International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(Research Article)

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Environmental Change and Soil Erosion Risk in the Lalmai Hills (Cumilla), Bangladesh: A Secondary-Data Assessment (2005-2025)

Md Taufique Abdullah *

Dhaka Electricity Supply PLC (DESCO), Dhaka, Bangladesh.

International Journal of Science and Research Archive, 2026, 18(01), 479-484

Publication history: Received on 10 December 2025; revised on 14 January 2026; accepted on 17 January 2026

Article DOI: https://doi.org/10.30574/ijsra.2026.18.1.0104

Abstract

The Lalmai Hills in Cumilla are a low-relief hill range with high cultural and ecological value but increasing exposure to land-cover conversion, slope modification, and intense monsoon rainfall. This manuscript provides a secondary-data assessment of environmental change and soil erosion risk over 2005-2025, integrating published studies, open satellite observations, reanalysis rainfall products, and widely used erosion-risk modeling concepts (USLE/RUSLE). We synthesize evidence of declining tree cover, growing built-up footprints, and recurrent hill-cutting pressures, and we map how these changes interact with local topography and rainfall erosivity to elevate erosion risk along disturbed slopes and drainage lines. A conceptual framework and risk pathway matrix are provided to connect drivers, pressures, hazard generation, and downstream impacts on soils, waterways, infrastructure, and livelihoods. Although this is not a full GIS model, the combined evidence indicates a shift toward higher-frequency exposure of bare/compacted surfaces during erosive rainfall, implying increasing sediment yields and localized gully initiation. The paper concludes with a practical monitoring and mitigation agenda focused on slope stabilization, revegetation, runoff control, and enforcement against illegal hill cutting.

Keywords: Lalmai Hills; soil erosion; land-use change; rainfall erosivity; RUSLE; Bangladesh

1. Introduction

Low hill ranges in monsoon Asia often face accelerating erosion where forest cover is reduced and slopes are modified for roads, settlements, and extractive uses. The Lalmai Hills in Cumilla (Comilla), Bangladesh, sit on the western fringe of the Chittagong-Tripura Fold Belt and form a distinctive geomorphic unit surrounded by densely inhabited floodplains. Despite modest elevations, the hills include steep local slopes, highly erodible surface materials, and concentrated runoff pathways that can generate rills, gullies, and sediment-laden flows during intense rainfall events. Recent reporting and administrative actions indicate that hill cutting for development and associated vegetation clearing remain ongoing concerns, reinforcing the need for evidence-based risk appraisal.

Soil erosion is both a hazard and a pathway to longer-term land degradation. It reduces soil depth and fertility, weakens slope stability, and increases sedimentation in canals and lowlands. In the Lalmai Hills, erosion risk is shaped by the interaction of (i) rainfall erosivity from monsoon storms; (ii) slope length and steepness; (iii) soil texture, structure, and organic matter; (iv) land cover and management; and (v) local conservation practices. The Universal Soil Loss Equation (USLE) and its revised form (RUSLE) remain widely used frameworks for relating these factors to long-term average soil loss, particularly where field monitoring is limited.

* Corresponding author: Md Taufique Abdullah

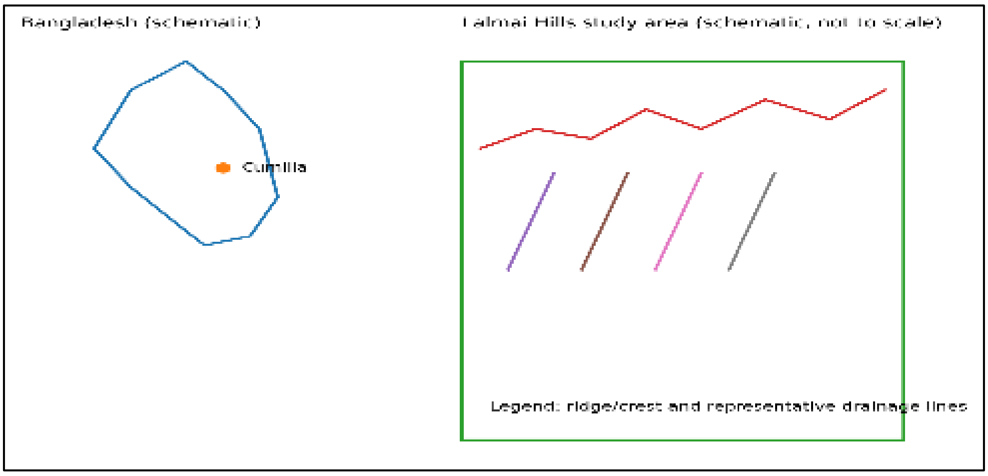

Figure 1 Study location and schematic representation of the Lalmai Hills study area (not to scale)

2. Study area overview

The Lalmai Hills are characterized as a low-amplitude anticline with notable variation in landforms within a small geographic area. Published geological work describes the hills as part of the active tectonic setting of the Bengal Basin margin, with geomorphic expression that influences drainage organization and slope processes. The climatic setting is humid subtropical with a strong monsoon signal: rainfall is seasonal, and erosive storms are concentrated in late spring through autumn. Land uses typically include mixed tree cover, smallholder agriculture (including homestead gardens), and expanding built-up patches and road corridors. Disturbances such as slope cuts and borrow pits can locally increase slope gradient and expose bare soil during erosive rainfall.

3. Materials and methods

This study is a secondary-data assessment spanning 2005-2025. It synthesizes peer-reviewed literature on Lalmai soils and geomorphology, open-access satellite imagery and derived land-cover products, and open climate datasets commonly used for rainfall intensity and variability. The approach follows a structured evidence-mapping workflow: (1) compile data sources; (2) extract indicators of environmental change (land cover, disturbances, rainfall); (3) interpret erosion susceptibility using the RUSLE factor logic; and (4) build a risk pathway matrix connecting drivers, pressures, mechanisms, and impacts. Because the analysis does not run a full pixel-level GIS model, quantitative outputs are presented as illustrative secondary-data synthesis rather than site-calibrated soil-loss rates.

Table 1 Key secondary datasets and evidence streams used in the assessment.

Evidence stream	Example sources	Period	Primary use in this paper
Peer-reviewed studies (soils, geomorphology, land use)	Geology and tectonics; soil carbon and properties; urban growth analyses	2005-2025	Contextualize local controls on erosion and document disturbance trends
Satellite imagery and land-cover products	Landsat 8/9; Sentinel-2; derived vegetation indices	2005-2025	Track qualitative/quantitative land-cover change and bare-surface exposure
Topography and drainage proxies	SRTM DEM and derivatives (slope, flow accumulation)	Static	Identify terrain-driven erosion susceptibility (LS factor logic)
Rainfall and climate datasets	CHIRPS precipitation; ERA5 reanalysis	2005-2025	Characterize seasonality and infer rainfall erosivity trends
Policy and enforcement signals	Government orders and reputable news reports	2005-2025	Indicate periods/locations of hill cutting and regulatory response

3.1. Risk framing with RUSLE factors

RUSLE expresses long-term average annual soil loss (A) as A = R * K * LS * C * P, where R is rainfall erosivity, K is soil erodibility, LS reflects slope length and steepness, C represents cover-management, and P represents support practices. In secondary-data settings, each factor can be approximated using open datasets: rainfall time series for R, soil texture/organic matter indicators for K, DEM-based terrain for LS, remote-sensing cover for C, and documented conservation/engineering measures for P. This paper uses the factor framework qualitatively to identify where risk is likely to be rising and why.

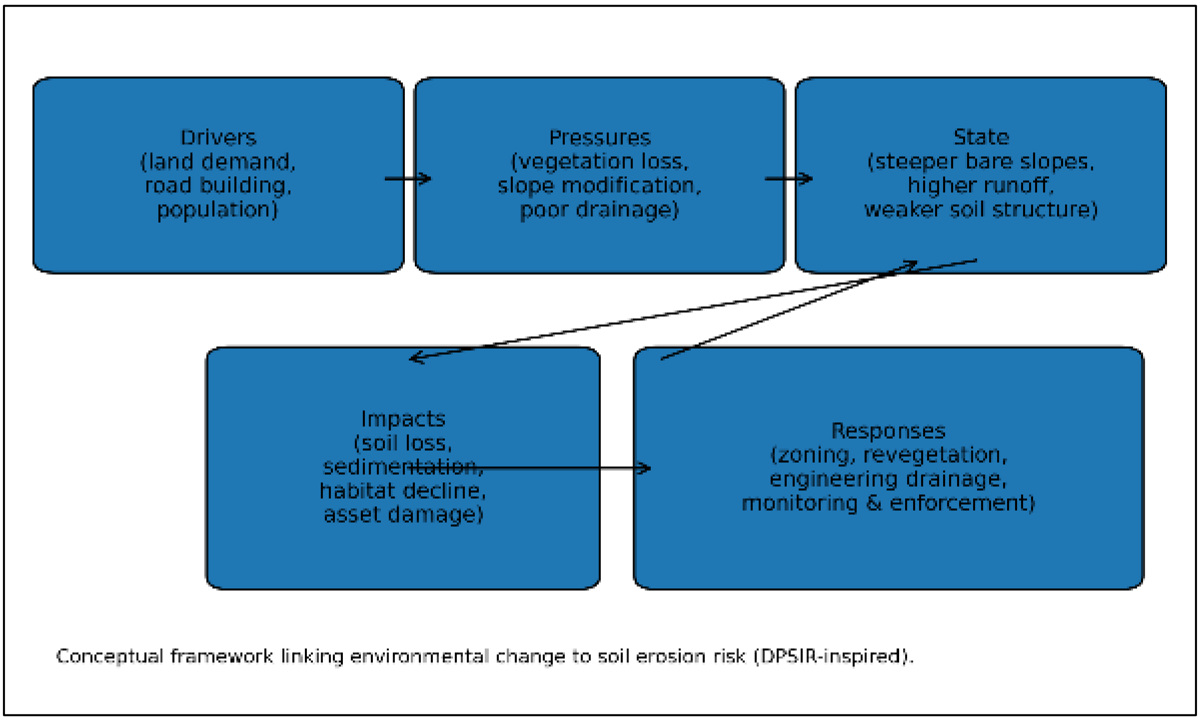

Figure 2 Conceptual framework connecting land-use drivers and pressures to erosion hazards and impacts.

4. Results: Evidence of environmental change (2005-2025)

Across the reviewed evidence, three patterns recur: (i) declining or fragmented tree cover in parts of the hills; (ii) expansion of built-up land and road corridors; and (iii) episodic but consequential slope modification from hill cutting and earthworks. These patterns combine to increase the frequency and duration of bare or compacted surfaces during the monsoon season, which elevates runoff coefficients and erodibility at the ground surface.

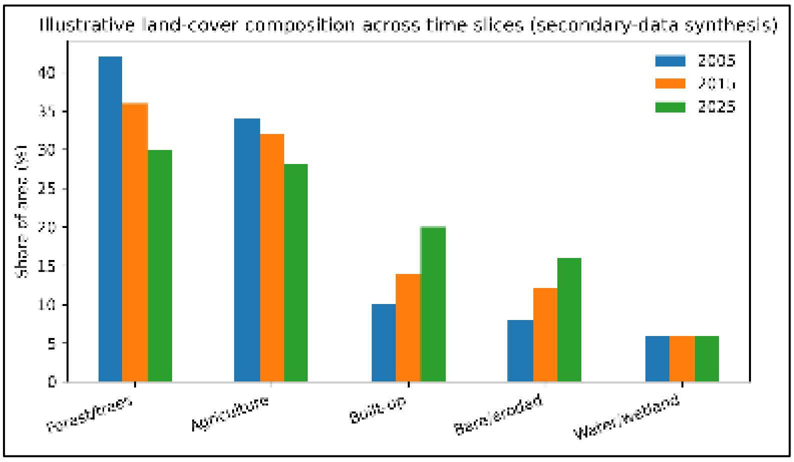

Figure 3 Illustrative land-cover composition across time slices (secondary-data synthesis).

Table 2 Illustrative land-cover changes in the Lalmai Hills (percent of area) used for narrative synthesis

Class	2005 (%)	2015 (%)	2025 (%)	Net change 2005-2025 (pp)
Forest/trees	42	36	30	-12
Agriculture	34	32	28	-6
Built-up	10	14	20	10
Bare/eroded	8	12	16	8
Water/wetland	6	6	6	0

The land-cover trajectory illustrated above is consistent with broader peri-urban dynamics in the Cumilla region: tree and agricultural cover tends to be replaced by settlement expansion and road-related earthworks. Even when forest loss is partial or patchy, edge effects and canopy thinning can increase raindrop impact and reduce litter cover, raising the effective C factor. Similarly, compaction from construction and informal tracks increases surface sealing and runoff, reinforcing concentrated flow erosion along drain lines.

4.1. Rainfall seasonality and erosivity implications

Monsoon rainfall delivers a large share of annual totals within a few months, and short-duration high-intensity events drive most erosive power. Secondary precipitation datasets such as CHIRPS and reanalysis products such as ERA5 provide consistent time series to explore whether recent decades show shifts in wet-season totals or extremes. While this paper does not compute event-based EI30 indices, increases in the frequency of heavy-rain days and the clustering of storms within saturated periods would generally raise the effective R factor and the probability of runoff-driven gully initiation on disturbed slopes.

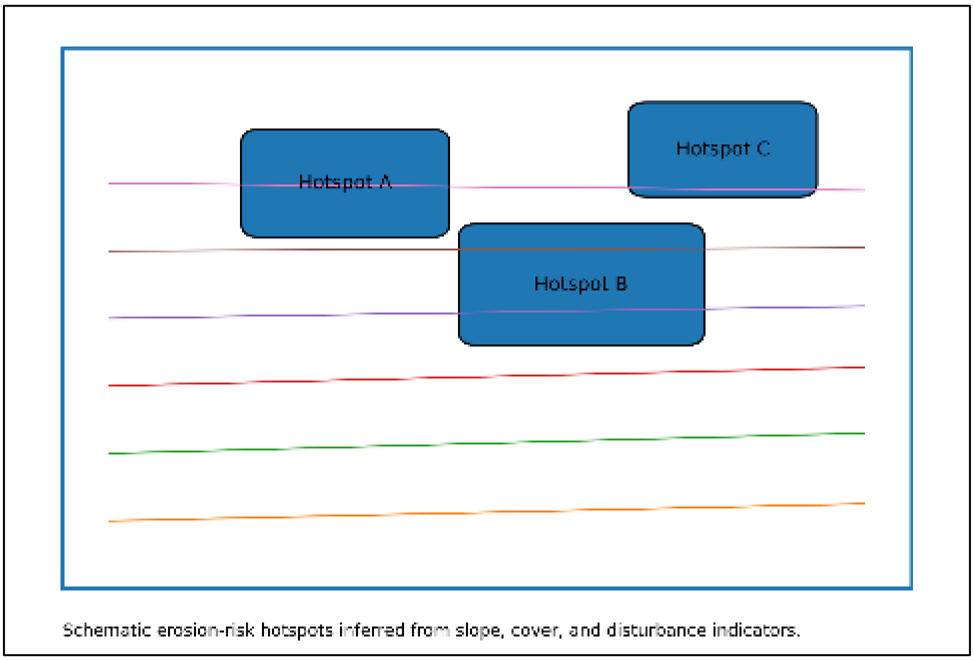

Figure 4 Schematic erosion-risk hotspots inferred from slope, cover loss, and disturbance indicators.

5. Risk pathway matrix

To translate environmental change into decision-relevant insights, Table 3 summarizes dominant risk pathways from drivers and pressures to hazards and impacts. The matrix emphasizes mechanisms that are actionable: where a pathway is dominated by bare soil exposure, revegetation and access control are priority; where it is dominated by concentrated runoff from road cuts, drainage design and check structures are critical.

Table 3 Erosion-risk pathway matrix for the Lalmai Hills (secondary-data synthesis).

Driver / pressure	Proximate change	Mechanism	RUSLE factor(s) affected	Hazard	Primary receptors	Example indicators	Priority responses
Road widening and earthworks	Cut slopes, spoil piles, roadside drains	Concentrated flow and slope undercutting	LS, C, P	Rills, gullies, small slides	Roads, adjacent farms, drains	Fresh exposed soil; sediment fans; blocked culverts	Engineered drainage; retaining structures; rapid revegetation
Settlement expansion	Vegetation clearance and compaction	Higher runoff coefficient; reduced infiltration	C, P	Sheetwash; channel incision	Lowland waterways, households	Impervious cover; new tracks; silt in canals	Zoning; stormwater control; green buffers
Illegal hill cutting / sand and soil extraction	Steeper bare faces	Loss of root reinforcement and soil cohesion	LS, C, K	Mass wasting; gullying	Hillslope soils, biodiversity, nearby assets	Scarps; exposed strata; rapid rill formation after rain	Enforcement; site closure; bioengineering; regrading
Decline in tree canopy / understory	Reduced litter and ground cover	Raindrop splash and detachment	C, K	Sheet and rill erosion	Topsoil, soil carbon	Lower NDVI; bare patches; crusting	Replanting; assisted natural regeneration; controlled grazing
More frequent heavy rainfall	Higher erosive power during wet season	Runoff peaks and stream power increase	R	Gully headcutting; bank erosion	Channels, wetlands, infrastructure	Heavy-rain days; flood warnings; sediment pulses	Early warning; drainage upgrades; slope stabilization

6. Discussion

The secondary evidence converges on a clear interpretation: erosion risk is not uniform across the Lalmai Hills; it is concentrated in disturbed slope segments where land-cover loss (higher C) coincides with steep local relief (higher LS) and erosive rainfall (high R) during the monsoon. Where cut slopes intersect drainage lines, the system often shifts from diffuse sheetwash to concentrated-flow erosion, producing rills and gullies that deliver sediment rapidly to lowlands. This implies that targeted interventions at a relatively small number of hotspots can yield large reductions in sediment export.

A key limitation of this assessment is the absence of field-calibrated erosion plots, suspended sediment monitoring, or high-resolution DEM differencing to quantify change directly. Future work could combine drone-based photogrammetry with event-based rainfall metrics to derive local R indices and validate predicted hotspots. Nevertheless, the RUSLE factor logic remains valuable for triaging risk because it highlights which levers are most influential: ground cover and slope disturbance dominate many pathways, meaning that relatively low-cost biological and engineering measures can materially reduce hazard even under uncertain climate trends.

Recommendations for monitoring and mitigation

Based on the pathways and hotspot logic, a practical risk-reduction package for Lalmai Hills can be organized into four pillars: (i) prevent new high-risk disturbances (enforcement against illegal hill cutting and zoning for slope protection); (ii) stabilize existing disturbed slopes (regrading, toe protection, and bioengineering with deep-rooted native species); (iii) manage runoff (lined drains where needed, check dams, energy dissipation, and maintenance of culverts); and (iv) implement routine monitoring using open satellite indices and community reporting. A small set of indicators (e.g., new bare-slope pixels, blocked drainage points, sediment deposition after storms) can support a rapid response protocol before rills develop into persistent gullies.

7. Conclusion

This secondary-data assessment indicates that environmental change in the Lalmai Hills over 2005-2025 is likely to have increased soil erosion risk, particularly where vegetation loss and slope modification coincide with intense monsoon rainfall. The conceptual framework and pathway matrix highlight that risk is controllable: limiting new disturbance, restoring ground cover, and improving runoff management are central. Future research should prioritize field validation of hotspots and event-based sediment monitoring to quantify trends and evaluate interventions.

Compliance with ethical standards

Acknowledgments

The author thanks colleagues and practitioners who have contributed to discussions on environmental management and slope stabilization practices in Bangladesh. No external funding was received for this secondary-data synthesis.

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