SUNSHINE AGRICULTURE
e-Newsletter

ISSN (E): 2583 – 0821

Sun. Agri.:e- Newsletter, (2026) *6*(3), 1-5

Article ID: 549

Soil Erosion in Chamba Block of Tehri Garhwal District, Uttarakhand: Processes, Impacts and Integrated Conservation Framework

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Open Access

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Available online at
www.sunshineagriculture.vitalbiotech.org

Article History
Received: 22. 2.2026
Revised: 27. 3.2026
Accepted: 3. 3.2026

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INTRODUCTION

The Chamba block of Tehri Garhwal district in Uttarakhand, located in the Lesser Himalayas, is one of northern India's most ecologically fragile mountain regions. Steep slopes (30–60%), weak geological formations, rugged terrain and intense monsoon rainfall (Joon *et al*., 2024) make the area highly vulnerable to soil erosion. Soil erosion here is not only a natural geomorphic process but also a serious socio-ecological issue affecting agriculture, rural livelihoods, infrastructure and water security. Around 16.4 tonne ha^{-1} $year^{-1}$ of topsoil is eroded in India each year, of which 29.0% is lost to the seas, 10.0% is deposited in reservoirs, and the remaining 61.0% is relocated (Dhruvanarayana and Babu, 1983). Many parts of Tehri Garhwal district experience soil loss beyond the tolerance limit (about 11.2 t/ha/year), especially during heavy monsoon rains. Soil texture, soil structure stability, soil permeability and infiltration, organic matter and soil mineralogy are some of the soil factors that affect soil erodibility (Singh *et al*., 1981). Major forms of erosion include sheet erosion, rill and gully formation, landslide-induced erosion and streambank erosion. Together, these processes contribute to ongoing land degradation and declining soil productivity in the region. A significant problem for the environment and agriculture, soil erosion has social, political, and economic ramifications (Grepperud, 1995).

Causes of soil erosion

Both natural and man-made factors contribute to soil erosion in the Chamba block. Steep slopes speed up runoff, which exacerbates soil loss, and heavy rainfall increases the kinetic energy of raindrops, which dislodges soil particles (Mahapatra *et al*., 2018). The terrain is particularly prone to erosion because fragile lithology and poor soil aggregation and seismic activity can destabilise slopes and cause landslides. One of the main causes of land deterioration in India and many other nations is soil erosion brought on by water (Mandal and Sharda, 2011).

Human activities also play a major role in the region's soil erosion: overgrazing reduces vegetative cover, improper terrace maintenance weakens cultivated slopes, unscientific road construction and slope cutting disrupt natural drainage and deforestation and forest degradation reduce root reinforcement and protective canopy cover (Figure 1).

Natural causes	Anthropogenic causes
▪ High rainfall intensity → Increased kinetic energy of raindrops ▪ Steep slopes → High runoff velocity ▪ Fragile lithology → Weak soil aggregation ▪ Seismic activity → Structural instability	▪ Deforestation and forest degradation ▪ Unscientific road construction and slope cutting ▪ Improper terrace maintenance ▪ Overgrazing

Figure 1: Soil erosion in Chamba block, Tehri Garhwal District, Uttarakhand

How soil erosion occurs ?

Surface runoff results from the breakdown of soil aggregates on bare land caused by intense monsoon rainfall. This starts sheet erosion, which leads to the formation of rills and gullies and the loss of productive topsoil. As a result, the Chamba block's agricultural output drastically decreases (Figure 2).

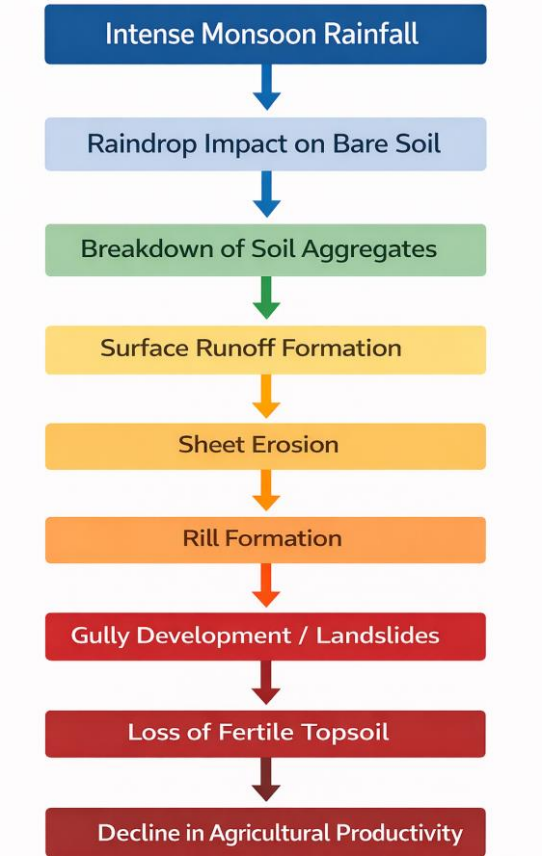

Figure 2: Stages of soil erosion

Impacts of Soil Erosion

Soil erosion in Chamba block has multi-dimensional impacts:

- **Agricultural Productivity Decline:** In rain-fed hill agriculture, the loss of nutritious topsoil immediately lowers soil organic matter, nutrient availability, and moisture retention, resulting in decreased yields.
- **Environmental Degradation:** Erosion increases vulnerability to landslides and surface runoff by hastening the shift from productive land to degraded gently vegetated surfaces and barren slopes.
- **Livelihood and Migration:** Seasonal or permanent migration from rural areas is frequently sparked by reduced agricultural viability, which adds to the socioeconomic strain on hill communities.
- **Infrastructure Risks:** Roads, constructed structures, and water management infrastructure are at risk from sedimentation in water channels and unstable slopes.

Soil conservation framework

In Chamba Block, a variety of structural, biological, agronomic, watershed, policy and technical approaches are used to conserve the soil. Terracing, contour bunds, check dams and retaining walls are examples of structural interventions that regulate runoff and stabilise slopes. Afforestation, agroforestry, cover crops, and grass plantations are examples of biological techniques that improve soil and lessen surface erosion. Crop rotation, conservation tillage, contour farming, and strip cropping are examples of agronomic techniques that increase soil resilience and fertility. Planning from ridge to valley, drainage treatment, and community involvement are all guaranteed by watershed management. While technology tools like GIS mapping, remote sensing and rainfall-runoff modelling enable focused, data-driven interventions, policy and institutional support, as well as initiatives like MGNREGA, assist sustainable land governance. Some of the soil conservation measures have been suggested in table 1.

Table 1: Soil conservation measures and their benefits

Category	Key Measures	Benefits
Structural (engineering) measures	Contour bunding and contour trenches; scientific terracing with drainage outlets and stone pitching; inspection of dams and gabion structures; and bioengineering of retaining walls alongside roadways.	Regulates runoff; maintains slope stability; stops terrace breaches; collects sediments and replenishes groundwater.
Biological & vegetative measures	Cover crops and mulching (Nagdev *et al.*, 2017); afforestation and supported natural regeneration (oak, rhododendron); agroforestry systems that integrate trees with crops; and grass plantations (vetiver, indigenous perennials); the areas of shallow soils which are not suitable for agriculture and tree growth may be used for pasture development; (Sidhu *et al*., 2010).	Promotes root binding; strengthens soil structure; lowers surface erosion; preserves moisture; increases fertility and stabilises slopes.
Agronomic practices	Contour farming; strip cropping; crop rotation with legumes; conservation tillage and the use of organic manure	Improves soil fertility and structure; lessens runoff and soil disturbance; and increases erosion resistance.
Watershed management approach	Micro-watershed planning; treatment of drainage lines; community involvement and monitoring of sediment yield	Guarantees efficient erosion control; integrated land-water management and methodical use of measures.
Policy & institutional measures	Control of unexpected building and slope cutting rewards for environmental friendly agriculture: Gram Land management based on panchayats MGNREGA-sponsored projects Building capacity and educating farmers	Strengthens governance; makes it possible to finance interventions; encourages long-term sustainability and raises community awareness.
Technological interventions	Erosion mapping using GIS; remote sensing for vegetation and erosion hotspots; modelling rainfall and runoff and early warning systems for landslides	Allows for accurate monitoring; data-driven planning; disaster risk reduction and susceptible area prediction.

CONCLUSION

Soil erosion in the Chamba block of Tehri Garhwal epitomises the broader environmental challenge confronting the Himalayan hills. Human activity and poor soil management exacerbate the natural tendency to soil loss caused by the delicate geomorphology, steep slopes and intense monsoon rainfall. The soil resource base of Chamba block will continue to deteriorate in the absence of immediate and coordinated conservation measures that include engineering, ecological and institutional interventions. This will jeopardise agricultural sustainability and ecological resilience.

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