Ph.D. Title: **Impact Analysis of Climate Change on the Dynamics of Glaciers in Bhagirathi River Basin, Garhwal Himalaya, Uttaranchal**

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ABSTRACT

The altitudinal organization of landforms has produced a distinctive landform association which is important for understanding landscape evolution and changes through time. The result of the impact assessment of geomorphic processes clearly portrays a picture of vulnerable areas of the Bhagirathi Basin. These vulnerable areas are the expression of surface configuration and presence of stream networks. The most significant aspect of this study was the identification of the fluctuation of snout elevation in the Gangotri basin in the last few years. The geomorphological studies are in great help in establishing the relation between the terrain geomorphology and pattern of glacier fluctuations. Besides, they are also indicative of the past glaciation record and also the extent of the past glacial activity.

Two results of the Hypsometric analysis, one is for Bhagirathi River Basin and another is for Gangotri Basin are clearly shows that Hypsometric curve starts from top in the shape of the concave and in the middle in changes and it become convex shape. So, this kind of shape is clearly shows that the basin is very dynamic and in-equilibrium stage in nature. So, it shows that the basin is vulnerable to the land slide, land erosion or any other natural phenomena.

The sub-basin wise analysis of the Bhagirathi basin is the approach to find the behaviour of small glaciers in a sub-basin. So, it has been clearly found in the sub-basin wise analysis that each sub-basin behaves differently in the same period and climatic condition. Imagery analysis shows that a linear decrease in the snow cover and debris cover. And also shows that there was little faster retreat in the year 1980-90 compare to the 2000-2006. The glaciers smaller in size are under a big threat.

The glaciers have vacated as much as 30% of their area. Moreover, the larger glaciers have shown a reduction in the areal extent, whereas the smaller glaciers have increased in number. With the gradual retreat, the tributaries of the glaciers are susceptible to a detachment from the main body, thus showing fragmentation. This fragmentation has been observed in the images during the interpretation and analysis process. Therefore, it can be said that smaller glaciers are more prone to the changes in climatic conditions and larger glaciers more susceptible to fragmentation.

The gradual shifting over a period of almost four decades can be a consequence of a shift in Equilibrium Line Altitude (ELA), which has been constantly moving upwards showing a retreat of glaciers in the region. Continuous snow cover study using MODIS data gives the clear picture of changes in the glacier area on weekly basis. The present result gives the detailed meteorological observations conducted for four-summer seasons (May–October, 2000–03) on the Gangotri Glacier. Results show less rainfall, low air temperature, high wind speed, high evaporation and moderately high humidity. Average seasonal (May–October) rainfall was about 260 mm. Daily rainfall hardly exceeds 15mm in the study area. About 77% rain events recorded daily rainfall of less than 5mm.

Results indicate that changes in minimum temperature are more significant than the changes in maximum temperature. Strong winds were observed during daytime and would have contributed to high rate of evaporation even at high altitudes. High sunshine hours in the region are also responsible for higher evaporation. In general, high relative humidity was observed throughout the melt period. The SRM results from Gangotri Basin shows that 9% seasonal difference in the total discharge volume and R^2 value of 0.8832. It shows that the SRM provides quite accurate simulation results even with very little historical data. But the adjustment of the model parameters represents a crucial task.

It has to be concluded that this process of adjusting the model parameters in areas of sparse ground truth has to be undertaken as carefully and thoroughly as possible. In addition, not only one melting period alone has to be considered but at least two or even more. The problems associated with glacier retreat in the face of climate change are not straightforward. On the one hand current increased melting induces a gradual increase in discharge. In the longer term however as glacial mass decreases there will be a ‘tipping point’ as runoff begins a decrease trend with massive implications.

These studies strongly suggest that there is need to collect continuous hydro-meteorological data in the high altitude regions to study the changes in the meteorology and hydrology of the high altitude regions. The utility of Remote Sensing and GIS has revolutionised the studies in the field of glaciology. The satellite data provides synoptic, multispectral and repetitive coverage, which can be highly useful for inventory based studies of natural resources and evaluation of terrain. But a detailed and long term monitoring programme still needs to be given a weightage by the policy making.

In order to manage the impacts of climate change on glaciers, the nature of these impacts with respect to individual glaciers or drainage basins need to be understood. In the Himalayas although there has been research at a large scale on glacier retreat there has been no work at the scale of the individual glacier or drainage basin. So current research is one of the first attempt to study sub-basin wise analysis to drive some policy response.