



## **Pastures under pressure: restoration of high-altitude rangelands in Bhutan and Nepal**

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**Keywords:** High altitude pasture; restoration; *Rumex nepalensis*; shrub encroachment; weeds

### **Abstract:**

Rangelands comprising 60% of the land area in the Hindu Kush Himalaya (HKH), are predominantly managed under pastoral production systems. The high-altitude rangelands provide critical nature-based solutions to societal challenges, including climate change, biodiversity loss, water scarcity, and food security. Mountain pastoralism, characterized by the seasonal migration of livestock between different elevation pastures, significantly contributes to the economy, food and water security, nutrition, health, cultural identity, indigenous knowledge systems, and biodiversity. In mountainous countries like Nepal and Bhutan, mountain pastoralism also alleviates pressure on lowland areas where land and resources are scarce. However, over the past few decades, government restrictions on traditional pasture management practices, such as cutting and burning, have led to alpine pastures being overtaken by shrubs, significantly reducing forage quality and availability. Additionally, these pastures face severe impacts from erosion, scree flows due to melting glaciers, permafrost thaw, and intense rainfall. Transitional and winter grazing areas suffer from overuse, erosion, and invasion by unpalatable plants, resulting in poor fodder production. Shrub invasion by *Rhododendron lepidotum* and *Berberis spp* and land erosion is further diminishing the availability of high-value medicinal plants and herbs, while critical water sources are also drying up for wildlife, livestock, and herders. This degradation is negatively affecting the biodiversity and ecosystem services, leading to the unprofitability of pastoralism, youth out-migration from mountain regions, and the erosion of traditional pastoral cultures. To address these issues, we are piloting rangeland restoration projects in Tseko, Bhutan, and Shailung, Nepal. These projects employ a combination of methods, including prescribed burning, cutting, thinning, uprooting of weeds such as *Rumex nepalensis* and water management. Through these efforts, we aim to restore and sustainably manage rangeland resources, thereby enhancing ecosystem services, improving pastoral livelihoods, and preserving cultural heritage.

### **Introduction**

Rangelands cover 60 percent of Hindu Kush Himalaya (HKH) and are home to more than 25 -30 million indigenous communities (Sharma et al. 2007). These high-altitude rangelands play a vital role in supporting pastoral livelihoods and maintaining ecological functions, including soil stabilization, carbon sequestration, water regulation, and biodiversity conservation (Joshi et al., 2013; Xu et al., 2019). Rangelands are socio-ecological systems, providing critical ecosystem services and sustaining indigenous knowledge systems (Hruska et al. 2017). The livelihoods of pastoral communities in the HKH are linked to rangeland health, as these ecosystems provide essential grazing resources for livestock. However, the increasing pressures from climate change, overgrazing, unsustainable land-use practices (Wang et al., 2019) and grazing-ban policies pose significant challenges to the sustainability of these rangelands (Singh et al. 2022). In addition, in recent decades the rapid encroachment of unpalatable shrubs and weeds in high altitude rangeland has been widely reported as one of the major causes of rangeland degradation that has drastically reduced forage availability, posing a serious threat to livestock productivity and herders' incomes (Wangchuk et al. 2013; Barsila 2022; Roomi et al. 2023). However, the sustainability of mountain pastoralism depends on the availability of high-quality fodder from seasonal pastures at different elevations. Shrub invasion and land erosion further diminish the growth and availability of highly valued medicinal plants and herbs. In some instances, pastures are fully overrun by pioneering woody species, while critical water sources for wildlife, livestock, and herders are drying up. Consequently, these trends have led to adverse effects on rangeland, making mountain pastoralism economically infeasible. Thus, an integrated approach and careful management are required to avoid negative implications of shrub encroachment and weed invasion. Several studies have reported that prescribed burning is a common tool used for rangeland management (Lohmann et al. 2014; Toledo et al. 2014). Prescribed burning frequently helps to lower the risk of wildfires, manage the spread of woody vegetation, reduce soil erosion, enhance plant diversity and wildlife habitats, and boost forage production for grazing livestock (DiTomaso et al 2010; Alcañiz et al. 2018). While some studies reported that prescribed burns implemented in the summer can benefit restoration by preventing woody encroachment while also controlling an invasive grass (Novak et al. 2021). The main objectives of our restoration trial were to assess the extent and impact of rangeland degradation in two high-altitude sites, Tseko in Bhutan and Shailung in Nepal, and implement targeted restoration interventions. In both the sites, due to the lack of proper management and other reasons, many of these pastures are degraded due to shrub encroachment and made unusable by rampant growth of *Rumex nepalensis* and other weeds species. To address these issues, we applied integrated approaches that include prescribed burning, cutting, thinning, water management, and weed removal. By combining traditional knowledge and modern restoration practices, we aim to enhance forage availability, support ecosystem services, and build resilience among pastoral communities.

## Methods

The study was conducted in two high-altitude rangelands: Tseko in Bhutan and Shailung in Nepal (Figure 1 and Figure 2). In Tseko, the first restoration efforts involved multiple methods: prescribed burning of *Rhododendron lepidotum*, cutting woody shrubs such as *Berberis* spp. and *Rosa* spp., thinning blue pine (*Pinus wallichiana*), water management through the construction of water ponds, and the management of weeds like *Rumex nepalensis*. Prescribed burning trails were carried out in March, April and June 2024. During these trails, the main plant communities of the rangeland and dominant species were identified in burned fenced, unburned fenced and unburned unfenced plots. A total area covering 0.28 ha area was used for burning. Water management interventions included the construction of strategically placed water ponds to improve water availability for livestock and wildlife and increase soil moisture in the landscape.

In Shailung, Nepal, restoration was carried out in Godavari Community Forest and Kalinchowk Community Forest in May 2024. The approach focused on measuring grass recovery and determining the carrying

capacity of rangelands through enclosures. We set up 10 enclosures covering the wider area, five were established at 3000 meters and five at 2900 meters. Each enclosure measured 2m by 2m, and biomass was harvested from 1-meter square plots to monitor growth. Additionally, 20 water ponds measuring 4.5m by 3 m by 0.6 m were constructed in collaboration with yak herders. These ponds were strategically placed to ensure water availability across grazing areas and enhance landscape-level water retention.



Figure 1: Restoration sites in Tseko, Bhutan

## Results

Preliminary results from Tseko indicate the effectiveness of prescribed burning and cutting in improving forage yields and managing shrubs. Two months after implementing prescribed burns, the forage yield in burned and fenced plots was 4.55 t/ha compared with 4.21 t/ha in unburned, unfenced plots. In burned but unfenced plots, forage yield was significantly lower at 0.21 t/ha, likely due to grazing pressure. Fern height was tallest in burned-fenced plots, suggesting that burning facilitated fern growth while protection from grazing allowed for recovery. Cutting management effectively controlled *Berberis* spp., with regrowth heights varying from 54 cm to 190 cm, depending on site conditions. Forage biomass was significantly higher on managed sites compared to unmanaged ones, highlighting the effectiveness of active restoration practices. The *Rumex nepalensis* plant population was highest in the mown plot and lowest in the dug plot, while *R. nepalensis* biomass peaked in the plot that was both mown and reseeded. Forage biomass was greatest in plots that were mown and reseeded, as well as those dug traditionally with branches of sapphire berry. In Shailung the estimated forage biomass is 366.5 kg/ha, with a utilization rate of 50% and a carrying capacity of 0.51 AU/ha, highlighting the overgrazed and degraded condition of the rangelands. With a yak population of 462, the area requires approximately 2,100 hectares of grazing land, further emphasizing the imbalance between forage demand and availability. The current biomass is measured at 145.5 kg/ha. Water ponds have shown promising results in improving water availability for both livestock and wildlife, enhancing moisture levels in the landscape, and supporting the regeneration of forage grasses.

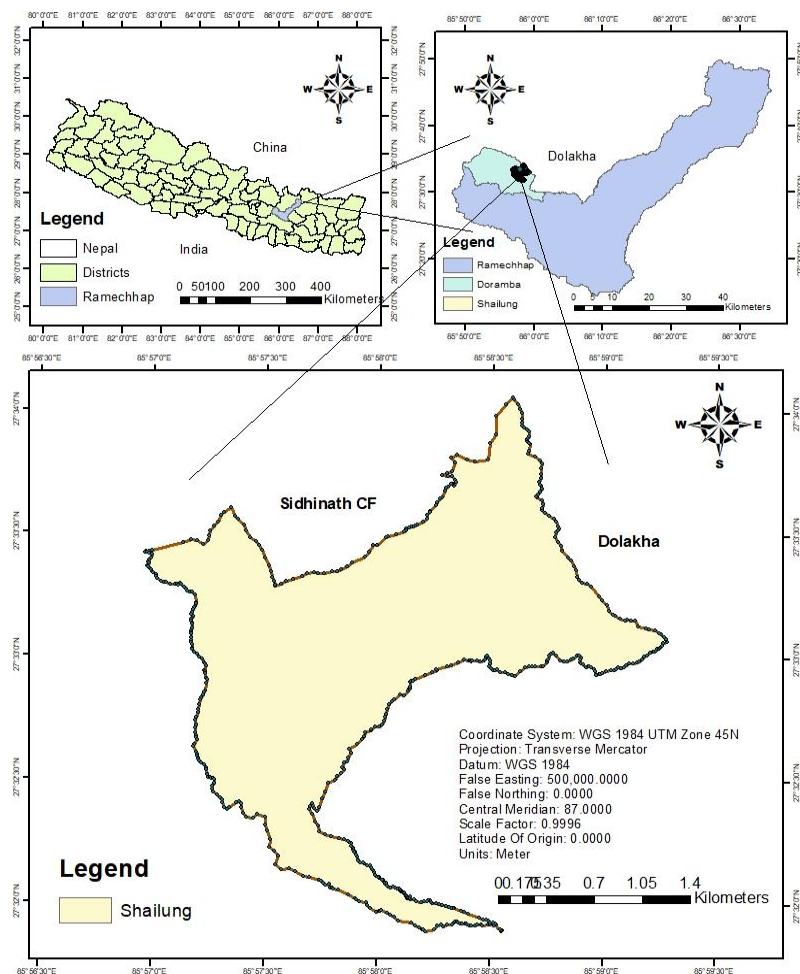


Figure 2: Restoration sites in Shailung, Nepal

## Discussion

High altitude rangeland provides vital ecosystem services including biodiversity conservation, livelihood support, carbon storage and water regulation. However, they are increasingly threatened by shrub encroachment, poor management, soil erosion, overgrazing, medicinal plant extraction, and climate change highlighting the urgent need for both protecting native vegetation and restoring degraded areas. Restoring high-altitude rangelands presents significant challenges, particularly in areas with limited accessibility and rugged terrain. The pilot restoration action in Tseko, Bhutan, and Shailung, Nepal, highlight the importance of integrated strategies to tackle pasture degradation in high altitude rangeland. The initial trials demonstrated benefits such as improved forage production, reduced shrub encroachment, and enhanced water availability through a combination of prescribed burning, cutting, weed removal, water management, and active community involvement. However, restoring degraded rangelands is a long-term process requiring sustained efforts, multidisciplinary collaboration, and continued monitoring (Kuniyal et al. 2021). The initial trials conducted in the first year of action are just the beginning, and these results must be closely monitored over time to ensure their effectiveness.

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