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On Himalayan Water Towers for Sustainable Development

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ABSTRACT

Introducing the superlatives of the unique Himalayas, the paper deals briefly the high altitude snow and glaciers as water towers, for freshwater resources with some meltwater estimations. It is also compared with the Arctic and the Antarctic Polar regions. Vulnerability to natural hazards due to immature geology and climatic extremes are briefly discussed making the region as a high risk zone for living which needs a careful and continuous monitoring. Sustainable development is defined and emphasis is laid on satellite monitoring of the snowing region for making the realistic estimates of fresh water resources and its variations in space and time for the whole region.

Introduction

One can talk of the Himalayas only in superlatives: the highest peaks; the steepest escarpments; the most precipitious ravines; great crests crowned with perpetual snows towering above the most deeeply scooped and verdant valleys, with shining lakes and rushing streams; swift, cascading, falling, foaming rivers that cut the deepest gorges; the most numerous mountain glaciers which feed large river and lake systems; the highest living species of plant and animal life found anywhere in the world, and most highly diversified and sharply contrasted ecological regions that cover practically a global range of climatic belts - from Tropical to Tundra in a brief vertical span of six to eight kilometers. These characteristic features make them unique living mountain systems (Bahadur, 2003).

Uniqueness of Himalayan ecosystems is related to the intense coupling of the snow-land-ocean-atmosphere system. Himalayas are the house of eternal snow and ice. The ever changing texture of the snow alters the radiation balance affecting ecosystems. Probably, the greatest importance of snow and ice is biological, just as snow provides insulation which permit plant and animals to survive the severity of winter, similarly the ice over a lake or a river prevents the loss of too great a quantity of heat, protecting the aquatic flora and fauna from cold injuries. The snow and glacier fields provide melt water for the sustenance of life. Both the snow and ice fields also are the reservoirs of micro-organisms which further nurture the agro-ecosystems of the mountain region and associated Indo-Gangetic plains.

The apex mountain is the youngest, tallest, most sensitive and extensive system on the Earth. The uplift of the Himalayas is largely responsible for the birth of Indian monsoon - the most spectacular and fascinating atmospheric phenomena as known to the world. The rugged mountain topography affects air circulation on all scales of time and space (from micro to planetary waves). The seasonal variation of thermal and dynamical effects, over the massif, forms the modulating mechanism for seasonal adjustment of the planetary long waves of the Northern Hemispheric Air Circulations (NHAC). Due to lower mass of air at high altitudes, the changes of heat and moisture get magnified in the rarefied environment, when compared to those existing at the sea level, thereby increasing the sensitivity of the high mountain atmosphere. In general, precipitation increases with altitude and it is maximum near the equilibrium line (the line on a glacier where a year's snow ablation balances a year's accumulation) on the glacier systems.

Immature geological conditions over the Himalayan region are responsible for its active

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geodynamic behaviour, resulting in frequent earthquakes. The mountain is still rising at differential rates at several locations. Due to enormous uplift, a substantial area of the mountain lies above the seasonal snow line, where the precipitation occurs throughout the year as snow, giving rise to vast snow and glacier fields which rival those in Polar Regions. Fluctuations of these huge snow and glacier fields, intense freeze-thaw cycle, slope instability and seismicity, create problems of frequent occurrence of natural disasters, such as, earthquakes, snow and ice avalanches, mud flows, landslides, flash floods, glacier-lake-outburst floods (GLOFs), adding a new dimension to geodynamical behaviour of the earth surface.

Biogeographically, the Himalaya is a complex region. A sharp and distinct contrast characterizes the eastern region with warm and humid conditions and the western region with cold and arid environment. The land is not so feretile and is prone to erosion. There are limited irrigation facilities and most of the region is under dry-land farming. Traditional farming is largely practised with crops maturing at different times of the year. Agriculture and animal husbandry are not practised in isolation but in combination as agri-silvi-cultural, agri-pastoral and agri-silvi-pastoral systems. The cultivars are individually poor in productivity but collectively, the crop mixes are reasonably productive.

About 20 per cent of the Himalayan region in the country is degraded. Urgent steps are needed to correct the situation based on scientific data so that the natural resources are conserved and their productivity is restored in mountains and the associated plains are saved from further desertifiation.

The rich biodiversity in plant and animal variety needs inventorisation and conservation. The sustainable development awaits a well coordinated and integrated multidisciplinary approach. This becomes even more important due to an increasing demand on Himalayan natural resources by ever increasing population. The over-exploitation of natural resources, increasing threats from pollution and introduction of exotic spices are further affecting the native rich biodiversity of the region.

To achieve a balance between food sufficiency and ecological stability, it is important to copy the nature by integrating different biota e.g. trees, shrubs, bushes, high value crops and/or animal husbandry. Unfortunately agriculture, forestry, and animal husbandry have grown independently due to separate departmental development programmes and there is little appreciation of the fact that these from land-use activities and need integration. The traditional systems have been evolved by trial and error by the farming community to satisfy their needs. These systems need to be preserved and improved by addition of scientific inputs for tree-crop-animal husbandry in the poly-cultural system and for sustainable development of the mountain agriculture.

High altitude Himalayan snows and glaciers as water towers

A sufficient area of the high mountain system lie higher than the snow line (isotherm O°C) and in this area, snow falls round thye year. It is estimated that 10 to 20% of the local surface area is covered by glaciers and an additional area from 30 to 40% is overlain by seasonal snow cover.

Snow cover has unique physical properties e.g. high effectively and low transmissivity, low vapour pressure and conductivity. Snow cover changes its properties continuously and has a variable density rnaging from less than 0.1g/cc to greater than 0.80g/cc. Variable snow cover on the ground creates horizontal temperature gbradient, resulting in cyclogenesis in mountains, modifying weather. The snow continues to be the most sensitive element of weather system, particularly at the dizzy heights of Himalayas. The seasonal snow cover vary from year to year.

Himalayan glaciers including Tibet occupy an area of about 95,000 Km^2 (Jigun, L; Shuying, X 1984). These investigators have given the area occupied in different mountain ranges including the percentage of areas occupied by glaciers. It ranges from 2 to 31%. The high percentage of 31% is for Himalayas (glacier area 29,685 Km^2). The glaciers on different mountain ranges exist in the altitude range from a little lower than 4000m to more than 6200 m. A consolidated study of fluctuations of Himalayan and Trans-Himalayan glaciers was represented since AD 1812 (Mayewski and Jeschke, 1979). In a grass regional sense, these glaciers have been in a state of retreat since AD 1850. Filtering of the fluctuation records with respect to glacier type (longitudinal versus transverse) and regional setting reveals that thje period AD 1870 to 1940 was characterized by alterations in the dominancey of retreat, advance and standstill regimes. On an average, the Himalayan glaciers and retreating at rates from about 4 m to more than 40m/yr for last several decades. The glacier fluctuation could be accidental, seasonal, short and long term depending on their rates of movement with time.

In absence of records of snow cover, its depth and water equivalent, it is difficult to assess the snow melt runoff. Thje maximum snow cover could vary from over 10^6 km^2. Assuming an average arial precipitation of 500 mm/yr over the whole region, an average snow melt runoff could 500 km^3/yr. Assuming 50,000 km^2 glaciers drain to Indian river system and observed water yield of 3 to 6 m/yr, the glacier melt contributions to an average to 150 to 300 km^3/yr. Thus, the total snow melt and glacier melt contribution could range from 650 km^3/yr to 800 km^3 averaging to about 725 km^3/yr. If we assume that 30% of this water is lost by evaporation, we are left with 507.5 km^3/yr. This is comparable to the specific run off of 515 km^3/yr from upper Himalayan river catchments as evaluated by Alford, 1992 and the specific runoff estimated by GSI (Ravi Shankar, 2001).

Enormous snow and glacier fields have a great cooling effect on the surroundings and affect weather and climate on all tempral and spatial scales. The fluctuations of snow over is related to monsoon activity while glacier fluctuations affect climate on decadal and higher time scales.

The Leader of the 1963 Amercan Scientific Expedition to Everest Dr. Norman Dyhrenfurth called Himalayas as a Third Polar Region (Killer, 1964). At attempt was made to compare three major cold environments viz. the Arctic, the Antarctic and the Himalayas (Bahadur, 1993). A quick comparison of three great cold region affecting the climate on earth and its environment.

Comparison of Himalayas with polar regions*

Features	The Himalayas	The Arctic	The Antarctic
Glacier Area (10^2Km^2)	~95	134	50
Ice Volume (10^3 Km^3)	~1000	30	10
Average Elevation (m)	~6000	100	~2400
Highest Elevation (m)	8848	3700	5140
Velocity of Ice flow (m/yr)	>>10	>1 to <1000	>1 to <1000
Average winter temp (°C)	-36 to -1 (West to East)	-40	-60
Average summer temp (°C)	41 to 23 (West to East)	5	-20
Lowest temp. recorder (°C)	-47	<-50	-89.2
Average precipitation (mm)	~500	25	189
Meltwater Contribution (Km^3/yr)	>1000	~1400	~2300

*Bahadur (1993)

Vulnerability to natural hazards

Vulnerability to natural hazards are associated with inherent Himalayan fragility due to its immature geology and extreme weather and climatic conditions resulting in intense freeze-thaw cycle and cloud bursts. Most important natural hazards in the region are associatd with high seismicity, climatic extremes, large snow/ice avalanches, debris flow, mudflows and debris slides, outburst from moraine dammed lakes and glacier-lake-outburst floods (GLOFs) which occur with varying intensity and frequency throughout the mountain region making it a high risk zone for living and needs a careful monitoring for description of these hazards, reference may be made to enormous published literature (Bahadur, 2003).

Some remarks on sustainable development

The critical objectives of sustainable development (SD) are reviving growth; changing the quaity of growth; meeting essential needs of job, food, energy, water and sanitation; ensuring sustainability level of population; conserving and enhancing the resource base; reorienting technology and managing risk, merging environment and economics in decision making; reorienting international economic relations and making development more participatory. SD has to base on maintaining the fragile balance between productivity function and conservation practices through constant monitoring and identification of problem area which require application of alternate agricultural practices, crop rotation, use of biofertilizers, integrated pest management (IPM), energy efficient farming methods and reclamation of underutilized degraded lands. It calls for the upgradation of various renewable and non-renewable resources, characterization of coherent genes of agricultural identities and identification of constraints ecological problems at micro level instead of present practice of beneficiary oriented, arbitrary, sectorial approach. satellite based remote sensing inputs ae the key to initiate integrated sustainable development of the Himalayan region.

Monitoring of apex Himalayan snow and ice fields

The study of snow and ice is truly an interdisciplinary science know as "Glaciology". Globally, the basic research in the field has already been closely integrated with engineering research and technology developments in the cold regions. For soils, the work involves geophysical exploration, geotechnical site investigation, mechanical properties of frozen soils, frost heave, groundwater movement and water supply, excavation and drilling, weapon effect, road and air field pavements and foundation of structures. For snow, the work covers snow drifts, snow removal from roads and runways, visibility problems, road loads, hydrology, vehicle mobility, avalanches and construction on permanent snow fields. For ice, work involves measurement of ice forces on hydraulic structure in rivers and lakes, construction on and inside glaciers. To utilize the hydroelectric potential of the region, it is necessary to study the Himalayan snow and ice covers in greater details and map the areas with permanent and seasonal snow cover for assessing the volume of water in different parts of the year. This needs a high level scientific, technical and financial support to ignite the intellectual curiosity of Indian researchers for constant monitoring of the apex natural snow and glacier fields fore solving attendant problems.

Due to immature geology, high altitudes large/ steep slopes and rugged terrain, it is difficult to monitor the huge Himalayan snow and ice fields by conventional grounde surveys and integrate the information for decision making. It may be noted that the earlier snow surveys about 50 years back failed due to high variability of snowfall both in space and time. We have to resort to remote sensing technology to monitor the physical characteristics and temporal and spatial variations of these apex renewable resource areas in order to manage the fresh water resources in different mountain catchments. Space imageries are available at different resolutions for developing an operational Himalayan snow cover information system (HIMSIS) as outlined by the Department of Space three decades ago and such a system is already in operation for the Alps in Europe. Researches are needed to overcome the bottlenecks for routine application by Remote Sensing Application Centres in cooperation with various user agencies and research groups. Utilization of Geographical Information System (GIS), Global Positional System (GPS) along with digital image processing and utilization of simulation models do provide newer possibilities for better environmental monitoring, forecasting and management of wider areas within a limited time for hazard forecasting, well waterr assessment for water supply, hydropower and irrigation and other optimal use of valuable freshwater resources. We have to strive hard to seek answers to the following questions:

- What is the total reserve of fresh water locked in permanewnt snow and ice?
- How much is the normal accumulation of seasonal snow cover and how its spatial and temporal variability afects stream flow of

different Himalayan streams?

- What are the possibilities to use glaceological research data for modeling climate and its changes on various ecosystems?
- How to harness snow and glacier melt water for managing the recurrent flood and droughts?

Thus, it is clear that the scientific investigations into dynamics and physical characteristics of Himalayan snow and ice fields, the interactions of cryosphere with atmosphere, hydrosphere and biosphere needs a special thrust through a high level nationally coordinated programme. The vast snow and ice fields feeding the Indian landmass and forming the tallest water tower and a large freshwater resourcew have to be mapped on a priority for study of their fluctuations both in space and time domain vis-a-vis the availability of freshwater resource for downstream uses and upkeep of the integrity of its agroecosystems. For this purpose, we should establish interactive data basis in cooperation with International Commission on Snow and Ice (ICSI) on the lines of other World Data Centres for the cold regions and seek UN assistance as 2003 is being globally celebrated as the International Year for freshwater Resource Supply.

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