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Spatial-Temporal Analysis of Soil Erosion Based on Spatial Model and GIS Technology

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Abstract: In recent years, with the increase of population and economic and social development, unreasonable agricultural farming methods, indiscriminate deforestation, overgrazing and other unreasonable human activities have aggravated the impact of regional soil erosion(SE), seriously affecting the security of land resources. In-depth study of the occurrence mechanism of regional SE, analysis of the distribution pattern and temporal and spatial characteristics of regional SE, and accurate assessment of the amount of regional SE are of great significance for protecting surface soil resources, reducing land degradation, protecting the ecological environment, and alleviating SE problems in my country and the world important meaning. In this paper, combined with spatial model and GIS technology, the RULE model is used to quantitatively evaluate wind erosion and hydraulic erosion in a county, calculate and count the modulus of wind erosion and hydraulic erosion, obtain the spatiotemporal distribution characteristics of SE factors in the county, and master the SE in the county. The spatial and temporal distribution of feng shui erosion. The research results show that the wind erosion factor reached the highest value in the year in May, and the overall space showed a decreasing trend from east to west. The hydraulic erosion is analyzed based on the rainfall erosion factor, which is relatively strong in June, July and August, and relatively weak in other months, and generally shows a decreasing trend from northwest to southeast in space.

1. Introduction

At present, SE has become one of the global ecological and environmental disasters. If SE cannot be effectively managed, it will pose a serious threat to human survival and social development. The innovative research on the SE process in this paper is of great significance for the effective prevention and control of regional SE and ecological environmental protection, and is a key entry point for the harmonious development of human survival and natural environment.

Internationally, the application of general soil loss equation and geographic information system (GIS) technology has been very mature, and many scholars have achieved a lot of research results.

Geographic Information System (GIS) is based on computers, processes information and data from different sources, and displays the relationship and interaction between them, which makes up for the difficulties and deficiencies of conventional monitoring methods, and provides important information for monitoring SE. Based on this, it is convenient for scholars from all over the world to explore the changes and distribution of SE, so as to quantitatively describe SE [1-2]. Some scholars use USLE and GIS to estimate SE in the Rift Valley. Based on the field test research of GIS technology, the vegetation coverage factor in the RUSLE model has been improved, and a new method of estimating vegetation coverage factor using remote sensing technology is proposed. characteristics of SE in the study area [3]. A scholar established the Universal Soil Loss Equation (USLE) model, which greatly improved the research efficiency of SE and the enthusiasm of scholars. Many scholars proposed a series of SE models that conform to local actual conditions [4]. A scholar combined the modified general soil loss equation (RUSLE), used ArcGIS to resample and analyze the SE factors, and then multiplied the factors to calculate the SE modulus in the study area. The results obtained are basically consistent with the research results of other scholars [5]. Although there are many methods to study the temporal and spatial characteristics of SE, the application of spatial models and GIS technology in SE assessment needs to be further developed.

This paper first introduces the concept of spatial model, and then proposes the evaluation method of SE. Then, taking SE in a county as the research object, using RUSLE and GIS technology to evaluate the value of SE factor and SE in the county, by analyzing the SE in the county Evaluation results of wind erosion factors and hydraulic erosion factors to understand the spatial and temporal distribution characteristics of regional SE.

2. Related Models and Methods

2.1 Spatial Model

Spatial models are the fusion and product of geostatistics and metrology, and are mainly used to analyze geospatial data [6]. The initial application of spatial econometric models is in econometrics, a model used to analyze the spatial correlation and spatial effects of things with geographic spatial characteristics [7]. The proposal of the spatial econometric model has changed the way people originally studied things with geographical spatial characteristics, and enabled people to study geographical things with spatial attributes from a new perspective [8].

2.2 SE Assessment Methods

SE can cause ecological damage and is a major threat to global environmental problems. The RULE model estimates the amount of SE in the study area by analyzing SE factors such as rainfall, topography, soil, surface cover management, and soil and water conservation in the study area [9-10]. The RUSLE model is currently the most widely used classical model for SE research in the world. It is an empirical SE prediction model modified from the USLE model [11-12]. However, the causes of SE are complex. The RUSLE model can be used to study the characteristics and influencing factors of SE. The formula is as follows:

$$A = R \cdot K \cdot LS \cdot C \cdot P \quad (1)$$

In the formula, A is the annual average soil loss, R is the rainfall erosivity factor, K is the soil erodibility factor, LS is the slope length and slope factor, C is the vegetation coverage and management factor, and P is the soil and water conservation factor.

$$Q_i = \alpha \sum_{j=1}^{k} (D_j)^{\beta} \quad (2)$$

Among them, Q_i is the rainfall erosive force in the ith month, D_j is the erosive rainfall on the jth day in the ith month, and α and β are both constants.

The spatial distribution characteristics of soil erodibility factors refer to the spatial differences in the ability of soil physicochemical structure to resist erosion in different spatial locations [13]. The slope length (L) and slope (S) factors are topographical factors that affect SE. Professionals are required to conduct field surveys to accurately determine the slope length, which is time-consuming and labor-intensive. This method is unrealistic for large-scale research scales. With the development of GIS technology, at present, the slope and slope length are mainly obtained through DEM data, and then the slope formula used by domestic researchers can be used to calculate LS [14-15].

3. Experimental Research

3.1 Research Objects

This study mainly analyzes the temporal and spatial differentiation characteristics of SE in a certain county. The total soil area of the county is 1956.8 km2, and the SE types in the study area are complex, mainly including hydraulic and wind erosion [16].

3.2 Research Content

This paper first analyzes the temporal and spatial characteristics of wind erosion in the county, analyzes the variation trend of wind erosion in the county, as well as the intensity and area of wind erosion; and then analyzes the temporal and spatial characteristics of hydraulic erosion in the county, by calculating the monthly rainfall erosion of meteorological stations within the study area of the county The spatial distribution data of rainfall erosivity factors from 2012 to 2020 were generated in Arc GIS software [17-18]. This paper analyzes the spatial and temporal distribution characteristics of rainfall erosivity factors from two aspects: monthly and annual.

3.3 Data Sources

The data collected in this study included the annual and monthly rainfall data of the province from 2012 to 2020, which were obtained from the meteorological data network, and then a soil database was established based on the actual investigation of soil types [19].

4. Analysis of Research Results

4.1 Spatial and Temporal Distribution Characteristics of Wind Erosion

Wind erosion in the county mainly occurred from March to July and November, with relatively weak erosion during the rest of the period. It can be seen from Table 1 that the wind erosion modulus in this county showed a gradual increase trend from January, until it reached 0.17 t/(km^{1-} a) in March and then began to decline, and reached 0.092 t/(km^{1-} a) in April) and then rose again to the annual maximum wind erosion modulus of 0.21 t/(km^{1-} a) in May, and then began to gradually decrease, reaching the annual minimum value of 0.056 t/(km^{1-} a) in October. The wind erosion area shows a trend of first increasing and then gradually flattening throughout the year. Among them, April and May are the largest months of the year, with an erosion area of 17.22 km^2.

Table 1. The change trend of wind erosion in the county in a certain year

	Average Erosion Index[t/(km^{-1} a)]	erosion area(km^2)
1	0.061	3.68
2	0.078	1.35
3	0.17	2.74
4	0.092	6.97
5	0.21	9.63
6	0.18	8.56
7	0.13	4.32
8	0.087	0
9	0.072	1.25
10	0.056	0
11	0.094	2.47
12	0.073	0.34

Table 2. Wind erosion intensity and area

	Area(km^2)	ratio of total land area(%)	wind erosion modulus [t/(km^{-1} a)]
Micro degree	1241.0	63.42	maximum value:67.29 Minimum value:0 average value:15.81
mild or above	195.2	9.98	
mild	117.6	6.01	
Moderate	28.3	1.45	
strong	0	0	

As shown in Table 2, wind erosion is divided into 5 grades, which are slight, above mild, mild, moderate, and severe. The total land area of the county is 1956.8km^2, the total area of wind erosion is 1555.1km^2, the area of slight erosion is 1241.0km^2, accounting for 63.42% of the total land area of the county; the area of mild erosion is 195.2km^2, accounting for 6.01% of the total area, The county does not have heavily wind-eroded soils. It can be seen from Table 2 that the maximum value of the wind erosion modulus in this county is as high as 67.29 t/(km^{1-} a), the minimum value is 0, and the average is 15.81 t/(km^{1-} a). The data show that most of the county's soil is eroded by wind, and the erosion intensity is mainly micro. After GIS monitoring, wind erosion showed a decreasing trend from east to west.

4.2 Spatial and Temporal Distribution Characteristics of Hydraulic Erosion

Figure 1 shows the time-series changes of rainfall erosivity factors and two rainfall indicators, such as precipitation and erosive rainfall, in the study area of the county from 2012 to 2020. From the analysis of the results in the figure, it can be seen that the rainfall erosivity factor in the study area shows a fluctuating change as a whole and has a significant decrease after 2018. Among them, the rainfall erosivity factor in 2010 has the largest value, indicating that the rainfall erosivity factor in that year was caused by rainfall. SE is very serious, and the rainfall erosivity factor value in 2020 is the smallest, indicating that the amount of SE caused by rainfall in this year is small. In addition, Figure 1 shows the time-series changes of the two rainfall indexes and the rainfall erosivity factor values in the same spatial unit. On the whole, the change trends of the two rainfall indexes and the rainfall erosivity factor in the time series are consistent., which showed high values in 2013, 2016 and 2018, and low values in 2014, 2017 and 2020, indicating that rainfall indicators determine the changing state of rainfall erosion. At the same time, comparing the time-series changes of the three rainfall indexes and the value of the rainfall erosivity factor, it can be found that the regional rainfall and the erosive rainfall are the dominant factors determining the value of the rainfall erosivity factor.

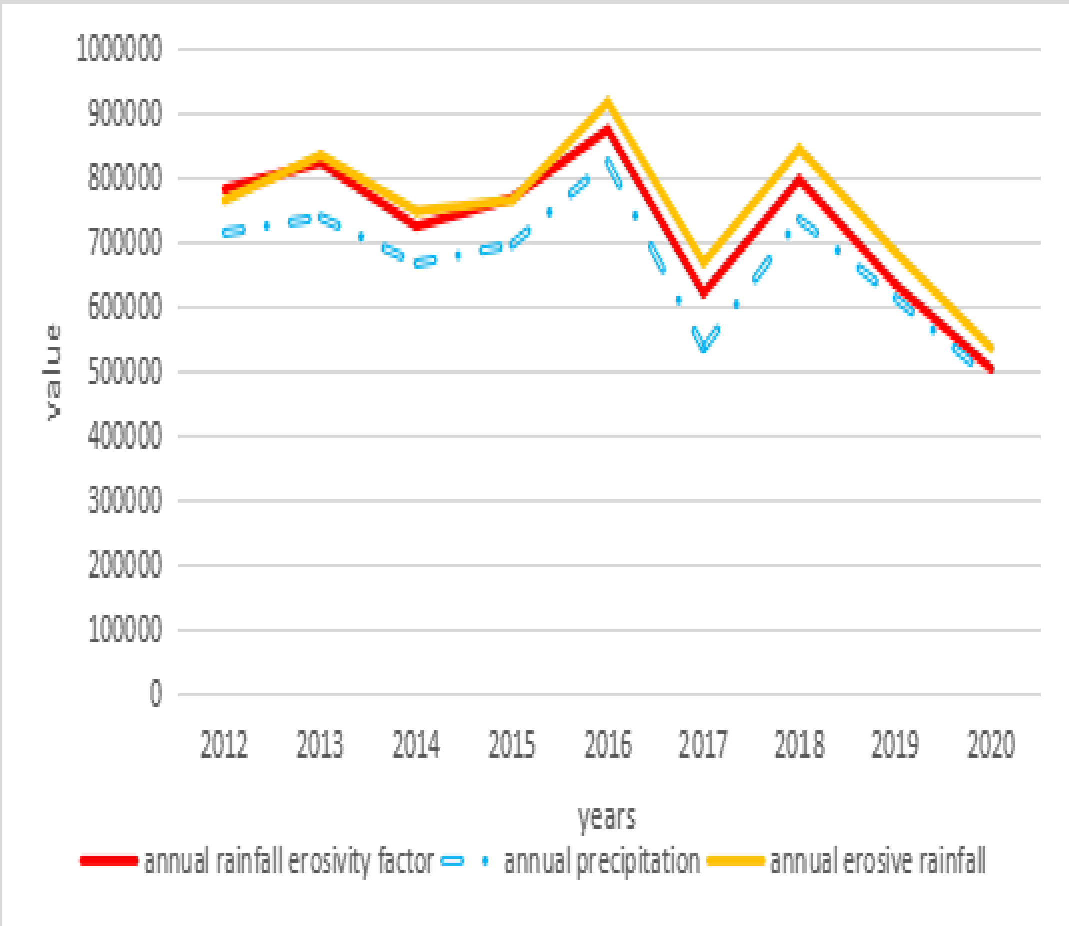

Figure 1. Inter-annual time series variation of rainfall erosivity factor and rainfall index

Since the peak value of rainfall erosivity factors in my country is mainly distributed between April and October, the spatial distribution characteristics of rainfall erosivity factors in the county for a total of 7 months from April to October were analyzed. In this paper, the intermonthly spatial distribution characteristics of rainfall erosivity factors are analyzed by combining the monthly spatiotemporal data of rainfall and erosive rainfall.

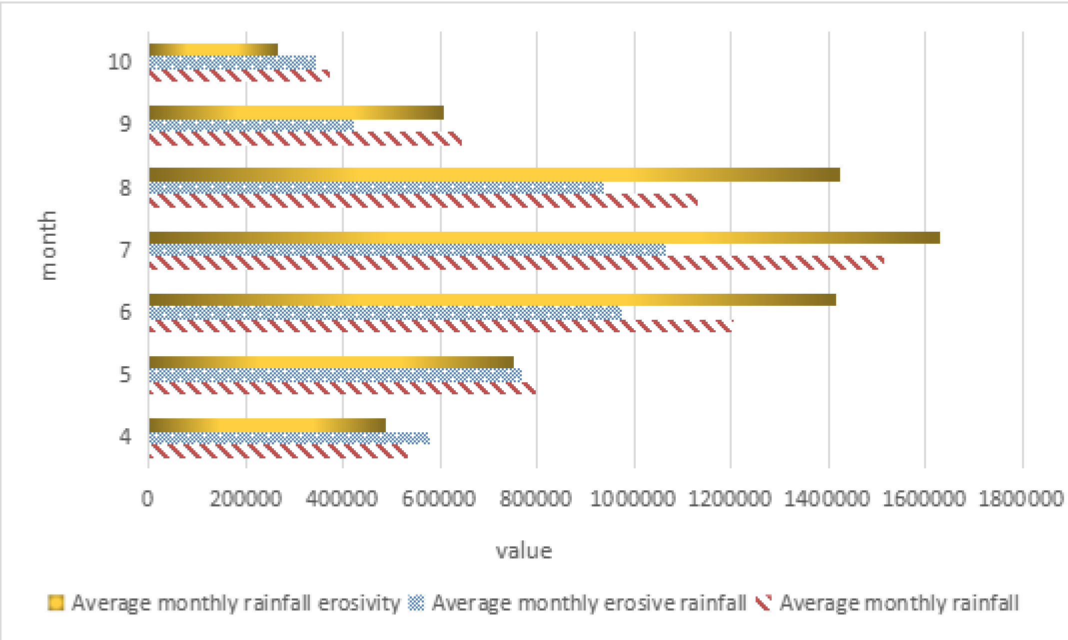

Figure 2. Monthly time series variation of rainfall erosivity factor and rainfall index

Figure 2 shows the change status of the rainfall erosivity factor and the rainfall index in the study area for many years from April to October. The results in the figure show that the monthly variation law of the rainfall erosivity factor and the two rainfall indexes is basically the same, and their variation patterns are close to According to the normal distribution curve, that is, it gradually increased from April to the maximum value in July, and showed a gradual downward trend from August to October. This result shows that the monthly distribution of the rainfall erosivity factor varies with It varies with the monthly distribution of rainfall, and the two have the same inter-monthly time-series variation law.

Table 3. Hydraulic erosion intensity and area

<table>
<tr><th></th><th>Area(km^2)</th><th>ratio of total land area(%)</th><th>wind erosion modulus [t/(km^{-1} a)]</th></tr>
<tr><td>Micro degree</td><td>536.4</td><td>27.41</td><td rowspan="5">maximum value:33.57
Minimum value:0
average value:6.92</td></tr>
<tr><td>mild or above</td><td>2.72</td><td>0.14</td></tr>
<tr><td>mild</td><td>0.48</td><td>0.024</td></tr>
<tr><td>Moderate</td><td>0</td><td>0</td></tr>
<tr><td>strong</td><td>0</td><td>0</td></tr>
</table>

Table 3 shows the erosion area corresponding to the 5 grades of hydraulic erosion. Among them, the total area of hydraulic erosion is 539.6km^2, the area of slight erosion is 536.4km^2, accounting for 27.41% of the total land area of the county; the area of more than mild erosion is 2.72km^2, accounting for 0.14% of the total area. Severely hydraulically eroded soils. The maximum value of the hydraulic erosion modulus in this county is 33.57 t/(km^{1-} a), the minimum value is 0, and the average is 6.92 t/(km^{1-} a). The data show that the area of hydraulic erosion in this county is small and the intensity is relatively light, and the distribution of water erosion is relatively concentrated and distributed in small pieces. After GIS monitoring, hydraulic erosion showed a decreasing trend from northwest to southeast.

5. Conclusion

Soil is the most precious natural resource on earth. Due to the complex and long-term process of forming soil, once soil resources are damaged, it is difficult to recover in a short period of time. Understanding the status quo and temporal and spatial pattern of SE, and clarifying the distribution of geomantic erosion types, is of great help for soil and water conservation planning and governance and improving the ecological environment. In this paper, the wind erosion model and the RUSLE model are combined with the Arc GIS platform to study the temporal and spatial distribution of SE patterns and the division of SE types in the study area, and optimize the calculation method of SE, provides a scientific basis for soil and water conservation planning and zoning management of soil and water conservation..

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