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STUDY ON THE MODEL FOR PREDICTING SOIL EROSION AND ITS APPLICATION IN ARID AREA①

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ABSTRACT: On the basis of analyzing the soil erosion factors in typical arid area basin, this article tries to build a model by using USLE (Universal Soil Loss Equation). The first step is to digitize the topographic map (1∶100000) and form the DEM (Digital Elevation Model), then use them to obtain necessary data of topographic factors. The second step is to get main elements causing soil erosion through using Main Element Analyzing Program. The third step is to systematically analyze all factors of soil erosion by applying Grey Dynamic Model and Fuzzy Mathematics, and then take GIS software to draw the colored map in the way that different colors present different intensities of soil erosion. At last the regional change of soil erosion amount on the basis of the color map is analyzed.

KEY WORDS: arid area, soil erosion, predicting model, GIS

1 THE ANALYSIS OF SOIL EROSION FACTORS

The intensity of soil erosion in arid area varies with altitude, moisture and heat condition and surface layer (Chen, 1995). In middle and high mountain sections, there is a little more precipitation (450－796.90 mm), richer vegetation cover more than 60 percentage, so soil has relatively stronger ability to restrain soil erosion. In low mountain section with the altitude less than 1500 m, there is less precipitation (282.3 mm), poorer vegetation cover from 20% to 50%, bare surface, and developed gullies, so the soil is easier to be eroded and scoured. The Toutunhe River, for example, originating from the north slope of the Tianshan Mountains is a typical mountain stream, having annual runoff about 2.34×10^8 m^3 and its sediment transportation is 87.8×10^4 t, 80% of the water and 33.26% of the sand come from the upper reaches of the middle and high mountain sections with the altitude more than 1500 m, conversely, 80% of the water and 66.74% of the sand come from the lower reaches of low mountain sections with the altitude less than 1500 m (Table 1) (Li, 1994).

At the same time, it can be concluded that the precipitation, vegetation, topographic gradient and gully density are the important factors affecting soil erosion through observing and analyzing the intensity of soil erosion in selected region. If the percentage of vegetation cover is more than 80% and gully density less than 10 km/km^2, the intensity of soil erosion will be weaker. If the vegetation cover is less than 25% and gully density more than 25 km/km^2, the intensity of soil erosion will be serious. For example, in the lower reaches situated in low mountain sections, the annual soil erosion accounts to 52500－63000 kg/ha (Table 2).

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Table 1 Runoff volume and sediment discharge in the Toutunhe River basin of the Tianshan Mountains

Section	Length of river		Area		Altitude		Runoff		Sediment discharge	
	Length (km	Percentage (%	Area (km^2	Percentage (%	Altitude (m	Average (m	Volume (10^8 m^3	Pertentage (%	Discharge (10^4t	Percentage (%
The upper reaches of Zhicaichang Station	47.5	55.43	840	53.78	1430	2774	2.16	92.31	29.2	33.26
From Zhicaichang Station to the experimental station	28.9	33.72	593	37.96	1040	2210	0.16	6.84	22.55	28.68
From the experimental station to Hadipo Station	9.3	10.85	129	8.26	966	1920	0.02	0.085	36.05	41.06

Table 2 The relationship between percentage of vegetation cover and soil erosion in the Toutunhe River basin of the Tianshan Mountains

Sections	Altitude (m	Percentage of vegetation cover (%	Slope gradient (°	Precipitation (mm	Soil erosion amount (kg/ha
Upper reaches	2160	90	35	534.2	10200
Lower reaches	1300	46	27	364.5	28050
		46	31	260.5	41550
Lower reaches	1100	21	25	208	51300
		21	28	208	63000

2 BUILDING OF SOIL EROSION MODEL

Through analyzing the former soil erosion factors, considering the characters of soil erosion in mountain section of arid area, we can build the following soil erosion model by applying USLE (Universal Soil Loss Equation (Wesbter, 1977; Lane, 1992 .

$$EUA = AK^{\alpha_1}R^{\alpha_2}LS^{\alpha_3}V^{\alpha_4}D^{\alpha_5}$$

Where EUA: annual soil erosion amount on per unit area ($t/km^2 \cdot a$; A: the area of checkerboards (km^2 ; K: the factors of probability of soil erosion; R: precipitation factors; LS: topographic length and slope gradient; V: vegetation factor; D: gully intensity (km/km^2 ; α_i($i= 1, 2, 3, 4, 5$: the parameter to be defined . So the soil erosion amount equation is:

$$EROS = \sum_{i=1}^{n} EUA_i \quad (1)$$

Where $EROS$: annual soil erosion amount in river basin ($t/km^2 \cdot a$; n: the number of checkerboard in river basin; EUA_i: the soil erosion amount of the ith checkerboard.

3 DEFINING AND EXTRACTING OF SOIL EROSION FACTORS

The topographic factors include slope gradient (s , length (l , gully density, etc. In the course of calculating, mainly take the ARC/INFO function of GIS to digitize the topographic map (1∶100 000 of the Toutunhe River basin and then build the DEM (Digital Elevation Model (Chen, 1995 . On the basis of these, refer to (Wesbter, 1977 USLE and calculate them.

1 Take the following equation to calculate the length and slope gradient.

$$LS = \frac{\sqrt{\sum_{i=1}^{n} L_i}}{100}(1.36 + 0.979 + 0.138S^2) \quad (2)$$

Where L_i: the length of slope on the neighboring checkerboard, on which the gradient equals to the same direction; i: the number of new neighboring checkerboard, on which the gradient equals to the same direction.

2 Gully intensity is:

$$G = \sum L / \sum S \quad (3)$$

Where G: gully intensity (km/km^2 ; ΣS: the total area of sample units; ΣL: the total length of gully on sample area.

On the basis of DEM data, we can transform checkerboard equation data into 0 or 1 belonging to binary system. These checkerboards who's number are 1 present position of bottom line. Take the number of each bottom-line checkerboard into equation (3 and get gully intensity.

3 Use these data collected from field investigation and observation stations, and divide them into three parts. Use following equation to calculate precipitation factor value(Table 3 .

$$R = \sum_{i=1}^{12} 1.735 \times \exp(1.5 \times \lg \frac{P_i}{P} - 0.8188) \quad (4)$$

Where P: the annual precipitation (mm ; P_i: the monthly mean precipitation.

Table 3 The precipitation factors in different sections of the Toutunhe River basin in the Tianshan Mountains

Section	The upper reaches of Zhicaichang Station	From Zhicaichang Station to Experiment Station	From Experiment Station to Hadipo Station
Precipitation factor value	108.871	60.594	39.782

4 Soil erosion index can be calculated from following equation.

$$K_i = SL_i \times (1.0 + K_{ci}) \times 0.1 / (1.0 - G_i / 100) \quad (5)$$

Where K_i: the soil erosion factors of the ith checkerboard; LS_i: the slope gradient of the ith checkerboard; G_i: the gully intensity of the checkerboard; K_{ci}: the soil index of the checkerboard. Use this equation to calculate k one by one.

5 Take GIS software to digitize the figure and spot before inputting them, and then bestow different number according to the cover degree of figure and spots, at last, use following equation to calculate vegetation cover value of figure and spot(Table 4 .

$$V = 18982.63 C^{-2.3}$$

Where V: vegetation cover value; C: percentage of vegetation cover.

Table 4 The percentage of vegetation cover and vegetation cover factor in Toutunhe River basin of the Tianshan Mountains

Percentage of vegetation cover	10	20	30	40	50	60	70	80	90	100
Vegetation cover value	95.138	19.139	7.602	3.923	2.348	1.534	1.083	0.796	0.607	0.476

4 THE DEFINITION OF MODEL INDEX

Define the model index to be confirmed α_i (i = 1, 2, 3, 4, 5 , by applying Grey Dynamic Model, and then transform all variables in equation(1 into logarithm, at last, get following linear equation group.

$$X_1^{(0)}(i) = b_1 X_2^{(0)}(i) + b_2 X_3^{(0)}(i) + \ldots b_{n-2} X_{n-1}^{(0)}(i) + a$$

b: the number of variables.

Given:

$$X_i^{(1)}(m) = \sum_{k=1}^{m} X_I^{(0)}(K)$$

Index row is:

$$\hat{b} = [b_1, b_2, \ldots, b_{n-2}, a]^T$$

$$Y_N(\bullet) = [X_1^{(1)}(2), X_1^{(1)}(3), \ldots, X_1^{(1)}(N)]^T$$

N: the number of data belonging to each variable.

So the data matrix is:

$$B = \begin{bmatrix} X_2^{(1)}(2) & \ldots & X_{(n-1)}^{(1)}, 1 \\ X_2^{(1)}(3) & \ldots & X_{(n-1)}^{(1)}, 1 \\ \vdots & & \vdots \\ X_2^{(1)}(N) & \ldots & X_{(n-1)}^{(1)}, 1 \end{bmatrix}$$

The discriminant is:

$$\hat{b} = [B^T B]^{-1} B^T Y_N(\bullet)$$

5 RESULT DISCUSSION

The former analysis indicates, in the regions where have not been cultivated or where the maintaining has not been carried on, that the soil erosion amount has close relationship to precipitation, vegetation cover and topographic factors. The calculating result indicates that soil erosion amount is from 0.11 to 70 t/(km^2•a in the Toutunhe River Basin: the middle and high mountain sections with altitude from 2100 m to 2700 m is the weak soil eroded area, whose annual soil erosion amount is from 0.01 to 1.00 t/(km^2•a). Conversely, the low mountain section is a strong soil erosion area with altitude less than 1300 m whose annual soil erosion amount is from 20 to 70 t/(km^2•a) and whose area is about 430 km^2 (Table 5).

Table 5 The comparison between the annual soil erosion amount and its presented color on the soil erosion picture in the Toutunhe River basin

Degree	Color	Annual soil erosion amount (t/km^2•a)	Altitude (m)	Area (km^2)
Weaker erosion	Red, white, green, blue	0.01– 0.50	2100– 2700	200
Light erosion	Pine, yellow, orange yellow, apple green	0.5– 5.00	1500– 2100	370
			2700– 3100	170
Middle erosion	Jade green, dark blue, purple	5.00– 20.00	1300– 1500	280
Strong erosion	Dark red, light grey, dark grey, grayish white	20.00– 70.00	900– 1300	430

The forecasting results are in good coincidence with the observed data (see Table 1 and Table 2), so it can be said that the model and calculating is rational and practicable.

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