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SOIL EROSION SUSCEPTIBILITY AND SEDIMENT YIELD MAPPING USING GEOSPATIAL APPROACHES IN SWAT RIVER BASIN, PAKISTAN

Abstract

The Swat River Basin in Khyber Pakhtunkhwa, Pakistan, is characterized by steep mountainous terrain, glaciated headwaters, intense precipitation, and recurrent floods, making it vulnerable to soil erosion and sediment production. Despite its environmental and socio-economic importance, detailed sub-basin-scale assessments of erosion susceptibility and sediment production remain limited, constraining effective watershed management and conservation planning. This study integrates GIS-based morphometric analysis with the Compound Factor Approach (CFA) and an empirical Sediment Production Rate (SPR) model to prioritize erosion-prone areas across 19 sub-basins throughout the Swat River Basin. A Digital Elevation Model (DEM) was used to derive 24 morphometric parameters representing linear, areal, and relief characteristics. Parameters were classified according to their positive or inverse relationship with erosion susceptibility, and ranked values were integrated to calculate a Compound Factor for each sub-basin.

The results revealed a considerable spatial variability in basin morphology, with sub-basin areas ranging from 48.87 to 743.73 km². CFA-based prioritization identified four sub-basins (SB-1 Utror (Bahrain), SB-2 Kalam (Bahrain) , SB-4 Mankyal / Balakot (Bahrain), and SB-6 Beshigram / Madyan (Bahrain) with high erosion susceptibility, representing 21% of the basin, while eight sub-basins (42%) i.e. SB-5 Bar Thana / Beha (Matta), SB-7 Gowlairaj (Bahrain), SB-10 Chuprial / Arkot (Matta), SB-12 Shawar / Tall (Matta), SB-14 Kala kalay/Shah Dehrai (Charbagh), SB-15 Manglawar / Aka Maruf (Babuzai), SB-17 Kokarai / Islampur (Babuzai)and SB-19 Barikot (Barikot) were classified as moderate and six (32%) i.e. SB-8 Miandam (Khwaza Khela), SB-9 Shin / Shalpin (Khwaza Khela), SB-11 Kishawara (Khwaza Khela) , SB-13 Charbagh / Taligram (Charbagh), SB-16 Udigram (Babuzai) and SB-18 Shamoza (Kabal) as low susceptibility.

The SPR model produced values ranging from 0.1016 to 0.2915 ha-m/100 km²/year. Two sub-basins 11 %, SB-3 Bahrain (Bahrain) and SB-17 Kokarai / Islampur (Babuzai) exhibited very high sediment production rates, 11 sub-basins (57%) namely SB-5 Bar Thana / Beha (Matta) , SB-6 Beshigram / Madyan (Bahrain), SB-7 Gowalairaj (Bahrain), SB-8 Miandam (Khwaza Khela) , SB-9 Shin / Shalpin (Khwaza Khela) , SB-10 Chuprial / Arkot (Matta), SB-11 Kishawara (Khwaza Khela), SB-14 Kala Kalay / Shah Dehrai (Charbagh), SB-15 Manglawar / Aka Maruf (Babuzai), SB-16 Udigram (Babuzai) and SB-19 Barikot (Barikot) have reported high levels of sediment production. Four sub-basins (21%) i.e. SB-2 Kalam (Bahrain), SB-12 Shawar / Tall (Matta), SB-13 Charbagh / Taligram (Charbagh) , and SB-18 Shamoza (Kabal), have a moderate sediment production rate of the sub-basins, the other Two, SB-1 Utror (Bahrain) and SB-4 Mankyal / Balakot (Bahrain) account for 11 % of the sub-basins have a low sediment production rate. The spatial correspondence between erosion susceptibility and sediment production patterns provides complementary evidence for identifying priority areas for watershed intervention.

The study demonstrates that integrating DEM-derived morphometric characteristics, CFA, and SPR modelling provides a practical and scalable framework for sub-basin-level soil erosion assessment under data-scarce mountainous environments. Conservation practices should prioritize high-risk sub-basins through slope stabilization, afforestation, check dams, sediment-retention structures, conservation farming, and riparian restoration. For future watershed management policy, erosion and sediment-risk maps should be integrated into watershed planning to guide targeted conservation interventions. Establishing a GIS-based monitoring and decision-support system incorporating latest satellite imagery, precise rainfall, improved land-use/land-cover, and appropriate sediment data would further support long-term erosion monitoring, evaluation of conservation measures, and climate-resilient management of the Swat River Basin. Similar framework can also be extended and applied to other erosion-prone mountainous regions of Pakistan and the wider Hindu Kush Himalayan region.