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Assessing soil erosion risk in the Trans Himalayan range of Ladakh: Implications of climate change and agricultural expansion

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ABSTRACT

The Himalayan region is undergoing significant changes in soil erosion due to rapid Landuse/landcover change and climate variations. This study employs the ICONA model along with the Analytic Hierarchy Process (AHP) and satellite-based precipitation data from 1981 to 2024 to assess changes in erosion across the Trans Himalayan region in Ladakh. Key study inputs include slope, lithofacies, land-use/cover and Normalized Differential Vegetation Index (NDVI) (1992 and 2020), to generate the erosion risk maps. Results reveal that in 1992, 60.88 % (10483.6 km^2) and 19.20 % (3302.9 km^2) of the area exhibited high and very high erosion risk respectively, with moderate risk in 14.59 % (2513.3 km^2), and low and very low risk together in 5.32 % (918.85 km^2). By 2020, high and very high erosion risk areas increased only by 1 %–61.80 % (10641.20 km^2) and 20.03 % (3445.5 km^2) respectively, with a decrease in moderate risk areas to 10.47 % (1804.37 km^2) and an increase in low and very low risk areas to 7.70 % (1327.58 km^2). Analysis of precipitation data from 1981 to 2024 suggests a significant (S = 0.05) increase, of 13.5 % (383 mm). RCI (Rainfall Concentration Index) result shows peak precipitation in the year 1992, 2010 and 2014. The increasing precipitation and intensity is likely contributing to changes in the erosional processes with enhanced agricultural activities and decreased erosion in certain regions and increase in other regions. Changes in erosion are also attributed to agricultural expansion and potential expansion in infrastructure development from 3.45 km^2 to 6.92 km^2 between 1991 and 2020. This study helps in identifying changes in the erosion-pattern in the region with changing precipitation, which is essential for formulating mitigation strategies, and for sustainable planning in the study area.

1. Introduction

Soil erosion is a critical environmental issue in the Himalayan regions, primarily driven by the area's steep topography, diverse land use and land cover, and distinct climate characteristics (Zaz and Romshoo, 2012). Soil erosion, primarily affecting the fertile topsoil, threatens the productivity of agroecosystems, thereby endangering food security in the region (Arnell and Gosling, 2013; Shrestha et al., 2012). The Himalayas, one of the most sensitive mountain ecosystems, are warming at higher rate than the global average (Sabin et al., 2020). As climate parameters, particularly precipitation and temperature, continue to shift, they are expected to have an even greater impact on land surface processes (Romshoo et al., 2018; Joris et al., 2022). The intensification of land use activities has further aggravated this problem, leading to substantial alterations in the fragile Himalayan ecosystem. In the Himalaya, soil erosion is generally severe, with approximately 25 % of the dissolved load to the world's oceans being discharged by Himalayan rivers (Albert and Christian, 2001; Raymo and Ruddiman, 1992). Field-based studies across various Himalayan River basins have reported soil erosion rates ranging from 20 to 25 tons per hectare per year, with some areas experiencing rates as high as 92 tons per hectare per year (Garde and Kothyari, 1987; Poreba and Prokop, 2011; Sharda and Ojasvi, 2016; Swarnkar et al., 2018). These rates are expected to increase under future climate change scenarios (Takhellambam, 2023). In

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