Pt. Govind Ballabh Pant

Memorial Lecture: XXIII

Prof. S.P. Singh

September 10, 2017
at
Kosi-Katarmal, Almora

G.B. Pant National Institute of Himalayan Environment & Sustainable Development
(An Autonomous Institute of Ministry of Environment, Forest & Climate Change, Govt. of India)
Kosi-Katarmal, Almora - 263 643, Uttarakhand, India

PROF. S.P. SINGH

- Chair of Excellence in Biodiversity and Ecology
  Forest Research Institute (FRI), Dehradun, Uttarakhand
- INSA Sr. Scientist, Central Himalayan Environment Association (CHEA), Nainital, Uttarakhand
- Former Vice-Chancellor, HNB Garhwal University, Srinagar Garhwal, Uttarakhand

Experience

- Advisor Planning Commission, Government of Uttarakhand, 2010-2012
- Vice Chancellor, HNB Garhwal University, Srinagar-Garhwal (UA), 2005 - 2008
- Professor and Head, Department of Botany, Kumaun University, Nainital (UA), 1987-2005
- Reader in Botany, Kumaun University, Nainital (UA), 1985-87
- Lecturer in Botany, Kumaun University, Nainital (UA), 1977-85
- Professor and Head, Department of Botany, Government P. G. College, Uttarkashi (UA), 1975-77
- Lecturer in Botany, DB Government College, Nainital (UA), 1966-75
- Chairman, Scientific Advisory Committe, GBPNIHESD

Other Professional Experience

- Co-ordinator of University Academic Administrative Auditing Committee
- Member, Peer Team, National Accreditation & Assessment Committee (NAAC) of UGC
- Member of Plant Science, Project Advisory Board, Dept. of Science & Technology, Govt. of India
- Member Project Advisory Committee, Ministry of Environmental & Forests, India.
- Member of Research Degree Committee of several Indian Universities.
- Chairman, Workshop on Managing Forest Fire in India, WWF, New Delhi
- Co-opted Member, Science Advisory Committee, GBPIHED, Almora
- Member of Ecologists team to visit Silent Valley for assessing the impact of dam construction.
- Chairman, Clean Development Mechanism Cell, Uttarakhand.
- Consultant to Lead India in the area of Climate Change.
- Member of Uttarakhand State University ACT Committee.
- Contributed actively to the formation of Himalayan Countries University Consortium for ICIMOD.

Awards & Recognition

- Fellow of Indian National Science Academy (FNA)
- Fellow of National Academy of Science, India
- Conferred peace award 'IL MANDIR DELLA PACE L'Oriente Incontra L'Occidente, Da'Course A Course by Shantimandir, Rome, Italy
- Courtesy Professor, Department of Botany and Plant Pathology, Oregon State University, Corvallis, USA
- Awarded Dr. Birbal Sahni Medal of 2003, India
- Honoured with Certificate of Felicitation in recognition of outstanding contribution in the field of Plant Science by Tribhuwan University, Nepal
- Uttarakhand Ratna Award, India

Summary of Research Contributions

- Outstanding contribution on the Himalayan ecology both terrestrial and aquatic, from tropical to alpine, with major emphasis on forest ecosystem processes and on applications of ecology to solution of Himalayan environmental problems. The forest communities studied are distributed along an altitudinal range of over 3000m, and 15°C mean annual temperature, easily one of the premier environmental gradients of the world.

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Climate Change in Himalayas:
Research Findings, Complexities and Institutional Roles

Prof. S.P. Singh

23rd Pt. Govind Ballabh Pant Memorial Lecture
September 10, 2017

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Climate Change in Himalayas
Research Findings, Complexities and Institutional Roles

Prof. S.P. Singh

INSA Sr. Scientist, Central Himalayan Environment Association (CHEA), Nainital, Uttarakhand

Former Vice-Chancellor,
H.N.B. Garhwal University, Srinagar Garhwal, Uttarakhand

(E-mail: spsecology@gmail.com, surps@yahoo.com)

It is a privilege and honour to get the opportunity of delivering 23rd Pundit (Pt.) Govind Ballabh Pant Memorial Lecture at this prestigious institute of Himalayas. I am thankful to concerned authorities for acknowledging my research contribution this way. Let me acknowledge that whatever little I have achieved in my field, is largely because of my research students, some of them are here. They continued to keep flocking around me, so I could continue to be in research till this age. I thank the Director, GBPNIHESD, who kept on encouraging me to continue to stay in the field.

Remembering Pant Ji

Before I begin let me say a few words about Pt. Govind Ballabh Pant Ji in whose memory this talk is organized. Pt. Govind Ballabh Pant Ji was one of the most respected leaders of our freedom movement and in the early decades of independent India. People know a lot about him. I cannot add much to what is already known, and written about him. Here, I will share a few things which I used to hear about him when I joined Dev Singh Bisht (D.S.B.) Government College about fifty years ago. Pant Ji played a key role in establishing D.S.B. Government Degree College, and took personal interest in its development. He persuaded Thakur Dan Singh Bisht to donate money to a government college just after Independence (approx Rs. 8 Lakh was donated). The college was named after his father Shri Dev Singh Bisht, popularly known as D.S.B. Dr. A.N. Singh, a noted mathematician was made the founder Principal of D.S.B. Government College. He was Dean of Science Faculty, Lucknow University before joining D.S.B., but was more known for his independent thinking and forthrightness. Pant Ji not only brought him to Nainital, he also saw to it that he is given due respect which a Principal deserves, despite the government hierarchy. In those days dignitaries in Nainital were received at the bus stand, the entry point of the city. The Principal would not go to receive the Chief Minister (Pant Ji) to show his annoyance and frustration whenever a genuine demand of the college was not accepted by the education department of the state government. Pant Ji, instead of feeling insulted, would tell his PA to call Dr. A. N. Singh, and he would discuss about the problem. The Principal would tell him that the education minister had not permitted him to start post graduate *classes, and he was thinking to go back to Lucknow University. Pant Ji intervened at the earliest! All of us know how quickly D. S. B. became a premier college in the country. The D. S. B. and Nainital of those decades that followed the Independence, still glitter in memory of many people who happened to be there at that time.*

His simplicity was reflected through the personal interest he took on simple issues such as getting houses on rent for the teachers. Such was his greatness and respect for academics! Unfortunately Pant Ji passed away soon after the establishment of the D. S. B., and the government interest in it declined. Thus the experiment of a government college as a centre of academic excellence was cut short. A degree college beginning to excel in research was uncommon. St. Stephens, Hindu, Loyola, St. Xavier's colleges, big names of these days were not known for their research outputs. They were known for their graduates and high intake quality. In D. S.B. village based young students with no record of higher education in the family were given quality education.

Importance of Himalayas

Himalayas are huge, massive and, highly heterogeneous; easily one of the greatest geo-ecological features of the planet. Nine out of 14 highest peaks of the world occur in Himalayas, the average altitude in the Greater Himalaya being 6100 m. With 2500 km wide arc from west-to-east, Himalayas along with Hindu Kush region are spread over in about 35°longitude and in 16°latitude. These mountain ranges are young and still rising, hence are vulnerable to landslides and landslips even without human presence. The slopes in the south of the main Himalayan

Table 1. Importance of Himalayas

- Himalayas influence the climate of much of the sub-continent, intercepting moist winds rising from oceans during summer and not allowing cold winds from the north to penetrate.
- A region of highest peaks, large glacier area (6100 km^2), snow and ice, hence called the third pole.
- Ten river basins originate from Himalayas and Hindu Kush, thus, called water tower.
- Highly heterogeneous in precipitation ranging from less than 500 mm to over 5000 mm, and more.
- Rich in biodiversity and endemism: 10,000 plant species, with 3136 endemic; endemism being particularly high near summits; 977 birds, 105 amphibians with nearly 40% endemic, 300 mammals.
- Rich in culture,~1000 languages; center of the at least three major religions.

ranges, exposed to the full thrust of monsoon, are among the wettest in the world, with annual rainfall often exceeding 3000 mm, while in the north of them are some of the major rain shadow areas, with well below 500mm annual precipitation (Table 1). With Himalayas, easily one of the largest wilderness areas in the world, are connected some of the most populated river basins with human density often exceeding, 1000 persons per km^2. The 10 river basins (Fig. 1) which originate from Hindu Kush Himalayas and adjoining mountain ranges have about 1.3 billion people. It must be one of the most incongruous marriages of rugged wilderness with anthropogenically shaped plains.

Figure 1. Ten river basins which originates in the Hindu Kush Himalayas (from ICIMOD, Kathmandu, Nepal).

The Himalayan heterogeneity is not limited to physical features, the region is known for cultural diversity and numerous languages (>1000) and dialects (Table 1.). The western part is known for age-old pastoralism, with herders taking their sheep and goats to alpine meadows during summer months. In contrast, large scale grazing has been absent from the eastern part. These two Himalayan regions differ sharply in biodiversity and agricultural practices. Rich in biodiversity, the Eastern part is known for shifting cultivation, while settled agricultural on terraces carved out of mountain slopes is the characteristic feature of much of the remaining Himalayas.

The Gangetic system owes its astonishing population supporting capacity to the ecosystem services[1] flowing from Himalayas through its several river systems. Evidences for it are as following: (i) Because of the flow of water and soil from Himalayas the plant water potential is higher in plains despite about 100 cm less rain fall and warmer temperatures (Fig.2.), (ii) Despite a history 10,000 years of agriculture in the plains, soil erosion is not a major environmental issue because of continuous flow and spread of slit from mountains to plains. People scoop out soil and make bricks in plains for several years, then again start growing crops, (iii) Some of the most productive ecosystems of the world are in the first plains that surround Himalayas presumably because water, soil and nutrients that Himalayan forests generate move down are trapped in the moist plains. How climate change- induced glacier melt and snow depletion and construction of proposed dams are affecting ecosystem services is poorly known.

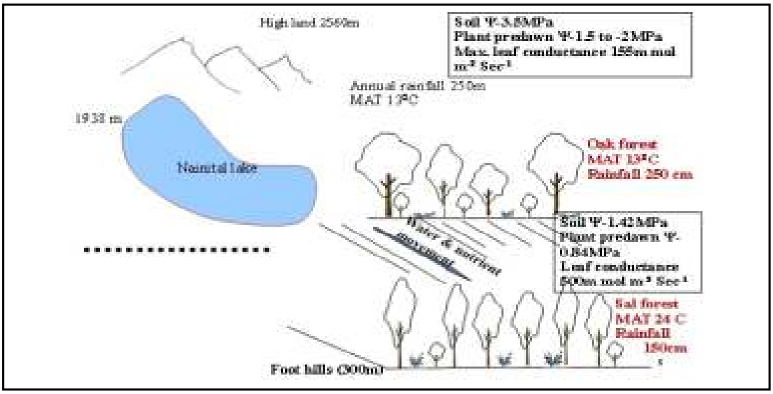

Figure 2. A comparison of highland and low land ecosystems in a central Himalayan region with regard to water status. The lowland sal *(Shorea robusta)* forest has a relatively higher water status, despite lower precipitation and higher temperature than highland forest, indicating flow of water and soil from mountains to plains.

Himalayas are globally important for its biodiversity, the region has about 10,000 plant species with 3,136 being endemic (Conservation International, 2016). Many of the species are in trade, and are marketed to far off regions including lichens, morels, medicinal and aeromatic herbs, trees and shrubs.

Himalayas are warming rapidly

Himalayas are warming at rates two to three times more than global average rate (Table 2). In Tibet Plateau the rate of warming is still higher

[1] The benefits people obtain from ecosystems. Include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as nutrient cycling that maintain the conditions for life on Earth.

(Yao et al, 2012). At Mukteshwar, not far off from where the GBPNIHESD is located, the minimum and maximum temperatures have increased at a decadal rate of 0.65°C and 0.25°C, respectively during last three decades or so (G.C.S Negi unpublished). The rate of temperature rise increases with altitude in most of mountains of the world (EDW Group, 2015) because of several reasons, and the Tibetan region is most documented example of this pattern (EDW Group 2015). The aerosols consisting of organics, minerals, dust, metals and inorganic pollutants and having cooling a effect, are in higher concentrations in low altitude areas than in high altitude remote areas (Sharma et al. 2014). Decrease in snow cover in high mountainous areas due to the global warming results in a decrease in albedo and higher absorption of solar radiation, and consequently in a temperature rise. This difference in the rate of temperature rise between lower and higher elevations can lead to lower temperature lapse rate (TLR) along the elevational gradients in Himalayas. The recent TLR estimates (under a coordinated Timberline Research Project of Indian Himalayas[2] based on observed temperature data are consistent with this. At Tungnath, Uttarakhand the winter TLR observed in a collaborative project of ours is 0.46° and 0.36°C/100m elevation for North-West and South-East aspect while values elsewhere in past are generally above 0.5°C (Rajesh Joshi and his team). If EDW were to stay, TLR will become more milder and species and vegetation distribution along elevation greatly modified. These complex processes along the elevation gradients may combine to expand species elevation ranges, form novel communities, and shrink alpine meadows, where so many medicinal and aromatic plants occur. Threat to what some people call Uttarakhand's "Sanjeevani Sites" is obvious.

Table 2. Some features of warming and precipitation in Himalayas (plus Hindu Kush, HKH)

- Warming in the HKH is increasing more than global average; however the rate varies considerably across the regions. For example, Tibetan Plateau (TP) is getting warmer more rapidly than other regions.
- The rate of temperature rise has increased with time e.g., in Tibet Plateau (TP), the mean temperature rise was 0.16°C/decade between 1955-1996 and 0.32°C/decade between 1961-2012; thus doubled the previous rate.

[2] This is a major research project on Indian Himalayan Timberline under National Mission on Himalayan Studies of the Ministry of Environment,

- Distinctly warmer events have increased and distinctly colder events declined during last several decades.
- Generally temperature rise is more during winters and in nights (minimum), and hence a narrower diurnal range.
- Recent data on Temperature Lapse Rate (TLR) with increase in elevation is lower (< 0.5°C per 100m increase in elevation) than generally perceived, so temperature of high mountain areas are greater than assumed. Elevation dependent amplification of temperature is probably one of the major contributors to decrease in TLR.
- Western disturbances have increased, resulting in more snow and glacier swelling in Western Himalayas and Karakoram.
- Monsoon rainfall is predicted to increase, but it has been declining since 1979 in Himalayas.
- Increase in winter precipitation in Karakoram but decrease in much of the Himalayas, particularly in Central Himalayas, are being observed.
- The events of heavy rainfall have increased and those of light showers have decreased.
- Tree ring width analysis suggests that pre-monsoon warming adversely affects growth, while pre-monsoon precipitation increases the growth.

Glacier Melt

Himalayas have more snow than any other region in the world outside the two poles, thus it is a great source of water. That is why how global warming is affecting glaciers in the region is a matter of great interest and concern. In fact in recent years, Himalayas are more in news because of glacier shrinkages and disasters, partly because even research journals tend to pay more attention to a alarmist view. Are glaciers going to disappear, and when they disappear what will happen to our rivers, and the springs which feed them and on which local people depend heavily for water? These are some of the questions of immediate concern. I am summarizing here some of the findings of research going on glaciers across the region. A very small fraction of glaciers are being monitored. Remote sensing can be effective in measuring changes in glaciers, but without ground truthing the data generated are unreliable.

To work in glacier areas, located generally between 4800-6200 m asl, researchers need a certain level of facilities and infrastructure, which are not readily available. For working in those remote areas, you need to be young and with strong calf muscles. This, in fact, is a necessity for doing field work in Himalayas in any research area. Himalayan glaciers and alpine vegetation are generally higher in altitude and more remote than in other mountain regions.

As for techniques, glacier tip based observations are easy to collect, but they are less reliable indicator of change in glaciers. Mass balance method[3] is reliable, but is far more time and energy consuming. Thus, data on glacier measurements generate controversies, first because of the extent of reliability of methods, and the second because the region is highly heterogeneous; data of one site are often not applicable to other sites. Environmental conditions in Karakoram where glaciers were reported to be swelling (or not shrinking) are different from those of Himalayan regions where glaciers are mostly shrinking. In Karakoram and some other extreme western parts, moisture is largely driven by westerlies[4], which have become stronger in recent decades while monsoon which influences much of the Himalayas has weakened during last several decades (Yao et al. 2012). It seems that the role of moisture is critical in a warming climate, also in relation to glaciers, but experts are generally not explicit about it.

What is the overall generalization with regard to Himalayan glaciers? In an analysis, based on 75 glaciers, Miller et al. (2011) showed that 63 glaciers were shrinking and 12 showing growth (Fig. 3); all the 11 mass balance based measurements, which are most reliable, indicated glacier shrinkage; and none of data showing glacier swelling was based on mass balance measurement (Fig. 3).

A third pole environmental programme study has shown that glaciers in Himalayas are depleting rapidly, on average at the rate of 930 mm / yr, than the glaciers of adjoining areas, at the average rate of about 400 mm / yr; and only one glacier, in Pamir, gained in mass, at the rate of 250 mm / yr (Yao et al., 2012). Another data set based on 7,090 glaciers of south-east Tibet, Central Himalaya and Western Himalayas indicates a loss of 1232.8 km^2 area from 1970s to 2000. The Department of Science and Technology of India has taken a major step of establishing a glacier institute for monitoring glaciers of Indian Himalayan Region (Box 1).

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[3] Mass balance is a measure of a glacier's health. Over time, mass balance data reveal how glaciers are responding to climate.

[4] Wind blowing from the west. Wind blowing from the west.

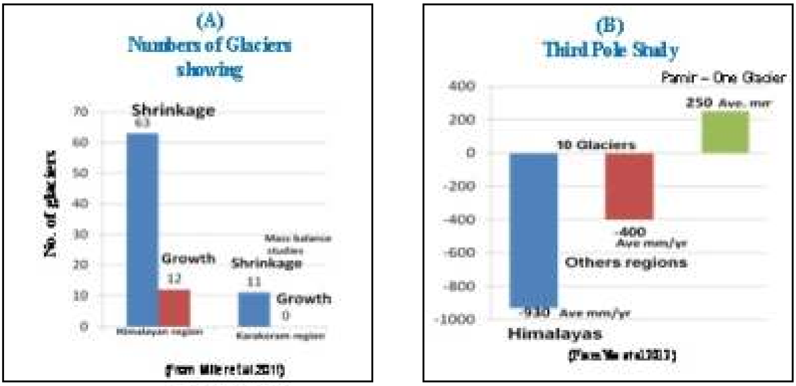

Figure 3. Summary of change in glaciers. (A) Based on 75 glaciers from Hindu Kush Himalayas (from Miller et al. 2011); (B) From Third Pole study (Yao et al. 2012).

Glacier studies: Policy and Practices

By deciding to establish a glacier institute, Department of Science and Technology, Government of India has made a good beginning to address this problem. However, the process is still slow, as the institute is still only an unconsolidated component of Wadia Institute of Himalayan Geology. The glacier institute is unlikely to deal alone with the huge task of glacier monitoring and glacier and snow-melt hydrology. The institute should take a lead and organize a network of glaciologists in the country to monitor glaciers. Communicating to lay persons about cryosphere is important, as glacier melt and glacier lakes which result from them often create controversies and doubts. The institute should not limit itself to only monitoring glaciers consequences of glacier melt to hydrology, high elevation springs and tree line communities and ecosystems need also to be studied.

How Glacier melt is affecting river charge?

The principal time of river discharge varies considerably from one region to other; it is spring in the snow-dominated Kabul, summer in glacier dominated Indus, and monsoon months in Ganga, Brahmaputra and Salween (Table 3). In the last group of rivers, snow-melt dominated during the first monsoon month (July) and rain during later monsoon months (August-September). These rivers, thus will be affected differently because of climate change. For example, in the case of Ganga and Brahmaputra rain may combine with snow melt water to cause floods during monsoon months. It is expected that for several more decades, river discharge due to glacier melt will not be affected, as the warming-induced increase in glacier melt water will be compensated by reduced glacier size, or reduction in glacier melt water may be compensated by increased precipitation such as in Indus basin.

How these rivers are likely to be affected by loss of glaciers and snow depends on their contributions to river discharge? The most severely affected river will be Indus, where glacier melt (26%) and snow melt (34%) together account for 60% of river discharge. In other major rivers, the river discharge is primarily monsoonal, so they are less likely to be affected by glacier and snow disappearance. However, local people who depend on springs and streams to meet their water needs during summer months, may be greatly affected by the loss of snow.

Related to glacier monitoring is the formation of glacier lakes and threats they pose to downstream areas (See Box 2).

Table 3: Contribution of Glaciers and Snow to the total Discharge in some Major River Systems of Himalayas.

Ganga basin, from Nepal catchment 2-20% -8.7% (Immerzeel 2012; Armstrong 2010)

Brahmaputra 21.1%

Indus 60% (34% from snow melt + 26% from glacier melt)

Glacier lakes in Uttarakhand

- Glacier lakes are moraine-dammed lakes formed beside the lateral moraines and at the front of glacier tips. Glacier and snow melt water coupled with heavy rains can break the moraine dams. The resultant release of huge amount of water and debris is called Glacial Lake Outburst Flood (GLOF), which can be very destructive.
- There are 1268 glacier lakes larger than 2500 m^2 area in Uttarakhand, located between 2900-5850m.
- The moraine dammed, lake, Chorabari contributed substantially to Kedarnath disaster of 2013.
- Yamuna basin has 7.6 km2 area under glacier lakes, Alakhnanda basin 3.4 km2 area, and Bhagirathi basin 1.6 km2.

*However, data suffer a lot from the lack of meteorological stations in higher reaches, and poor quality of glacier-hydrological modelling.

(Source: Bhambri et al. 2015. Glacier lake inventory of Uttarakhand, Wadia Institute of Himalayan Geology.)

Climate change-induced disasters

Being young and rising, Himalayan mountains are unusually vulnerable to landslides and slope instability. Since the number of days with high intensity rainfall is predicted to increase, climate change is likely to increase frequency and intensity of landslides, overflow of rivers and floods. Uttarakhand alone has been affected by 6 to 7 major water-induced disasters during last decade or so. Not all disasters might have climate change connection, but higher disaster frequency in recent years is consistent with climate change predictions. One of the greatest threats is likely to come from glacier lakes, which when burst, can wreak havoc in downstream Table 4 areas (Box 2).

Table 4. Six disasters between 2010 and 2014: is it not too high? (from Singh and Sharma, 2014)

Year and Type	Affected Town	Impact
2010 (August) Flash Flood after heavy downpour	Leh	255 killed, Several missing. Estimated Damage Rs. 1.33 billion
2010 (September) Flash Flood	Almora & Nainital	Loss of property. Road blocked for several days.
2012 (August) Heavy rainfall and Landslide	Shimla	Two evacuated houses collapsed in Totu area of Shimla following heavy rainfall.
2013 (May) Thunderstorm accompanied by strong squall	Aizawl	10 killed, few missing, Injured 16 People.
2013 (June) Flood	Kedarnath, Srinagar & Several others areas	Thousands died as well as missing. Heavy loss of property and infrastructure, Rs.250 billion.
2014 (September) Flood	Srinagar & Jammu	Still nothing is certain. Rescue operations are in place.

*Subsequently, major disasters have occured in Shrinagar (Jhelum flood), Pithoragarh (Malpa, 2017) and Kotdwar (2017) in Uttarakhand

In Himalayas climate change adaptation is largely an issue of managing flowing water- primarily to preventing damages that uncontrolled flowing water can cause during monsoon months, and retaining water for human use during the rest of 8 to 9 months where there is little

Figure 4. A disaster in high mountains can devastate many lower areas. The effect of heavy rains of June was seen in all areas along the river in 2013.

rainfall. Even ice and snow reserves have begun to move and disappear due to climate warming. Glacier Lake Outburst Floods (GLOFs), cloud burst or excessive rainfall events, all can be highly destructive to infrastructures like roads, bridges and buildings. Such destructions (Figure 4) lead to speed up out migration as well as adversely affect tourism and other economic activities even long years after the disaster. According to an observation the June 2013 Kedarnath disaster not only induced migration to plains from affected areas, but it also shifted settlements within mountains. Many capable people left mountains for plains.

Intensification of Pre-Monsoon Drought a Critical Factor in Himalayas

There are now several evidences to suggest that the intensification of pre-monsoon (March to May) drought is becoming a major climate change impact in the region. Warmer temperatures without additional water affect plant growth adversely even in a cold region. An analysis of meteorological data of Mukteshwar shows that while annual rainfall has not decreased during last three decades or so, pre-monsoon has become drier (GCS Negi, unpublished). Some of the observations which are related to warmer and drier pre-monsoon period are as following: (I) Spring drying and water scarcity particularly during pre-monsoon period; (II) Unusually higher decline in water level in water bodies, such as Nainital lake; (III) Widespread fires in the years of drier pre-monsoon months; (IV) Negative relationship of tree ring growth with temperature of pre-monsoon period and positive relationship with pre-monsoon and rainfall; (V) Desiccation of banj oak (*Quercus leucotrichophora*) seeds to the extent that they fail to germinate by the time rains arrive. Though not yet investigated, forest with dried up spring is likely to be more inflammable than one with extand springs. How fire affects a spring is not investigated?

Spring extinction

Of these, spring drying is a major problem not only in rural areas, but also in cities, particularly in tourist towns like Shimla, Mussorie and Gangtok. It may be pointed out that climate change is simply one of the several factors that account for spring drying. A preliminary data compilation indicates that of the 45 cities / town for which information was collected, all depend on spring water to an extent, and 17 are entirely spring-dependent (Table 5).

Table 5. Water sources based on a survey of 45 towns/cities (31 UK, 10 HP, Meghalaya, 1 Sikkim, Arunachal, 1 J&K) (from Singh and Sharma 2014)

Category	Number of towns/cities	Examples
At least some dependence on water of springs and streams	45	**All towns surveyed**
Entire dependence on springs and streams	17	**Shillong, Gangtok, Itanagar Mussori,**
River water lifting from a distant place along with other sources	7	**Manali, Almora, Ranikhet,**
Water from river at the bank of which city is located, along with others	10	**Bliaspur (HP), Srinagar (Garhwal) Bageshwar, Devprayag,**
Stream, spring and ground water	9	**Palampur, Solan, Berinag,**
Lake	2	**Srinagar (Kashmir), Nainital**

The interesting point is not that springs are no more able to meet water demand of cities like Shimla and Mussorie, but that they have been supporting them for more than a century. It is good that NITI Aayog of the country has already initiated programmes for spring restoration.

Scientists are required to address several questions related to springs to develop a package of solutions. First, could springs be 'tamed', enough to get water in a predictable way? Second, what is the realistic assessment of spring as a source of water and to what extent water yield could be increased by treating spring-sheds? Third, what are co-benefits or co-ecosystem services of spring-shed restoration? To understand the functioning of springs we need to understand the related geological, biotic and soil components, apart from precipitation. It seems that the lean period spring water output could be raised by 20% or so at a large area basis. Then, what could be other water sources if springs can only partially meet people's needs of water? River water lifting is already in practice in Almora and recently Shimla has also gone that way. What is the scope of recycling water, water harvesting, and creating new cities keeping in view water sources? These need to be worked!

In a way, springs' main role is to provide water, long after monsoon months. During dry seasons rivers also depend on spring water, therefore if springs are getting degraded, then the lean period water in rivers would also get depleted. Forest degradation[5] is one of the causes of spring extinction, and drying springs cause forest to degrade. Restoration of a degraded forest and treatment of slopes to retain water longer can contribute to spring water supply and other ecosystem services, such as species richness, water interception by forest floor litter, carbon sequestration in increased forest biomass and others. The relationship between ecosystem services, such as spring water, and recreational service of lakes and forests (Fig. 5) and mountain urban sustainability should be made explicit in policies and practices (Box 3).

Tourism activities in cities like Nainital and Mussorie or Shimla have considerable environmental costs, adversely affecting the life of local people. The lake water declined by about 6 m in Nainital during pre-monsoon months, which make the principal tourist season, is largely because of (i) increased consumption of lake water; (ii) increased evapotranspiration loss due to climate warming; (iii) deterioration of Sukhatal, a valley fill, supplying a considerable amount of subsurface flow water to lake Nainital; (iv) drying of springs;(v) deterioration of

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[5] Forest degradation is the changes within the forest which negatively affect the structure or function of the stand or site, and thereby lower the capacity to supply products and / or services.

slopes, which results in increased runoff (root tops and roads are impervious surfaces to water infiltration), and (vi) some reduction in the amount of water returning to lake after domestic use.

Figure 5. High lake level and rich forest biodiversity-high recreational value- Nainital.

Figure 6. Pollution and seasonal drying of Nainital lake-low recreational value.

Box 3. Springs: Policies and Practices

- Institutionalize ownership and management of springs.
- Map springs and monitor them with the help of local people by developing citizen science.
- Evaluate and promote co-ecosystem services of springs, such as increase in biodiversity, carbon sequestration, and

recreation connect them with accounting systems.

- Explore the scope of springs and stream-and waterfall based tourism, and ensure sustainability.
- Orient human settlements in relation to spring water supply and spring shed conservation. Declare that mountain cities are ecosystem services supported systems and manage them accordingly. Let spring water availability decide the location and size of human settlements, instead of allowing the growth of settlements to force to supply from any source at any cost.
- If populations and human activities are to be expanded beyond the carrying capacities of spring water, then alternative water sources and supply from these should be clearly worked out.
- Time has come to decide whether tourism should be supported at all costs. Costs could be deterioration in life of local people, and permanent damage to water sources?

Interestingly, despite a drastic reduction in the lake water level and depressing look of the lake (Fig. 6), tourist number did not decrease. In contrast, locals were depressed and concerned because of the lake deterioration, and organized demonstrations. Now, this leads to a question: should mountain tourist spots be converted simply into an extension of big cities like Delhi for recreation, or the present mass tourism should be replaced with quality tourism with fewer tourists? Should economic activities be supported even at the cost of ecosystems which are central to them? Should we not pay attention to the condition of local people?

Figure 7. Construction activities in and around Sukhatal valley fill.

The contribution of Sukhatal to lake Nainital hydrology was established by a research carried out by National Institute of Hydrology, Roorkee, and the research was supported by public money. The research findings were constantly communicated to different groups of decision makers by scientists and Centre for Ecology, Development and Research (CEDAR), Dehradun and earlier by Central Himalayan Environment Association (CHEA), Nainital. But Sukhatal continued to deteriorate and lose its function of providing subsurface water to lake like a kind of spring. Sukhatal was used for constructing buildings and as dumping ground of waste material; its silt got contaminated by cement while construction work was going on, which reduced water infiltration(Fig. 7).

Scientists are often asked about the usefulness of their research. Here useful research was not only carried out but was also communicated along with repeated appeals and applications from various stakeholders and sensitive groups. But attention was paid only after a PIL, yet we are not sure of Sukhatal's fate.

Pre-monsoon is also the time of forest fires. Though the fire scale and intensity are driven by several factors, a decline in pre-monsoon precipitation and warmer temperature have increased both frequency and area affected. Fire incidents are fewer in the year's with more pre-monsoon rains (Fig. 8).

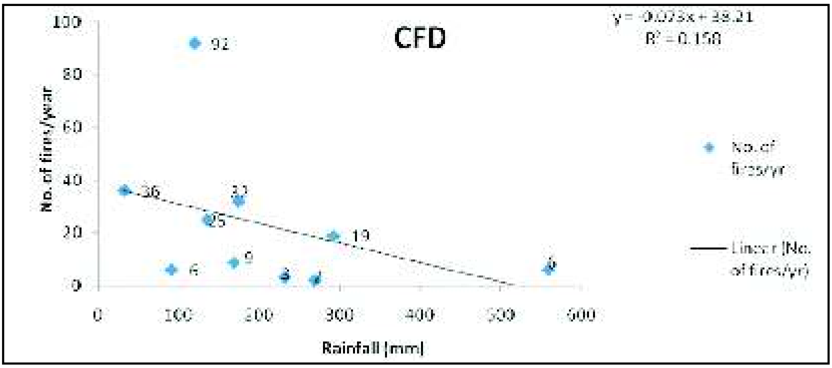


Figure 8. Relationship between fire incidences and rainfall during pre-monsoon season (March to mid-June) across the years, from 2004-2013 in Chamoli Forest Division (CFD). (*Source*: Singh *et al*. 2016)

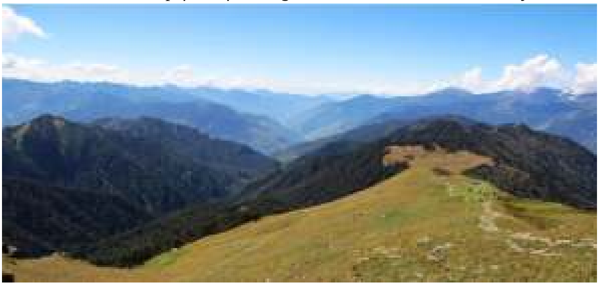
How much drying of springs contribute to fires and how much fires contribute to the drying up of springs have not been investigated, but they are likely to be interconnected to an extent. Fire and smoke pollute air, and deteriorate living condition for local people and tourists. Wild animal mortality is partly related to the water shortage in forests during a fire incident.

Treeline, Climate Change and Pre-Monsoon Drought

The theoretical line which connects the uppermost trees in a mountain site is called treeline (Fig. 9). Because of the low temperatures, trees cannot grow beyond that elevation. Since tree growth stops in high mountains because of heat deficiency, climatic warming is expected to raise treeline elevation. In a way, treelines are sensitive indicators of global warming. Little research has been done on Himalayan treelines, though the highest treeline of the Northern Hemisphere occurs in Himalayas-*Juniperus tibetica* at 4900m in Tibet (Miehe et al. 2007). Lack of facilities in remote high mountains is one of the major reasons of our poor understanding of treeline areas (in Europe a treeline may occur at

Quercus semecarpifolia forming timber line in Chaudas vallye 3800 m

(A) Abrupt timberline/ treeline



Courtesy: Vikram Negi, GBPNIHESD

Betula utilis and Rhododen dron campanula turn forming treeline at Lata-Khark Nanda Devi Biosphere Reserve 4000 m

(B) Diffused treeline

Courtesy: Vikram Negi, GBPNIHESD

Finger like tree line Betula utilis & Abies pindrow

(C) Finger like treeline

Figure 9. Various forms of treeline: (A) Abrupt treeline; (B) Diffuse treeline; and (C) Finger like treeline.

1000m because of colder conditions due to high latitudes). Himalayas have all form of treelines (Fig. 9.), generally formed by species of *Abies* (fir), *Betula* (birch), *Juniperus* (juniper) and *Rhododendron*.

Whether treeline moves up a slope in a warming world, partly depends on pre-monsoon conditions. Warming alone may, in fact suppress treelines by causing soil water deficiency. Treeline advancement, thus requires pre-monsoon rains. At several sites treelines have gone higher possibly because of reduced grazing. Grazing in Alpine meadows has kept treeline low as tree seedlings recruited in Alpine meadows are damaged by sheep and goats. Studies on the relationship between tree ring growth and past climate have highlighted the importance of pre-monsoon rain. Research in treeline dynamics warrants long term, multi-site, multi partner research. Changes in treeline elevation would have consequence for herb species diversity, soil carbon and several vital ecosystem processes. Studies on treeline landscapes call for ecosystem approach, treeline should not be treated simply as a landmark, it is possibly most physiognomically diverse landscape. Within a few hundred meters one can find fir (*Abies spectabilis*) forests, open birch (*Betula utilis*) forests, scattered individual trees, stands of twisted, tilted and stunted trees, called krummholz, such as of Rhododendron campanulatum, juniper mats, and herbaceous communities of different physiognomies.

Species growing in treeline and near summits can be in problem because of climatic warming if space above their occurrence is limited. *Quercus semecarpifolia,* a major evergreen oak of high elevation forest belt is one such species. It is distributed in island like fashion near summits with distances 30-70km. A warming of even 1°C temperature can halve its area in a longer run. The species has not been regenerating well because of growing pressure for quite sometime. Climate warming and grazing together might drastically affect its distribution (Fig. 10).

Impact of pre-monsoon drying due to climatic warming is seen on banj oak regeneration. Banj oak seeds mature and fall during winter months, remain on forest floor for several months and germinate only when monsoon arrives or there are pre-monsoon rain showers. But because of global warming they get desiccated well before rains arrive. Forest floor litter removal makes conditions drier for oak acorns lying on ground. Banj oak being a foundation species need to be given importance in management of forests in view of climate change (see Box 4).

Figure 10. Recalcitrant oak acorns tend to dry out and lose viability well before the arrival of monsoon because of warmer winters, and early maturation, hence longer period of stay on ground and more post-dispersal predation.

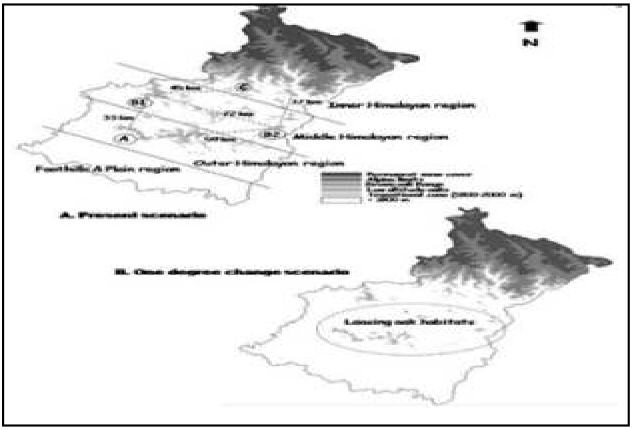


Figure 11. Example of how warming temperatures can lead to the disappearance of certain species: The Kharsu oak (*Q. semecarpifolia*) which occurs in isolated islands separated by 30-72 km (A) is likely to be loser with rise in temperatures (B) (*Source*: Sharma and Singh, (2004).

Box 4 Policy and Practices: Forest Fires, Treelines and Oak regeneration

Man made forest fires are largely a social issue, however its consequences are no more confined to the forest patch burned. It is a source of Black Carbon (Fig. 12.) and other particulate matter, which not only affect human health, but are also reported to be a major cause of glacier melt. Frequent fires now have begun to bring about change in forest composition at a regional level. Fires in combination with ban on tree cutting have favoured chir-pine (*Pinus roxburghii*) at the expense of banj oak, which continued to be lopped and grazed after. Being fire-tolerant, chir-pine has intruded upon banj oak in many areas. Banj oak, though not in use as timber, is a foundation species supporting several other species, and ecosystem processes which result in precious ecosystem services, such as spring discharge, rich soil formation, and better hydrological regulation. There is a need to review the decision of clamping ban on tree cutting imposed several decades ago. Given the importance that springs have in mountains, forest policies should be such that they promote them.

- Impact of Forest floor litter removal should be analysed in view of its impact on seeds and seedling recruitments and, fine root and associated mycorrhizae.
- Treeline should not be simply treated as an indicator of climate change, but as a landscape consisting of several ecosystems with consequences for species diversity and ecosystem processes. It should be treated as a separate conservation entity where physiognomically different communities and ecosystems are under continuous flux.

Black carbon (BC) concentration at a mountain site (Nainital), India

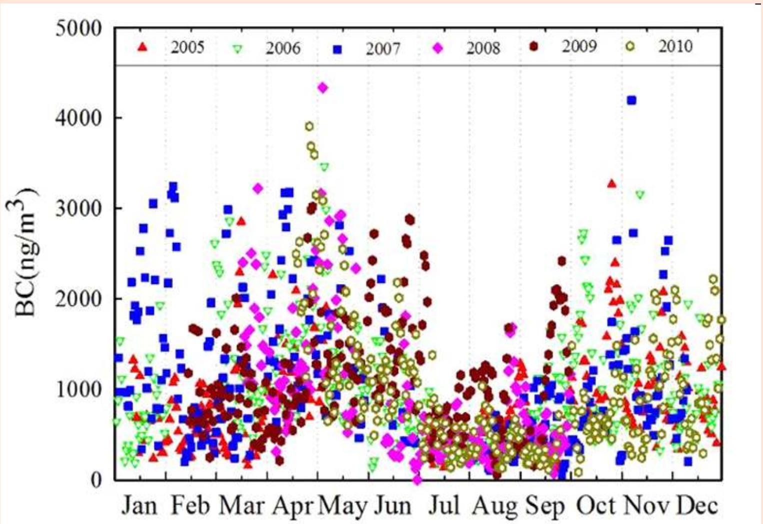


Figure 12. The black carbon concentration is lowest during the months of the summer monsoon (Source: Dumka et al. 2010).

Agriculture in Mountains

Agriculture in relation to climate change in mountains is a complex subject, and beyond the scope of this article which is about giving an overview. In general, agriculture abandonment because of non-viable holdings and lack of irrigation is already quiet common. Climatic uncertainties, by making things more difficult, may induce more abandonment of agriculture, at least in states like Uttarakhand.

Apple cultivation in Himachal is one of the major success stories; it raised the living standard of a large number of families. There are indications that in traditional apple crops of Shimla and Kullu valleys, farmers are finding difficulties because of warming temperature and, uncertain and extreme weather events. Apple requires 1200-1500hours of chilling, which is now available at 2700m and above (Basannagari and Kala, 2013) because of global warming. There are evidences to suggest the shift of apple cultivation to higher valleys like Lahul-Spiti, in Himachal. This can be called a kind of adaptation at a regional level, however, increase in cultivation in Lahul-Spiti is unlikely to compensate for decrease in apple cultivation in Shimla and Kullu valleys. However, at individual level, shifting to other crops and other economic activities may be a preferred option. Relatively rich apple farmers in Shimla have begun to grow other fruit crops and take up other economic activities, resulting in fall in the contribution of apple to their earnings (Table 6.). Shifting a complex infrastructure of apple cultivation and trade from one area to another has enormous costs and difficulties. Uttarakhand, Nepal and eastern Himalayan states might need to think about cultivating tropical crops like mangoes in valleys, many of which have large areas are below 1000 m.

Table 6. Apple cultivation in three major valleys of Himachal Pradesh (Source: Rana et al. 2008).

Valley	**Mean annual temperature (°C)**	**Orchard area /household/yr**		**Income from fruit (% of total income**	
		1995	**2005**	**1995**	**2005**
Kullu	17	0.55	0.45	69.9	39.6
Shimla	15.4	0.62	0.60	59.3	32.8
Lahul-Spiti	<14	0.48	1.09	17.2	29.1

These valleys may contribute to prolong the mango season, as mangoes are likely to ripen up to September–October or so. The more important point is to think differently in view of the fact that geographical area of tropical fruit crops is to increase in Himalayan region.

Forest degradation, forest carbon and women drudgery

Day-to-day dependence of people on forest for fuel wood and fodder has been age-old feature of subsistence life living much of the Himalayas. In the 1970s, a unit of agronomic production entailed the expenditure of 10 energy units from forests (Singh and Singh, 1992). This ratio seems to have declined, but the dependence on day-to-day collection of forest biomass continues in many areas. The labour involved in collection of biomass severely affect the health of women and child care by them. Though changes have begun, more are needed to improve the condition of women drudgery. Access to clean cooking energy, development of grasses and legumes-based fodder, and improved composting may trigger several processes of social and ecological improvements. The quality fodder production could be used to develop dairy, and save trees from lopping of branches and leaves, which in turn may increase carbon sequestration in forests. Access to clean cooking energy can contribute to improving women health, regional biodiversity and carbon stock of forests, and reducing black carbon release into atmosphere. Black carbon is known to accelerate glacier melt by getting deposited on snow, and thus reducing albedo. So the value of benefits both social and ecological would be far more (Fig. 13.) than the cost of providing clean cooking energy such as LPG and electricity and replacing tree leaf fodder with grass-based fodder.

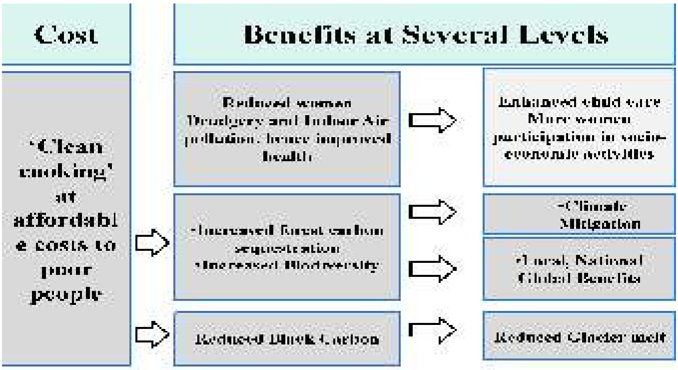


Figure 13. A technological intervention in cooking energy can generate several developmental steps, leading to enhancement in the quality of women life and ecosystem services.

Climate Change Justice

Very low ratio of per capita CO_2 emission from fossil fuels to the burden of climate change impact is a common feature across the Himalayan region. Per capita fossil fuel CO_2 emission of India is among the lowest in the world, less than 2 t CO_2, compared to global average of ~ 5 t CO_2 or so. It is ridiculously low in Himalayan countries and states (0.4 t CO_2 for Nepal,). Forests over a large area in Himalayas sequester carbon, and the rivers of the region are tamed to generate hydropower used also by regions outside Himalayas which favourably contribute to their carbon budgets. It is quite possible that some Himalayan regions are net carbon sequesters, that their fossil fuel CO_2 emissions are less than CO_2 saved by electricity generation plus forest carbon sequestration. However, people in Himalayas suffer most as a consequence of climate change. Cloud burst, GLOFs, avalanches, landslides, forest fires, road disruption and road blocks, water scarcity, and crop failures. The cost of infrastructure development in Himalayas is much higher than in plains, and often because of the shortage of finances their quality does not correspond to the requirements in a geologically fragile region. The extra finances required should be made available to mountain states to develop better roads, stable slopes, and climate change proofing. An example could be the construction of roads on high columns through forest areas to allow safe movements of wild animals, such as elephants and in mountain cities for pedestrians, as the roads meant for walking of people are now occupied by automobiles.

Problem Solving Research and Research Institutes

"What is the use of your research" is the question often raised by people in government and public. In a way, it emphasizes that the research should be applicational, not basic or fundamental, at least in institutes meant for solving a certain type of problems. Well, since public money is used to conduct research, the question is justified. As for research, my opinion is that the first requirement should be to conduct clean and high quality research comparable with the best internationally on topics relevant to mountains. If research quality is high and based on right questions, it will become useful soon. Remember, Nobel prizes in science are given only for basic sciences. In early half of the 20th century, particularly in Physics, some of the most fundamentals research questions were successfully addressed by scientists, like Einstein, Rutherford, Niel Bohr, Planck, Haisenberg, Dirac and Fermi. Those great physicists raised the level of human excellence to new heights. Nobel prize owes its exceptionally high prestige to some of these names, many other Nobel laureates simply enjoyed their reflected glory. The fundamental research by these geniuses subsequently led to numerous applications, which benefitted humanity immensely. So, a basic research is a research, the application of which has yet not been made.

However, in a problem solving institute one cannot have a luxury of doing basic research in a discipline hardly relevant to mountains. When research problems of immediate societal relevance are well recognized there is no reason not to address them. How can an institute on mountain development avoid research on drying springs? However, developmental research warrants considering the entire package of solution to which scientists are less familiar. For example, in case of spring water, the research should not be confined to demonstrating that spring discharge can be increased. It should also include a realistic assessment of additional water that can be generated from springs in a region and how meaningful is that additional amount in relation to the demand of people, what will be the cost of the treatment of spring sheds that increased spring water, and its co-benefits in terms of ecosystem services? Finally, if increased spring water is not going to meet the people need, what are possible alternatives?

Future R&D Research

I think, GBPNIHESD should focus on "back stopping", developing networks, and leading in only a few mountain specific areas. For example, the Wadia Institute of Himalayan Geology (WIHG) should take lead in glacier research. But in high altitude biodiversity, you ought to be the leader, but also involve BSI, WII, Garhwal University, Kashmir University and others. Your research should be Pan-Himalayan. You should establish research partnerships, not only with Indian organizations, but also others. Why should India remain a spectator or follower of other countries research agenda? Or why other organizations should set agenda for our research, though they are not research organizations? Why Himalayas cannot have more than one institute with Pan-Himalayan coverage. Remember, the Nobel prize enabled Sweden to have a global presence, and promoted science and scientists of Sweden by enabling them to come in touch with best scientist of the world frequently. GBPNIHESD should be international in its presence.

The last but one point!

This is about the geographical limit of our research area / region. How much HKH is Himalyan when it comes to regional analysis say for glaciers and climate change and forests? I think, much less than manageable. Himalayas are already heterogeneous both altitudinally and longitudinally (from east to west). By adding Tibet, Karakoram and others, ICIMOD has further complicated the heterogeneity. Tibet is not a mountain, it is a huge flatland in sky. It has high elevation, but not change in elevation, a character, central to mountains. HKH is dominated by grasslands, while Himalayas by forests. When regional analysis of climate change is made, the take home messages turn out to be confusing because of the many differences between the two land forms. ICIMOD did it to have a larger coverage, so is doing now the third pole. But the resulting heterogeneity, obstructs any attempt to generalize findings for a region. GBPNIHESD, by confining itself to the Himalayas mountains! Would be more successful in developing strategies to deal with climate change and various developmental issues. But to do that India, must take a lead, allocate enough money to developing a centre that facilitates top researchers of the region to improve science and development, focussed on mountains of our region (Himalayas).

The last point

A reason of public confusion is that many of our problems are because of poor implementations, rather than lack of scientific knowledge (Table 7). For example, during the Kedarnath disaster 2013, many buildings were damaged because they were constructed in flood plains illegally not because science of deciding where buildings should be constructed is faulty (Table 7).

Table 7. Problems which are not because of the lack of science, but are presented as if they require scientific inputs- a few examples.

- Damage to buildings constructed in the way of water flows- it is because of illegal construction.
- Damage to mountain roads- it is partly because green road technology developed is not used.
- Depletion of water in Nainital Lake- it is partly because Sukhatal the main source of subsurface water to lake Nainital is being disturbed and damaged; research evidence provided by scientists were not used.
- No advancement in community forestry in Uttarakhand- Local people can undertake some steps of measurement of forest carbon; but never used.
- Ecosystem services of forests developed- but not adequately put to use in the forestry.
- Air pollution of mountain towns- it is because of uncontrolled tourism, with little mass transport service.
- Mal nutrition- it is because of poor communication, poverty, and other facts little do with science.

Researchers all over the world are being scrutinized about their roles. Partly, it is because people have faith in science research. Scientists need to be aware of this issue, they need to be more accountable than they have been. However, scientists too should- proactively communicate to people, and involve them in their research programmes in some way. Scientists should also have right to discuss openly issues of people's interest, such as pollution of air and rivers, and climate, explaining what comes within science realm and what are outside to it.

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- The research has resulted in (i) expanding the focus to encompass the biosphere level understanding, and (ii) in constructing and improving some important generalisations and theories in ecology, pertaining to leaf phenology, leaf related ecosystem characters, nutrient cycling, tree regeneration, community organisation, and ecological sustainability. These were made possible by developing a potent group of ecologists, initiated by Prof. J.S. Singh, BHU, Varanasi in the early eighties.
- Emphasised importance of spatial scale in achieving sustainability way back in 1991, a concept now accepted widely.
- The evergreen forest with ca. 1-year leaf longevity and yearly leaf replacement is recognised as a distinct category (from the more known evergreen tropical rain forest). The work on *Quercus* and *Pinus*, the two greatest forest forming genera of the Northern Hemisphere, has greatly improved the understanding of their nutrient cycling characters, and their implications to forest management.
- Characterised the tree water relations in monsoon systems famous for strong seasonality of rainfall (in collaborations with Prof. Donald B. Zobel, Oregon State University, Corvallis, USA).
- The study on phenologically differentiated oak populations throws new light on intraspecies variability in plant adaptation to environment stress.
- A leading role in research on ecosystem services including carbon sequestration, particularly of Uttaranchal Himalaya, and in necessary policy changes, so that the values of ecosystem services are better reflected in accounting systems.
- Enabling local communities of Uttaranchal Himalaya to monitor carbon sequestration in community forests and make claim for payment and relationship between species diversity and ecosystem functioning are the current research interests. These researches have begun to influence policy decisions. For example, ecosystem services have been included in National Biodiversity Strategy and Action Plan of India.

G.B. PANT MEMORIAL LECTURES

I
Dr. M.S. Swaminathan, Director, CRSARD, Madras – 1991

II
Dr. T.N. Khoshoo, Jawaharlal Nehru Fellow, TERI, New Delhi – 1992

III
Mr. V. Rajagopalan, Vice President, World Bank, Washington – 1993

IV
Prof. U.R. Rao, Member, Space Commission, New Delhi – 1994

V
Dr. S.Z. Qasim, Member, Planning Commission, New Delhi – 1995

VI
Prof. S.K. Joshi, Vikram Sarabhai Professor, JNCASR, Bangalore – 1996

VII
Prof. K.S. Valdiya, Bhatnagar Research Professor, JNCASR, Bangalore – 1997

VIII
Prof. Vinod K. Gaur, Distinguished Professor, IIA, Bangalore – 1998

IX
Prof. H.Y. Mohan Ram, INSA Senior Scientist, University of Delhi, New Delhi – 2000

X
Prof. J.S. Singh, Emeritus Professor, BHU, Varanasi – 2004

XI
Prof. Madhav Gadgil, Centre for Ecological Sciences, IISc, Bangalore – 2005

XII
Dr. S.S. Handa, Ex-Director, RRL (CSIR), Jammu – 2006

XIII
Dr. Lalji Singh, Director, CCMB, Hyderabad – 2007

XIV
Prof. Roddam Narasimha, Chairman, EMU, JNCASR, Bangalore – 2008

XV
Dr. R.S. Tolia, Chief Information Commissioner, Govt. Of Uttarakhand, Dehradun – 2009

XVI
Prof. Raghavendra Gadagkar, CES & CCS, IISc, Bangalore – 2010

XVII
Prof. Vidyanand Nanjundiah, JNCASR, IISc, Bangalore – 2011

XVIII
Dr. Kirit S. Parikh, IRADe, New Delhi & Former Member Planning Commission – 2012

XIX
Prof. Jayanta Bandyopadhyay, Former Prof. & Head, IIM, Calcutta – 2013

XX
Prof. T.S. Papola, Honorary Professor, ISID, New Delhi – 2014

XXI
Dr. David Molden, Director General, ICIMOD, Nepal – 2015

XXII
Prof. K. Vijayraghavan, Secretary-DBT, New Delhi – 2016

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