

Soil Erosion Assessment of the Ghaggar Watershed Using GIS Techniques

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ABSTRACT

Soil erosion is one of the most significant forms of land degradation affecting watershed environments worldwide. It leads to the loss of fertile topsoil, reduces agricultural productivity, and contributes to sedimentation in rivers and reservoirs. Accurate estimation of soil erosion is therefore essential for sustainable watershed management and soil conservation planning. The present study evaluates soil erosion risk in the Ghaggar watershed using the Revised Universal Soil Loss Equation (RUSLE) integrated with Remote Sensing and Geographic Information System (GIS) techniques. The RUSLE model incorporates five key parameters: rainfall erosivity (R), soil erodibility (K), slope length and steepness (LS), land cover factor (C), and conservation practice factor (P). Spatial datasets, including Digital Elevation Model (DEM), satellite imagery, rainfall data, and soil maps, were used to derive these factors and generate a soil erosion risk map for the watershed. The results indicate that soil erosion risk varies significantly across the watershed due to terrain characteristics, land-use patterns, and soil properties. Higher erosion risk is primarily concentrated in the upper catchment areas of the Shivalik foothills, where steep slopes and sparse vegetation cover accelerate runoff and soil loss. The downstream alluvial plains exhibit relatively low erosion potential due to their gentle slopes and intensive agricultural land use. The study demonstrates the effectiveness of integrating geospatial techniques with the RUSLE model to identify erosion-prone areas and support soil conservation planning. The findings can assist policymakers and environmental managers in implementing sustainable watershed management strategies to reduce soil erosion and land degradation.

Keywords: Soil Erosion, RUSLE Model, Watershed Management, GIS, Remote Sensing.

INTRODUCTION

Soil erosion is a major environmental problem affecting agricultural productivity, ecosystem stability, and sustainable land management worldwide. It refers to the detachment and transportation of soil particles by natural agents such as water, wind, and gravity. Among these agents, water-induced erosion is considered the most significant form of soil erosion in humid and semi-humid regions. Accelerated soil erosion from human activities such as deforestation, overgrazing, and improper agricultural practices has become a serious concern in many watersheds. The removal of fertile topsoil reduces soil fertility and negatively affects crop productivity. In addition to on-site impacts, soil erosion also causes off-site problems such as sedimentation in rivers, reservoirs, and irrigation channels. Sediment deposition reduces reservoir storage capacity and increases flood risk. Therefore, assessing soil erosion risk is essential for designing effective soil conservation and watershed management strategies.

Watersheds are natural hydrological units in which precipitation drains through a network of streams toward a common outlet. The interactions among terrain, soil properties, vegetation cover, and land-use patterns within a watershed significantly influence soil erosion processes. Steep slopes, erodible soils, intense rainfall, and sparse vegetation cover generally increase erosion risk. Dense vegetation and proper land management practices can reduce soil loss by protecting the soil surface and improving infiltration. Over the years, several models have been developed to estimate soil erosion rates. Among these models, the Universal Soil Loss Equation (USLE) and its revised version, the Revised Universal Soil Loss Equation (RUSLE), are widely used to predict soil erosion from rainfall and surface runoff. The RUSLE model estimates soil loss by integrating rainfall erosivity, soil erodibility, topographic characteristics, land cover conditions, and conservation practices. Recent advances in Remote Sensing and Geographic Information System (GIS) technologies have greatly improved the ability to assess soil erosion at watershed scales. Satellite imagery and digital elevation data allow researchers to analyse spatial variations in terrain, vegetation, and land use. GIS tools facilitate the integration of datasets required for soil erosion modelling and enable the generation of spatial maps that represent erosion risk.

The Ghaggar watershed, located in northwestern India, is characterised by diverse physiographic conditions ranging from the rugged Shivalik foothills to the fertile alluvial plains downstream. The upper catchment areas experience intense rainfall and steep slopes, which make them vulnerable to soil erosion. The plains are dominated by agricultural

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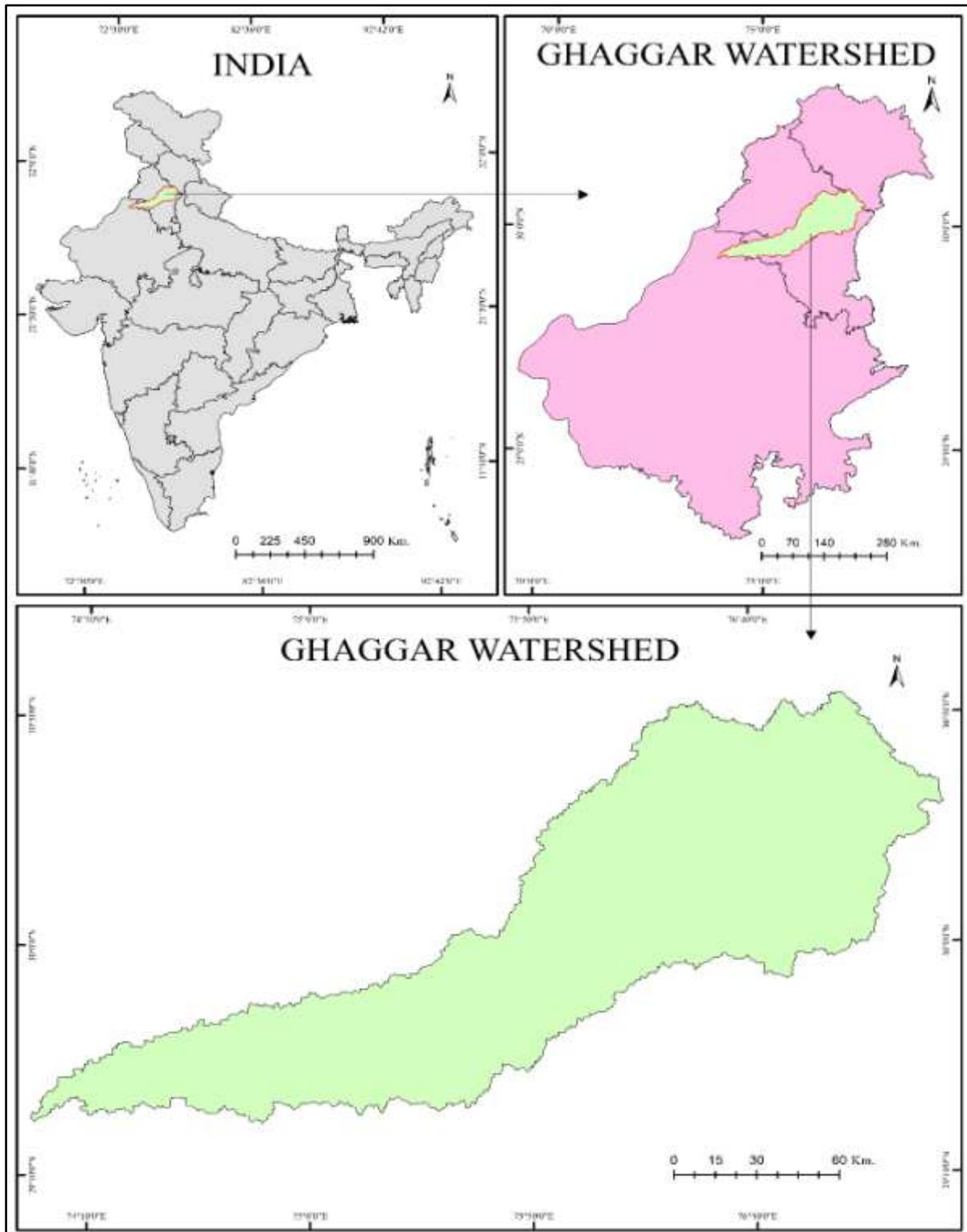
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activities and relatively gentle terrain. Understanding the spatial distribution of soil erosion within the watershed is therefore essential for developing sustainable land management strategies. The main objective of this study is to assess soil erosion risk in the Ghaggar watershed using the RUSLE model integrated with GIS techniques.

STUDY AREA

The Ghaggar watershed is located in northwestern India and is an important river basin.

Map 1: Location of the Study Area



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The Ghaggar River originates in the Shivalik foothills of the Himalayas and flows through several plains before dissipating in arid regions downstream. The watershed covers a diverse landscape characterised by hills, valleys, and extensive agricultural plains. The upper parts of the watershed are dominated by the Shivalik hill range, characterised by steep slopes and fragile geological formations. These areas are highly susceptible to soil erosion due to intense rainfall and rapid surface runoff. As the river flows downstream, the terrain gradually flattens and transitions into fertile alluvial plains, where agriculture is the dominant land use.

The watershed has a subtropical monsoon climate with hot summers, mild winters, and seasonal rainfall during the monsoon months. Most of the annual precipitation occurs between June and September, which significantly influences runoff generation and erosion processes within the basin.

METHODOLOGY AND DATA SOURCES

The estimation of soil erosion in the Ghaggar watershed was carried out using the Revised Universal Soil Loss Equation (RUSLE) model integrated with Geographic Information System (GIS) techniques. The RUSLE model is widely used to predict long-term average annual soil loss from rainfall and surface runoff. The model estimates soil erosion using the equation $A = R \times K \times LS \times C \times P$, where A denotes the average annual soil loss (tons per hectare per year). The factor R denotes the rainfall erosivity factor, which reflects the impact of rainfall intensity and energy on soil erosion. The K factor represents soil erodibility and indicates its susceptibility to erosion based on its physical and chemical properties. The LS factor refers to slope length and slope steepness, which influence the velocity of surface runoff and the capacity of flowing water to detach and transport soil particles. The C factor represents the land cover and management factor that reflects the protective effect of vegetation and cropping practices against soil erosion. Finally, the P factor represents conservation support practices, such as contour farming, terracing, and other soil conservation measures, that reduce erosion.

In this study, each RUSLE factor was derived from spatial datasets and processed in a GIS environment to generate thematic layers representing the spatial distribution of erosion-related parameters. Several geospatial datasets were utilised for the analysis, including Digital Elevation Model (DEM) data, satellite imagery for land use and land cover mapping, rainfall data, soil maps, and topographic maps. DEM data were used to derive slope and topographic parameters required to calculate the LS factor, while satellite imagery was used to classify land use and land cover to determine the C factor. Soil maps were used to estimate the K factor representing soil erodibility, and rainfall data were used to calculate the rainfall erosivity factor. These datasets were integrated and processed using GIS techniques to compute the individual RUSLE factors and produce a spatial soil erosion risk map for the Ghaggar watershed. The resulting erosion map provides valuable insights into the spatial distribution of soil erosion and helps identify areas that require soil conservation and watershed management measures.

RESULTS AND ANALYSIS

The soil erosion assessment using the RUSLE model revealed significant spatial variation in erosion risk across the Ghaggar watershed. The variation in soil erosion is largely influenced by terrain characteristics, rainfall patterns, soil properties, and land use conditions.

The rainfall erosivity factor (R) represents the effect of rainfall intensity on soil erosion. The analysis indicates that areas with higher rainfall intensity, particularly in the upper catchment, exhibit greater erosion potential.

The soil erodibility factor (K) reflects a soil's susceptibility to erosion based on its physical and chemical properties. Soils with a loose texture and low organic matter content tend to be more vulnerable to erosion than soils with a stable structure.

The slope length and steepness factor (LS) derived from DEM data shows that steeper slopes significantly increase erosion potential. The upper parts of the watershed located in the Shivalik hills exhibit higher LS values due to steep terrain, which accelerates surface runoff and soil loss.

The land cover factor (C) indicates the protective effect of vegetation cover on soil erosion. Areas covered by forests and dense vegetation have a lower erosion risk, while barren lands and sparsely vegetated areas are more susceptible to erosion.

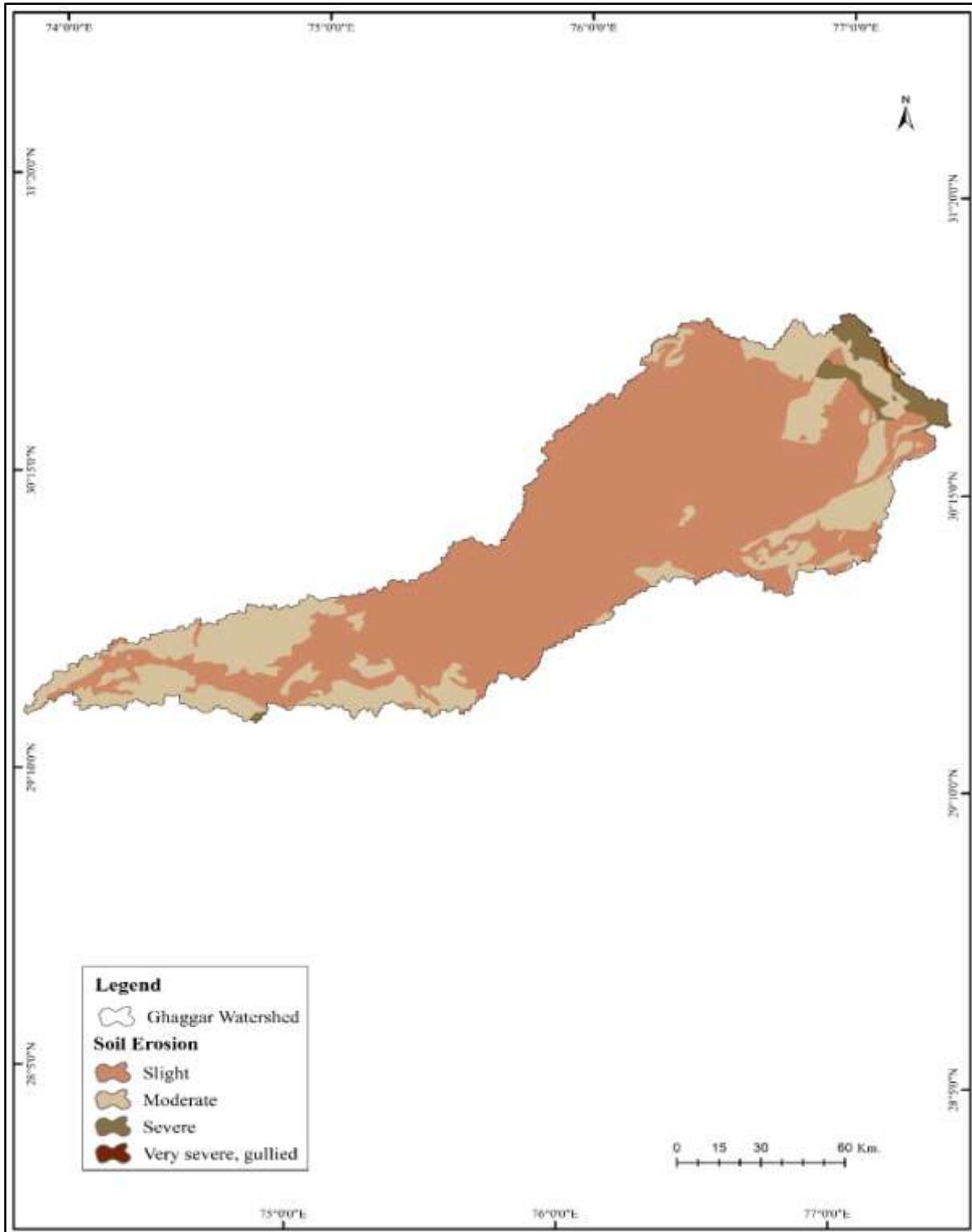
The conservation practice factor (P) reflects the influence of soil conservation measures such as contour farming and terracing. Agricultural areas with proper conservation practices exhibit lower erosion rates than those without such measures.

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The integrated soil erosion map generated using RUSLE indicates that the upper catchment areas of the watershed experience moderate to high erosion risk, whereas the downstream plains generally exhibit low erosion potential. The soil erosion map of the Ghaggar watershed highlights spatial differences in erosion intensity, classified into the categories slight, moderate, severe, and very severe (gullied). The majority of the basin falls under the slight erosion class, particularly across the central and southwestern alluvial plains. These zones are marked by gentle slopes, stable geomorphic features, and fine-textured alluvial soils.

Map 2: Soil Erosion Risk in the Ghaggar Watershed



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The low relief and gradual gradients slow runoff, reducing soil detachment and transport. These areas remain relatively stable and agriculturally suitable, though occasional sheet erosion may occur during heavy monsoonal rains. Moderate erosion is observed in transitional belts, particularly in piedmont zones and in certain middle reaches of the watershed. Here, slope gradients increase slightly, leading to greater runoff concentration. Soil loss in these areas is active but manageable, often linked to farming practices, sparse vegetation, or seasonal runoff events.

Severe and very severe (gullied) erosion is concentrated in the northeastern portion of the watershed, corresponding to the Shivalik foothills. This region is characterised by steep slopes, higher relief, and structurally controlled drainage. The combination of unconsolidated sediments, intense monsoon rainfall, and rapid surface runoff fosters gully development and channel incision. These severely eroded zones act as sediment sources, contributing to downstream deposition in the alluvial plains.

Morgan (2009), notes that soils deficient in organic matter are especially vulnerable to degradation due to weak structural cohesion. Removal of vegetation or intensive cultivation further exposes soil surfaces to rainfall, accelerating erosion. The transported material often accumulates downstream, leading to channel sedimentation, reduced drainage efficiency, and altered flood dynamics.

Understanding soil erodibility is crucial for applying predictive models such as the Revised Universal Soil Loss Equation (RUSLE), in which the soil erodibility factor (K) is a key parameter for estimating potential soil loss.

CONCLUSION

The present study assessed soil erosion risk in the Ghaggar watershed using the RUSLE model integrated with remote sensing and GIS techniques. The analysis revealed that soil erosion within the watershed is strongly influenced by terrain characteristics, land use patterns, and soil properties. The results indicate that steep slopes and sparse vegetation cover in the upper catchment areas increase erosion risk, whereas the relatively flat agricultural plains have lower erosion potential. The study highlights the importance of vegetation cover and proper land management practices in reducing soil loss. The integration of RUSLE modelling with geospatial technologies proved effective for identifying erosion-prone areas and understanding the spatial distribution of soil erosion within the watershed. The study's findings can support the implementation of soil conservation measures, such as afforestation, contour farming, and watershed management programs. Sustainable land management strategies are essential for minimising soil erosion and maintaining the long-term productivity of the watershed. The results of this study provide valuable information for environmental planners and policymakers involved in watershed management and soil conservation initiatives.

REFERENCES

- [1]. Morgan, R. P. C. (2005). *Soil erosion and conservation*. Blackwell Publishing.
- [2]. Panagos, P., Borrelli, P., & Meusburger, K. (2015). Global soil erosion modelling. *Science of the Total Environment*, 511, 801–814.
- [3]. Renard, K. G., Foster, G. R., Weesies, G. A., & Porter, J. P. (1991). RUSLE: Revised Universal Soil Loss Equation. *Journal of Soil and Water Conservation*, 46, 30–33.
- [4]. Wischmeier, W. H., & Smith, D. D. (1978). *Predicting rainfall erosion losses: A guide to conservation planning*. USDA.