at higher elevations, and also owing to the impacts of more frequent and severe droughts, and the breakdown of traditional trade routes and patterns of exchange (http://www.fao.org/documents/card/en/c/CA5561EN).

Climate change is particularly threatening sustainable development, especially poverty alleviation and livelihood improvement programmes, in the mountains as critical livelihood resources such as agricultural crops, storage of food and seeds, and agricultural land have come under increasing threats of climate change triggered natural risks particularly in developing countries.

The mountain communities are expected to face more stern impacts in future due to the likelihood of more and more frequent occurrences of extreme events, and their economic development prospects are coming under increased risks of natural calamities. The long-term impacts of **c**limate change may thus further widen the existing socio-economic inequalities between highland and lowland communities.

Mountain Urbanization: Trends and Impacts

Urbanization has emerged as one of the important drivers of global change transforming mountain regions, particularly in developing countries where the process of urban growth has been fast, but mostly unplanned and unregulated.

Urbanization has contributed significantly not only to economic growth through the improvement of infrastructure, development of tourism and the generation of employment opportunities in the mountains; but has also increased community sustainability by strengthening social services, particularly, education, health and communication in their vast rural hinterlands in high mountains .

At the same time, rapid and unplanned urbanization is intensifying land use within the cities as well as in their peri-urban zone and unlocking even remote areas of mountains for exploitation of their natural resources by the growing

global markets. These changes are increasing the vulnerability of anthropogenically modified slopes to a variety of natural risks, particularly under rapidly changing climatic conditions.

Himalaya representing tectonically alive, and densely populated mountain ecosystems has experienced rapid urbanization during recent decades mainly in response to population growth, improved road connectivity, development of tourism and economic globalization.

The fast expansion of road linkages has facilitated the rapid urbanization through emergence and growth of rural service centers and improved access to markets. Consequently, more recently, comparatively less accessible areas have also come under the process of speedy urbanization due to growth of domestic tourism, marketing and increasing popularity of new tourists destinations; and resultant gradual shift from primary resource development practices to secondary and tertiary sectors in the region. The pattern of Urban growth and the recent trends of urbanization have been shown in Figures 14 and 15.

This has resulted into tremendous increase in size, area, number and complexity of urban settlements in Himalaya resulting into the expansion as well as intensity of urban land use within the towns and their rural hinterlands (https://www.nationalgeographic.com › environment › habitats › urban-threats).

The sprawling urban growth in fragile mountains and resultant land use intensifications have disrupted hydrological system of urban areas, and consequently increased susceptibility of the Himalayan towns to recurrent slope failures, landslides and flash floods (Figure 16). Moreover, climate change has stressed urban ecosystems by increasing the frequency, severity and intensity of extreme weather events. The natural risks of this unplanned urban sprawl are now clearly discernible in most of the urban centres and their peri-urban zone, all across the densely populated Lesser Himalayan ranges in India. The urban development in the region is also having long-term impacts on the fragile ecosystem and environment of the urban fringe consisting of natural forests, wildlife habitats, critical headwaters, and prime agricultural land.

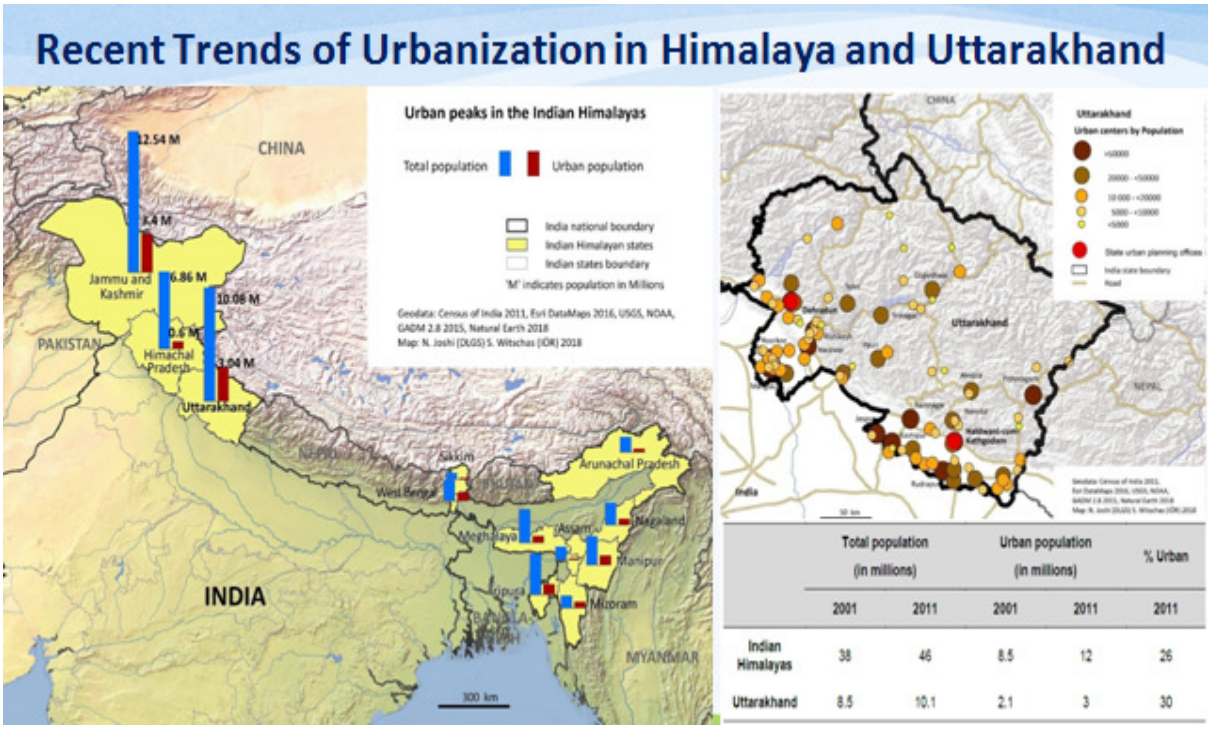

Figure 14: Pattern of Urban Growth in Himalayan Provinces of India

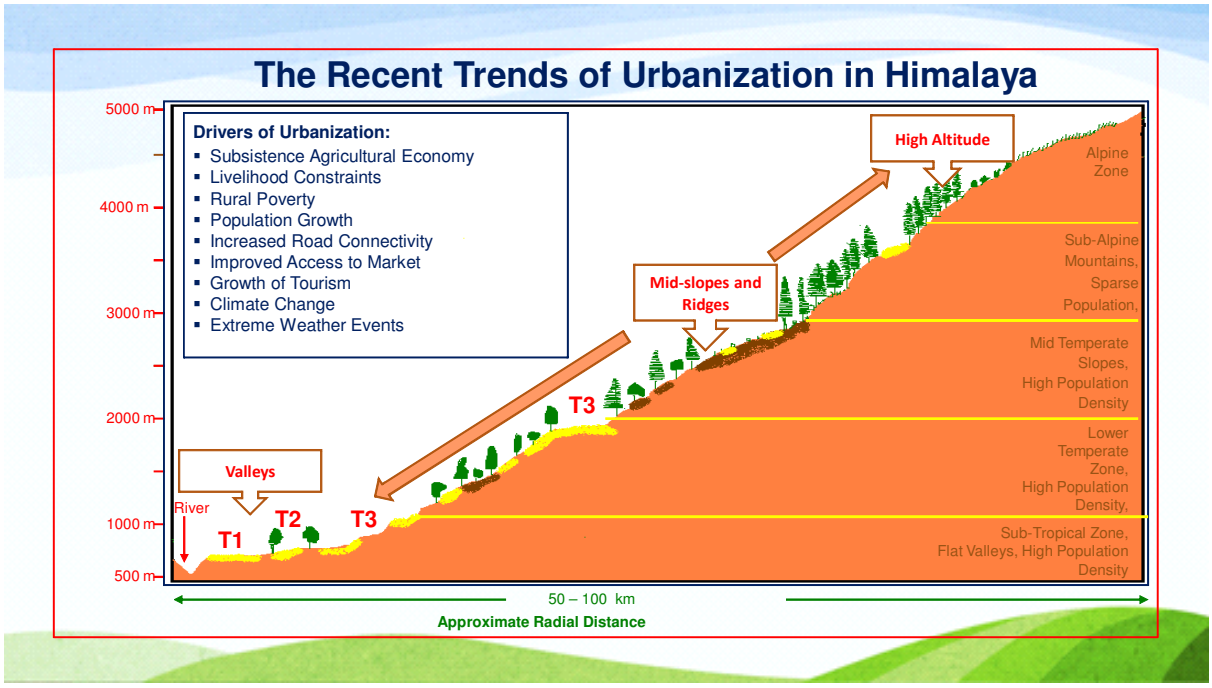

Figure 14: Recent Trends of Urbanization in Indian Himalayan Region

The natural components of the urban fringe zone are being degraded and depleted steadily and significantly through the expansion of urban land use, deforestation, habitat destruction, mining construction material, waste and sewage disposal, encroachment of productive agricultural land, and changes in the traditional land use and resource management practices under the multiplier

effect of urban growth. The paper analyzes the emerging threats of unplanned urban growth in the densely populated Lesser Himalayan ranges with a case illustration of Nainital Town located in Uttarakhand Himalaya (https://www.mdpi.com › pdf)

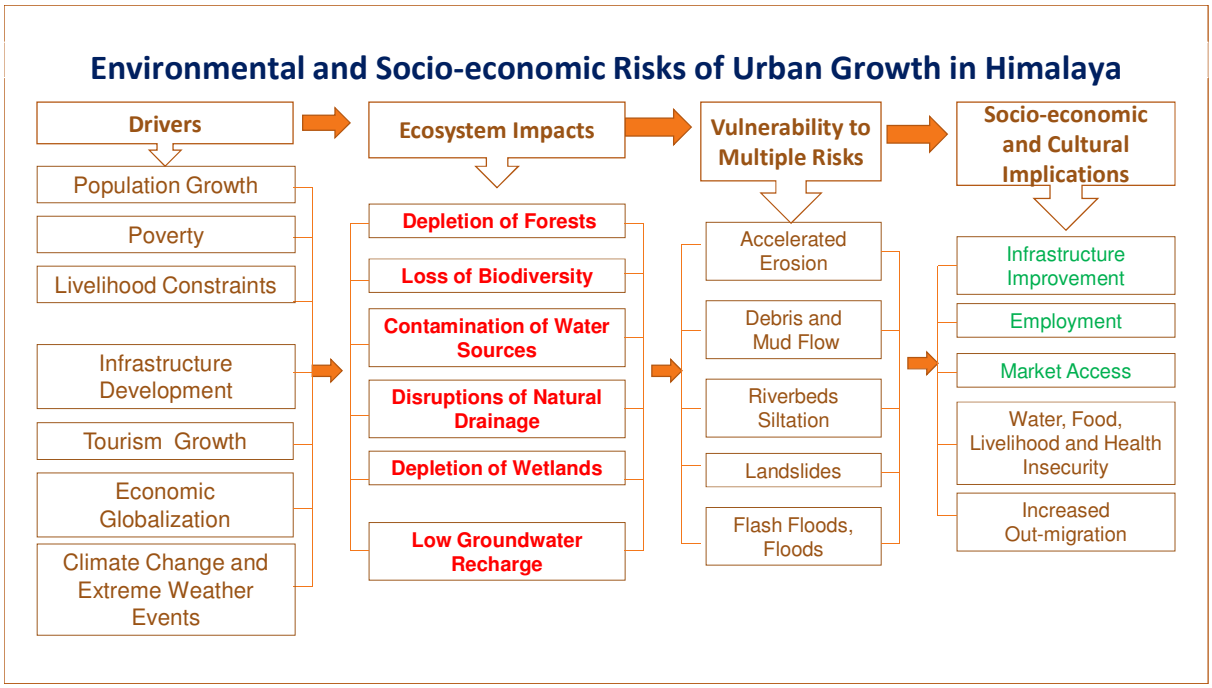

Figure 16: Socio-ecological Risks of Unplanned Urban Growth in Himalaya

Figure 17: Unplanned Urbanization in Himachal Pradesh Himalaya, India

Figure 17: Unplanned Urban Growth in Uttarakhand Himalaya, India

Figure 18: Urban Sprawl in Fragile Mountains in Northeast Himalaya, India

Figure 19: High Rise Building Modifying Fragile Slopes in Northeast Himalaya, India

Urban development has emerged one of the most important global change drivers influencing the mountain regions all across the world. However the high mountains in developing world have experienced rapid urban growth during the last three decade which is most unplanned and unregulated. The drivers of this fast urban development in the mountains of developing countries include, population growth, increasing trends of rural-urban migration, economic globalization, and growth of tourism and infrastructure in high mountains.

This unplanned urban growth has severe impacts on both ecological and social systems, within the urban footprint and beyond. Expanding urban areas are depleting and degrading natural resources. Nevertheless, urbanization also contributes significantly to not only economic growth through the improvement of infrastructure, the development of tourism and the generation of employment opportunities, but also increased community sustainability by strengthening social services, particularly, education, health, and communication infrastructure and services. At the same time, rapid urbanization alters land use far beyond the urban periphery and unlocks the world's mountains, particularly their remote and comparatively inaccessible areas for exploitation of their natural resources by growing global markets (https://www.ncbi.nlm.nih.gov › pmc › articles › PMC4113860).

Urbanization is responsible for depleting biodiversity, destruction of wildlife habituates, increasing surface runoff, decreasing groundwater recharge, and polluting water sources. It was also observed that the process of urbanization is adversely affecting ecosystem services, such as groundwater recharge. The increasing urbanization is also contributing towards warming through creating large urban heat islands.

These heat islands are affecting the cooler piedmont zones that have traditionally acted as a source of airflow which cleans the heavily polluted city atmosphere during the night. The continual expansion of cities, towns, tourist and skiing resorts are now threatening even the more remote and inaccessible mountains. Tourist complexes are significantly contributing to the rising level of urbanization in the sensitive mountains (http://www.fao.org/mountain-partnership/our work/focusareas/climatechange/en/).

Urban development has emerged one of the most important global change drivers influencing the mountain regions not only in the North American and Europe but also in developing countries in Asia, Africa and Latin America where mountain regions offer high value human habitat and where urban growth has been rapid and mostly unplanned.

Urbanization as a general term covers a variety of dynamics. Large cities proximate to the mountains expand into the mountains. Smaller towns grow through amenity migration by distant immigrants while others grow by offering new economic or human development options to proximate rural migrants. Some grow as gateways to mass tourism. Yet others grow with ongoing economic development and penetration of global economies. While in all cases, population densities increase and urban footprints expand, the nature of the population and the footprint vary as do the longer-term development trajectory.

Urbanization has impacts, both ecological and social, within the urban footprint and beyond. Expanding urban areas consume and pollute resources, and frequently put inhabitants in harm's way. But urbanization also contributes significantly to not only economic growth through the improvement of infrastructure, the development of tourism and the generation of employment opportunities, but also increased community sustainability by strengthening social services, particularly, education, health, communication etc.

At the same time, rapid urbanization alters land use far beyond the urban periphery and unlocks the world’s mountains, particularly their remote and comparatively inaccessible areas for exploitation of their natural resources by

growing global markets. As urbanization is to a large extent at least theoretically under policy control, it is conceivable that the mix of costs and benefits attributable to urbanization, and the distribution of those costs and benefits across the many social groups inhabiting these areas can be influenced by policy.

Our mountains across the planet are rapidly urbanizing. In the Andes the proportion of urban population has increased tremendously during the last few decades. Out of the total population of Andean countries 69% and 91% now living in urban areas compared to 55% to 87% in 1990. Bolivia and Ecuador have emerged as the most urbanized countries in the continents.

The environmental and socio-economic impacts of rapid urban growth in the Andes are have reached at an alarming level (*www.fao.org › fileadmin › docs › ANDES FINAL Andes_report_eng_final).* Chile has experienced a more rapid, persistent and comprehensive process of economic development in the last 20 years that resulted in fast urban growth in high mountains as well as in their pediment zones. As a result, 87% of Chile population lived in urban areas in 2002 which is having severe impacts on mountainous ecosystems (*https://bioone.org › issue-S1 › MRD-JOURNAL-D-11-00120.S1.full).*

Urbanization is responsible for increasing surface runoff, decreasing groundwater recharge, and polluted water sources. It was also observed that the process of urbanization is adversely affecting ecosystem services, such as groundwater recharge. The increasing urbanization is also contributing towards warming through creating large urban heat islands. These heat islands are affecting the cooler piedmont zones that have traditionally acted as a source of airflow which cleans the heavily polluted city atmosphere during the night.

The expansion of urbanized centres is threatening the very last natural relics in the European Alps. Many Alpine valleys have already lost most of their biodiversity value due to urban sprawl. In the Alps, the initial process of the evolution of settlement started in elevated areas of the most accessible alpine valleys which offered the best conditions for housing and agriculture. Later, with the growth and gradual spread of urban settlements in the side valleys, the catchments of the easily reachable Rhone, Rhine, Inn, and Adige rivers have already lost most of their biodiversity prosperity.

Natural habitats and ecosystems in the valley bottoms - riverbeds, floodplain forests, wetlands, and alpine steppes are now disappearing with expanding urbanization. The development of transport infrastructure associated with this

urban growth is a major barrier for many species in the Alps, preventing the establishment of ecological networks. Currently, the Alps is experiencing a new level of urbanization with the average living space occupied by a person has doubled since 1950.

The continual expansion of cities, towns, tourist and skiing resorts are now threatening even the more remote and inaccessible areas in the Alps. Tourist complexes are significantly contributing to the rising level of urbanization in the sensitive mountains. The urban expansion coupled with the growth of population has reduced the permeability of land surfaces and, hence, the time of concentration of floods, in the absence of mitigating solutions in the design of urban drainage systems. Similarly, the Rockies which are intensified by the increasing urbanization, growing demands for water, and altered precipitation and stream-flow patterns driven by climate change.

In Himalaya, with the growth of population and infrastructure, particularly increasing road connectivity, the region has experienced rapid urban growth during the recent past. The fast expansion of road linkages has facilitated the rapid urbanization, emergence and growth of rural service centers and increased access to markets.

The rapid growth of urban settlements in the high Himalayan Mountains, particularly in tectonically alive and ecologically fragile Lesser Himalayan ranges has been resulting in the depletion and destruction of nature as well as increased incidence and severity of natural risks, such as, slope failures, disruption of natural drainage and water pollution, degradation of forests etc. within the urban ecosystems as well as in their surrounding areas. More recently, comparatively less accessible areas of the region are also being affected by process of fast urbanization mainly owing to the extension of road network, development of horticulture, gradual shift from primary resource development practices to secondary and tertiary sectors, and the growth of domestic tourism through the publicity and marketing of new tourist sites.

Consequently, there has been tremendous increase in size, area, number and complexity of urban settlements in the region resulting in the expansion of urban land use (i.e., expansion of urban land use in surrounding agricultural zone, forests and rural environments) in urban fringe areas as well as intensity of land use (i.e., increase in the density of covered area, density of building, density of population; increase in the height of buildings, increase in the volume of traffic on roads and increase in the consumption of energy and water etc.) within the towns.

The natural risks of this unplanned urban growth are now clearly discernible in most of the urban centres and their surroundings, in the densely populated Lesser Himalayan ranges of Himalaya in India. It is expected that the urban growth cannot be stopped or reduced but can be steered in a more sustainable way by a proper integrated land use management.

The urban development in the mountain regions is also having long-term impacts on the fragile ecosystem and environment of the urban fringe areas consisting of natural forests, wildlife habitats and water sources including, lakes, streams and natural springs, and agricultural land.

The natural components of the urban fringe zone are being degraded and depleted steadily and significantly through the expansion of urban land use, deforestation, habitat destruction, mining of aggregate material for construction, waste and sewage disposal, and facilitating changes in the traditional land use and resource management practices by the multiplier effect of urban growth.

A large proportion of cultivated land and other areas are being encroached upon by the process of rapid urbanization and expansion of infrastructure, services and economic activities in Himalaya, every year. Study indicated that the most densely settled and rapidly growing urban centres of Uttarakhand Himalaya have been fast intruding upon productive agricultural land in their surrounding rural regions. This has caused huge transformation of cultivated land within urban centres as well as in their peri-urban zones leading to land use intensifications.

Global Change and Emerging Opportunities in Mountains

Changing climatic conditions, particularly changes in temperature and precipitation patterns and other processes of global changes have increased the vulnerability of mountain communities to various natural and socio-economic risks and posed serious environmental as well as developmental threats on the one hand, and created several opportunities and possibilities for the sustainable development of mountain regions and well being of their people on the other. The emerging opportunities include conservation of biodiversity and genetic resources, growing demand for high-value mountain niche products, such as, eco-tourism, hydro-energy generation, carbon trading, compensation for ecosystem services and production of high value fruits, flowers, vegetables and medicinal plants. The mountains provide very little scope for the development multiple livelihood options to mountain communities other than subsistence

agriculture, primarily due to constraints of terrain and climate and the resultant inaccessibility. However, tourism is now emerging as major livelihood option in mountain areas in both the developed and the developing world. Tourism is now a major source of employment and foreign exchange in the developing countries, and it may also check the increasing rate of rural outmigration of educated and entreprenuering population. At the same time, with rising temperatures mountain destinations in the subtropics and tropics attracting increasing numbers of visitors, particularly during summer months (Hoermann and Kollmair 2009).

Mountain systems consisting nearly 50% of global biodiversity hotspots sustain and support half of the world's biological diversity and genetic resources of which some are very rare. With rising temperatures upwards shifts of vegetation belts to higher elevations and northward advances in It is expected that the geographical ranges of species may shift upward with increase in global temperature in the northern hemisphere. These changes are likely to bring a variety of changes in the composition, structure and spatial distribution of biological resources creating a set of opportunities for their conservation and sustainable development in high mountain ecosystems across the planet. Thus mountain ecosystems would be able to provide necessary protection to a variety of species which may face extinction in lowlands (Körner 2009).

The drivers of global change have contributed significantly towards increasing awareness and improving understanding of ecosystem goods and services flowing down from mountains and called for sustainable development of mountain ecosystems and creating new livelihood opportunities for mountain communities through restoration of ecosystem services. The emerging opportunities for sustainable development in mountains include the growing demand demands for mountains as popular destinations for recreation. Furthermore, the globalization has provided mountain communities with a set of new economic opportunities in the production of high value mountain products, such as, fresh-water, fruits, nuts, off-season vegetables, flowers, honey, dairy products, and cosmetic, aromatic and medicinal plants. However, the value added by mountain dwellers will likely remain proportionally small unless local processing replaces the export of raw produce (Jodha 2002). These trends are likely to accelerate as market forces gain primacy. The rise in global demand for mountain herbs and other organic and non-timber forest products is leading to over-extraction. Climate change may also provide new opportunities in agricultural sector by increasing the length of growing seasons for certain crops

or the possibility of growing crops at higher altitudes, providing shelter for rare and endangered species of plants and animals, generation of hydro-power, and potential carbon sink. The value addition to raw produce through local processing would be necessary for ensuring the maximum benefit of these emerging opportunities should go to the mountain communities However, these changes may lead to the over-exploitation of mountain natural resources (Jodha 2002).

It is now well understood that the carbon sequestration and conservation potential of the forests is much higher than total carbon sequestration capacity of all other terrestrial ecosystems of the planet. The forests of the world account for 90% of the annual carbon flux between the atmosphere and the land surface of the earth (Gupta 2007). This has further improved our understanding of the importance of forests to the global environment, and has influenced forest management policy decisions around the world during the recent years. Over the past decades, forests have emerged as a major consideration in Global discussion on sustainable development. Since, the United Nation's Earth Submit held in Rio de Janeiro, Brazil in 1992, remarkable progress has been made in advancing the worldwide consensus on the protection, conservation and sustainable development of forest resources (Tiwari & Joshi 2001). At the same time, the globalizing economy has increased the demand of forests in various economic sectors, and thus unlocked the valuable and rich forest resources of remote and inaccessible regions, such as high mountains, for their exploitation, degradation and depletion. However, the Clean Development Mechanism (CDM) of The Kyoto Protocol gives more emphasis on afforestation and reforestation programmes, and conservation and management of existing forests are not included under the Clean Development Mechanism (CDM) (Geoffrey 2005). Since, a significant proportion of population is currently involved in the conservation and management of their forests, particularly in the developing countries, the incorporation of forest management in the Kyoto Protocol or alternatively voluntary carbon market would benefit a large number of communities in developing countries (Climate Community & Biodiversity Alliance 2005).

Economic globalisation, participatory resource management systems, decentralized governance mechanism, public-private partnership based infrastructure development, growing urbanization, development of information technology and communication system have sensitized mountain communities for capturing the potential of these drivers of transformation. Fast emerging

economies, particularly in South and East Asia and Latin America have also increased flow of resources and there by accelerated the pace of economic growth in mountains. As result, mountain communities which suffered from marginalization and underdevelopment have been able to attract the attention of national as well as international agencies for their sustainable development. Despite prevailing uncertainty on comprehensive climate change impact scenario it is clear that mountains ecosystems will be essential building blocks for long term sustainable global development. Now it is the responsibility of mountain-countries and those countries with sizeable areas under mountain eco-system to build and improve their respective individual capabilities to take up the challenge to collaborate in order to benefit from these opportunities of global change.

Mountains in International Sustainable Development Agenda

Mountains have long been marginalized from the view point of sustainable development of their resources and inhabitants. However, our understanding about the problems of mountain regions and approach to their development has undergone drastic changes, during the recent years (ICIMOD 2010). The first UN conference on the 'Human Environment' held in Stockholm in June 1972 figured the subsequent international mountain conferences. This was followed by the pioneering publication of famous report 'The Limits to Growth' by Club of Rome's (Meadows et al., 1972) which initiated research in globalization through bringing into focus the projections of high populations increase and growth of economy and technology in the world. Over the next years a large number of international conferences took place in different mountain regions of the world which was followed by the establishment of the International Centre for Integrated Mountain Development (ICIMOD) involving all eight countries of the Hindu Kush-Himalaya (HKH) in Kathmandu, Nepal in 1983, the African Mountain Association in Ethiopia in 1986, and Andean Mountain Association in 1991 in Chile. This facilitated developing countries to support the proposal of a mountain chapter in the Agenda 21 at the third preparatory conference for Rio in 1991, and consequently, increased awareness and improved understanding of the effects of climate change and globalization on world' mountains (Borsdorf et al. 2010).

The significance of mountain social-ecological systems was acknowledged for the first time on a global scale in Agenda 21 of the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro, Brazil, in 1992. The Chapter 13 titled 'Managing Fragile Ecosystems: Sustainable

Mountain Development' of Agenda 21 recommends two priority programmes for the sustainable development of the world mountains. These include: (i) generating and strengthening knowledge about the ecology and sustainable development of mountain ecosystems; and (ii) promoting integrated watershed development and livelihood opportunities in mountains. The Food and Agriculture Organization (FAO) of the United Nations was assigned with the responsibility of facilitating and reporting if the implementation of these two programmes.

This resulted in several specific initiatives by different governments of mountainous countries, international organizations, NGOs and scientific agencies across the world during the decade following the UN Conference on Environment and Development. Establishment of Mountain Forum in 1995 was one the important initiatives taken for a global network for information exchange, mutual support, and advocacy towards equitable and ecologically sustainable mountain development and conservation of mountains ecosystem across the world. This was followed by designating 2002 as the International Year of Mountains (IYM) by United Nations General Assembly which was followed by Global Mountain Summit in Bishkek, Kyrgyz Republic in the same year. The International Year of Mountains provided with the great opportunity for raising awareness about the importance of mountains for sustainability of global environment. This resulted in the manifestation of several new initiatives, including the Adelboden Group which lead to the creation of Sustainable Agriculture and Rural Development in Mountains (SARD-M), Global Change in Mountain Regions (GLOCHAMORE) and the Mountain Research Initiative (MRI). Further, Mountain Partnership was launched at the World Summit on Sustainable Development held in Johannesburg in 2002 to promote, strengthen and facilitate closer collaboration between governments, civil society organizations, inter-government agencies, and the private sector toward achieving sustainable mountain development. All these initiatives and actions have been quite successful in raising awareness of the importance of mountains, and some of them also initiated successful interventions for sustainable mountain development.

On the other hand, in spite of all these successful initiatives and actions and the UN General Assembly continued emphasis on the sustainable mountain development, the mountain regions of the world have never received the desired consideration in the global development agenda. One of the important reasons for mountains not receiving adequate attention was the international

developmental agenda is always dominated by the sustainable development agenda, such as the Millennium Development Goals (MDGs) and the Poverty Reduction Strategy Papers (PRSP), which were largely implemented as national programmes ignoring the ecology and specific developmental requirements of mountain areas. Furthermore, the outline of United Nations Framework Convention on Climate Change (UNFCCC) still lacks a mountain perspective, largely because of substantial knowledge gaps and an uncoordinated approach by the countries that are most affected by climate change in their mountains. In view of this, several critical issues related with sustainable mountain development, particularly, management of water resources; conservation of biological and cultural diversity; infrastructure development, access to health services and markets; proper recognition and valuation of mountain ecosystem services and the aesthetic, recreational and spiritual significance of mountains need to be fully addressed (Sonesson and Messerli 2002).

The Second UN Conference on Environment and Development (Rio+20) did not adequately and satisfactorily addressed the critical issues related to sustainable mountain development. However, mountains have been as one of the important thematic areas under the framework for action and follow-up under Para 210, 211 and 212 which are appended as follows (United Nations 2012):

210. We recognize that the benefits derived from mountain regions are essential for sustainable development. Mountain ecosystems play a crucial role in providing water resources to a large portion of the world's population; fragile mountain ecosystems are particularly vulnerable to the adverse impacts of climate change, deforestation and forest degradation, land use change, land degradation and natural disasters; and mountain glaciers around the world are retreating and getting thinner, with increasing impacts on the environment and human well-being.

211. We further recognize that mountains are often home to communities, including indigenous peoples and local communities, who have developed sustainable uses of mountain resources. These communities are, however, often marginalized, and we therefore stress that continued effort will be required to address poverty, food security and nutrition, social exclusion and environmental degradation in these areas. We invite States to strengthen cooperative action with effective involvement and sharing of experience of all relevant stakeholders, by strengthening existing arrangements, agreements and centres of

excellence for sustainable mountain development, as well as exploring new arrangements and agreements, as appropriate.

We call for greater efforts towards the conservation of mountain ecosystems, including their biodiversity. We encourage States to adopt a long-term vision and holistic approaches, including through incorporating mountain-specific policies into national sustainable development strategies, which could include, inter alia, poverty reduction plans and programmes for mountain areas, particularly in developing countries. In this regard, we call for international support for sustainable mountain development in developing countries.

It is therefore highly imperative to place sustainable mountain development in developing countries and the increasing socio-economic vulnerability of their population at the centre of climate change mitigation and adaptation strategy. Further, in view of increasing demands for fresh-water and hydro-power and other mountains ecosystem services, it would also necessary to realize the need of integrated framework for addressing upstream-downstream interlink-ages, as well as comprehensive trans-boundary river-basin management approaches. The emerging need of adaptation to climate change, particularly in developing countries, calls for further redefining the global sustainable development agenda focusing on eco-region based integrated development. With the rapid retreat of mountains glaciers across the planet and its potential serious long-term impacts on the fresh-water ecosystem and availability of water resources in large part of the world, the mountains regions have suddenly gained global attention, which need to be seized into concrete actions and effective programmes for sustainable development of mountain regions and improvement of the livelihood of their inhabitants, particularly in developing countries.

Sustainable Development of Mountain Regions

The word sustainable defines the use of a resource without depleting or permanently damaging it. In the report of the World Commission on Environment and Sustainable Development titled, "Our Common Future" *(https://sustainabledevelopment.un.org)* sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The recommendations of Rio 1992 (https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf) and Rio+20 'Future We Want' (https://sustainabledevelopment.un.org/content/documents/733FutureWeWant.p

df) recognizes, both the benefits, derived from mountain regions, as essential for sustainable development and the crucial role played by Mountain ecosystems in providing a variety of ecosystem services such as water, energy, biological diversity and key resources. Mountain environments represent major ecosystems which are essential to the survival of the global ecosystem *(https://sustainabledevelopment.un.org).* The 'Future We Want' warns about the vulnerability of fragile mountain ecosystems to the adverse impacts of climate change, deforestation and forest degradation, land use change, land degradation and natural disasters, the marginalization of its communities *(https://sustainabledevelopment.un.org).*

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The significance of mountain social-ecological systems was acknowledged for the first time on a global scale in Agenda 21 of the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro, Brazil, in 1992. The Chapter 13 of Agenda 21 titled 'Managing Fragile Ecosystems: Sustainable Mountain Development' of Agenda 21 recommends two priority programmes for the sustainable development of the world mountains. These include: (i) generating and strengthening knowledge about the ecology and sustainable development of mountain ecosystems; and (ii) promoting integrated watershed development and livelihood opportunities in mountains. The Food and Agriculture Organization (FAO) of the United Nations was assigned with

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largely because of substantial knowledge gaps and an uncoordinated approach by the countries that are most affected by climate change in their mountains. In view of this, several critical issues related with sustainable mountain development, particularly, management of water resources; conservation of biological and cultural diversity; infrastructure development, access to health services and markets; proper recognition and valuation of mountain ecosystem services and the aesthetic, recreational and spiritual significance of mountains need to be properly realized and fully addressed.

It is therefore highly imperative to place sustainable mountain development in developing countries and the increasing socio-economic vulnerability of their population at the centre of climate change mitigation and adaptation strategy. Further, in view of increasing demands for fresh-water and hydro-power and other mountains ecosystem services, it would also necessary to realize the need of integrated framework for addressing upstream-downstream interlink-ages, as well as comprehensive trans-boundary river-basin management approaches. The emerging need of adaptation to climate change, particularly in developing countries, calls for further redefining the global sustainable development agenda focusing on eco-region based integrated development. With the rapid retreat of mountains glaciers across the planet and its potential serious long-term impacts on the fresh-water ecosystem and availability of water resources in large part of the world, the mountains regions have suddenly gained global attention, which need to be seized into concrete actions and effective programmes for sustainable development of mountain regions and improvement of the livelihood of their inhabitants, particularly in developing countries.

Mountains of the planet despite their marginality and remoteness are changing rapidly under increasing pressure from globalization and climate change. These changes have unlocked the natural resources of mountains for exploitation without serious concern for sustainable development of mountain and well being of their inhabitants. Consequently, mountain ecosystems as well as mountain communities, specifically in developing and underdeveloped countries are particularly threatened by a series of drivers and processes of global change and emerging new international economic and political orders. However, we are experiencing an emergence of responsiveness of the ecological significance of mountain systems and their importance for the sustainability of global community, particularly after the United Nations Conference on Sustainable Development – the Rios Earth Summit in 1992. As a result, our understanding about the dilemmas of mountain regions and approach to their

development has undergone drastic changes, during the last two decades**.** The climate change has emerged as one of the major drivers transforming consistently the natural environment, society and economy of the mountains regions in all parts of the world, and mountains ecosystem being highly sensitive are extremely vulnerable to these changes. However, there is still a high degree of uncertainty about the trends and magnitude of climate change and its impacts on mountain systems. It is therefore highly imperative to improve our understanding of the trends of changes in temperature and variability in precipitation pattern at local level through downscaling of regional climate models. This would require establishment of a comprehensive networks of hydro-meteorological monitoring stations in mountain areas across the world, particularly in the mountains of developing countries where currently, such monitoring is extremely lacking. Furthermore, a sharp focussed and comprehensive research on climate change impacts assessment, vulnerability and adaptation to climate change would be necessary at micro-regional scale.

An effective mechanism for the sharing of information, data, experience and knowledge generated from local, regional to international levels and international level transfer of knowledge would be crucial for better understanding of changing climatic conditions and evolving appropriate strategies for mitigation of climate change and responding to its impacts in an amicable manner. Since mountains constitute headwaters of some of the largest trans-boundary basins on the earth, it would also be indispensable to establish and strengthen international research collaboration, and develop international mechanisms on knowledge and data sharing. A regional geo-political cooperation framework among riparian countries is therefore highly crucial not only for evolving framework of adaptation to climate change and improved governance of headwaters resources, but also for security and peace in the entire world. The international conventions, initiatives and organization can play an effective role in initiating trans-boundary climate adaptation diplomacy in different mountain regions.

All mountain regions across the world are currently facing the common threats from climate change and economic globalization in the backdrop of the similar constraints of terrain, fragility; geographical isolation and socio-political marginalisation. In many developing countries, policy decisions and planning processes have plains perspective largely ignoring the disproportionate vulnerability of social-ecological systems of mountains. Hence, effective mountain-specific policies need to be designed not only at the national level but

also at global scale, as these challenges are independent of national territories. In order to address the challenges posed by climate change, the mountain countries and regions should develop mountain specific adaptation and mitigation policies, programmes, institutions and think tank which would be necessary to enhance their resilience and ensure socio-economic and ecological sustainability in mountain areas.

Mountain communities through their traditional resource management practices contributed significantly towards preservation of forest and biodiversity, climate change mitigation through carbon sequestration, water conservation and preservation of cultural heritage and natural landscapes that provide a variety of ecosystem services and goods to considerably large population in downstream. In turn, the global community should contribute towards the conservation of natural ecosystem and improvement of the quality of life of mountain people by providing adequate incentives for these high value services flowing down from mountains. Moreover, mountain areas, especially those situated in subtropical and tropical zones have contributed the least to global greenhouse gas emissions. The mountain inhabitants therefore need to be supported in their sincere efforts to adapt to the challenges and facilitated to be benefited from emerging opportunities of global change. Payment for environmental services (PES) can pave the way for rewarding mountain communities for the critical services they provide. Payment for environmental services would help in preventing further depletion of mountain natural resources and restoration of ecosystem services which in turn will make them more resilient to long-term impacts of climate change.

Reducing Emissions from Deforestation and Degradation (REDD) and Enhancement of Carbon Stocks (REDD+) are other important opportunities under the United Nations Framework Convention on Climate Change (UNFCCC) which offer incentives for developing countries to reduce emissions from forested lands and invest in low carbon activities for their sustainable development *(https://www.un-redd.org).* Mountains accounting for nearly 28% of the world's forests bear a huge potential for carbon storage and sequestration and are therefore in a privileged position to attract such funds for climate change mitigation bear a huge potential for carbon storage and sequestration and are therefore in a privileged position to attract such funds for climate change mitigation. Hence, the mountain forest-ecosystems are one of the most vital mainstays of Green Economy and in attaining the goals of both REDD and REDD+. The forests conservation in mountains therefore needs to be linked

with climate change mitigation and adaptation, poverty alleviation and food and livelihood security of local people. In view of this, the recent experiences of Forest *Pnchayats* and lessons learned from Joint Forest Management (JFM) in Indian Himalaya (*www.forest.uk.gov.in › pages › display › 174-van-panchayat)* and Community Forestry (CF) in Nepal can best be replicated and used for institutionalizing forests and for their community oriented conservation and development (https://iges.or.jp › publication_documents › pub › policyreport › 01Nepal) This would provide mountain people with the opportunity of getting involved in global carbon credit process and enhancing their quality of lives through reduction of poverty, improvement of livelihood and restoration of ecosystem services. In addition, several ecological benefits, such as conservation of biodiversity, increased forest productivity, erosion control, slope stabilization and hydrological restoration, could be obtained by integrating participatory forest management with existing carbon markets.

A considerably large proportion of population in mountain regions of developing countries depends for its livelihood on severely limited arable land symbolizing distress husbandry of land. Paradoxically, on the other hand, nearly large forest area put together with water-bodies, high altitude pastures etc. characterized with charismatic landscapes, natural splendor, variety of flora and fauna, enthralling wilderness and rich biodiversity have so far been utilized to provide livelihood to small percentage of rural population. The situation therefore calls for looking beyond the traditional agricultural system and generation of rural employment opportunities in off-farm and non-traditional sectors in the mountains area of less developed countries. This brings out the fact very clearly that restoration of ecosystem services through sustainable utilization and conservation of critical natural resources, such as, land, water, forests, and biodiversity, and generating economically viable options of rural livelihood other than agriculture, and ensuring food security would constitute the critical components of the process of climate change adaptation in mountain areas of less developed countries. The strategy should have wider scope for the generation of off-farm livelihood employment opportunities particularly through the promotion of local rural enterprise in different sectors of tourism. Hence, tourism presents great potential for the inclusive development of the region

However, the agriculture will remain as one of the important economic activities in the mountains of developing countries, and thus will constitute one of the core components of overall climate change adaptation strategy in the

mountains in times to come. This is primarily because, the agriculture is not merely an important economic activity and fundamental source of livelihood of local rural communities, but also constitutes an integral part of their culture, history and traditions, and an invaluable treasure of traditional ecological knowledge required for adapting to climate change. Secondly, mountains have some of the highly productive and agriculturally prosperous valleys and mid-slopes which have still potential of contributing towards the food as well as livelihood security. Thirdly, the potential of varying agro-climatic zones from valleys to higher elevation can be utilized for growing variety of crops and producing seasonal as well off-season agricultural products. Fourthly, for making tourism ecologically conducive, economically viable and pro-poor livelihood and adaptation strategy it need to be linked with local agricultural and food systems. Lastly, integration of tourism with local production system will create local viable market for the agricultural products and thus make local agriculture economically viable. In view of this, 'Ecological Tourism' which is now popularly known as 'Ecotourism' has immense potential to be developed as potential adaptation strategy to climate change in mountain areas of less developed countries. Ecotourism capitalizing upon both the socio-cultural and biophysical strength of the mountain landscape would contribute significantly towards securing viable alternative livelihood opportunities, particularly for the poor and marginalized mountain communities in the mountains.

Regional initiatives, including the Mountain Research Imitative (MRI), Mountain Forum (MF), Alpine Convention (AC) and the recent global Mountain Initiative (MI) floated by the Government Nepal need to be strengthened. The Mountain Partnership sponsored by FAO play significant role in inter-connecting these various regional and global initiatives. Regional information networks need to be established which would act as effective learning and awareness generation forums between specialists, civil society organizations, and government agencies and to support capacity building activities through focussed education, training and research. Further, in order to build resilient mountain social-ecological systems, the support and cooperation of civil society, including Non-Government Organisations (NGOs), Civil Society Organisations (CSOs), the private sector, educational and research institutions would be inevitable. These institutions play effective role in sensitising policy planners, decision makers and society at large about the importance and significance of mountain eco-systems in sustaining global society as well as about their fragility, marginality, vulnerability and the emerging opportunities.

Therefore, it underlines the urgent need to reinforce cooperative action with effective involvement and sharing of experience of all relevant stakeholders and to adopt a long-term vision and holistic approaches, including through incorporating mountain-specific policies into national sustainable development strategies, which could include, inter alia, poverty reduction plans and programmes for mountain areas, particularly in developing countries. The principal components of sustainable mountain development should include: (i) Conservation and sustainable utilization of mountain natural resources at watershed level: (ii) reducing poverty through improving livelihood of mountain communities; (iii) evolving and implementing effective community based-participatory climate change adaptation and disaster risk reduction programmes; (iv) reducing gender gap in natural resource management; and (v) development of infrastructure and services in the mountain regions.

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