RESEARCH ON BASIC ECOLOGICAL LANDFORM UNITS FOR SOIL EROSION ESTIMATION AND PREDICTION IN A SMALL WATERSHED, LOESS PLATEAU, CHINA

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Abstract
The northern region of loess plateau in China is a typical fragile ecosystem with serious soil and water erosion. Research into soil erosion prediction is urgently required for this region. However, due to the geography, social and economic conditions, the application of prediction models developed in other countries is limited. Hence, there is a need to develop local prediction models. This project used the Liudaogou watershed, which is located in a cross zone of water-wind erosion on the northern loess plateau in China, as the study area. The landform surface material composition, slope gradient and land utilization were selected as cartographic layers with relevance to soil erosion. Ecological landform units were identified using these layers. For the Liudaogou watershed, there 83 different ecological landform units were identified scattered in 284 plots. Soil erosion would found to occur on waste land, slope land and sparse shrub land with slope gradients of 15-25°. These area represent about 50% of whole watershed.

Additional Keywords: ecological landform, cartographic generalization, slope gradient, land utilization

Introduction

The northern region of loess plateau in China, where is cross water-wind erosion, is typical ecosystem environment fragile zone with serious soil erosion. National soil erosion announce reported from Ministry of Water Resources, P. R. China, in 2002. There is 26×10^4 km^2 of soil erosion area in the zone cross water-wind erosion. The zone is the current controlling region of soil erosion. However, as a result of special geography of Loess plateau and social and economic condition, China, the application of overseas prediction models is limited. So, there is a need to develop a soil erosion predicting equation in keeping with the local conditions. Up against the problem, many practical and theoretical models have been established and brought into play in China with the development and perfecting of erosion processes and mechanisms studies (Yang 1990; Bao and Chen, 1994; Cai *et al*.,1996; Tang, 1996; Chen and Trouwborst, 1997; Ma and Xie, 1998; Li *et al*.,1999; You and Li, 1999; Niu, 2001).

The soil erosion process is one of main geomorphology and substance circulation processes. It occurs at all times. Some erosion processes, which occur in unmanned regions, do not impact on humankind's livings and production. They are not the main research objects for soil erosion. What we research soil erosion is the accelerated erosion processes caused by irrationally using land resources, which has been impacting humankind's productions and livings. Accordingly, it requires that we put the focus on land resources using. The soil erosion prediction unit should be on a practical ecological landform surface. For this, we put forward the conception of soil erosion ecological prediction, which introduces the basic prediction units named ecological landform surface. The ecological landform surface means a topographical surface with relative coincident topography, material constituting, soil, vegetation, weather and land make use way.

Materials and Methods

Field sites

Because the Liudaogou small watershed is located in the typical cross zone of water erosion and wind erosion the north of loess plateau in China, from the edges of Maowusu Desert to loess hill and gully region, it is taken as studying area in this work. It is one of the second-level branches of Kuye River that is one of the first-level branches of Yellow River. Its geographical position is about from 110°21′ E to 110°23′ E and from 38°46′ N to 38°51′ N. Its area is up to 6.84 km^2. Its main channel's length is 4.21 km with the gradient of 26.25 ‰. The Liudaogou small watershed is a typical undulate landforms region with loess hills and gullies topography covered with sheet of sand. The average height above sea level in this watershed is 1081 m, and the highest point named Geliumao (as one of national height reference point), is 1273.9 m. The relative height is 192.9 m. There are a great number of channels and gullies on the land surface, without a flat nearly, which the average density of gully is up to 7.4 km km^{-2} and the area of channel and gully accounts for 32.66 % of whole watershed. The land surface material composites are Mesozoic sandstone and shale with coal beds, loess, drifting sand. The biological climate zone is a typical grassland zone of arid and semiarid with the characteristics of continental monsoonal climate of temperate zone. Its mean annual precipitation is 400-430 mm and mean annual temperature is 8.4°C. The percentage of vegetation cover is 5 %. Because there are little rain and lots of wind in winter and spring with serious wind erosion, and there is a great lot of rainstorm in summer and autumn with severe water erosion, wind erosion and water erosion take place alternately in the Liudaogou small watershed during the year. Consequently, the soil erosion in the Liudaogou small watershed is the most severe with the average erosion modulus of 15000 t km^{-2} yr^{-1}.

Methods

According to the principle of soil erosion and the aim of predicting soil erosion, with the methods of cartographic generalization with the aid of GIS, the works are divided into three steps. Firstly, review of the available published and unpublished reports on Liudaogou small watershed, including topographic maps, satellite photographs, and survey data, provide a base data for drawing map of ecological landform unit. Secondly, on the base data, the land surface material composites are divided into 6 types, which are listed in Table 1. And the slope gradient is divided into 6 grades, which are listed in Table 1.

Table 1. The types of land surface material composites and the grades of land surface slope

Slope gradient	Code name	Percentage of area (%)	Material constitution	Code name	Percentage of area (%)
0~3°	1	0.46	Loess	SL	73.13
3°~8°	2	20.85	Sandy loess	L	12.14
8°~15°	3	41.79	Draft sand	S	12.43
15°~25°	4	14.42	Rock	R	1.08
25°~35°	5	21.91	Alluvial deposit	A	1.00
>35°	6	0.57	Water area	W	0.22

Because of small area of watershed, the soil type is similar and the degree of vegetation cover is thin, the soil and vegetation are not further divided. The main causes of severe soil erosion are deferent land utilization ways. According to satellite photographs of 2002 year, the land utilization ways can be divided into 17 types, which are listed in Table 2. Thirdly, each map of main soil erosion occurrence factor is changed into digital map with the aid of GIS, and every digital map is corrected with GPS in the field. Then, the digital maps of landform slope, material

Table 2. The land utilization types in the Liudaogou small watershed

Land utilization types	Code name	Percentage of area (%)	Land utilization types	Code name	Percentage of area (%)	Land utilization types	Code name	Percentage of area (%)
Gully platform	11	2.80	Forest land	41	3.93	Residential area	61	0.35
Check dam land	12	2.83	Sparse shrub	42	24.57	Mine area	62	0.83
Slope terrace	13	0.54	Sparse Forest land	43	0.80	Draft sand	71	0.41
Bench terrace	21	5.15	Natural grassland	51	13.01	Exposure rock	72	1.07
Slope platform	22	0.29	Artificial pasture	52	5.58	Water area	73	0.22
Slope land	23	10.06	Sparse Shrub and grassland	53	0.82			
Orchard	31	0.05	Wasteland	54	26.67			

constitution, and soil are synthesized with graphics. In this way, erosion landform unit digital map is brought out. Lastly, the land utilizing present condition map is placed on the erosion landform unit digital map. The smallest unit to estimate and predict soil erosion, ecological landform unit, is certain. Per ecological landform unit is named, in order, after material composition and slope gradient and land utilization.

Results and Discussion

According to the research methods above mentioned, with GIS, the landforms slope gradient map is drawing up and the area of different slope gradients are counted (Table 1) on the topographic map, and the material composition map and land utilization map are drawing up and the area of different material composition are counted (Table 1 and

Table 2) on the satellite photographs. Table1 and Table 2 show that the area of slope with 3~15° is up to 62.64 %, and the area of slope with <3°and >35° is only 1.03 %. The land surface material is main loess, the draft sand and sandy loess is the second. Wasteland and sparse shrub are main land utilization ways with the percentage of 51.2 %.

By cartographic generalization, ecological landform unit is formed. In the Liudaogou small watershed, there are 83 kinds of ecological landform unit scattered in 284 plots (Table 3). Table 3 shows that only there are 25 types of ecological landform unit with a percentage of >1 % of whole, their area account for 81.52 % the all small watershed. Among of them, the area of type of ecological landform unit named L-5-54 is the largest, it is up to 16.2% of whole small watershed.

Table 3. The types of ecological landform unit in the Liudaogou small watershed

Types of ecological landform unit	Area (km^2)	Types of ecological landform unit	Area (km^2)	Types of ecological landform unit	Area (km^2)	Types of ecological landform unit	Area (km^2)	Types of ecological landform unit	Area (km^2)
L-1-23	0.855	L-3-22	0.508	L-4-42	5.584	S-2-42	10.798	SL-3-41	1.630
L-1-52	0.720	L-3-23	41.9618	L-4-43	2.4583	S-3-22	1.987	SL-3-42	22.471
L-2-11	10.087	L-3-31	0.325	L-4-45	0.523	S-3-23	0.821	SL-3-51	15.207
L-2-12	8.576	L-3-42	40.883	L-4-51	16.853	S-3-41	7.815	SL-3-52	6.242
L-2-21	1.371	L-3-43	1.526	L-4-52	4.958	S-3-42	30.204	SL-4-21	2.119
L-2-22	0.564	L-3-45	0.523	L-4-53	0.792	S-3-51	0.381	SL-4-42	1.354
L-2-23	20.203	L-3-51	29.976	L-4-54	28.787	S-3-53	0.907	SL-4-51	5.681
L-2-41	5.655	L-3-52	9.286	L-5-42	5.078	S-4-42	7.432	SL-4-52	8.565
L-2-42	44.829	L-3-53	3.897	L-5-43	0.365	S-4-62	1.159	SL-4-54	0.690
L-2-51	11.320	L-3-54	29.867	L-5-51	3.456	S-5-54	9.006	SL-5-13	0.778
L-2-52	3.195	L-3-61	0.534	L-5-52	3.899	S-5-71	2.805	SL-5-51	3.595
L-2-54	0.874	L-3-62	1.888	L-5-54	110.906	SL-2-13	2.905	SL-5-54	2.712
L-2-61	1.883	L-4-12	1.607	L-6-42	0.388	SL-2-21	0.998	R-5-72	7.361
L-2-62	2.647	L-4-21	3.933	L-6-43	1.154	SL-2-22	0.134	A-2-12	6.868
L-3-11	7.675	L-4-22	0.282	L-6-51	1.954	SL-3-11	1.456	WATER	1.539
L-3-12	0.427	L-4-23	5.161	L-6-52	0.424	SL-3-12	1.922		
L-3-21	19.072	L-4-41	0.759	S-2-41	9.747	SL-3-21	6.614		

Discussion

According to the basic factors of causing soil erosion, land surface with a slope gradient of 0-3° does not have soil erosion, in universal conditions, in any case. The vegetation is protector of soil. However, the percentage of vegetation cover only is 5% in the Liudaogou watershed, so what are called forestland and grassland are, in fact, scattered litter trees and grasses, and their area is only about 17%. The forestland main is on the slope surface with slope of 3-15°. A majority of wasteland is distributing on the landforms surface with slope of 20-35°. The draft sand distributes on windward slope of the west and north in the watershed. There are not croppers on the draft sand slope surface. The permeability coefficient of draft sand is very great, and it offers little sediment for river. The sandy loess antierodibility is very weak. There are various land utilization ways on sandy loess landform surface as slope gradient changes. The exposure rock presents both sides of main channel. It is exposed due to building road and excavating stone. It impacts land utilization way and is rock desert, but it gives little sediment from eroding. Alluvial deposit is result of holding up silt with warp land dams. Water area is some artificial collecting water ponds, which are built in recent years.

Conclusions

For the above results and discussions, we can summarize some conclusions as following. On the based of cartographic generalization with GIS, according to combinatorics principles, the main types of ecological landform unit are combined of different types or degree with greater area percentage in the various factors of affecting soil erosion. They are not combined formally but materially. The soil erosion in Liudaogou watershed basically occurs on wasteland, slope land and sparse shrub land with the slope gradient of 15-25°, and does not on the whole watershed. Their areas sums up about 50% of whole watershed. Thus, we can deduce that the erosion modulus is most greater than that 15000 t km^{-2} yr^{-1}.

On the based of ecological landform unit, we may purposefully arrange observing and testing plots of soil erosion and we can get soil loss data from different plots on different ecological landform units. According to the data and areas of different ecological landform units, we can set up a new soil erosion prediction model, which is named as

SEEPM (soil erosion ecological prediction model). This works will be finished during next phase. If we will SEEPM combined with LISEM (De Roo and Jetten, 1999), we can truly predict small watershed soil erosion. Thereby, we can reasonably plan and lay soil and water conservation measures.

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