DEM Based Extraction and Analysis of Loess tableland

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Abstract

Landscape is an important part of the natural environment, it has an significant impact for the formation and development of various surface hydrological processes. So the object of this study is to develop morphology analysis methods for extracting loess tableland automatically. The study area lies between 32° and 41°N, and between 107°and 114°E . The data used includes an ASTER GDEM and geomorphologica map. The methodology developed for loess tableland extraction includes preprocessing of the digital data-that is, filtering of the Digital Elevation Model (DEM) for noise removal. A classification technique is then expand. At the first, DEM is enhanced. For the second, binaryzation is implemented and two terrain factors are assisted the extraction. For the three, broken patches and boundary line will be modified. Finally, we used expert knowledge to verify the result. At the end, the extracted loess tableland is compared to the boundary that is delineated manually and the standard deviation between them is satisfactory. Then, we compute some index about the result. And we find that most patches`s areas are 1~10km$^2$. Beam tablelands`s areas are usually less than 5km^2 and broken tablelands`s area are usually less than 20km^2. The minimum value of fractal dimension is 1.15 ,the maximum value is 1.40 and the mean value is 1.27. Edge density is negatively related to the area but shape index is positive correlation.

Keywords: Loess tableland; DEM; morphology

1 INTRODUCTION

Loess plateau is under the action of accumulation and transportation, as well as the impact of wind, water, gravity and human interaction, and is based on the geomorphology of underlying strata, according to a variety of developmental pattern, ultimately forming the basic landscape of the loess plateau and the regular combination of landform. Loess plateau as the accumulation of the world's largest and youngest plateau, with its unique formation, typical geomorphic features, holds an important role in the ecological environment, and it has attracted the attention of Chinese and many researchers in the world for a long time, and got guiding significance achievements in a lot of production and practice.

Geomorphic type is an important factor for basin erosion and sediment yield in hydrologic model parameters. The traditional landscape classification and cartography mainly adapt the method of topographic map measurement combined with the field survey[1,2]. But it is low precision and strong subjectivity. Along with the development of computer graphics and GIS technology, people began to use remote sensing, and digital elevation model to extract geomorphic feature. By these photos and methods, it has greatly improved the speed and accuracy of the landscape classification[3].

In 1964, Hammond first suggested automatic classification method for geomorphic types, he pointed out that the slope and relief amplitude in statistical cell can identify types[4]. This idea was completed by Dikau in 1991[5] and then it was modified by Brabyn and Morgan[6,7]. Dikau use a square grid as a statistical unit while Brabyn use a circle one in order to reduce the error when calculated the small relief terrain. Philip T. Giles[8] use DEM to extract slope unit automatically; Dragut[9] extracted elevation, slope, profile curvature and plane curvature etc, and then he used image segmentation method to classify. Weiming Cheng[10] used SRTM-DEM quantitatively extract basic landform types of Chinese landscape. Since then, many experts studied automatic classification of regular statistical unit[11-14]. All these studies used regular statistical region to calculate all kinds of terrain factors(such as relief degree, surface roughness, elevation etc), and realized the rapid classification. While their disadvantages are obvious.

2 DATA SOURCE

The ASTER Global Digital Elevation Model (ASTER GDEM) is a joint product developed and made available to the public by the Ministry of Economy, Trade, and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA). It is generated from data collected from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), a spaceborne earth observing optical instrument. The ASTER GDEM covers land surfaces between 83°N and 83°S and is composed of 22,600 1°-by-1° tiles. Tiles that contain at least 0.01% land area are included. The ASTER GDEM is in GeoTIFF format with geographic lat/long coordinates and a 1 arc-second (30 m) grid of elevation postings. It is referenced to the WGS84/EGM96 geoid. Pre-production estimated accuracies for this global product were 20 meters at 95 % confidence for vertical data and 30 meters at 95 % confidence for horizontal data.

Study Area lies between 32° and 41°N, and between 107°and 114°E. It is situated east of Taihang mountains, west to Riyu mountain in Qinghai, south to Qinling and north to Ordos plateau and occupies an area of about 648700 km^2.

3 METHODOLOGY

(1)Image enhancement

It is conducive to extract the morphological unit when the line of the morphology cell of the loess plateau is clear. So it uses median filter method to remove noise and keep the image details.

(2) Image binaryzation

After the enhancement, it needs to set a proper threshold to divide the image into black and white. Because the features of the two classifications are very similar, so it is difficult to implement segmentation and there is a need to add additional information. Here we choose slope and relief amplitude to assist the extraction. According to the previous study, we choose 5 degree as the critical point. In this study, we choose 17*17 as the analysis window and then accord to the specific situation in the study area to adjust the threshold. Through many experiments and statistics of each patch, we use 20meters to 100meters as interval.

(3) Morphological filter

There are some broken patches for the extraction due to the grid data feature or arithmetic reason, it is very essential to deal with the result. First, we use boundary clean tool to clean up the outline of the type to smooth it. Then, using region group tool to statistic the number of the pixel in each type, and the result is named of ‘RegionGroup’. In the attribute table of statistical result, there is a field named ‘COUNT’ and we need it to judge a proper threshold to eliminate.

(4) Expert knowledge

The extracted results will be transfer into vector format and then superimposed on the remote sensing image to judge whether the boundary line is right or not.

3.2 Accuracy assessment

Accuracy test is executed from two aspects. It uses the extracted result to compare with the previous work and then computing the error. It should compute the standard deviation between the automatic one and the manual region. In order to make the result more accurate, we choose three regions to test. They are Changwu, Xiaoyi and Yanchang.

(1) Qualitative evaluation

Qualitative evaluation mainly judge whether the automatic one within the corresponding type of the 1:10 000 000 geomorphologic map. And on the other hand, checking whether the outline of automatic one surpass outline of the manul one.

(2) Quantitative evaluation

The extraction accuracy was discussed according to area discrepancy(Ad) between the automatic one and the manual one. Table 1 shows the comparisons of the two results. Both of the results have satisfying accuracy. It is obviously that the main advantage of this approach is good accuracy and good application suitability.

TABLE 1 COMPARISONS OF THE EXTRACTED RESULT BETWEEN AUTOMATIC ONE AND MANUAL ONE

Site	**Automatic one （Km^2）**	**Manual one （Km^2）**	**Percentage of Ad(%)**	**Ad （Km^2）**
Changwu	140.440	161.071	12.81	20.631
Xiaoyi	9.385	10.264	8.60	0.879
Yanchang	32.657	36	10.24	3.343

4 QUANTITATIVE DEPICT

Systematic indicators are necessary for the depiction of the loess tableland quantitatively.Considering the characteristics of tableland on the Loess Plateau, four indices were proposed to quantitatively depict the geomorphologic landscape properties. Table 2 shows the definition for calculation these indices. Fig.a is curved according to the smallest area and other graphs are curved according to the number of fig.a.

TAVLE 2 DEFINITION FOR TABLELAND INDICATORS

Indicators	**Definition**	**Remark**
Area		
Fractal dimension（FD）	$2*\ln P/\ln A$	P is perimeter A is area
Edge density(ED)	$(P/A)*10^6$	
Shape index(SI)	$P/2Sqrt(\pi*A)$	

In the study area, small area patches are main part. Less than $10km^2$ area patches are 80.2%。Among these, most patches area are $1\sim10km^2$。More than $10km^2$ patches are mainly distribute on both sides of the Weihe river. After superposition 1000000 terrain data and through analysising the corresponding patch on geomorphic types, we find that beam tablelands`s area are usually less than 5km$^2$ and broken tablelands`s area are usually less than 20km^2, and some famous loess tablelands ,such as Dongzhi tableland and Luochuan tableland, the area of which are more than 100km^2.

TABLE 3 AREA STATISTICAL

Area（km^2）	<1	1-10	10-100	>100
number	392	516	174	50
percentage（%）	34.6	45.6	15.4	4.4

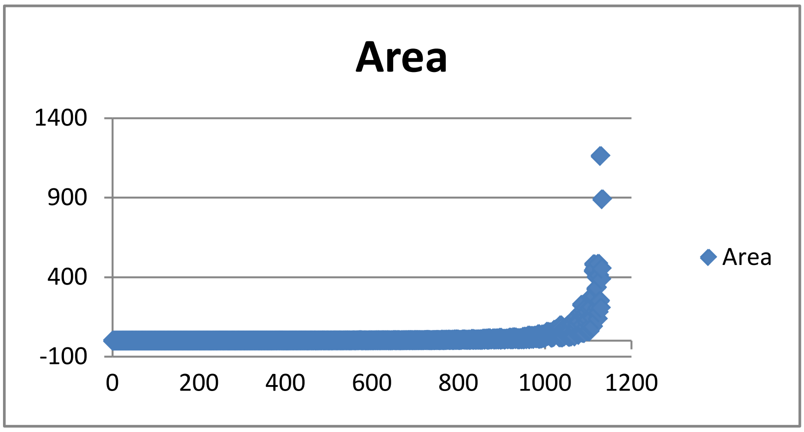

Fig. a

Fractal dimension is an indicator which reflects the shape complexity of the loess tableland. This index reflects the difference between different physiognomy types. The more complex landform is, the bigger the fractal dimension value is. The minimum value is 1.15 ,the maximum value is 1.40 and the mean value is 1.27. This results are almost the same with previous study[16]. At the same time, Fig.b shows that fractal dimension and graphic area are not correlative. We can deduce that erosion maybe not on the surface in the process of loess tableland.

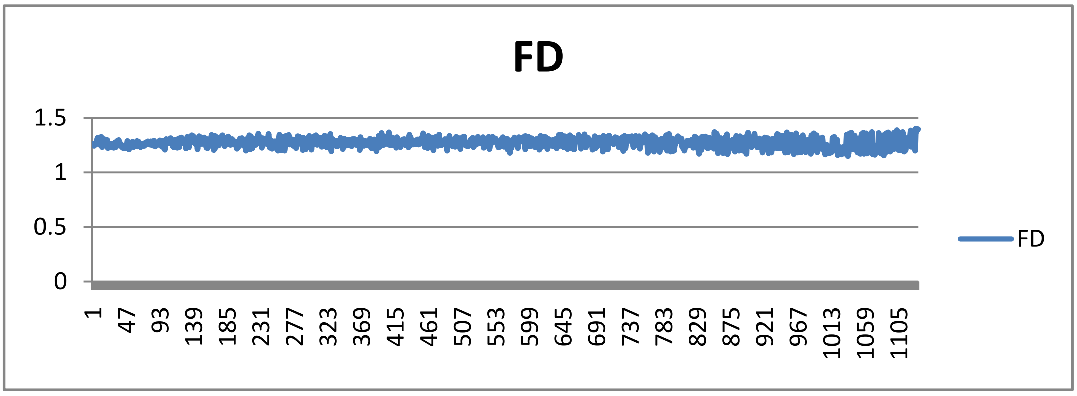

Fig. b

Edge density can quantify the change of the boundary of the loess tableland in the process of relief development. By the Fig.a and Fig.c, we can know that the larger the area of the patches are, their edge density are smaller.

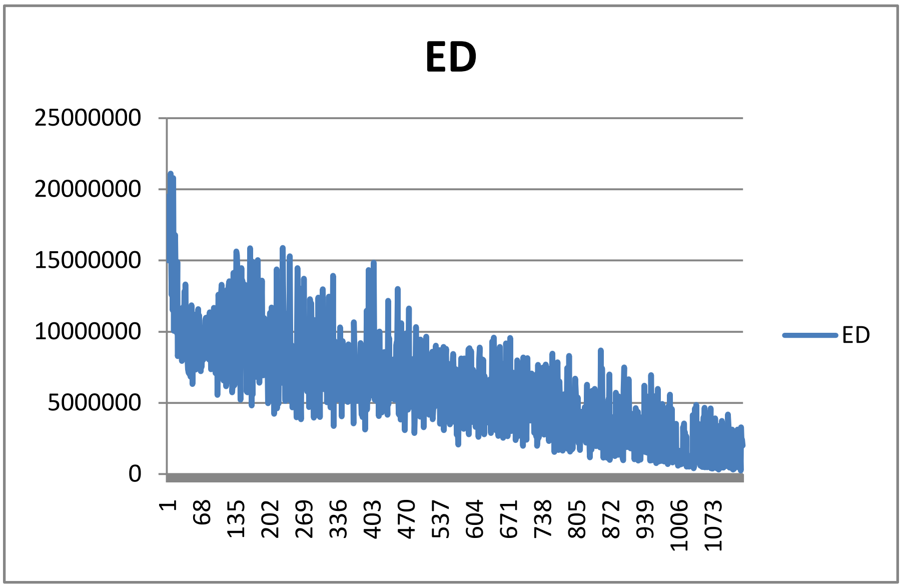

Fig. c

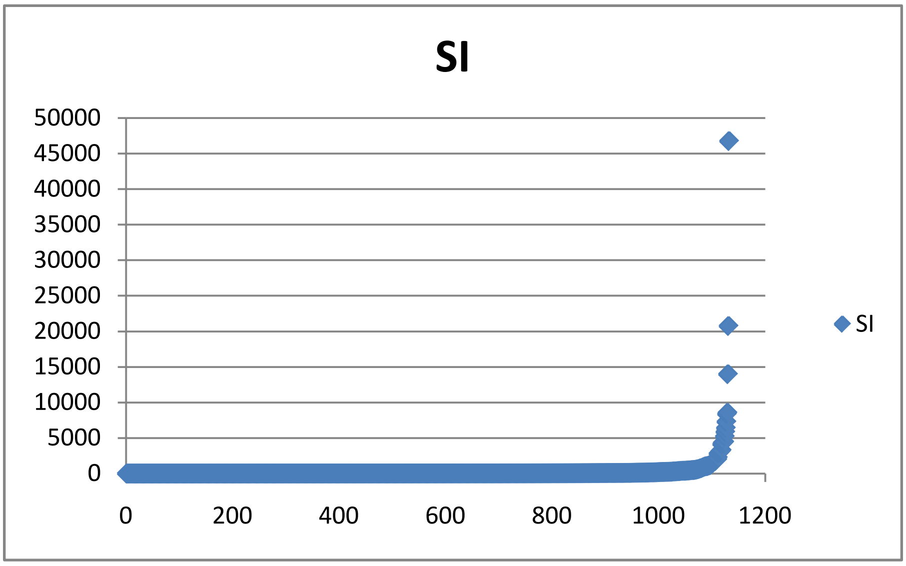

Fig. d

Shape index shows the deviation between patches and the same area circle. Using this index is to quantify the process from complete tableland to beam tableland. When graphic shape is round, its value is one. The more SI is, the greater long and narrow of the graphics. Combining with the area of statistical analysis, fig.d shows that complete tableland which area are more than $100km^2$ increases, the greater deviation from one。 But beam tableland and broken tableland are more like circle.

5 Conclusions

(1) By the technique of GIS and digital terrain analysis, a semi-automatic extraction method based upon the terrain character is proposed. Validation test shows that this method has obvious advantages on extraction accuracy and application adaptability compared with the manual extraction.

(2) Four indices of loess tableland are proposed for quantifying the geomorphologic land, statistical characteristics and spatial distribution characteristics. Most patches`s areas are $1\sim10km^2$. Beam

tablelands`s areas are usually less than 5km$^2$ and broken tablelands`s area are usually less than 20km^2. The minimum value of fractal dimension is 1.15 ,the maximum value is 1.40 and the mean value is 1.27. Edge density is negatively related to the area but shape index is positive correlation.

Since this is just the initial stage of the research, more issues are needed to make deeper cognition on this topic. In the following study, we will further study the morphology of the loess tableland and relative age.

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