Postprint: Soil Erosion Assessment and Driving Factor Analysis in the Weibei Mining Area

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Abstract

The Weibei mining area in Shaanxi Province is located on the Loess Plateau. Under the dual influence of the natural environment and human activities such as coal mining, soil erosion in this region is particularly severe, and the ecological environment is highly fragile. This study takes the Weibei mining area as the research object to evaluate soil erosion based on the RUSLE model. By integrating influencing factors including vegetation coverage, multi-year average precipitation, slope, land use type, and annual coal production, the geographical detector method was applied to perform quantitative attribution of soil erosion. The research findings provide valuable reference for the prevention and control of soil and water loss in mining areas. The results indicate that: (1) Soil erosion in the Weibei mining area is predominantly slight and mild, with severely eroded regions mainly distributed in the southwestern, central, and southeastern parts of the study area. (2) Vegetation coverage and multi-year average precipitation are the dominant factors influencing soil erosion in the study area. Areas with slopes ranging from 20° to 25°, regions with vegetation coverage below 0.3, and bare land constitute high-risk zones for soil erosion. (3) The explanatory power of factor interactions on soil erosion in the Weibei mining area exceeds that of individual factors, indicating that the combined effects of multiple factors significantly influence soil erosion.

Full Text

Spatial Distribution of Soil Erosion and Its Driving Factors in the Weibei Mining Area Based on GIS and RUSLE

Abstract

The Weibei mining area in Shaanxi Province, China, is located in the Loess Plateau. Affected by natural environment and human activities such as coal mining, soil erosion in this area is more serious and the ecological environment is more fragile. In this paper, the simulation of soil erosion and its quantitative attribution analysis have been conducted in the mining area based on the RUSLE model and the geographical detector method. The influencing factors, such as vegetation cover, perennial average precipitation, slope, land use type, and annual coal output have been taken into consideration. The results of this study provide advice on soil and water conservation in mining areas. The results indicate as follows: (1) The intensity of soil erosion in general was mainly slight and mild in the Weibei mining area. The soil erosion was severe in the central, southeastern, and southwestern regions of the study area. (2) Vegetation coverage and perennial average precipitation are the dominant factors of soil erosion in the Weibei mining area. Moreover, the conditions that are likely to induce soil erosion are: slopes between 20° and 25°, vegetation coverage less than 0.3, and bare lands. (3) The synergistic effect of the factors on soil erosion is greater than that of single factors. Therefore, the combined action of multiple factors has a significant impact on soil erosion in the Weibei mining area.

Keywords: soil erosion; RUSLE model; Loess Plateau; geographical detector; coal mining area; driving factors

1. Study Area and Methods

The Weibei mining area is situated in the Loess Plateau of Shaanxi Province, with geographical coordinates ranging from 34°38 to 35°47 N and 108°40 to 110°37 E, covering approximately 8,000 km^2. The region is characterized by fragile ecological conditions exacerbated by intensive coal mining activities. This study employs the Revised Universal Soil Loss Equation (RUSLE) model integrated with GIS technology to assess soil erosion dynamics and utilizes the geographical detector method for quantitative attribution analysis.

The RUSLE model calculates soil erosion as a function of rainfall erosivity, soil erodibility, topographic factors (slope length and steepness), vegetation cover management, and support practice factors. Data were processed at a spatial resolution of 2 km × 2 km using ArcGIS 10.2. Key influencing factors considered include vegetation coverage, perennial average precipitation, slope gradient, land use type, and annual coal output. The geographical detector method quantifies the explanatory power of each factor and their interactions on the spatial heterogeneity of soil erosion.

2. Results

2.1 Spatial Distribution of Soil Erosion The simulated soil erosion rates for 2018 ranged from 0 to 2,542.46 t · hm ^{2} · a ^{1} across the study area. [Figure 2: see original paper] illustrates field research data from coal mines in the Weibei mining area. The spatial distribution reveals that soil erosion intensity was predominantly slight to mild across most of the region. However, severe erosion was concentrated in the central, southeastern, and southwestern portions of the mining area. According to the classification standards for soil erosion intensity

(SL190-2007), areas with vegetation coverage below 0.3 and slopes exceeding 20° exhibited the highest erosion susceptibility, accounting for 83.92% of severe erosion patches, while bare land contributed 7.90% of severe erosion cases.

[Figure 3: see original paper] presents the spatial distribution of soil erosion in the Weibei mining area for 2018, showing clear zonation patterns correlated with topography and land cover. The erosion modulus varied significantly with slope and vegetation conditions, with critical thresholds identified at slope gradients of 20°–25° and vegetation coverage below 0.3.

2.2 Dominant Factors Analysis The geographical detector analysis identified vegetation coverage and perennial average precipitation as the primary driving factors controlling soil erosion spatial patterns. summarizes the q-values for individual influencing factors, where q represents the explanatory power of each factor. The q-values for vegetation coverage, precipitation, slope, land use type, and coal output were 0.0172, 0.0594, 0.0169, 0.1142, and 0.0103, respectively, indicating that land use type and precipitation exert the strongest influence.

The interaction detector revealed that the combined effects of factor pairs produced significantly higher q-values than individual factors alone. presents the interaction q-values between covariates, demonstrating synergistic enhancement effects. For instance, the interaction between vegetation coverage and slope generated a q-value of 0.435, substantially exceeding the sum of their individual effects, confirming that factor interactions amplify erosion risk.

2.3 High-Risk Area Characterization delineates high-risk erosion areas and their mean factor values. The most critical combinations include: - Precipitation: 536.42–548.62 mm - Slope: 20°–25° - Vegetation coverage: <0.3 - Mean erosion modulus: 13.77–29.32 t · hm ^{2} · a ^{1} - Total erosion amount: 19.22 × 10 t · a ^{1}

These high-risk zones are predominantly distributed across bare land, sparse grassland, and mining-disturbed areas with compromised vegetation cover.

3. Discussion

The results demonstrate that soil erosion in the Weibei mining area is governed by complex interactions between natural and anthropogenic factors. The geographical detector method effectively quantifies these relationships, revealing that no single factor dominates but rather combinations of factors create hotspots of erosion vulnerability. The critical role of vegetation coverage underscores the importance of ecological restoration in mining areas. Precipitation patterns characteristic of the Loess Plateau' s monsoonal climate intensify erosion on steep, unvegetated slopes.

The synergistic effects between slope and vegetation coverage (q = 0.435) and between precipitation and land use type (q = 0.240) indicate that management strategies must address multiple factors simultaneously. Simply controlling one factor proves insufficient for effective soil conservation. The study' s findings align with previous research on the Loess Plateau [?, ?, ?], confirming that vegetation restoration remains the most effective mitigation measure, particularly on slopes exceeding 20°.

4. Conclusion

Soil erosion in the Weibei mining area exhibits significant spatial heterogeneity, with severity concentrated in regions characterized by steep slopes, low vegetation coverage, and mining disturbances. Vegetation cover and precipitation emerge as the dominant controlling factors, while their interactions produce amplified effects exceeding individual factor contributions. The critical thresholds of 20°–25° slope gradient and vegetation coverage below 0.3 provide clear targets for conservation prioritization. These results offer scientific guidance for implementing targeted soil and water conservation measures in mining areas of the Loess Plateau.

Data Availability: The datasets used in this study are available from the corresponding author upon reasonable request. Meteorological data were obtained from the China Meteorological Data Service Center (http://www.resdc.cn).

Author Contributions: All authors contributed to the study conception and design. Data collection and analysis were performed by the research team. The first draft of the manuscript was written by the corresponding author. All authors read and approved the final manuscript.

Conflict of Interest: The authors declare that they have no conflict of interest.

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Note: Figure translations are in progress. See original paper for figures.