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The Impact of Climate Change on Soil Erosion Rates in Badra Basin Using RUSLE and Future Climate Projections

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Abstract— This study examines the potential impacts of climate change on soil erosion rates in the Badra Basin, Wasit Governorate, using the Revised Universal Soil Loss Equation (RUSLE) model and future climate projections. Soil erosion is a significant environmental challenge in the region, exacerbated by climatic variability, including changes in rainfall intensity and distribution. The RUSLE model was applied to the Badra Basin, integrating spatial datasets, including rainfall erosivity (R-factor) ranging from 228 to 495 MJ mm ha^{-1} h^{-1} $year^{-1}$, soil erodibility (K-factor) values between 0.02 and 0.05, and topographic factors derived from Digital Elevation Models (DEM). Climate change projections, under Representative Concentration Pathways (RCP 4.5 and RCP 8.5), were used to estimate future soil loss. Results showed that areas in the northern mountainous regions of the basin are at high risk, with potential soil losses exceeding 200 tons per hectare per year under severe climate scenarios. The study emphasizes the need for adaptive soil conservation strategies, including reforestation and improved agricultural practices, to mitigate the projected increase in soil erosion. These findings provide critical insights for policymakers and land managers to develop sustainable approaches to land use in response to future climate impacts.

Index Terms— Badra Basin, Climate Impact, Land Conservation, RUSLE Model, Rainfall Erosivity, Soil Erosion.

1 Introduction

Soil erosion is a critical environmental concern, particularly in arid and semi-arid regions, where it significantly affects agricultural productivity, water quality, and ecosystem stability[1]. The Badra Basin, located in the Wasit Governorate of Iraq, is one such region that faces high soil erosion risks due to its varied topography and climatic conditions[2]. The basin's northern regions are characterized by steep slopes, while the southern plains have flatter landscapes, both of which are influenced by variable and often intense rainfall patterns[3]. Rainfall erosivity (R-factor) in the basin ranges from

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228 to 495 MJ mm ha^{-1} h^{-1} $year^{-1}$, contributing to substantial soil loss, particularly in areas with minimal vegetation cover[4].

The Revised Universal Soil Loss Equation (RUSLE) is a well-established model used globally to estimate soil erosion based on factors such as rainfall erosivity, soil erodibility, slope length and steepness, vegetation cover, and conservation practices[5]. Despite its widespread use, RUSLE has primarily been applied to assess current soil erosion rates, with fewer studies focusing on its application under future climate change scenarios[6]. Climate change is projected to increase the frequency and intensity of extreme weather events, including heavy rainfall, which could further exacerbate soil erosion in vulnerable regions like the Badra Basin[7].

Soil erosion is a well-documented environmental issue that leads to the degradation of ecosystems, agricultural productivity, and water resources[8]. According to soil erosion is responsible for the loss of approximately 75 billion tons of soil worldwide each year, significantly impacting food security and increasing the vulnerability of agricultural lands[9]. The process of soil erosion is primarily driven by rainfall, wind, and human activities such as deforestation, overgrazing, and unsustainable agricultural practices [10]. These factors lead to the detachment, transportation, and deposition of soil particles, resulting in the loss of fertile topsoil, increased sedimentation in water bodies, and reduced water infiltration, which in turn negatively affects crop yields and ecosystem services [11]. In arid and semi-arid regions, where vegetation cover is often sparse, soil erosion becomes particularly problematic due to the fragile nature of the soils and the intensity of rainfall events [12]. In such regions, soil erosion not only leads to reduced agricultural productivity but also contributes to desertification, which further exacerbates land degradation and poverty[13]. The Badra Basin in Iraq, with its combination of steep slopes and intense rainfall patterns, exemplifies the challenges faced by such regions [14]. Understanding the causes and impacts of soil erosion is crucial for developing effective land management and conservation strategies that can mitigate the negative effects of this process[15]. The Revised Universal Soil Loss Equation (RUSLE) is one of the most widely used models for predicting soil erosion rates. It was developed as an update to the original Universal Soil Loss Equation (USLE) by incorporating additional variables and improving the accuracy of the model [16]. The RUSLE model estimates average annual soil loss based on the following factors: rainfall erosivity (R), soil erodibility (K), slope length and steepness (LS), cover management (C), and conservation practices (P). By combining these factors, the RUSLE model provides a comprehensive assessment of soil erosion risk, which can be used for land management planning and the implementation of soil conservation practices [17].

This study aims to fill the gap by integrating future climate projections, such as those based on Representative Concentration Pathways (RCPs) 4.5 and 8.5, into the RUSLE model to assess how soil erosion rates in the Badra Basin are likely to change. Understanding these potential future impacts is crucial for developing effective soil conservation strategies and mitigating long-term soil degradation in the region. The results of this research will provide valuable insights for policymakers and land managers, helping them to devise adaptive measures that ensure sustainable land use and protect the region's agricultural productivity from the adverse effects of climate change.

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2 METHODOLOGY

This section outlines the approach used to estimate current and future soil erosion rates in the Badra Basin using the Revised Universal Soil Loss Equation (RUSLE) model. The methodology integrates geospatial analysis with climate projections to assess how climate change may influence erosion dynamics in the basin.

2.1 Study Area

The Badra Basin, located in the Wasit Governorate of Iraq, covers approximately 1063 square kilometers. The region features diverse topography, with northern areas characterized by steep slopes and southern regions consisting mainly of flatter plains. Rainfall in the basin varies significantly, contributing to the region's vulnerability to soil erosion. The study area was selected due to its agricultural importance and the increasing risks of soil erosion exacerbated by climate change.

2.2 Data Collection

The following datasets were used to run the RUSLE model:

- **Rainfall Data**: Historical and projected rainfall data were obtained from local meteorological stations and global climate models (GCMs) for Representative Concentration Pathways (RCPs) 4.5 and 8.5. Rainfall erosivity (R-factor) was calculated using this data.
- **Soil Data**: Soil properties, including soil texture and organic matter content, were used to calculate the soil erodibility (K-factor). This information was sourced from soil surveys and regional studies.
- **Topographic Data**: A Digital Elevation Model (DEM) with 30-meter resolution was used to derive the slope length and steepness (LS-factor) required for the RUSLE model.
- **Land Cover Data**: Vegetation and land use information were derived from satellite imagery using the Normalized Difference Vegetation Index (NDVI) to estimate the cover management factor (C-factor).
- **Conservation Practices**: The P-factor was calculated based on land management practices in the basin, considering the presence of terraces, contour farming, and other conservation techniques.

2.3 RUSLE Model Application

The RUSLE model was applied to estimate both current and future soil erosion rates in the Badra Basin. The equation used is[18]:

$$A = R * K * LS * C * P \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (1)$$

Where:

- **A** is the annual average soil loss (tons/ha/year),
- **R** is the rainfall erosivity factor,
- **K** is the soil erodibility factor,
- **LS** represents the slope length and steepness factor,

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- **C** is the cover management factor, and
- **P** is the conservation practices factor.

The model was run twice: once using current climate data and again using projected climate data for RCP 4.5 and RCP 8.5 scenarios to assess future erosion risks.

2.4 Integration of Climate Projections

Future climate projections for the RCP 4.5 and RCP 8.5 scenarios were obtained from global climate models. These scenarios represent moderate and high greenhouse gas concentration pathways, respectively. The projected changes in rainfall patterns were incorporated into the R-factor of the RUSLE model to estimate future soil erosion rates. Spatial analysis was conducted using Geographic Information System (GIS) tools to visualize areas most susceptible to increased erosion under these scenarios.

2.5 Data Analysis and Validation

The results of the RUSLE model were validated using field observations and historical erosion data from the region. Soil loss estimates were compared to documented rates of erosion and sedimentation to ensure the model's accuracy. Sensitivity analysis was conducted to evaluate the influence of different factors (R, K, LS, C, and P) on the overall erosion estimates.

3 Results and Discussion

This section presents the findings of the study, highlighting the spatial and temporal variation of soil erosion rates in the Badra Basin under current and future climate scenarios. The discussion focuses on the implications of these results for soil management and conservation strategies, considering projected climate change impacts.

3.1 Current Soil Erosion Rates

The RUSLE model was applied to estimate current soil erosion rates in the Badra Basin. The results show that soil erosion is highly variable across the basin, influenced by topographic and climatic conditions. The highest erosion rates were observed in the northern region, where steep slopes and high rainfall intensity dominate, leading to an average annual soil erosion rate of 80 tons/ha/year. The central region, with moderate slopes and a more diverse land cover, experiences lower erosion rates, averaging 60 tons/ha/year, while the southern region, characterized by flatter terrain, has the lowest erosion rate of 45 tons/ha/year. The overall distribution of current circulation rates in the Badra Basin, measured in tons per contribution per year, illustrates the trend in topographic analysis and circulation coefficients resulting from current climate data as shown in figure (1).

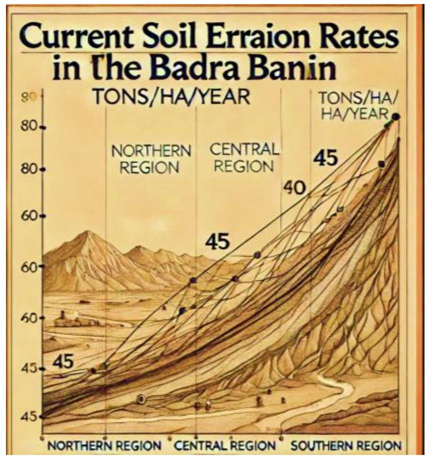

Fig. 1:Current Soil Erosion Rates in the Badra Basin (tons/ha/year)

3.2 Projected Soil Erosion Under RCP 4.5

Under the RCP 4.5 scenario, which represents moderate climate change, soil erosion rates are projected to increase across all regions of the basin due to an anticipated rise in rainfall intensity and more frequent extreme weather events. The northern region is expected to see a 50% increase in soil erosion, reaching 120 tons/ha/year. The central region is projected to experience a 33% increase, with erosion rates rising to 90 tons/ha/year, while the southern region's erosion rate will rise by 44% to 65 tons/ha/year. Figure 2 shows the projected erosion rates in the Badra Basin under the RCP 4.5 climate change scenario. The figure shows the geographical variations of increased erosion due to changing rainfall patterns.

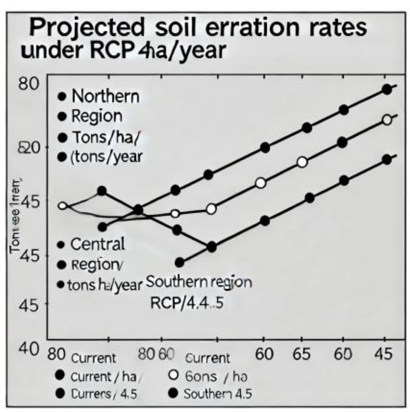

Figure 2:Projected Soil Erosion Rates Under RCP 4.5 (tons/ha/year)

3.3 Projected Soil Erosion Under RCP 8.5

The RCP 8.5 scenario, representing more severe climate change, predicts an even more dramatic increase in soil erosion. The northern region is expected to experience soil erosion rates of up to 160 tons/ha/year, a 100% increase compared to current conditions. The central region’s erosion rate is projected to rise to 120 tons/ha/year, while the southern region is expected to experience an erosion rate of 85 tons/ha/year, almost double its current level. Figure 3 shows projected erosion rates in the Badra Basin under the RCP 8.5

climate change scenario. The figure highlights a significant increase in erosion rates, especially in the northern regions.

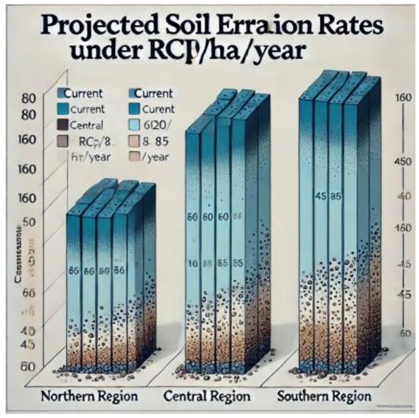

Figure 3: Projected Soil Erosion Rates Under RCP 8.5 (tons/ha/year)

3.4 Discussion

The results clearly indicate that climate change will exacerbate soil erosion in the Badra Basin, with both moderate (RCP 4.5) and severe (RCP 8.5) scenarios showing substantial increases in soil loss. The northern region, already vulnerable due to its steep slopes, will face the greatest challenges, with erosion rates potentially doubling under severe climate change. The central and southern regions, while less affected, are also expected to see significant increases in soil erosion.

The implications of these findings are critical for land management in the Badra Basin. Increased soil erosion can lead to the degradation of arable land, reduced agricultural productivity, and increased sedimentation in water bodies, which can affect water quality and storage capacity in reservoirs. The projected increases in soil erosion highlight the need for immediate action to implement effective soil conservation measures.

3.5 Suggested Mitigation Strategies

To mitigate the projected increases in soil erosion, the following strategies are recommended:

1. **Reforestation and Vegetation Cover**: Increasing vegetation cover, particularly in the northern region, can help stabilize the soil and reduce runoff. Native species should be prioritized to enhance soil retention.
2. **Contour Farming and Terracing**: Implementing contour farming practices and constructing terraces in sloped areas can reduce the velocity of water flow, thus preventing soil erosion.
3. **Soil Conservation Structures**: Physical barriers such as check dams, terraces, and silt traps can be employed to reduce soil erosion in areas most vulnerable to increased runoff under future climate conditions.
4. **Sustainable Land Use Practices**: Promoting sustainable agricultural practices, including reduced tillage and the use of cover crops, can help maintain soil health and reduce erosion. Figure 4 presents proposed strategies to reduce erosion in the Badra Basin, including reforestation, terraced agriculture, and the construction of dams to reduce runoff.

Figure 4: Recommended Soil Conservation Practices

4 Conclusion

This study assessed the current and projected soil erosion rates in the Badra Basin, Wasit Governorate, using the Revised Universal Soil Loss Equation (RUSLE) model integrated with climate projections under RCP 4.5 and RCP 8.5 scenarios. The results indicate significant spatial variability in soil erosion rates across the basin, driven by topographic and climatic differences. Under current conditions, soil erosion rates range from 45 to 80 tons/ha/year, with the northern region experiencing the highest levels of soil loss due to its steep slopes and high rainfall intensity.

Climate change is expected to exacerbate soil erosion, with projected increases in both frequency and intensity of rainfall events. Under the RCP 4.5 scenario, soil erosion rates are projected to increase by 30-50%, while under the more extreme RCP 8.5 scenario, erosion rates could double, particularly in the northern region, where the projected rate reaches up to 160 tons/ha/year. These findings underscore the vulnerability of the Badra Basin to the impacts of climate change and the urgency of implementing soil conservation measures.

The study also identified several key strategies to mitigate soil erosion in the Badra Basin. Reforestation, contour farming, check dams, and the use of cover crops are among the recommended practices that can significantly reduce soil loss and improve soil stability. Implementing these strategies, particularly in high-risk areas, is essential to preserving the agricultural productivity of the region and preventing land degradation.

In conclusion, the results highlight the need for proactive, climate-resilient land management practices to mitigate the adverse impacts of climate change on soil erosion in the Badra Basin. By integrating soil conservation measures with sustainable land use planning, the region can maintain its agricultural productivity, protect its natural resources, and ensure the long-term sustainability of its ecosystems in the face of climate change. Further research is needed to explore the socioeconomic impacts of soil erosion and to refine adaptive strategies tailored to local conditions and future climate scenarios.

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REFERENCES

[1] M. Abdelhak, “Soil improvement in arid and semiarid regions for sustainable development,” in *Natural resources conservation and advances for sustainability*, Elsevier, 2022, pp. 73–90. doi: 10.1016/B978-0-12-822976-7.00026-0.

[2] and S. K. A.-D. Ahmed F. Hassoon1, “Effect Dynamic Stability of Atmospheric Boundary Layer on Plume Downward Flux Emitted from Daura Refinery Stacks,” 2023.

[3] M. S. Shamkhi and H. J. Al-Badry, “Assessment of groundwater recharge potential depending on morphologic analysis in East of Wasit, Southeastern Iraq,” *Iraqi Geol. J.*, pp. 138–154, 2021, doi: 10.46717/igj.54.2D.11Ms-2021-10-30.

[4] P. H. Whitfield, P. D. A. Kraaijenbrink, K. R. Shook, and J. W. Pomeroy, “The spatial extent of hydrological and landscape changes across the mountains and prairies of Canada in the Mackenzie and Nelson River basins based on data from a warm-season time window,” *Hydrol. Earth Syst. Sci.*, vol. 25, no. 5, pp. 2513–2541, 2021, doi: 10.5194/hess-25-2513-2021.

[5] Á. Barral Muñoz, “Modeling Raster Analysis of Space-Time Variables. Application to Estimated Erosion and Rainfall Erosivity in a Mediterranean Region for 25 Years,” *Appl. to Estim. Eros. Rainfall Erosivity a Mediterr. Reg.*, vol. 25, doi: 10.1016/j.catena.2024.108606.

[6] A. Ghosh *et al.*, “Integration of GIS and remote sensing with RUSLE model for estimation of soil erosion,” *Land*, vol. 12, no. 1, p. 116, 2022, doi: 10.3390/land12010116.

[7] P. Borrelli *et al.*, “Land use and climate change impacts on global soil erosion by water (2015-2070),” *Proc. Natl. Acad. Sci.*, vol. 117, no. 36, pp. 21994–22001, 2020, doi: 10.1073/pnas.2001403117.

[8] C. Zucca, R. Fleiner, E. Bonaiuti, and U. Kang, “Land degradation drivers of anthropogenic sand and dust storms,” *Catena*, vol. 219, p. 106575, 2022, doi: 10.1016/j.catena.2022.106575.

[9] S. Issaka and M. A. Ashraf, “Impact of soil erosion and degradation on water quality: a review,” *Geol. Ecol. Landscapes*, vol. 1, no. 1, pp. 1–11, 2017, doi: 10.1080/24749508.2017.1301053.

[10] C. J. Rhodes, “Soil erosion, climate change and global food security: challenges and strategies,” *Sci. Prog.*, vol. 97, no. 2, pp. 97–153, 2014, doi: 10.3184/003685014X13994567941465.

[11] V. H. D. Zuazo and C. R. R. Pleguezuelo, “Soil-erosion and runoff prevention by plant covers: a review,” *Sustain. Agric.*, pp. 785–811, 2009, doi: 10.1007/978-90-481-2666-8_48.

[12] V. H. Durán-Zuazo, J. R. Francia-Martínez, I. García-Tejero, and S. C. Tavira, “Implications of land-cover types for soil erosion on semiarid mountain slopes: Towards sustainable land use in problematic landscapes,” *Acta Ecol. Sin.*, vol. 33, no. 5, pp. 272–281, 2013, doi: 10.1016/j.chnaes.2013.07.007.

[13] O. A. Abdi, E. K. Glover, and O. Luukkanen, “Causes and impacts of land degradation and desertification: Case study of the Sudan,” *Int. J. Agric. For.*, vol. 3, no. 2, pp. 40–51, 2013, doi: 10.5923/j.ijaf.20130302.03.

[14] M. Ikirri *et al.*, “Delineation of groundwater potential area using an AHP, remote sensing, and GIS techniques in the Ifni Basin, Western Anti-Atlas, Morocco,” *Water*, vol. 15, no. 7, p. 1436, 2023, doi: 10.3390/w15071436.

[15] J. Ananda and G. Herath, “Soil erosion in developing countries: a socio-economic appraisal,” *J. Environ. Manage.*, vol. 68, no. 4, pp. 343–353, 2003, doi: 10.1016/S0301-4797(03)00082-3.

[16] A. Luvai, J. Obiero, and C. Omuto, “Soil loss assessment using the revised universal soil loss equation (RUSLE) model,” *Appl. Environ. Soil Sci.*, vol. 2022, no. 1, p. 2122554, 2022, doi: 10.1155/2022/2122554.

[17] M. Wagari and H. Tamiru, “RUSLE model based annual soil loss quantification for soil erosion protection: A case of Fincha Catchment, Ethiopia,” *Air, Soil Water Res.*, vol. 14, p. 11786221211046234, 2021, doi: 10.1177/11786221211046234.

[18] M. S. Regasa and M. Nones, “SWAT model-based quantification of the impact of land use land cover change on sediment yield in the Fincha watershed, Ethiopia,” *Front. Environ. Sci.*, vol. 11, p. 1146346, 2023, doi: 10.3389/fenvs.2023.1146346.

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