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To cite this article: Jianxiang Zhang et al 2019 IOP Conf. Ser.: Earth Environ. Sci. 242 052021

View the article online for updates and enhancements.
Progress in research on land use and soil erosion in the Loess Plateau of China

Jianxiang Zhang1,2*, Duoyong Zhang3, Wanfeng Liu1,2, Aiping Hu1, Bo Sun1 & Yaolong Zhang1

1 College of Civil Engineering and Key Disciplines of Geotechnical Engineering, Longdong University, Qingyang, Gansu, 745000, China;  
2 Provincial Key Laboratory of Loess Engineering Properties and Applications in Gansu Province Universities, Qingyang, Gansu, 745000, China;  
3 Research Center of Desertification Control, Longdong University, Qingyang, Gansu, 745000, China;  
*Corresponding author’s e-mail: zhangjianxiang_67@163.com

Abstract. Soil erosion is a major environmental problem for human survival and sustainable development, which has been seriously threatening human ecological security. The Loess Plateau is one of the most severe areas of soil erosion in the world. Unreasonable land use is an important cause of soil erosion. In recent years, the significant progress has been made on land use and soil erosion. The paper finds: (1) soil erosion models have gradually improved; (2) assessment results of land use and soil erosion which are based on RS and GIS technology have become more accurate and efficient; (3) the research has been gradually increasing at different spatial and temporal scales. However, the current existing models are less versatile and most of them are focus on single-scale research. The achievement of the above results and the continuous research in the future are of great significance for the optimization of land use pattern and the comprehensive management of regional soil erosion in the Loess Plateau.

1. Introduction
The construction of ecological civilization is a long-term plan that affects the people's well-being and the future of the nation. Soil erosion was listed as one of the “Top Ten Environmental Problems in the World”, which seriously threatened human ecological security. Soil erosion refers to the destruction and loss of water and soil resources and land productivity under the influence of external forces such as hydraulic power, gravity and wind power, including surface erosion and soil and water loss. Soil erosion has caused more than 80% of global land degradation[1] and is a major environmental issue for human survival and sustainable development[2-3]. The main occurrence of soil erosion in the world is between 40° N and 40° S. The soil erosion area has exceeded 60 million km², mainly involving the United States, China, India, the Philippines, Australia and African countries. However, China is the most severely soil erosion in those countries. The area of soil erosion was 2,941,100 km² by the end of 2011, accounting for more than 30% of the land area in China (China Soil and Water Conservation Bulletin, 2016).

The Loess Plateau is located in the upper and middle reaches of the Yellow River. It is the largest loess accumulation area in the world, between 33°31’-41°05’N, 100°29’-114°02’E, across 7 provinces (districts) such as: Shaanxi, Gansu, Qinghai, shanxi, Ningxia, Henan and Inner Mongolia, with a total
area of about 624,000 km$^2$. The Loess Plateau is one of the most severely soiled areas in the world. Over the years, various soil and water conservation projects carried out in the area have effectively improved local agricultural production conditions and regional ecological environment, but unreasonable land use by humans is an important cause of soil erosion\cite{4}. In the process of land use, humans can influence the occurrence and development of soil erosion by changing vegetation cover, soil properties, and runoff rate. The mechanism of land use and soil erosion will change significantly under different scales. At present, land use and soil erosion research is undergoing development from slope scale to small watershed, watershed, regional and even global scale. The impact of land use on soil erosion on different scales is the frontier and hot issues of physical geography research\cite{5}. With the support of RS and GIS platforms, combined with a variety of remote sensing data and field observation data, the effects of land use on soil erosion at different scales of the Loess Plateau will be studied, which will contribute to the optimization design of multi-scale land use patterns and provide a reference for the comprehensive management of regional soil erosion.

2. Research on soil erosion model

As early as 1877, German soil scientist Ewald Wollny began to quantify soil erosion\cite{6-7}. For more than one hundred years, soil erosion model research has made significant progress, especially the general soil loss equation (USLE) which was first proposed by the US Department of Agriculture\cite{8}. It can predict the erosion, eclipse and rill erosion of sloping farmland accurately, but the portability is poor. Therefore, the USLE model has been revised by Renard in 1992, established the revised universal soil loss equation (RUSLE), and solved the shortcomings of the USLE model which cannot calculate the secondary rainfall erosion. With the development of GIS and RS technology, the application of the model is more extensive, and the calculation of soil erosion under different land use modes is easier and more accurate. However, USLE/RUSLE is a semi-empirical model for predicting soil erosion in agricultural land. In order to simulate the physical process of soil erosion, the US Department of Agriculture released the WEPP (Water Erosion Prediction Project) based on erosion process in 1985, which includes erosion, handling and sedimentation. The runoff and sediment transport in the time range of day, month and year could be calculated by simulating and forecasting the erosion and sediment transport caused by each rainfall and surface runoff \cite{9-10}. The WEPP model has high calculation accuracy\cite{11}, but the parameters are too numerous and the acquisition is difficult, which may lead to the limited practicality of the model. In contrast, the RUSLE model is simple in structure and the fewer parameters is easy to acquire. It is still widely used in the world, especially in regional and basin scales\cite{12-16}.

The research on soil erosion model in China was later started. In the 1980s, the first erosion models were studied by Jin Jinze and Meng Qingmei; in the 1990s, Chen Fayang and Wang Zhiming and others; the USLE model was revised as a soil process erosion model. It was more suitable for China established by Wang Lixian and Duan Jiannan in 1994 and 1998 respectively. Liu Baoyuan and others used the successful experience of USLE/RUSLE to establish the Chinese Soil Loss Equation (CSLE) in 2001. The model of CSLE not only considered the sturdiness of soil erosion on slopes in China, but also comprehensively considered the cultivation measures, biological measures and engineering measures for controlling soil erosion, and was suitable for calculating the annual average annual soil loss of gentle slopes. The CSLE model has been successfully applied to the first national water conservancy survey for soil and water conservation.

3. Study on the relationship between soil erosion and land use

Land use change is the core issue of global environmental change research. The soil erosion would be accelerated by the unreasonable land use\cite{11}. Land use patterns were closely related to soil erosion. Because of the different soil erosion patterns and strengths of cultivated land, woodland and pasture, changes in land use structure can significantly change the state of soil loss. Soil erosion, as one of the main environmental effects caused by land use change, is the result of the superposition of natural and human factors, and is also the number one environmental problem in the world\cite{17}.
Thomas et al. used RUSLE and GIS to assess soil erosion in a mountainous basin in southern India. The results of the study demonstrate that changes in human land use patterns, deforestation, agriculture and construction have accelerated soil erosion processes. Gelagay et al. used the RUSLE model to estimate the amount of soil loss in the Gujia basin in northwestern Ethiopia. It is believed that the slope length factor is the main cause of local soil erosion, while humans have a large number of deforestation, inappropriate tillage and uncontrolled grazing leads to accelerated soil erosion. Tadesse et al. used the Landsat TM remote sensing image and RUSLE model of the Yezat Basin in northwestern Ethiopia in 2001, 2010 and 2015 to compare the spatial and temporal variation patterns of land use/land cover and soil loss, and proved the reduction of soil erosion in the basin. The restoration of degraded land is mainly due to the increase in vegetation coverage and the reduction of agricultural land. Many scholars in China also believe that unreasonable land use patterns and reductions in surface vegetation cover have an amplified effect on soil erosion[18]. Yu Quangang et al. (1998) used remote sensing information to study land use and soil erosion in loess hilly areas. It was found that the annual soil erosion amount was negatively correlated with the proportion of flat cultivated land, and positively correlated with the proportion of slope farmland. Fu Bojie et al.[19] studied the Yangnougou watershed in Yan'an City, and proved that the soil erosion amount will decrease with the decrease of sloping farmland and the increase of forest and grassland. Zhang Jianxiang et al.[20] established the USLE model with the Malian River Basin on the Loess Plateau as an example, and obtained the soil loss in different years, and analyzed the relationship between land use pattern change and soil erosion. Wang Hongbin[21] used the experimental data of soil erosion law of Xifeng Soil and Water Conservation Science Experiment Station for more than 60 years, and found out the basic laws of soil losses on the Loess Plateau, and proposed a comprehensive management model of soil erosion. Liang Haibin et al.[22] analyzed the temporal and spatial changes of soil moisture in Robinia pseudoacacia forest land on the Loess Plateau. It was found that large-scale artificial Robinia pseudoacacia forest caused soil moisture to decrease, soil dry layer appeared, accelerated soil erosion, and the relationship between land use and soil erosion was further advanced.

In general, most of the previous studies focused on the study of the relationship between land use change and soil erosion on a single scale. However, the connotation, process, mechanism and influencing factors of soil erosion will change under the change of time and space scale[23-24]. Renschler found that soil erosion is mainly affected by soil texture, structure and soil infiltration, raindrop kinetic energy and foliar closure on the microscopic scale of the occurrence of erosion; on the slope or field scale, it is mainly affected by factors such as soil thickness, soil chain (longitudinal section of soil on a certain topographical area), land use, etc.; when rising to small watershed scale, topography, soil and vegetation become the main factors affecting soil erosion; under a more macroscopic basin or regional scale, climate and lithology become critical[24]. Comprehensive research on land use and soil erosion for different scales is a frontier and hot topic in the study of physical geography. Zhao Wenwu et al.[25] proposed a multi-scale soil erosion evaluation index (indicated by SL), which has a good application prospect in the study of trans-scale land use and soil erosion. The index describes rainfall erosivity and soil availability. Eclipse, crop cover and management factors, topographic factors and other different evaluation factors on slopes, small watersheds, watersheds and regions of the different scales and GIS implementation techniques, for in-depth study of multi-scale land use and soil erosion and more Scale soil erosion assessment provides technical and theoretical support. The soil erosion evaluation index model is a semi-empirical model between the empirical model and the physical model. It can not only evaluate the impact of land use on soil erosion, but also avoid the increase in error caused by excessive parameter calculation. Xu Chunchen[26] took the Ansai catchment area as an example, and revised the SL soil erosion evaluation index model under the small watershed scale. The average soil erosion intensity classification map of sub-basin was obtained. The corresponding soil and water conservation measures were proposed based on the erosion intensity and the main impact factor. The application function of the SL index was further improved.
4. Problems and development trends
The latest research at home and abroad has found that the current research on soil erosion has made important progress. On the one hand, the application of RS and GIS technology to soil erosion research has made soil erosion simulations more accurate and efficient, and has increased the scales of research on time and space; on the other hand, the application of soil erosion model was more mature and can be improved on the basis of conventional models according to different geographical conditions and characteristics, and can make the research results more realistic and reliable.

Although the existing research has achieved remarkable results, the following questions should be discussed in depth. First, the impact of human factors on soil erosion has been significantly enhanced under the context of returning farmland to forests, and existing research were not considered human factors. Second, various models have been established for the study of the relationship between land use and soil erosion. However, it is mostly limited to qualitative empirical analysis, that is, correlation analysis, and correlation analysis can only reflect the trend of the two. The causal relationship is unknown, so the model itself has great limitations. Third, most of the research focused on single scale, while the multi-scale soil erosion evaluation research was less, especially in the application of multi-scale soil erosion models. In the future, multi-scale research methods should be used to explore the soil erosion effects of the Loess Plateau on four different land use scales: slope/field scale, small watershed, watershed, and region, and reveal the soil erosion law of multi-scale land use. It will be of great significance to optimize the multi-scale land use pattern and comprehensive management of regional soil erosion in the Loess Plateau.

5. Conclusion
The research of the impact of land use on soil erosion has been receiving much attention, especially in the Loess Plateau. The study of the relationship between land use and soil erosion is the basis for revealing the source of sediment in the Yellow River and carrying out the Yellow River sediment prediction. Comprehensive research on land use and soil erosion at different scales is a frontier and hot topic in the study of physical geography. It is a very urgent task to strengthen multi-scale research on land use and soil erosion and accurately simulate and predict soil erosion in the Loess Plateau.

Acknowledgments
This study was supported by the National Natural Science Foundation of China (No. 31460090) and the Youth Science and Technology Innovation Foundation of Longdong University (No. XYBY140212).

References
[1] Oldeman L R. (1994) The global extent of soil degradation. Soil resilience and sustainable land use, 09: 19-36.
[2] IGBP. (2010) Integrating Traditional and Scientific Knowledge of Forest Regeneration in Swidden Cultivation Systems of Northern Thailand for Tropical Forest Restoration. GLP news.
[3] Wang R H. (2017) Gully Erosion Monitoring at Multiple Scales Based on Multi-Source Remote sensing Data of the typical black soil area, Northeast China. Changchun: Jiling University.
[4] Gao G Y, Fu B J, Lv Y H, et al.. (2013) The effect of land cover pattern on hillslope soil and water loss in the arid and semi-arid region. Acta Ecologica Sinica, 33: 12-22.
[5] Fu B J, Zhao W W, Chen L D, et al.. (2006) Multi-scale soil erosion assessment index. Chinese Science Bulletin, 51: 1936-1943.
[6] Meyer L D. (1984) Evaluation of the universal soil loss equation. Journal of Soil and Water Conservation, 39: 99-104.
[7] Wang D C, Lu Y D. (2004) Development of Soil Erosion Models Abroad. Development of Soil Erosion Models Abroad, 02: 35-40.
[8] Wischmeier W H, Smith D D. Predicting Rainfall Erosion Losses[M]. USDA Agricultural Handbook, 1978.
[9] Laflen J M, Lane L J, Foster G R. (1991) WEPP A new generation of erosion Prediction technology. Journal of Soil and Water Conservation, 01: 34-38.

[10] Teng H F. (2017) Assimilating multi-source data to modal and map potential soil loss in China. Zhejiang University.

[11] Liu C S, Qi S, Shi C M. (2001) Process of Study on Relationship between Land Use Change and Soil Erosion. Journal of Soil and Water Conservation, 15: 10 - 17.

[12] Devatha C P, VaibhavDeshpande, Renukaprasad M S. (2015) Estimation of Soil loss using USLE model for Kulhan Watershed, Chattisgarh-A case study. Aquatic Procedia 04:1429-1436.

[13] Gelagay H S, Minale A S. Soil loss estimation using GIS and Remote sensing techniques: A case f Koga watershed, Northwestern Ethiopia. International Soil and Water Conservation Research, 2016, 04: 126-136.

[14] Tamene L, Adimasu Z, Aynekulu E, Yaekob T. (2017) Estimating landscape susceptibility to soil erosion using a GIS-based approach in Northern Ethiopia. International Soil and Water Conservation Research, 05: 221-230.

[15] Tadesse L, Suryabagavan K V, Sridhar G, Legesse G. (2017) Land use and land cover changes and Soil erosion in Yeat Watershed, North Western Ethiopia. International Soil and Water Conservation Research, 05: 85-94.

[16] Thomas J, Joseph S, Thrivikramji K P. (2017) Assessment of soil erosion in a tropical mountain river basin of the southern Western Ghats, India using RUSLE and GIS. Geoscience Frontiers, 06: 1-14.

[17] Wu X Q, Cai Y L. (2003) Advances of Researches on Relationship Between LUCC and Soil Erosion. Progress in Geography, 22: 576-584.

[18] Zou Y R, Zhang Z X, Zhou Q B, et al. (2002) Analysis of the Relationship Between Soil Erosion and Land Use Based on GIS. Research of Soil and Water Conservation, 9: 67-69+75.

[19] Fu B J, Chen L D, Ma K M. (1999) The effect of land use change on the regional environment economy In the Yangjiagou catchment in the Loess Plateau of China. Acta geographica sinica, 54: 241-247.

[20] Zhang J X, Zhang B, Zhang H, et al. (2011) Landscape Pattern Change and Soil Erosion Research Based on RS/GIS——Take the Example for Malian River Basin. Journal of natural resource, 26: 1513-1524.

[21] Wang H B. (2016) Experimental observation on soil erosion law of loess sorghum gully area in Xifeng Water Conservation Station. Soil and Water Conservation in China, 10: 27-28.

[22] Liang H B, Xue Y Y, Li Z S, Wang S, Wu X, Gao G Y, Liu G H, Fu B J. (2018) Soil moisture decline following the plantation of Robinia pseudoacacia forests: Evidence from the Loess Plateau[J]. Forest Ecology and Management, 412: 62-69.

[23] He X B, Zhang X B, Wen A B. (2004) Multi-scale Methods for Soil Erosion Assessment in Hilly Regions of Middle Sichuan Province. Bulletin of Soil and Water Conservation, 24: 18-20.

[24] Renschler C S, Harbor J. (2002) Soil erosion assessment tools from point to regional scales-the role of geomorphologists in land management research and implementation. Geomorphology, 47: 189-209.

[25] Zhao W W, Fu B J, Guo X D. (2008) The Methods and GIS Techniques for Calculating Multiscale Soil Loss Evaluation Index. Progress in geography, 27: 47-52.

[26] Xu C C. (2016) Modification and application of soil erosion assessment index model in small watersheds: A case study of Aiisai catchment. Nanjing: Nanjing University of Information Science and Technology.