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Review of Digital Elevation Model (DEM) Based Research on China Loess Plateau

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Abstract: The Loess Plateau is one of the hot research areas for its specific geographical features. In resent years, with the establishment of national multi-scale DEMs and the perfection of DEM based digital terrain analysis methods, new thoughts and methodologies have been constructed for the Loess Plateau research. This paper introduces the characteristics of DEM data, analyses the development stages of DEM applied in the Loess Plateau research, and discusses its further possible research direction. More discussions are focused on slope spectrum and its concept, as well as the significance in the Loess Plateau research.

Key words: Review; DEM; the Loess Plateau

Introduction

The Loess Plateau is located in the upper and middle reaches of the Yellow River, among the western Taihang Mt, eastern Riyue-Helan Mt, northern Qinling Mt, and southern Yinsan Mt (from 100° 54′ to 114° 33′ E and 33° 43′ to 41° 31′ N; Figure 1). It covers a total area of 624,000 km^2.

The Loess Plateau of China has drawn worldwide attention in geographical research for its unique morphological features, abundant nature resources, most serious soil erosion, as well as its potential contributions to economic development and ecological reconstruction in the region.

The initiation of the studies on the Loess Plateau can be traced back to the middle 20th century when researchers started investigations on loess paleontology and soil formation (ZHANG 1989, LIU 1964 & 1985 & 1996, Guo 1996, LUO 1988, SUN 1997, ZHAO 2002, CAO 2003). However, the knowledge on spatial distribution pattern of loess terrain at a macroscale is still scant. Loess plateau (*Yuan* in Chinese), loess ridge (*Liang* in Chinese) and loess hillock (*Mao* in Chinese) are three basic terrain types and the processes leading to their differentiation are only poorly understood. In 2001, Liu Tongsheng, a leading scholar in loess research, stressed the need to investigate the spatio-temporal variability in soil erosion and relief in loess region at large scale (LIU *et al.* 2001).

Digital Elevation Models (DEMs) digitally demonstrate the earth's surface and are potential tools for terrain analysis at varied spatial and temporal scales. In recent years, along with the establishment of DEM database of the Loess Plateau, GIS based research on the Loess Plateau has made great headway, especially for digital loess terrain analysis (CHEN 2000, QI 2001, ZHANG 2001). This paper introduces the characteristics of

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DEM datasets, summarizes the research achievements resulted from DEMs and expounds the application of DEMs in the Loess Plateau research.

1 DEM Datasets of the Loess Plateau

At present, the DEMs for the Loess Plateau, with the available data sets, can be constructed at four different scales (Table 1).

Figure 2 shows the DEM hillshade effect at the 4 different scale levels.

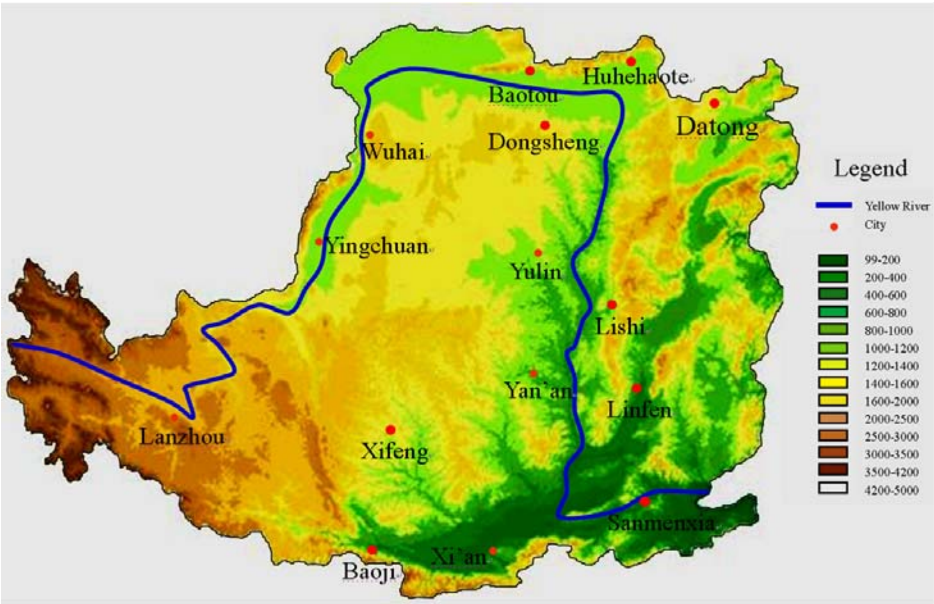

Figure 1 Topographic map of the Loess Plateau

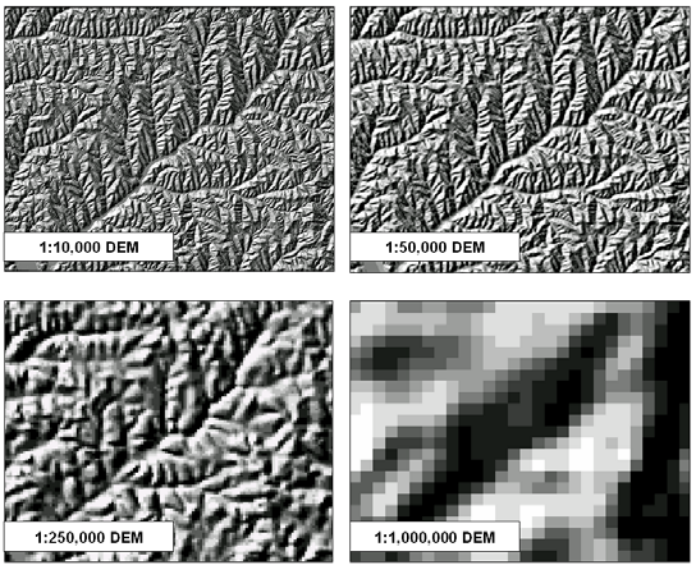

Figure 2 DEM hillshade effect at the 4 different scale levels

Table 1 Comparison of DEM characteristics at the 4 scale levels

	1:10,000	1:50,000	1:250,000	1:1,000,000
Data sources	Topographic maps of 1:10,000 scale	Topographic maps of 1:50,000 scale	Topographic maps of 1:250,000 scale	Elevation from the contours on the topographic maps of 1:50,000 and 1:100,000 scales
Grid size	5 m×5 m	25 m×25 m	100 m×100 m	1000 m × 1000 m
Map projection	Gauss-Kruger projection with 3-degree division	Gauss-Kruger projection with 6-degree division	Geographical coordination	Gauss-Kruger projection with 6-degree division
Geodestic coordinates systems	Xi'an coordinates system, 1980	Xi'an coordinates system, 1980	Beijing coordinates system, 1954	Beijing coordinates system, 1954
Altitude datum	1985 national altitude datum	1985 national altitude datum	The yellow sea height system, 1956	The yellow sea height system, 1956
Establishment methods	Grid DEMs are established per a series of interpolation processes from TINs, which is constructed from digitized contour, independent height points, and terrain features, i.e., ridge, valley and terrain break lines.			Building an elevation matrix. The elevation data are from geographic mesh of large scale topographic maps.
Application availability	Deriving topographic parameter at slope scale	Deriving topographic parameter and at small watershed scale	Digital terrain analysis at regional scale	Digital terrain analysis at regional and macroscale.

2 Research Progress

Along with the development of GIS technology and DEM database, DEMs are making more and more contributions in different aspects. DEM based research on the Loess Plateau in China could be divided into three different periods, primitive exploration period, extensive application period and intensive knowledge/discovery period.

Until 1990s, DEMs were rarely applied. There were only a few efforts on evaluating the scope of DEMs in environmental management of the hilly and gully areas of the Loess Plateau (TANG 1991). The way of automatic extraction of surface channel and drainage network worked out efficiently (HE *et* *al.* 1993). Later slopes and aspects were computed using the DEM, which is required for estimating soil erosion in loess hilly and gully areas (FU *et al.* 1994).

DEMs were widely applied from 1990s onwards. With the fast development of IT and the popularity of computers, the demand for digitized geographical information increased tremendously. With implementation of NSDI projects by state-run survey agencies, the task of establishing the DEMs for the whole country at 3 different scales was completed. Almost at the same time, a project was initiated to establish DEMs at 1:10,000 scale for the northern Shaanxi Loess Plateau, and they were commonly regarded as the most important database for research and development in the region. In 1990s, some scholars made significant great contributions to the enhancement of basic knowledge on DEM (DU 1997, LIU 2000). Scholars not only concentrated on working out a new and effective procedure of automatic extraction of stream channel networks, shoulder line of valley and other terrain factors (LU *et al.*1998), but also concentrated on investigating the magnitude and sources of slope errors derived from DEMs of different map scales (TANG 2000, 2001a, 2001b). An excellent monograph explicated update on DEM and DEM based digital terrain analysis (LI 2001).

Some researchers focused on the uncertainty of DEMs and DEM based terrain analysis at different scales (TANG *et al.*2001c, TANG & ZHAO 2003a, ZHAO 2002, LIU & TANG 2002). The precipitation-runoff was simulated using DEM outputs in a watershed (LI *et al.* 2002). The steep farmland areas that are required to be reforested for the sustainable landscape management and ecosystem reconstruction were identified (TANG *et al.* 2002, YANG *et al.* 2002, ZHU 2003).

DEMs were also successfully used in the data mining and knowledge discovery of loess relief. The concept of terrain information capacity of DEMs advanced (CHEN *et al.* 2004, WANG *et al.* 2004). The Loess Plateau was still considered as a test area in this investigation. A comparison of DEMs between 1:10,000 and 1:50,000 showed how terrain information capacity attenuated along with DEM scale, which would be greatly significant in developing DEM application rules and standards.

A new concept and theory about slope spectrum was proposed and attracted great attention in 2003 (TANG 2003b, TANG 2003c; Figure 3).

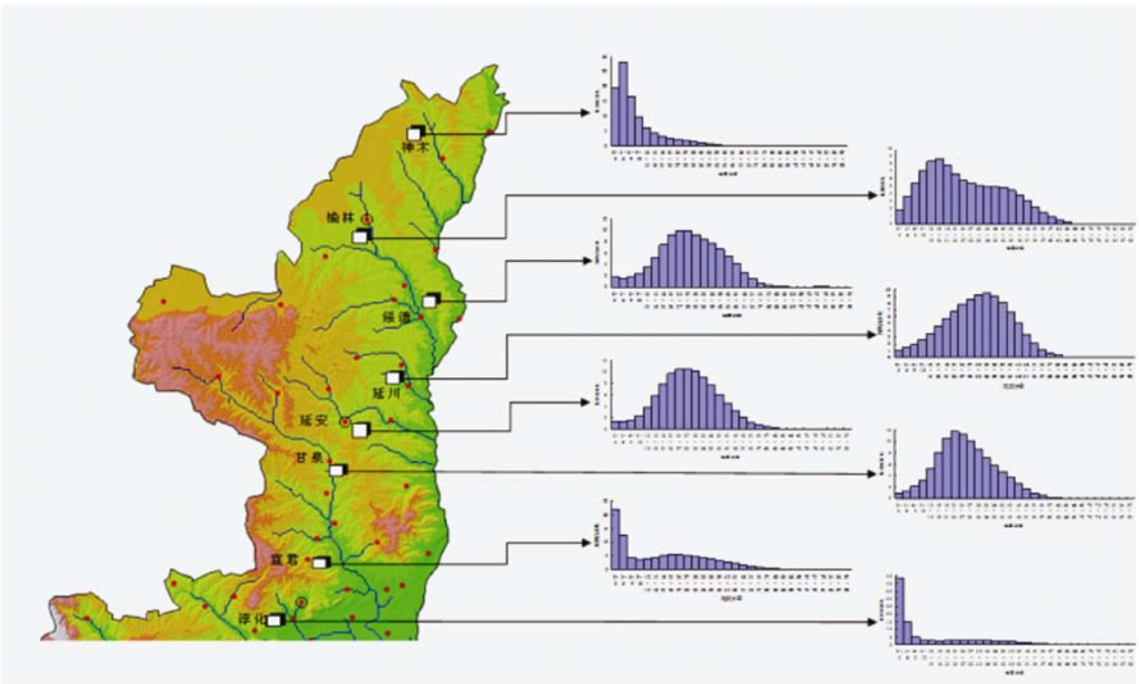

Figure3 Slope spectra of different terrain types in northern Shanxi Loess Plateau (TANG 2003)

A slope spectrum could be defined as a statistic diagram with its x-axis denoting the gradient value and its y-axis denoting the corresponding area. Slope spectrum analysis method is a new and effective methodology in revealing the macro-geomorphologic features through a microcosmic terrain index. A continuous change in the slope spectrum from south to north of the plateau showed an obvious spatial variation of surface roughness in the area, which was proved to be of great significance in describing the ground fragmentation and geomorphologic development period as well. Any geomorphic type could find its corresponding slope spectrum, which existed uniquely and stably only if the test area was larger than the statistic critical area. Hence, the slope spectrum could be used to distinguish terrain types and analyze the development stage of loess terrain as well (TANG *et al.* 2005). The inherent mechanism and extrinsic conditions for forming the spectrum, the relation between slope spectrum and the loess terrain types, soil erosion intensity, and the spatio-temporal changes in slope spectrum were investigated. These new achievements should hopefully help us understand the geomorphic genesis and spatial distribution rules of the Loess Plateau.

3 Conclusions

As digitally demonstrating earth's true surface, the DEMs provide valuable geographical information. For its regular spatio–temporal sequence and complexity, the Loess Plateau could be considered an optimal study area for DEM based digital terrain analysis. More work should be done, focusing on the data mining and knowledge discovery based on DEMs, so as to set up a new theory and methodology for DEM based digital terrain analysis.

References

CAO Yu, YANG Zhifeng, YUAN Baoyin, SHEN Zhenyao. 2003. Appraisal of Soil Erosion Factors on Chinese Loess Plateau Based on GIS. *Journal of Soil and Land Water Conservation* **17** (2): 93~96.

CHEN Nan, LIN Zongjian, LI Chengming. 2004. Comparison of Topographic Information from Different Scales DEMs Based on Information Theory. *Remote Sensing Information* **3**: 5~9.

CHEN Shupeng, YUE Tianxiang, LI Huiguo. 2000. Studies on Geo-Informatic TUPU and Its Application. *Geographical Research* **19**(4): 337~343.

DU Jiangang. 1997. Generating Fishbone DEM from Contour Data. *Journal of Northern Jiaotong University* **21**(4): 437~440.

FU Bojie, WANG Xilin. 1994. Application of DEM in Studying Soil Erosion Type and Process in the Loess Hilly and Gully Area. *Journal of Soil and Land Water Conservation* **8**(3): 17~21.

GUO Zhengtang, DING Zhongli , LIU Tungsheng. 1996. Sediment-soil Forming and Quaternary Climate Cycle in Loess. *Chinese Science Bulletin* **41**(1): 56~59.

HE Longhua, ZHAO Rui, GAN Huiping. 1993. An Improving Way of Automated Extracting Surface Channel and Drainage Network from DEM. *Acta Geodaetica et Cartographica Sinica* **1**: 28~30.

LI Qinghe, LI Changzhe, QI Shi, SUN Baoping. 2000. Numerical Simulation Technique for Routing Precipitation-Runoff in Watershed. *Geographical Research* **19**(2): 210~215.

LI Zhi-lin, ZHU Qin. 2001. Digital Elevation Model. Wuhan: Wuhan University Press. (In Chinese)

LIU Aili, TANG Guo'an, QIN Hongru. 2002. Research on Scaling of Digital Slope Conservation Models under Grid Resolution. *Journal of Soil and Land Water Conservation* **16**(1): 144~147.

LIU Tungsheng, SUN Jimin, WU Wenxiang. 2001. Past, Present and Future of the Chinese Loess Research: A Discussion of the Reality of Facts and Myth. *Quaternary Sciences* **21**(3): 185~207.

LIU Tungsheng. 1985. *Loess and Environment*, Beijing: Science Press. (In Chinese)

LIU Tungsheng. 1964. *Loess of Middle Reaches of Yellow River*. Beijing: Science Press. (In Chinese)

LIU Tungsheng. 1996. *Material and Structure of Loess*. Beijing: Science Press. (In Chinese)

LIU Xuejun. 2000. The Principle and Method of Integral Creating Digital Terrain Model for Highway. *Journal of Xi'an Highway University* **20**(3): 16~20.

LU Guonian, Qian Yadong, Chen Zhongming. 1998. Study of Automated Mapping of Channel Network in Hilly Loess Region. *Acta Geodaetica et Cartographica Sinica* **18**(6): 567~573.

LUO Shuyun, SUN Xun, CHEN Yongzong. 1988. *Research on Natural Condition of Loess*. ShanaXi: ShaanXi People Press. (In Chinese)

QI Qingwen. 2001. Research on the Geo-Info-TUPU of the Landforms of Loess Plateau. *Acta Geographica Sinica* **56** : 32~37

SUN Jimin, DING Zhongli. 1997. Spatial and Temporal Changes of Dray and Wet Climate during the Last 130, 000 Years in the Loess Plateau. *Quaternary Science* **2**: 168~175.

TANG Guo'an. 1991. Establishment and Application of Digital Slope Model. *Journal of Northwest University* **21**(1): 33~41.

TANG Guo'an, ZHAO Mudan, CAO Han. 2000. Investigation of the Spatial Structure of DEM Errors. *Journal of Northwest University* **30**(4): 349~352.

TANG Guo'an, YANG Qinke, ZHANG Yong. 2001a. Research on Accuracy of Slope Derived from Dems of Different Map

Scale. *Bulletin of Soil and Land Water Conservation* **21**(1): 53~56.

TANG Guo'an, GONG Jianya, CHEN Zhengjiang. 2001b. A Simulation on the Accuracy of DEM Terrain Representation. *Acta Geodaetica et Cartographica Sinica* **30**(4): 361~365.

TANG Guo'an, CHEN Nan, LIU Yongmei. 2001c. Comparison on Digital Terrain Models of Different Scales in Loess Hill and Gully Area. *Bulletin of Soil and Land Water Conservation* **21**(2): 34~36.

TANG Guo'an, YANG Weiying, QIN Hongru. 2002. An Application of Using GIS Technology to Return Hillside Cultivated Land for Forestry and Grassland in Loess Plateau Region. *Bulletin of Soil and Land Water Conservation* **22**(5): 46~50.

TANG Guo'an, ZHAO Mu-dan. 2003a, Modeling Slope Uncertainty Derived from DEMs in Loess Plateau. *Acta Geographica Sinica* **58**(6): 824~830.

TANG Guo'an. 2003b. Research on Digital Terrain Analyses and Slope Spectrum of Loess Plateau. Report of post-doctoral research in Northwest University.

TANG Guoan. 2003c. Slope Spectrum of the Loess Plateau and Its Spatial Distribution. Proceedings 2003 annual meeting of the geographical society of China, Wuhan.

TANG Guoan, LIU Xuejun, LU Guonian. 2005. *DEM and Its Application in Geo-analysis*. Science Press. (In Chinese)

WANG Lei, Tang Guoan. 2004. Terra in Complexity Index and Its Derivation from DEMs. *Bulletin of Soil and Water Conservation* **24**(4): 55~58.

YANG Cunjian, LIU Jiyuan, ZHANG Zengxiang, ZHAO Xiaoli. 2002. Decision Marking on Returning the Dry Upland to Forest or Grass Land with Support of GIS and Remote Sensing in China. *Journal of Remote Sensing*. **6**(3):205~211.

ZHANG Qingnian, QIN Jianxin, LIAO Ke. 2001. On Geo-informatic TUPU and Digital Earth. *Geographical Research* **20**:55~61.

ZHANG Yong. 2003. Mathematical Simulation of DEM Terrain Representation Error. *Journal of Mountain Science* **21**(2): 252~256. (In Chinese)

ZHANG Zonghu, ZHANG Zhiyi,Wang Yunsheng. 1989. *Loess of China*, Beijing: Geological Publishing House. (In Chinese)

ZHAO Bangyuan. 2002. Producing of 1:250000 Map Scaled DEM in Different Terrain Roughness. *Bulletin of Soil and Water Conservation* **22**(2): 45~48.

ZHAO Jingbo. 2002. *Deposition theory and evolvement of Loess Plateau environment*. Beijing: Science Press. (In Chinese)

ZHU Hongchun. 2003. DEM Based Landforms Extraction and Application—a Case Study in the Hilly-Gully Areas of the Loess Plateau. *Geo-information Science* **4**: 110~113.