Spatial Influence of Geographical Factors on Soil Erosion in Fuyang County, China

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Abstract

The effect of geographical factors on soil erosion is an important aspect of the monitoring environment changes. The spatial relationship between soil erosion and its geographical factors was carried out. The results showed that soil erosion exhibited high selectivity of geographical factors. 94.5% of soil erosion occurred in areas less than 500 m, 85.3% presented on the areas between 15°- 35°, 57.2% distributed on southern slope, and 76.8% of strong erosion were found in garden land. It provided a basis for governing soil erosion, which was an important significance to local economic development.

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Introduction

Soil erosion is one of the most serious eco-environmental problems in China [1], which poses great hazards to soil degradation, agricultural production, water quality, natural resources and ecological security [2,3]. Protection measures to lessen these problems can be effectively carried out if the intensity and spatial distribution of soil erosion are known. Various models have been developed to simulate the process of soil erosion and assess its risk since the 1930s [4]. These models range from empirical Universal Soil Loss Equation (USLE) [5] and Revised Universal Soil Loss Equation (RUSLE) [6] to physical process-based models such as Erosion Productivity Impact Calculator (EPIC)[7], Kinematic Erosion Simulation Model (KINEROS)[8] and so on. Variables used in models are not always easy to be acquired, such as historical data requirement of neural-network method [9]. So, mapping soil erosion on a large scale is often impractical using these traditional models solely. The applications of GIS in estimating soil erosion were reviewed by Wilson and Lorang [10], as well as the difficulties and limitations of previous research being discussed. It was concluded that GIS and RS provide tremendous potential for improving soil erosion evaluation. In general, parameters of underlying surface features can be derived through RS images. In this study, information was extracted from RS images and field investigation with
the study area of Fuyang Country, Zhejiang Province. Environmental database of watershed was established in the support of GIS. Quantitative evaluation and monitoring for spatial background characteristics of soil erosion were conducted by spatial overlaying of soil erosion intensity maps and geographical factors distribution.

1 Materials and Methods

1.1 Study area

Fuyang Country is located in north of Zhejiang Province between 29°44'~30°11'58"N, 119°25'~120°19'13"E covering a total area of 1831.2 km². Fuchun River runs through its center stretching about 52.0 km. All the rivers in study area belong to Fuchun River system. Fuyang is characterized by one river between two mountains with many mountains in southeast, northwest and hilly regions in center. Plains distribute along rivers and valleys. Average elevation of Fuyang is 300m, with maximum of 1067m and minimum of 6 m. Soils can be divided into five main groups: Red soils, Yellow soils, Limestone soils, Alluvial soils and Paddy soils. Fuyang lies in south edge of the northern subtropics with annual mean temperature of 16.1℃. The accumulated temperature of ≥10℃ in study area is 5100℃ with frostless period of 232days and annual mean sunshine duration of 1995 hours. There are two main reasons for soil erosion: natural factors (terrain, precipitation, soil and vegetation) and anthropogenic factors (vegetation destruction, improper reclamation and mining). Because of high population density and intensive management, the human disturbance for hilly and mountain regions is very frequently. Coupled with low quality of forest, soil erosion often occurs, as well as landslide, debris flow and other natural hazards in local regions.

1.2 Data and Study Method

1.2.1 Data

Landsat ETM+ image for study area of 2006 was collected, as well as land use map in the same year. DEM and soil map dated back to 1989 with scale of 1:50000 were also collected. Maps above were scanned, digitized and constructed using ArcGIS software.

1.2.2 Extracting factors

(1) Maps of elevation, slope and aspect
Maps of elevation, slope and aspect were derived from DEM on the basis of ArcGIS.

(2) Vegetation coverage map
Normalized Difference Vegetation Index (NDVI) was used to calculate vegetation coverage in the regions with high forest coverage of 68.5%. The formula is given as follows:

\[ f_c = \frac{(I_{\text{NDVI}} - I_{\text{NDVI}_{\text{min}}})}{(I_{\text{NDVI}_{\text{max}}} - I_{\text{NDVI}_{\text{min}}})}. \]

Here, the \( I_{\text{NDVI}} \) is value of NDVI, \( I_{\text{NDVI}_{\text{min}}} \) is minimum of NDVI and \( I_{\text{NDVI}_{\text{max}}} \) is the maximum of NDVI.

(3) Land use and soil type maps
Maps of land use and soil type were directly generated from those maps with scale of 1:50000 after vectorization.

(4) Hydrology and topography maps
Watershed is divided into plain, hilly, mountain, platform and other ecological regions by spatial analysis according to hydrological and topographic conditions, coupled with elevation, slope and other geographic factors. Raster data were converted into grid format with 25m×25m resolution. In addition, all the data should be fitted to map projection of Krasovsky_1940_Transverse_Mercator for spatial analysis.

1.2.3 Soil erosion intensity maps
According to the national classification standards of soil erosion types, soils in Fuyang are eroded mainly by hydraulic power, which is characterized by erosion on slopes. Besides, gravity erosion can be
found in parts of mountain regions, such as landslide and collapse. Different degrees of soil erosion were classified by integration of the following materials: current land use maps, vegetation coverage maps, slope maps and indices from table 1. Soil erosion intensity maps (Fig. 1) were generated through field survey. Given geographic factors, areas for soil erosion of different degrees were calculated.

### 1.2.4 Correlation analysis between soil erosion and geographic factors

The most important geographic factors that influence soil erosion are: elevation, slope, aspect, land use and soil type. In order to obtain the correlation between soil erosion and factors above, overlaying analysis was conducted, the tables of correlation between soil erosion and geographic factors were also computed.

**Fig. 1 Spatial distribution of soil erosion in the study area**

## 2 Results and discussions

### 2.1 General characteristics of soil erosion

Statistical results show that the soil erosion area of Fuyang is 1390.6 km², accounting for 76.3% of total area. The primary soil erosion degrees are slight and moderate, accounting for 94.9% of total erosion area. Very strong and strenuous soil erosion is scarce, with proportion of only 3.8%.

### 2.2 Relationship between soil erosion and slope, aspect

Overlaying analysis of slope, aspect maps and soil erosion intensity charts was conducted. Statistical analysis (table 1 and table 2) shows that soil erosion mainly occurs in 15°–35° slope belt, accounting for
85.3% of total erosion area. The slope in 25°–35° regions cover the largest erosion area, accounting for 58.0% of total erosion area. Vegetation covers consist mainly of tea trees, fruit trees and seedlings in that area, where the slope is steep with thin soil. Moreover, immoderate exploring and other unreasonable human activities are conducted over slope land, resulting in soil erosion in hilly regions, even more severe in some parts. It is easily understood that soil erosion is closely related to slope, the steeper the slope, the more severe erosion happens. Soil erosion in slope lands above 35° only accounts for 4.5% of total erosion area. The main reasons are that these lands have been conserved with high forest coverage and few human activities.

As to aspect, soil erosion mainly occurs on sunny slope, accounting for 57.2% of erosion area, following with semi-sunny and semi-shady slope. Analysis shows that soil erosion has close relationship with aspect. With good water and heat conditions, south slope is suitable for agriculture cultivation. Agriculture activities focus on sunny slope, leading to corresponding soil erosion.

| Degree Level       | Very Slight Erosion | Slight Erosion | Middle Erosion | Strong Erosion | Very Strong Erosion | Strenuous Erosion |
|--------------------|---------------------|----------------|----------------|----------------|---------------------|-------------------|
|                    | area/km² ratio/%    | area/km² ratio/% | area/km² ratio/% | area/km² ratio/% | area/km² ratio/%    | area/km² ratio/%   |
|                    | 379.6 88.2          | 15.9 4.0        | 0 0            | 0 0            | 0 0                 | 0 0               |

Table 1 Related feature tables between soil erosion and slope in the study area

| Degree Level       | Shade | Semi-sunny | Sunny | Flat | Semi-shade |
|--------------------|-------|------------|-------|------|------------|
|                    | area/km² ratio/% | area/km² ratio/% | area/km² ratio/% | area/km² ratio/% | area/km² ratio/% |
| Very Slight Erosion| 38.6 9.0 | 106.5 24.7 | 183.3 42.6 | 4 0.9 | 98.2 22.8 |
| Slight Erosion     | 4.0 1.0 | 91.4 23.1 | 213.8 54.1 | 0 0 | 86.1 21.8 |
| Middle Erosion     | 4.4 0.5 | 179.2 19.4 | 548.4 59.3 | 0 0 | 193 20.9 |
| Strong Erosion     | 1.5 2.7 | 14.9 25.8 | 27 46.7 | 0 0 | 14.4 24.8 |
| Very Strong Erosion| 0.4 3.1 | 2.9 25.4 | 6.1 52.7 | 0 0 | 2.2 18.9 |
| Strenuous Erosion  | 0 1.3 | 0.2 19.8 | 0.6 69.6 | 0 0 | 0.1 9.3 |
| ratio/%            | 0.7 20.8 | 57.2 | 0 | 21.3 |

Table 2 Related feature tables between soil erosion and aspect in the study area

2.3 Relationship between soil erosion and elevation

Overlaying analysis of soil erosion intensity maps and elevation map reveals that the lower the elevation is, the more severe the soil erosion is. Soil erosion mostly happens in regions below 500 m, accounting for 94.6% of total erosion area. The soil erosion areas of strong and very strong severe degree below 200 m are 29 km² and 2.3 km² more than those in 200–500 m zone respectively. Besides, the region above 500 m accounts for a small proportion. Due to high elevation, inconvenient traffic, high forest coverage and agriculture producing cost, little human disturbance exists in regions above 500 m, therefore, soil erosion less occurred.
Table 3 Related feature tables between soil erosion and elevation in the study area

| Degree Level            | <200 m  | 200~500 m | 500~800 m | >800 m |
|-------------------------|---------|-----------|-----------|--------|
|                        | area/km² | ratio/%   | area/km²  | ratio/% | area/km²  | ratio/% | area/km²  | ratio/% |
| Very Slight Erosion    | 427.5   | 99.3      | 2.8       | 0.7     | 0.2       | 0.0     | 0         | 0       |
| Slight Erosion         | 305.1   | 77.2      | 79.2      | 20.0    | 10.9      | 2.8     | 0.1       | 0       |
| Middle Erosion         | 262.8   | 28.4      | 599.8     | 64.8    | 61.7      | 6.7     | 0.7       | 0.1     |
| Strong Erosion         | 42.6    | 73.6      | 13.6      | 23.5    | 1.7       | 2.9     | 0         | 0       |
| Very Strong Erosion    | 6.7     | 58.6      | 4.5       | 38.8    | 0.3       | 2.6     | 0         | 0       |
| Strenuous Erosion      | 0.4     | 41.5      | 0.5       | 54.0    | 0         | 4.5     | 0         | 0       |
|                        |         |           |           | 44.4    | 50.2      | 5.4     | 0.1       |

2.4 Relationship between soil erosion and land use

Soil erosion is closely related to land use type. It is mainly concentrated on forest land and shrub grassland with middle or slight degree, and erosion area in these two types account for 88.3% of total erosion area. Although the forest coverage in study area is as high as 68.4%, the overall quality is still low, as well as the low stand volume with mean value of 29.9 m³/hm², which is below the average level of 40.5 m³/hm² in Zhejiang Province. The coniferous, such as Pinus massoniana and Cunninghamia lanceolata, are main forest species, accounting for 52.5% of total forest land. Shrub and bamboo forests also cover large area with proportion of 22.0% and 19.1% respectively. The water and soil conservation functions of these forest species are weak, while the broadleaf forest with effective function only account for 9.7%. In addition, unreasonable exploiting and cultivation also aggravate the soil erosion in parts of mountain areas. Results show that 76.8% of intensive and above occurs in garden plots, which suggests soil erosion in gardens is much serious in study area. For highly intensive management of economic crops, such as Phyllostachys edulis (Carr.) and drastic human disturbance, soil erosion often occurs in garden plots.

Table 4 Related feature tables between soil erosion and land use in the study area

| Degree Level     | Farm land | Garden land | Forest land | Shrub land | Urban and water |
|------------------|-----------|-------------|-------------|------------|----------------|
|                  | area/km²  | ratio/%     | area/km²    | ratio/%    | area/km²       | ratio/% |
| Very Slight Erosion | 158.1    | 36.7        | 38.9        | 2.3        | 3.8            | 9.0    |
| Slight Erosion    | 22.1      | 5.6         | 13.2        | 3.3        | 292.4          | 74.0   |
| Middle Erosion    | 23.1      | 2.5         | 3.9         | 3.9        | 714.8          | 77.3   |
| Strong Erosion    | 10.8      | 18.7        | 43.8        | 1.7        | 75.7           | 0.7    |
| Very Strong Erosion| 1.5       | 13.3        | 9.4         | 0.1        | 81.7           | 0.1    |
| Strenuous Erosion | 0.1       | 10.1        | 0.8         | 0.1        | 85.7           | 0.4    |
|                  | 4.1       | 7.4         | 72.5        | 3.6        | 0              | 0.2    |

3 Conclusion

Soil erosion shows significant spatial heterogeneity patterns. It mainly occurs in regions below 500m, accounting for 94.5% of total erosion area. Slope has significant effects on soil erosion, which mainly occurs in 15°~35° slope area, accounting for 85.3% of total erosion area. Soil erosion shows high selectivity in aspect, it mainly occurs in south slope, covering 57.2% of total erosion area. Soil erosion is severe in garden plots, where 76.8% of strong and above degree soil erosion occurs. The integration of
GIS/RS techniques with geographical factors is practicable and effective on monitoring soil erosion in large areas. The research can provide reference for local eco-environment protection and sustainable economic, social development.

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