Need to declare the Higher Himalaya an eco-sensitive zone

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The recent disasters in Uttarakhand, India (e.g. 2013 Kedarnath, 2021 Rishi Ganga and 2023 Joshimath) and Himachal Pradesh (e.g. 2000 and 2013 Satluj–Kinnaur floods and 2023 Beas floods) have reignited the debate of anthropogenic impact on Higher Himalayan valleys and potentially increased impact of disasters in the region[1]. It is feared that under the impending climate change scenario, the sustainability of the geologically fragile Higher Himalayan ecosystem would be threatened, endangering the safety of infrastructure such as habitation sites, roads and hydropower projects. The climate-sensitive Higher Himalaya is not only the abode of endemic and endangered flora and fauna but also contains a large number of glaciers which sustain millions of people inhabiting the Indo-Gangetic Plains. Therefore, it is now being increasingly considered that similar to the Bhagirathi Eco-Sensitive Zone, the river stretches between the headwaters till the southern flank of the Main Central Thrust (MCT) covering a stretch of ~125 km should be declared as eco-sensitive zones (Figure 1).

Fragility, diversity and divinity are the hallmarks of the Higher Himalaya. An outcome of continent–continent collision was the maximum horizontal shortening of the Higher Himalayan domain along the MCT, for example, extreme topography developed with elevation range of <1000–>7000 m as in Uttarakhand and Himachal Himalaya.

This is manifested by the over-steepened topography, the presence of convexity along the river longitudinal profile, and the development of stationary knick points. These features suggest that uplift (convergence) is outpacing the incision (downcutting by the river), thus implying that the slopes of the Higher Himalayan valleys are unstable.

The Himalayan rivers contribute ~10% of the total global sediment budget, where ~44% of total sediments are stored in the glacially scoured Higher Himalayan valleys[2]. Therefore, it is considered that the Higher Himalayan valleys are sediment-surplus and transport-limited. These sediments are left behind by the receding glaciers, and the valleys where they are sequestered are called the paraglacial valleys (zones), having reasonably long sediment residence time (10^3–10^4 years). A study pertaining to past floods in the Alaknanda valley suggested that since the last 6000 years, multiple floods have originated from the Higher Himalaya (around the MCT), transporting 86–45% sediment[3]. Similarly, studies in the Satluj basin indicated that the Higher Himalayan paraglacial valleys have been the source of sediments for the last 14,000 years[4]. In the upper Ganga catchment, during the 20 July 1970 Alaknanda flood, ~15.9×10^6 tonnes of sediment was generated within a 30 km radius of the MCT[3]. Similarly, in 2013, most of the sediments were mobilized from the Higher Himalaya responsible for the destruction of under-construction and operational barrages along the Mandakini, Alaknanda and east Dhauli Ganga rivers[3]. The eastern Dhauli Ganga transported ~6.2 million cubic metres of sediment during June 2013 and filled an operational dam (above Dharchula) with ~2.8 million cubic metres of debris in just a one-day flood event[3]. These sediments sometimes damage the hydropower project gates constructed in the Higher Himalaya. For example, the radial gates of the Vishnuprayag Hydropower Project in the Alaknanda Valley were damaged during the June 2013 floods and, more recently, during the July 2023 Beas floods, the Malana dam gates were obstructed by sediments in the Parvati valley.

Unusual weather events in the Himalaya are showing an increasing trend. This is manifested by the rise in the frequencies and magnitude of springtime forest fire events, avalanches, flash floods and landslides. Is this an unpredictable response to climate warming in the Himalayan region? Global warming is more rapid at higher elevations, attributed to elevation-dependent warming[5]. It is projected that by the end of the 21st century, the temperature in

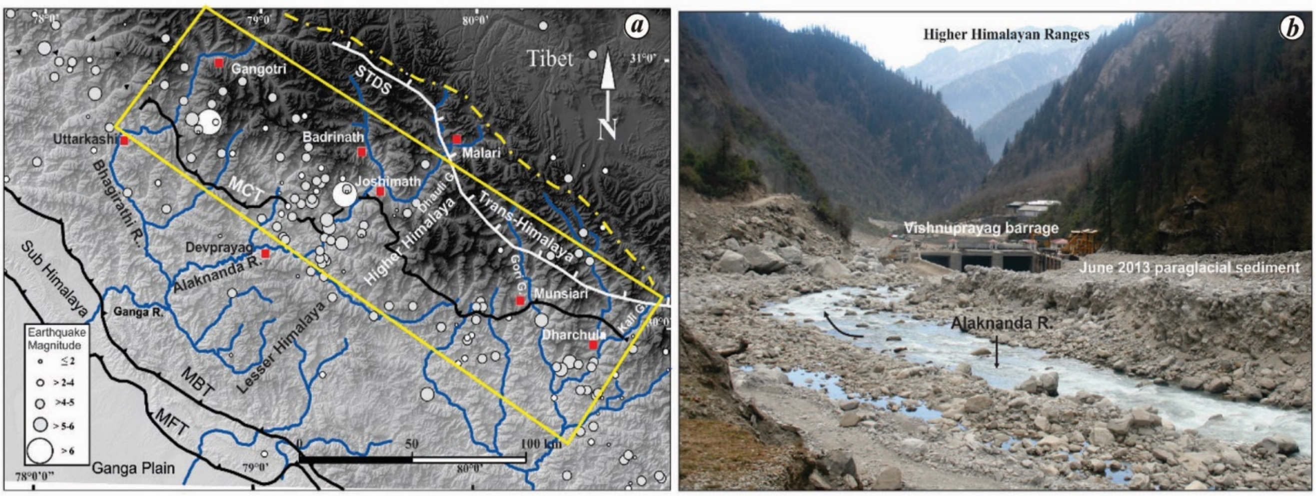

Figure 1. Digital elevation model showing major structures (MFT, Main Frontal Thrust; MCT, Main Central Thrust; MBT, Main Boundary Thrust and STDS, South Tibetan Detachment System) traversing the upper Ganga catchment. Yellow rectangle marks the area to be declared as the eco-sensitive zone in Uttarakhand, India.

the Higher Himalayan region will be between 2.6°C and 4.6°C (ref. 5). Consequently, it can be speculated that the unstable paraglacial sediments sequestered in the Higher Himalayan valleys, if not allowed to flow freely (obstructed by built-up structures), will adversely impact the infrastructures[6]. In addition, the increasing anthropogenic interventions are adversely impacting the stability of the precariously stabilized valley slopes, as seen in the recent example of Joshimath town in Uttarakhand[7]. A recent study by Li *et al*.[8] warned that global warming-induced melting and thawing of the cryosphere is likely to impact High Mountain Asia, which would adversely affect the downstream food and energy systems, particularly the hydropower projects in the Higher Himalaya that are vulnerable to a complex set of interacting processes.

Considering the above, we must tread cautiously in this region to safeguard the Higher Himalayan ecosystem, life and property, including the vital infrastructure. The sentiment towards protecting the Higher Himalaya through eco-sensitive zones was recently echoed in Parliament by the Minister of Environment, Forest, and Climate Change, Government of India (GoI). While replying to a question on the declaration of eco-sensitive zones in 13 Himalayan states, GoI willingness was shared to create 'shock absorbers' which can act as transition zones between specialized ecosystems such as protected areas (or other natural sites) and more resilient zones at lower elevations. GoI has already notified two ecologically sensitive areas and 92 eco-sensitive zones in 13 Himalayan states, a welcome initiative.

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