REGIONAL MONITORING AND EVALUATION OF SOIL AND WATER CONSERVATION: A CASE STUDY ON LOESS PLATEAU, CHINA

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Abstract
Loess Plateau in China is well known for its unique landscape and severe soil erosion. To meet the need of decision-makers, Soil and Water Conservation Monitoring Information System (SWCMIS) was developed, which is oriented to supply the data on the current situation of soil and water erosion and appropriate decision-making models of soil conservation for this region. The system consists of two parts: database of soil erosion and conservation including data collection and processing; and knowledge library including models involved. The Multi-level Remote Sensing Monitoring Information System in the Loess Plateau, as the sub-system of data-collection, consists of 3 levels. Soil erosion is a very complex process and it is affected by many factors, such as climate, landform, soil, vegetation and human activities. Therefore it is necessary to integrate remotely sensed data and other data, such as, DEM, observed data, the fluvial sediments and runoff plot data, as well as social economy.

Based on the database and results of related researches a model of soil erosion evaluation at regional scale was developed. It is exponential function correlation erosive ability with rainfall in rain-season, gully density, ration of slope-land, content of soil particle (>0.25 mm), and vegetation cover. The main procedures of model developing include to making base-map by overlaying maps of main factors mentioned above, to extract parameters from remote sensing data and thematic maps or observing data, to establish a statistical regression model and to evaluate and predict the regional situation of soil and water conservation on the Loess plateau. Multi-correlative modulus R=0.9369, F=2984.64>>F0.05=2.21. The relativity is very remarkable.

Additional Keywords: erosion, information system, evaluation model

Introduction
China is one of the countries that suffer most from severe soil erosion in the world (Zhu *et al*., 1999; Yang, 1994). Also, there are very rich experiments accumulated by Chinese during the long history of struggle against soil erosion. With the development of the economy in China, soil and water conservation has got into a new stage that is from the small watershed scale to region scale (China's Agenda 21, 1994). It is very urgent and meaningful to apply advanced technique, such as remote sensing, GIS and expert system to provide decision-makers with updating information. Regional monitoring and evaluation of soil and water conservation have been considered as the key technology to be developed in China. Loess Plateau is taken as a case study to establish a monitoring system and evaluation model.

Materials and Methods
Study area
The Loess Plateau region is located in the middle reaches of Yellow River of China. The landform is unique loess hills, sand-loess hills and loess tableland, with the gully density of 4-6 km km^{-2}. And the land of inter-gullies takes about 40-60%. The climate is typical continental climate, with annual mean temperature varying between 6.6ºC and 14.3ºC and annual mean rainfall between 250 mm and 700 mm from northwest to southeast. The precipitation is concentrated in summer accounting for 50-70% of the whole year. The population density is 40-270 people km^{-2}. The Loess Plateau in China is well known for its unique landscape and severe soil erosion. This region has a long cultivation history of nearly 6000 years. During the last few centuries, especially the last hundred years, natural vegetation had been destroyed due to the increasing population and civil wars. With the great strategy of Western-China development, Loess Plateau has been put in a more and more important position. The biggest national energy base of heavy and chemical industries is located on the Loess Plateau. This region is considered the best base of apple production in China due to the special climate with big differences in temperature between day and night. Here the sunlight and heat energy are abundant, the soil layer is thick, and there are vast areas of land suitable for forestry, fruit trees and grass respectively. So it is considered as one of the key regions for ecological rehabilitation in China.

Multi-level remote sensing monitoring information system in the loess plateau
In order to meet the needs of decision-makers the Soil and Water Conservation Monitoring Information System (SWCMIS) has been developed recently, which is oriented to supply the most updated data of soil and water erosion and appropriate decision-making models of soil conservation for this region. Generally speaking, the system consists of two parts: database of soil erosion and conservation including data collection and processing; and knowledge

library including models involved. The Multi-level Remote Sensing Monitoring Information System in the Loess Plateau, as the sub-system of data-collection, consists of 3 levels. The top level is based on the environmental satellite images, such as FENGYONG(China), NOAA(AVHRR) and MODIS. It is focused on the general change of the whole plateau region, especially the boundaries of forestry in the central part, and desertification in the northern part. The middle level uses Landsat (TM) or SPOT to monitor the key regions, such as key catchments for soil conservation, mining areas, and main exploitative areas. The dynamic changes of land-use and degradation and key engineering works are monitored and analyzed. The lower level is focused on small experimental catchments and observation stations distributed in different regions. The main data are regular aerial photographs of big scale. Land use, soil erosion, conservation practices and their effectives are monitored in detail. From the basic monitoring of small catchments to the middle regions, then to the whole plateau area, a monitoring network has been established. Remotely sensed data provides more accurate and updated information, GIS supplies a flexible data management method, and modeling/expert systems increase practicable functions.

Regional model of erosion
Based on the systematic analysis of genesis, evolution and related factors of soil erosion at the multi-scales, general form of the model for regional erosion should be as follows:

$$A = f(Q, S, g, v, c)$$

Where: Q – hydrological factor, S – soil factor, g – geomorphologic factor v – vegetation factor; C – soil conservation measure factor.

It is exponential function correlation among erosive ability, rainfall in rain-season, gully density; ration of slope-land, content of soil particle (>0.25 mm), and it is exponential correlation with vegetation cover. So this model can be expressed with mathematical formula:

L = 0.4735P 0.9282.S - 0.08855.G2.2666.M0.07254.c-0.00047

Where: L: erosive intensity (t km^{-2} yr^{-1}); P: rainfall in rain-season (mm); S: content of soil particle (>0.25 mm) (g kg^{-1}); G: gully density (km km^{-2}); M: percent of slope-land (%); C: vegetation cover (%).

Multi-correlative modulus R=0.9369, F=2984.64>>F0.05=2.21. The relativity is very remarkable. From the regression result, we can see that the erosive intensity present positive correlation with the following factors, which is rainfall in rain-season, gully density, ration of slope-land while it present negative correlation with the content of soil particle and vegetation cover.

Theme data collection and processing
Regional soil erosion is a very complicated and integrated process affected by many factors, including geomorphology conditions, soils, climate, hydrology, land-use, vegetation and soil conservation measures. In this study, the following data have been collected and used.

Precipitation data: All rainfall data from 178 stations (1955-1986) in loess plateau have been collected. Using this data, we calculated the mean annual rainfall in rain-season (July-Oct), and measured the position information (latitude and longitude coordinate) of each station.

Soils data: Main information is based on the Soil Map of Loess Plateau (which was made by Chinese Academy of Sciences, 1991). The content of soil organism has been extracted from several soil monograph of survey.

Gully density data: of the points were extracted from the soil erosion map of loess plateau.

Land-use data: The ratios of the cropland and forest/grass were extracted from land-use map (1:250000) in ARC/INFO Coverage format.

Precipitation, sediment and gullies intensity are in point format, they are processed in ARC/INFO and SURFER software to generate contour-line map. All the data have been transformed into common projection, Albers projection is used.

In this study we divided the study area into 3380 map units, according to the TM imagery. All the parameters have been pre-processed into maps and then integrated into each of the basic polygons. In the processing of integration, positing data and topology relationship is in the standard of basic information unit map, the boundaries of basic unit are changeless, that is the number of units is fixed. The attribute will be added again and again. The basic information units will be the key words to relate many kinds of attribute data layers.

Results and Discussion

Selection and integrating of data

The current space observation system can provided abundant data for the dynamic monitoring of environment. But the satisfying analysis result can not be obtained only relying on the remotely sensed data because soil erosion is a very complex process and it is affected by many factors, such as a climate, relief, soil, vegetation and various kinds of human activities. Therefore it is necessary to integrate remotely sensed data and other data such as, DEM, observed data, the fluvial sediments and runoff plot data, as well as social economy. In addition, the appropriate data should be chosen for different studying objects. For example, the data from environment satellites can only be used in general analysis on wide scope, and it is difficulty to meet the requirement on quantity analysis. According to the studies in Mizhi, north part of Shaanxi, using a large scale color infrared air-photo, the precision from the interpreting of land variety is over 95%, forest land 87%, soil conservation practices over 95%, vegetation type on farmland, grass land (including rotated cropland) 75%, and the error of image interpretation of linear objects were 0.5-1.74%, of sampling polygons 1.1-3.2%. Comparing with common method, working time in the field was shortened by 80%. These result also showed that TM, SPOT image and the color infrared air-photo of 1/50000 can still not meet the requirement of the precision.

Image classification procedures

Although manual interpretation and mapping is still a basic method, computer-assisted classification represents the development direction. It is difficulty for common image processing software to identify the same objects with different spectrum or different objects with same spectrum. Especially in the Loess Plateau, topography is so complex that the spectral features depended on landforms to some degrees. So it is necessary to develop an image processing technology for this case study.

1) Integrating remotely sensed data with others such as DEM, field station observation data, thematical maps.
2) Pro-precessions are necessary before classification. The PCA, Edge-extraction, LOG/EXP, and CURVATURE have been used for deferent regions.
3) Interface-classification of image procedures.
4) Post-processing is important to improve the result of classification.

Procedures of soil erosion evaluation at regional scale

(1) Making base-map (or Map-unit map): Map-unit map is the base map for this study. Each map-unit has the uniformed landscape conditions and erosion. It is the basic unit of data collection and analysis. The map was made through overlaying maps of main factors mentioned above.

(2) Extract the parameters from remote sensing data and thematic maps or observing data, and integrate all the parameters into the basic unit map derived from the step 1, then a parameter database will be built.

(3) Establish a statistical regression model between sediment and the factors with correlative analysis and geo-statistics method.

(4) Using the model to evaluate and predict the regional situation of soil and water conservation on the Loess plateau.

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