Global Warming on Himalayan Ecosystem with special reference to Glacial lake Outburst Floods (GLOF)

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At the outset, one should admit that the geographical position of India is extremely vulnerable towards the onslaught of global warming. Almost three-fourth of its boundary line is contiguous with ocean and in the north there situates World's tallest and largest mountain range the Himalayas. Serious threats would come not only from the coastline, but also from the Himalayas embracing the vast river basin area of the Gangetic plain. Virtually due to the presence of Himalayas we have so long been enjoying congenial climate, enough water, high soil fertility, but due to human fault we are perhaps going to see the other face of the Lord Shiva, the cruel face of destruction, devastation and misery.

The length of the Himalayan ranges is over 1,500 miles. The snowline starts, on an average, from the altitude of 16,000 feet. Snows and glaciers have been stocked in various depths and dimensions on ridges and furrows of this vast area of the mountain ranges. A small fraction of the glacier melts and supplies enough water to the snowfed mountain streams and rivers. Due to rising of temperature if a major portion of the ice block starts to melt there may be incident of long lasting off season floods. A chain of catastrophic events may result in due to outburst of glacial lakes, the glaciers will gradually diminish in volume and ultimately the reduced water supply coupled with high temperature would pose serious threats to the entire forest cover of the Himalayan ranges as well as agricultural and horticultural productions of the Gangetic plain.

C_3 and C_4 plant species

Plant species can be divided into three groups based on their method of fixing carbon dioxide. These include the C_3 Calvin-cycle type (C_3, plants), the C_4 dicarboxylic acid cycle type (C_4 plants) and the crassulacean acid pathway type (CAM plants). Most of the evergreen and deciduous trees of the Himalayas and Himalayan horticultural fruit trees like apple, apricot, almond, pear, peach, plum, chestnut, walnut, cherry, strawberry and crop plants like rice, wheat, oat, barley, soybean, cotton, jute, tobacco, etc., are belonged to C_3 group. These C_3 plants are more adaptive to lower temperature, their optimal temperature range for photosynthesis is 10-25°C. Hence, their growth and yield would be severely reduced at high temperature. On the other hand, most of the weeds including grasses and sedges along with a

Table 1. Some of the Characteristics which distinguish Plants of High Photosynthetic Capacity (C_4 plants) and low Photosynthetic Capacity (C_3 Plants)[1].

Characteristics[2]	Capacity for Net Photosynthesis[3]	
	C_4 plants	C_3 plants
1. CO_2 compensation point	0-10 ppm CO_2	50-150 ppm CO_2
2. Photorespiration	Present only to a slight degree and therefore difficult to detect	Presented and easily detectable
3. Net rate of photosynthesis in full sunlight (10,000-12,000 ft.c.)	40-80 mg of CO_2 per dm^2 of leaf area per h	15-35 mg og CO_2 per dm^2 of leaf area per h
4. Response of net photosynthesis to increasing light intensity	Difficult to reach saturation even in full sunlight	Saturation intensity reached in the range of 1000-4000 ft.c.
5. Highly developed bundle sheath cells with unusual concentration of organelles	Present	Absent
6. Major pathways of photosynthesis CO_2 fixation	C_4-dicarboxylic acid and reductive pentose phosphate cycles	Only reductive pentose phosphate cycle
7. Temperature optimum for photosynthesis	30-45°C	10-25°C
8. Response of photosynthesis to O_2 concentration in the external atmosphere	Not inhibited in air (=21% O_2), as compared to an external atmosphere containing no O_2	Markedly inhibited in air (=21% O_2), as compared to an external atmosphere containing no O_2

few crop plants, like sugar cane, maize and Italian millet, etc., are C_4 plants. These C_4 plants physiologically and an atomically are more adaptive to high temperature. Their optimal temperature range for photosynthesis is 30-45°C. Hence, with the increase of global temperature these C_4 weeds with their better competitive advantages would create serious problems in the orchards and crop fields of C_3 plants. The crop loss due to the mite and other insect attacks may also be increased as the growth of these insects is generally favoured at hotter and drier climate. In order to cope with the global warming the agricultural scientists, specially the plant physiologists and crop breeders are advised to concentrate on the researches for raising temperature and drought resistant new cultivars of C_3 plants which could be grown under hotter and drier climate. Physiological and anatomical differences between C_3 and C_4 plants have been shown in Table 1.

Glacial lake Outburst Flood (GLOF)

Since the last few decades the International Centre for integrated Mountain Development (ICMOD) and its partner institutes have been surveying the glaciers and glacial lakes of Himalayan mountain range. World's largest mountain range covering six countries (India, China, Nepal, Bhutan, Pakistan and Afghanistan) is divided into three parallel rows, e.g., the Greater Himalaya is one the extreme north, Lesser Himalaya in the middle and Shivalic range is in the south. There are 800 peaks in Himalayas which are taller than 24000 feet. The total amount of snow and glaciers present in Himalayas is next to that of Antarctic and Arctic circles. The international Centre for Integrated Mountain Development (ICIMOD) along with its collaborating institutes have recorded as many as 15,003 glaciers and 8,790 glacial lakes. Table 2 will show the numbers and areas of glaciers and glacial lakes at different regions of Himalayas and the number of glacial lakes which are vulnerable and potentially dangerous for out bursting. It is observed that glaciers are retreating and melting at a much faster rate than usual. Huge quantity of water is accumulating in the glacial lakes. Due to mounting pressure of water a lake with unstable bank may be exploded partially or entirely causing devastating floods which is called glacial lake outburst flood (GLOF). In the past decades a number of GLOF events have been studied closely. Explosion may be mainly of two types, partial and total GLOF. When cracks are developed horizontally a partial release of water occurs at a very high pressure, but if the cracks are developed perpendicular to the base and at multiple spots, the entire lake may be exploded a chain of catastrophic event follows. An enormous amount of water with extreme pressure suddenly falling upon other glacial lakes causes their spontaneous explosion, creates new glacial lakes, causes multiple avalanches, landslides, destruction of mountain forests, roads, bridges, houses, and dams of the rivers. Ultimately, it ends up with the devastating flood in the river basin.

Table 2 will show that there are 203 potentially vulnerable glacial lakes exist at different regions of Himalayas, GLOF may occur with them at any time. Hence, various effective measures for mitigation are

Table. 2. Summary of Glaciers and Glacial Lakes in Himalayan Regions.

River Basins	Glaciers		Glacial Lakes		
	Number	Area (Sq. km)	Number	Area (Sq.km)	potential GLOF
India Himalayas					
Himachal Pradesh	2554	4160	156	385.22	16
Uttaranchal	1439	4060	127	2.49	0
Tista River	285	376	266	20.20	14
Pakistan Himalayas					
Indus Basin	5218	15040	2420	126.35	52
Tibet Himalayas (People's Republic of China)					
Ganga Sub-basins	1578	2864	824	85.19	77
Nepal Himalayas					
Nepal	3252	5324	2323	75.70	20
Bhutan Himalayas					
Bhutan	677	1317	2674	106.87	24
Totall	**5003**	**33341**	**8790**	**801.72**	**203**

Source : Survey Report of the International Centre for Integrated Mountain Development (ICMOD).

urgently required. But unfortunate truth is, most of them are situated at unapproachable regions and little could be done for their amelioration.

In fact, the entire Himalayas have been converted to an enormous manmade time bomb, which is almost impossible to diffuse. It is estimated that if the 30 of the 203 vulnerable glacial lakes outburst within a short interval of time, a vast area of agricultural land of the country present in the extensive basin area of three vital and perennial river systems, e.g., Sindhu, Ganga, Brahmaputra along with their branches would be totally devastated. It would create a perfect scenario of deluge. The whole episode of global warming including GLOF and its aftermath may be recorded in the history of mankind as a topmost manmade disaster, which in turn, may reduce the span of existence of many species of plants and animals including the growth of human civilization.

Aftermath of Deluge

Due to impact of global warming when most of the snow will disappear from the mountain top, mountain streams will start to dry up and its adverse effect on the Himalayan temperate forest ecosystem will be intense. The phytogeographical boundaries will be shifted with shifting of isothermal lines. The evergreen oak forests, coniferous forests, alpine scrub and meadows at higher altitude of the Himalayas will suffer most. They would perhaps be replaced with C_4 thorny hedges and grasses and similar other xerophytic plant species.

The Himalayas are said to be the home of about 3,000 endemic plant species. If these species lost their homeland, most of them perhaps would disappear from the face of the Earth. Many rare endemic species of orchids, *Rhododendrones, Saussureas, Primulas, Impetiens, Gentianas, Meconopsis*, etc., may become totally extinct. Trees of temperate and semi-temperate forests, e.g., *Abies, Acer, Alnus, Cedrus, Pinus, Taxus, Cryptomeria, Cupressus, Salix, Juniperus, Quercus* (Oak) associated with under growth and annuals with attractive flowering rhythm and unique ecological cycle, e.g., Brahma Kamal (*Saussurea obvallata*), Sow's ear (*Saussurea tridactyla*), Stuarts' primrose (*Primula Stuarti*), Musk thistle (*Carduus nutans*), Stalked gentians (*Gentiana stipitata*), Himalayan trumpet gentian (*Gentiana depressa),* Himalayan poppies, blue and yellow (*Meconopsis aculeata* and *M. robusta*), Wallich's poppy (*Meconopsis wallichii*), Himalayan lily (*Lilium oxypetalum*), Knotweed (*Polygonum affine*), Himalayan rose (*Rosa macrophylla*), Jocobs' ladder (*Polemonium caeruleum*), Himalayan edelweiss (*Leonto-podium stracheyi*) and numerous other cold loving plant species of Himalayan ecosystems would be seriously affected.

The deleterious effect of rising of temperature also will be visible on the yield of apples and other temperate fruit crops of Himalayas, e.g., almond, apricot, peach, plum, chestnut, walnut, strawberry and cherry, etc. At still higher altitude, above the present snow line, congenial low temperature may be available, but the limitations of water and soil cover would become the barriers for mass migration of these temperate species. Melting of snows and glaciers would expose the underneath bare rock surfaces and it would take many thousand years to build up suitable soil cover over there if other factors, e.g., water supply, temperature, microbial activity remain constant at a congenial level. Such disruption of primary productivity of the temperate forest ecosystem also would restrict the growth and distribution of consumers of all the orders. Many animal species of high altitude, like yak, ibex, snow-leopard, mountain goat, lynx, etc., can not tolerate high temperature, when yaks are brought down to the plains they develop a strange liver disease and die within a few months. All the snow loving consumers of the Himalayan ecosystems would become biological refugees and most likely would perish.

If global warming occurs, as observed by Peters and Myers (1991-92), that the ensuing ecological reorganization could be as great as the one at the end of last ice age, a time of mass extinction of species and reshuffling of biological communities. The IPCC* predicts that the most likely rate of warming will be one-degree rise in average temperature above today's by 2025 and three degrees before the end of this century. This rate would be 15 to 40 times faster than past warming periods. A three degree increase would make the Earth warmer than at any time in the past 100,000 years, and 4 degrees would make it the warmest since the – Eocene period, 40 million years ago. David Maddox, and ecologist with the Nature Conservancy, in collaboration with John Kartesz of the North Carolina Botanic Garden, USA concluded that if the Earth warms 3 degrees, climatic conditions would become unsuitable for roughly 20% of 14,000 native vascular plant species of USA. (For those plants already on the endangered or threatened lists for other reasons such as habitat destruction, the figure is 70%. Unless these species can migrate or be moved to suitable new habitat, they are likely to become extinct.

With a 3-degree rise of temperature, according to a moderate estimation of the present author, 70 to 80 per cent of plant species of the Himalayan forests would find the climate extremely hostile and unsuitable for their existence. But the most tragic part of the drama is – there would be hardly any place available for them for natural migration unless they adapt themselves with changing climate. Such possibility for adaptation perhaps is greater among the short lived herbs than that of valuable tree species. Shorter life cycle permits a more rapid evolutionary development through a more rapid genetic turnover. Many new species also may be evolved. But a long time span would be necessary for such adaptation, speciation and stabilization.

The Strategy for Mitigation

In order to mitigate the greenhouse effect a number of international strategies have been put forward and hotly debated in Rio Conference in June 1992. One such strategy, as formulated by Mick kelly of the Climatic Research Unit in the School of Environmental Science at the University of East Anglia, England, is as follows :

1. A 30 per cent reduction of carbon dioxide emission from burning of fossil-fuels from the present amount by the year 2020.

2. A 25 per cent reduction of accumulation methane and nitrous oxide in the atmosphere by the year 2020.

3. A ban on the production of CFCs and halon and avoidance of other compounds that may produce greenhouse effect.

4. A halt of deforestation by the year 2000, followed by extensive reforestation, which could absorb 1.6 billion tons of carbon dioxide from the atmosphere per year.

Growing human number place greater demand on fossil-fuel, food and forests. It seems almost impossible to implement this strategy unless we restrain our demand by reducing the population growth successfully. The present growth rate of human population is beyond the bearing capacity of this planet. In fact, it is a challenge to our survival, perhaps we have to alter our life-style altogether to cope with the changing climate in future.

The figure 1 shows that the global warming may be halted and stabilized around the year 2050 if the aforesaid strategy is followed by all the nations. The upper limit for such stabilization 2.5°C, lower limit 1.0°C and the average 1.75°C increase from the pre-industrial norm. Even such average limit of rising temperature, according to experts, may cause such a shift to climate change which is unseen and unprecedented in human civilization.

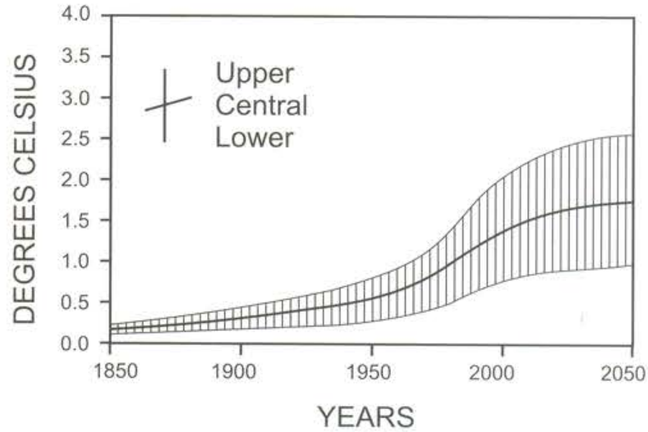

Fig. 1. Global warming may be halted and stabilized around the year 2050 if an international strategy is implemented rigorously. Upper line of projection indicates the maximum limit (2.5°C), lower line for the minimum limit (1°C) and the central line denote the average (1.75°C) increase of temperature from the pre-industrial norm.

Influence of Other factors

Virtually all scientists agree that if the emissions of greenhouse gasses are not controlled and all other factors remain the same, the Earth will warm up. But the crucial issue is to what extent other factors remain the same. With slight climatic change host of other factors would start to play their role simultaneously and many of them may work in favour of keeping the climate in an equilibrium. Critics of the greenhouse effect argue on following points :

The ocean and oceanic planktons have enormous capacity to absorb carbon dioxide. Past geological history and fossil records show that many times over millions of years the Earth faced large-scale volcanic activity which had loaded the atmosphere with carbon dioxide and heated the climate. Oceans themselves did act as biophysical buffer system. Along with the absorption of carbon dioxide by oceanic water the population of phytoplankton as well as micro-foraminifera and other shell forming organisms increased many folds. These oceanic creatures took carbon dioxide and used the carbon to make their protective shells. When the organisms died, their shells sank to the bottom of the ocean, locking the carbon away in mineral deposits that one day would rise from the sea as white chalk cliffs. A vast coastal area of England is crowded with lofty chalk cliffs which indicates that long time ago the climate of this region was warmer and carbon dioxide in the atmosphere was plenty. Almost similar history about the dolomite cliffs of Northern Italy and Austria, which stand majestically dominating the sky line of these countries, the height of the highest dolomite peak is over 3,000 metres. Dolomites are the double carbonates of calcium and magnesium, their origin was from warm, shallow sea water.

These chalk and dolomite cliffs are the products of greenhouse effect of the past. Hence, in future, in a similar way the greenhouse effect would be mitigated, critics are apprehending. But it should also be borne in the mind that deficiency of iron and high pollution level on the continental shelf would pose a serious impediment against such unlimited growth of these oceanic creatures in future.

1. After Black, 1971 (Table 1).
2. These characteristics apply to fully differentiated tissues only.
3. All comparisons are at 21% oxygen, 0.03% carbon dioxide, or otherwise as near physiological conditions as possible.

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