Dayara Bugyal (pasture): a sensitive ecosystem requiring critical care

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The principal traditional functions of pastures are to capture solar energy, convert it into plant biomass for feeding ruminants, and efficiently recycle nutrients and water. Additionally, ecosystem functions such as carbon sequestration, mitigation of greenhouse gas emissions and opportunities to diversify the forage–livestock system are the hallmark of alpine pastures[1]. Besides, they also act as the first line of defence by way of protecting the organic-rich soils which are known to sequester a considerable amount of organic carbon. The Himalayan (similar to Alpine) pastures, located between tree and snow line, act as a cushion for the falling rain over the higher Himalaya and thus, recharge the groundwater. In Uttarakhand Himalaya, India, as in most of the Himalayan regions, local inhabitants traditionally consider the region as the abode of God. Therefore, customs such as wearing shoes, plucking unripe flowers, wearing bright colours and making noise are forbidden. These unwritten traditional laws/customs were passed on from generation to generation to protect and conserve the ecologically sensitive, high-altitude fragile pastures. As rightly suggested by Negi[2], the religious beliefs were in fact blended intelligently with the conservation of the fragile Himalayan ecosystem. Be it the glaciers, pastures, village springs or forests, the conventional worship practices and the natural resources in Uttarakhand Himalaya have always been inseparable entities.

In Uttarakhand Himalaya, ~24% of the total geographical area is under the alpine zone which is significantly threatened by increased population pressure and growing tourism[3]. The Dayara Himalayan (alpine) pasture, henceforth the Dayara Bugyal, is no exception. It is in the Uttarkashi district of Uttarakhand at ~3600 m amsl. The nearest villages, Barsu and Raithal are ~8 km from this magnificent pasture nestled between the deodar and rhododendron trees. According to the Uttarakhand Forest Department, the bugyal is spread over an area of ~400 ha and consists of 14 threatened and endangered plants. In recent years, due to anthropogenic pressure superimposed by climate change extremes (increasing incidences of extreme events focused in the higher Himalaya), there is growing concern about the geological and ecological stability of this pasture (http://webline.co.in/cf/presentation-eco-restoration-of-alpine-meadows-sandeep-kumar.pdf).

Geologically, the Dayara Bugyal lies in the vicinity of the tectonically active Main Central Thrust (MCT). The rocks (dominantly crystalline) are highly sheared and fractured because of infrequent earthquakes, the recent one being the 1991 Uttarkashi earthquake, the epicentre of which was located in the vicinity of the Dayara Bugyal.

Recently, a large team of researchers from multiple institutions carried out geodetic monitoring of the landslide-prone area in the Bhagirathi valley, Uttarakhand[4]. They installed a continuously operating GPS at the villages of Raithal and Bhatwari (Figure 1 *a*). The relative motion between Raithal and Bhatwari was observed to increase with time, and it was consistent with the ground deformation features observed in the region. Raithal village is located a few kilometres east of Dayara Bugyal. The movement was predominantly eastward, varying from 12 (2006) to 22 mm/yr (2015). This would imply an increase in the rate of slope movement (Figure 1). Further, the study also observed that the area was subsiding at a rate of ~6 mm/yr (during 2012–16). This has implications for the stability of the Dayara Bugyal located in the upper reaches. The development of multiple scarps and gullies in the Bugyal could be geomorphic manifestations of the creep observed in the lower reaches. It seems logical to expect that the creep must have already moved upward towards the Dayara Bugyal. However, before we arrive at this inference, scientific validation is necessary. Needless to say that Dayara requires critical care as also the other alpine pastures in the Himalaya. The headward erosion of the otherwise gently sloping and undulating pasture has also been observed by the Uttarakhand Forest

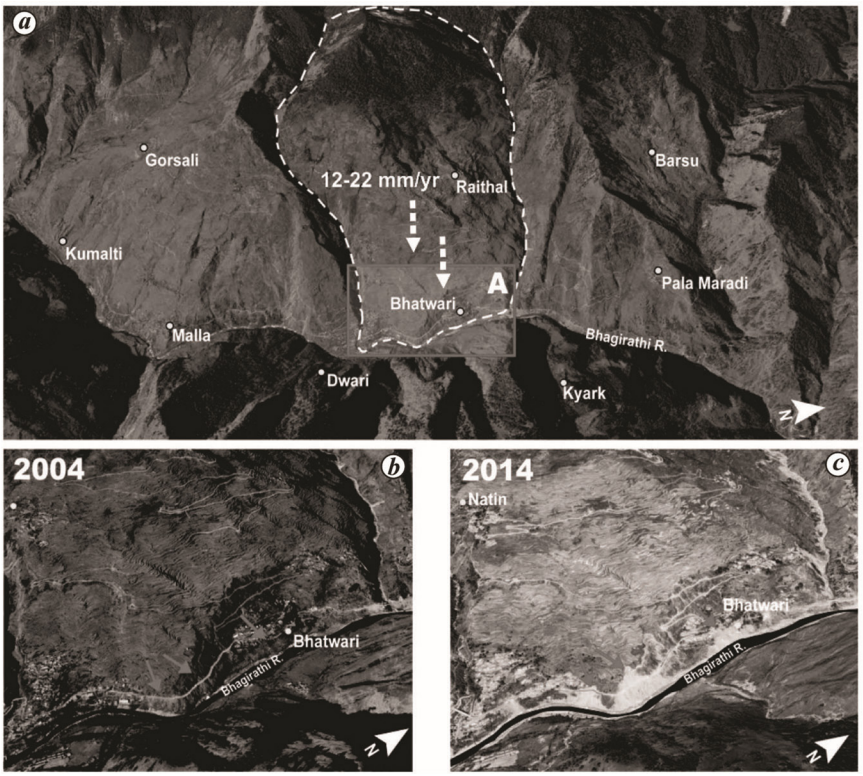

Figure 1. ***a***, Satellite images showing the location of the Bhatwari and Raithal which are creeping at a rate of 12–22 mm/yr. Dayara Bugyal is located in the upper reaches (not shown in the image). ***b***, ***c***, Images of 2004 and 2014 showing an increase in slope instability along the Bhagirathi and an increase in sediment flux in Papad and Swari Gad. (Figures taken from Yadav *et al.*[4]).

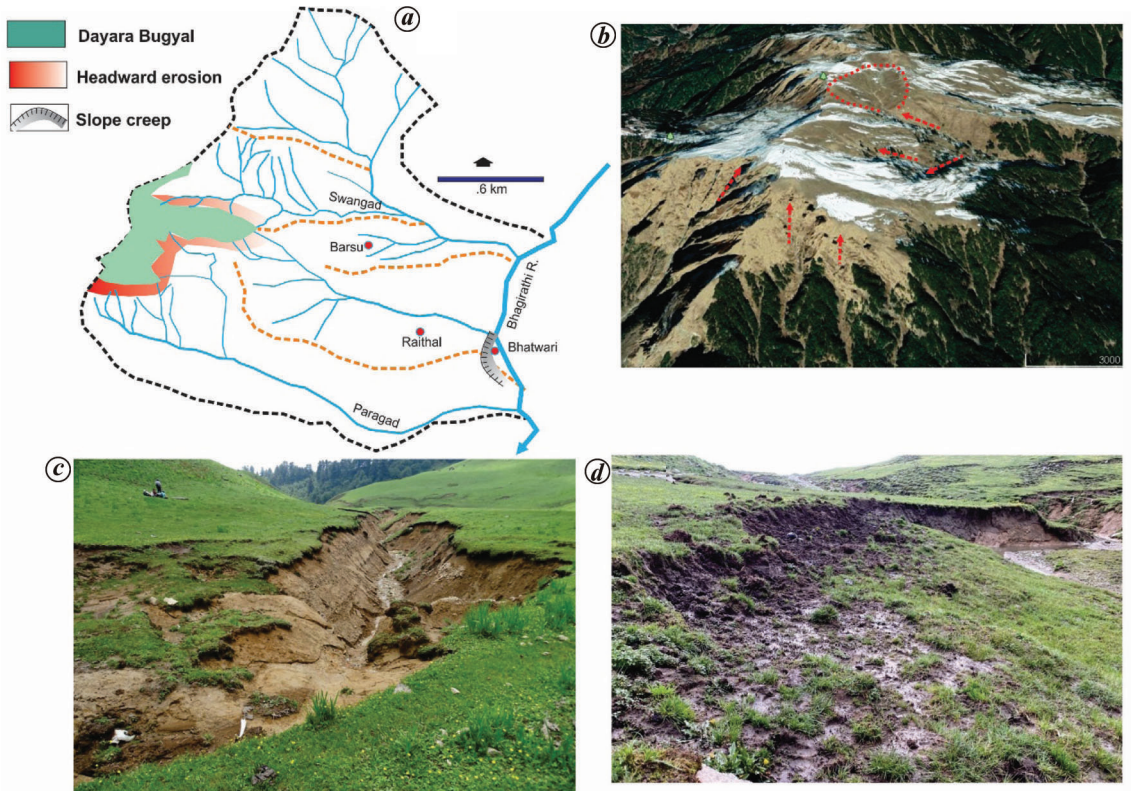

Figure 2. ***a***, Map of Dayara Bugyal along with three major sub-watersheds. ***b***, Google image of Dayara, the red dotted semi-circle indicates area of subsidence. The red dashed arrows show the trend of headward erosion. ***c***, ***d***, The field photographs of headward erosion (initiation of gullies) and solifluction on the bank of a gulley. (Field photographs are from http://webline.co.in/cf/presentation-eco-restoration-of-alpine-meadows-sandeep-kumar.pdf.)

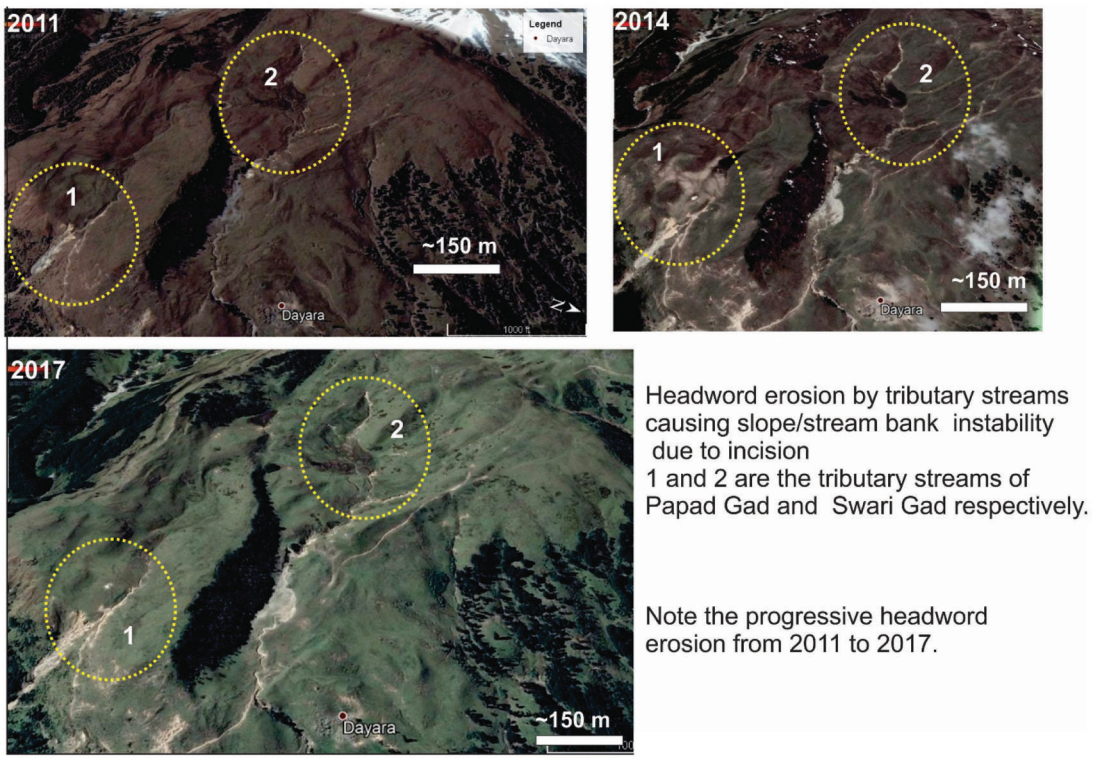

Figure 3. Google Earth images (2011, 2014 and 2017) around Dayara Bugyal showing progressive ingression of channels, particularly by the tributaries of Papad gad and Swari gad.

Department. The Forest Department officials and recent reports have raised serious concerns about protecting this fragile ecosystem. Proactively, they have already undertaken bioengineering measures in order to arrest erosion of the topsoil and headward progression of the gullies. However, with ~16,000 m^2 area degraded, Dayara Bugyal is in need of a massive restoration plan (http://webline.co.in/cf/presentation-eco-restoration-of-alpine-meadows-sandeep-kumar.pdf). If the erosive processes are not countered with mitigation measures, it is highly likely that rills and gullies would widen transforming the pasture into a bad land topography, along with increasing the sediment flux into the tributary stream of the Bhagirathi river (Figure 2 *a–d*).

Thus, the efforts made by the Forest Department need to be expanded to the subwatershed level. At least two watersheds must be red-flagged for conservation measures along with measures for regulating flux of people (Figure 3).

Our preliminary observations based on Google Earth images indicate that all the streams are showing accelerated erosion in their headwaters (upper reaches ~2500–3000 m). There are several first-order streams flanking the Dayara Bugyal (shown by the pink curvilinear envelope in Figure 2). This area is extremely unstable and fragile in terms of slope stability and has already begun to show signs of degradation by way of westward (headward) progression of the gullies. If not checked this would lead to significant ingression into the pasture and eventually erode the carbon (organic)-rich topsoil which provides a substrate for the ecologically sensitive flora along with sequestering organic matter.

Dayara Bugyal lies within the winter snow line (paraglacial zone). The paraglacial zones are known to be extremely sensitive to minor changes in temperature and precipitation conditions. Due to the dominance of solifluction (gradual movement of wet soil down the slope where usually subsurface frozen soil acts as a barrier to water percolation) as well as the freezing and thawing of snow, tampering with hooves/feet can create small depressions in the organic-rich topsoil. This depression when filled with snow meltwater becomes unstable and eventually collapses to facilitate soil creep. This was one of the reasons that our ancestors had advised not to use shoes while in bugyals, which could impact their fragility.

Global warming has become a reality and according to IPCC AR6 (9 August 2021), warmer temperature would significantly impact the Himalayan cryosphere. The report mentions that we may reach a tipping point, where some changes to the earth are going to be irreversible for decades or centuries. This may include the Himalaya pastures located in climate-sensitive paraglacial zones such as Dayara Bugyal. We have already begun to witness the impact of a warm earth by way of unprecedented global fires, including in the Himalaya, extreme rainfall events, flash floods mobilizing voluminous sediments from regions once occupied by glaciers and more recently, avalanches during autumn[5].

We do not yet fully understand the impact of changing climate on these ecologically fragile zones. Any intervention without a critical assessment of the carrying capacity of this zone and possible outcomes must not be carried out. Our traditional and scientific wisdom suggests the ecological fragility of such regions and against any undue intervention. We may cause irreversible damage to the very wilderness which we are trying to harness for economic benefits.

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