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First GLORIA Site in Indian Himalayan Region: Towards Addressing Issue of Long-Term Data Deficiency in the Himalaya

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Abstract Under changing climate scenario, the need for Long-term Ecological Monitoring is well recognized for climate sensitive alpine environments in the Himalaya. Present study briefly describe the outcome of the attempt made for establishing first site of Global Observation Research Initiative in Alpine Environments in Uttarakhand, India. Base line on plant diversity (121 species) across observational sites (4 summits) has been prepared for comparison and detecting changes in vegetation diversity in future.

Keywords Climate change · Long-term ecological monitoring · GLORIA · Mountain summits

The Intergovernmental Panel on Climate Change (IPCC) described the Himalayan Region as data-deficient in terms of climate monitoring [1]. Further, the paucity of long-term climate data in the region, and uncertainty of data quality, has been underlined specifically on account of compatibility mismatch of instrumentation and methodology [2]. This calls for an urgent attention of researchers in the region. Further, the urgency for Long-term Ecological Research (LTER) in the region, following standard methods, has recently been highlighted [3].

As elsewhere in the mountains, the alpine environments in the Himalaya are very rich and unique in plant diversity

[4, 5] and represent one of the most sensitive ecosystems to global warming [6]. Numbers of studies from other mountain regions have provided evidences establishing that as a consequence of global warming plant species and communities in high mountains are changing fast and moving upwards which may get eliminated if already at mountain summits [7–10]. However, in absence of long-term monitoring sites in alpine region of Indian Himalaya, no such data sets or evidences are available to assess the trends of vegetation changes due to changing climate.

Towards addressing this data gap in the Indian Himalayan Region (IHR), especially in alpine areas, the G.B. Pant Institute of Himalayan Environment & Development (GBPIHED) under its Biodiversity Conservation and Management Programme and in collaboration with Kailash Sacred Landscape Conservation and Development Initiative (KSLCDI) has initiated establishing Long-term Ecological Monitoring (LTEM) sites in Chaudans Valley of Pithoragarh, Uttarakhand, following the Global Observation Research Initiative in Alpine Environments (GLORIA) procedure.

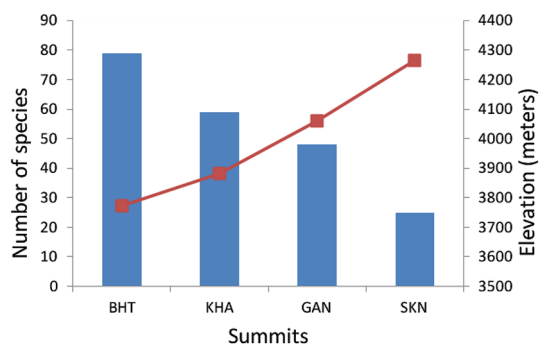
GLORIA standard design of Multi-Summit Approach was followed to establish the observation sites [9, 10]. The observation sites, known as the target region consisted of four summits, exposed to the same regional macroclimate, along an altitudinal gradient from above the natural tree line ecotone up to the uppermost vegetation zone (Table 1; Fig. 1). In each summit, sampling was made in 16 permanent quadrats (1 m × 1 m) and eight summit area sections (SAS), which were well demarcated with an understanding to continue temporal monitoring, possibly at an interval of 5 years. Detailed sampling of species of vascular plants within each quadrat and SAS provided a baseline for detecting changes in species diversity and composition over the time. The details of the summits,

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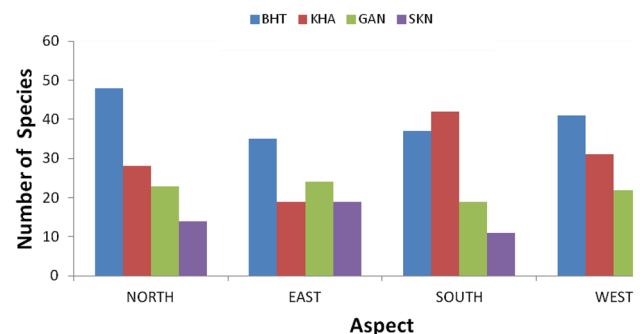
Table 1 Summits of GLORIA's active target region (TR) in Chaudhans Valley, India

Locality (Summit code)	Altitude and geographical location	Vegetation zone	Plant species richness
Bhairav Ghati (BHT)	3773 m Lat: 30°02.782'N Long: 80°39.122'E	Lower alpine; above the tree line. <i>Danthonia</i> , <i>Kobresia</i> and <i>Jurinea</i> dominated	A total of 79 species (62 genera; 31 family)
Kharangdhang (KHA)	3881 m Lat: 30°02.927'N Long: 80°39.320'E	Transition between the lower and upper alpine. <i>Oxygraphis</i> , <i>Geranium</i> and <i>Trachydium</i> dominated	A total of 59 species (45 genera; 26 family)
Ganglakhan (GAN)	4060 m Lat: 30°03.113'N Long: 80°39.575'E	Upper alpine; the top region. <i>Trachydium</i> , <i>Kobresia</i> and <i>Potentilla</i> dominated	A total of 48 species (40 genera; 22 family)
Sekhuakhan (SKN)	4266 m Lat: 30°03.783'N Long: 80°39.927'E	Transition between the upper alpine and nival. <i>Potentilla</i> , <i>Kobresia</i> and <i>Geum</i> dominated	A total of 25 species (24 genera; 19 family)

**Fig. 1** Plant species richness at different summits

altitude, geographical location and plant species richness are presented (Table 1).

The floristic diversity analysis of the GLORIA site revealed presence of a total of 121 species. While comparing the number of species across summits, the lower elevation summit was represented by highest number of species; and the number of species declined with increasing altitude of summits (Fig. 1). Richness of species across diverse aspects of summits varied considerably (Figs. 2, 3). It was interesting to note that the North and the West aspects followed the general pattern of species decline with increasing altitude of summit.

**Fig. 2** Species richness trends across different aspects of TR region

However, the East and the South aspects did not follow this trend.

As defined in the GLORIA protocol, the vegetation cover will be resurveyed at 5 years interval so as to detect patterns of changes. Further, GBPIHED plans to establish more GLORIA sites in representative areas of IHR, to understand variations in trends of the Climate Change impacts on vegetation across the region. The data generated from the present site have formed first of its kind base line and will definitely help in detecting the changes of vegetation diversity in sensitive alpine area in IHR. Also, the data sets will feed to global GLORIA network data-base.

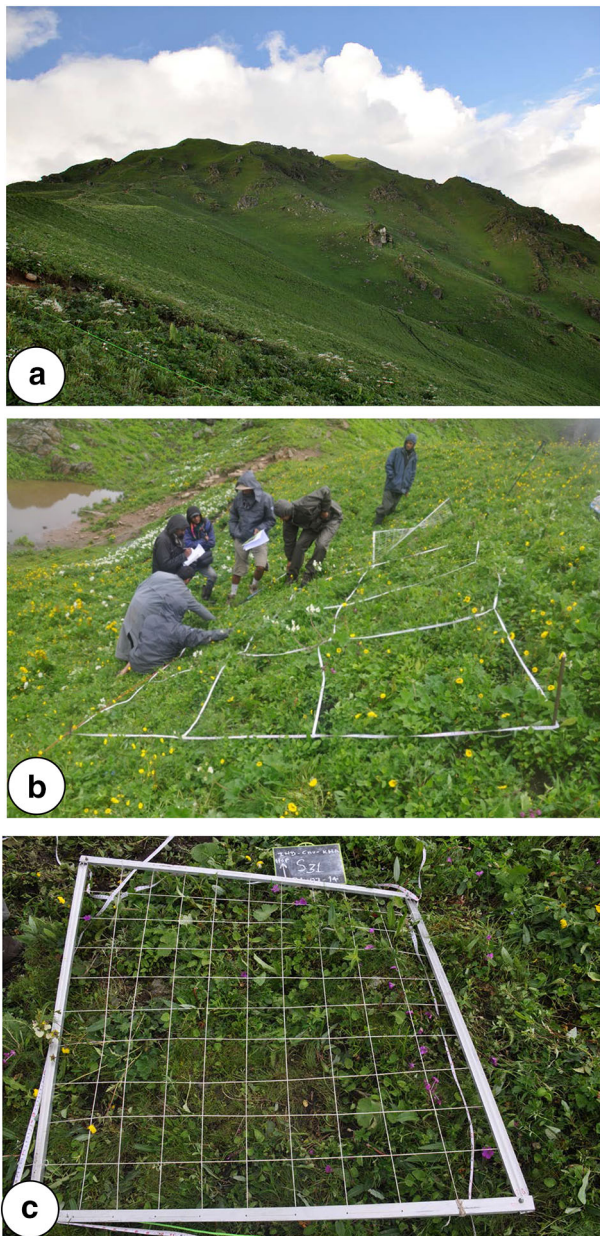


Fig. 3 GLORIA TR in Chaudans Valley; **a** KHA summit region; **b** Quadrat cluster in North aspect of KHA summit; **c** 1 × 1 m grid frame for frequency counts in S31 of KHA summit

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