Distribution of Soil Erodibility K Value in Gansu Province Based on Positioning Monitoring Data

YANG Ye1,2, ZHANG Song-lin*1 and WANG Lei2

1. Institute of Geography and Environmental Sciences, Northwest Normal University, Lanzhou, China.
2. School of Environmental Science and Engineering, Xiamen University of Technology, Xiamen, China.
E-mail: 15339135388@163.com

Abstract. This paper explored the spatial distribution characteristics of soil erodibility K value in Gansu Province by using the calculation model of soil erodibility factor. The influencing factors of the K value was analysed by traditional statistics and geostatistics. The located monitoring data of the natural ecological station was supported by China Ecological Research Network. The following conclusions could be obtained according to this study: (1) The average soil erodibility K of Gansu Province was 0.331 t·hm⁻²·h/(hm²·MJ·mm). (2) Gansu Province were mainly medium-high and high erosion areas. (3) The organic matter, rainfall, slope and elevation could influence K value. The rainfall and organic matter content were negatively correlated to the K value. And the slope and elevation have the law of inverted U-shaped distribution with the K value.

1. Introduction

The soil erosion areas account for 49.65% in Gansu Province according to the results of the first national water census [1]. The ecosystem of Gansu Province is severely constrained due to the soil erosion. Studying and fixing this problem could strongly promote sustainable development of agro-ecology.

The soil erodibility refers to the possibility of the soil being destroyed which is usually measured as K value [2]. The K value can be calculated as the amount of soil erosion caused by the unit rainfall erosivity on the standard area. The research methods of soil erodibility mainly include chemical properties determination method, instrument measurement method and mathematical model method, etc. The mathematical model of Erosion-Productivity Impact Calculator (EPIC) was widely used due to its advantages for the large areas.

The positioning monitoring data was supported by the China Ecological Research Network. The map of soil erosion in Gansu was drawn by ArcGIS for the first time which was used to research the related characteristics, influencing factors and spatial distribution of soil erodibility factors.

2. Materials and methods

In this study, the data is derived from the positioning monitoring data of China Ecology Research Network from 1998 to 2010. The EPIC model[3] was used to calculate the K value. The formula is:

\[
K = 0.2 + 0.3\exp \left( { - 0.0256 \times S_a } \right) \times \left( { \frac{S_I}{C \times S_I} } \right)^{0.3} \times \left( { 1 - \frac{0.25C}{C + \exp \left( { 3.72 - 2.95C } \right) } } \right) \times \left( { 1 - \frac{0.75n}{S_n + \exp \left( { - 5.51 + 22.9S_n } \right) } } \right)
\]

\[S_n = 1 - S_a / 100\] (2)

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

Published under licence by IOP Publishing Ltd.
Where $S_a$ is the content of sand (%), $S_i$ is the content of silt (%), $C_l$ is the content of clay, $C$ is the content of organic carbon (%). However, the system of unit is different between data and the EPIC model. The soil data was transformed based on the Hermite mathematics [4]. The soil data was transformed by the software of MATLAB R2014a. The accuracy of calculation results was verified by the SPSS 22.0. The GS+ 7.0 calculated the optimal semi variogram theoretical model [5]. The ArcGIS 10.2 geographic software drawn the spatial distribution map of the soil erodibility $K$ value.

3. Results and discussion.

3.1 The soil properties

The researched soil includes 7 classes 21 types, 47 subtypes, 64 genera and 106 species in this study. (Table 1).

| Classes          | Type             | Area (km$^2$) |
|------------------|------------------|---------------|
| Semi-leaching    | Cinnamon soil    | 16497.58      |
|      soil        | Black soil       | 1394.03       |
| Arid soil        | Gray earth       | 15767.88      |
|      Leaching    | Yellow cinnamon  | 21.34         |
|      soil        | soil             |               |
|      Windy sand  | Yellow brown soil| 977.16        |
|      Red clay    | Gray desert soil | 7276.30       |
|      Yellow loess| Brown soil       | 977.16        |
| Early breeding   | Gray brown desert| 2751.38       |
|      soil        | soil             |               |
|      New fill    | Irrigation desert| 7605.80       |
| Calcaceous soil  | Black earth      | 9652.16       |
|      Black earth(II)|              |               |
|      Chestnut soil|                |               |
| Desert soil      | Brown desert soil| 46009.66      |
|      Irrigation  | Irrigation soil  | 6710.69       |
|      soil        |                 |               |
| Artificial soil  |                  | 1747.54       |

The Coefficient of Variation (CV) was described the range of variation. The pH value and organic matter content of soil is shown the Table 2.

| Classes          | Type             | Area (km$^2$) |
|------------------|------------------|---------------|
| Early breeding   | Black earth      | 9652.16       |
|      soil        | Black earth(II)  |               |
|      Chestnut soil|                |               |
| Artificial soil  |                  | 1747.54       |

3.2 Calculating data

The MATLAB R2014a software was used to transform date. The coefficient $R^2$ and Pearson correlation coefficient were verified the converted result. The results below can be obtained from Figure 1: $R^2=0.943$, Pearson correlation coefficient =0.972.
Figure 1. Interpolated estimates and measured values

The $K$ value was calculated by the EPIC model. The range of the soil erodibility $K$ value is 0.068–0.417 t·hm²·h/(hm²·MJ·mm). The average value is 0.331 t·hm²·h/(hm²·MJ·mm). The result is shown in Table 3:

| Classes               | Max    | Min    | Average | Standard deviation | Range  | CV (%) |
|-----------------------|--------|--------|---------|--------------------|--------|--------|
| Early breeding soil   | 0.397  | 0.067  | 0.329   | 0.103              | 0.330  | 31.268 |
| Semi-leaching soil    | 0.392  | 0.235  | 0.307   | 0.040              | 0.156  | 13.137 |
| Calcareous soil       | 0.417  | 0.281  | 0.339   | 0.039              | 0.136  | 11.560 |
| Arid soil             | 0.380  | 0.257  | 0.335   | 0.039              | 0.123  | 11.782 |
| Leaching soil         | 0.399  | 0.191  | 0.317   | 0.060              | 0.207  | 18.723 |
| Desert soil           | 0.393  | 0.272  | 0.349   | 0.042              | 0.122  | 12.141 |
| Artificial soil       | 0.413  | 0.304  | 0.351   | 0.027              | 0.108  | 7.781  |
| Total                 | 0.417  | 0.067  | 0.331   | 0.057              | 0.349  | 17.379 |

The degree of the soil erosion is divided into five categories: low corrosive soil ($K<0.15$), medium and low erodible soil (0.15<$K<0.25$), medium erodible soil (0.25<$K<0.30$), medium high erodible soil (0.30<$K<0.35$) and highly corrosive soil ($K>0.35$).

3.3 Drawing the map

The GS+ analysis software was used to calculate the optimal semi-variogram models. The results shown that the Gaussian model is the most suitably. The Kriging interpolation method is used to draw the spatial distribution of soil $K$ values in Gansu Province (Figure 2).
Figure 2 shows the spatial distribution characteristics of the soil K values in Gansu Province. The major areas are the serious soil erosion areas. In summary, the high-erosion areas are mainly located in the Loess Plateau, the Tengger Desert and the vicinity of the Badain Jaran Desert. The low-erosion areas mainly distribute in the hinterland of the Hexi Corridor.

This paper contrasted that the K value of Gansu Province and other regions. Results show that: The K value of Gansu Province is higher than the Yimeng Mountain [6], the Tai Lake basin [7] and the Qinghai-Tibet Plateau [8], and slightly lower than Qinghai Lake Watershed [9].

3.4 Influencing factor
3.4.1 Organic matter
As shown in Figure 3: There is a medium negative correlation between the desert soil and the arid soil.
Figure 3. The Linear fitting diagram of soil type and organic matter content

The K value become diminish with the organic matter content increased[10]. Because of increasement of the soil agglomerate, the soil physical properties improve. However, the desert soil and arid soil have less organic matter content. So, the K value may affect by other factors.

3.4.2 The annual rainfall
The date of annual rainfall is divided into eight intervals (the annual rainfall <100 mm, 100~200 mm, 200~300 mm, 300~400 mm, 400~500 mm, 500~600 mm, 600~700mm and >700 mm) for conveniently analyze data. Figure 4 shows that: when the annual rainfall is less than 500 mm [11], there is the positive correlation for the K value and precipitation. When the annual rainfall is more than 500 mm, there is no significant correlation between the K value and precipitation.

y=-0.1665x+0.3804
R²=0.5262

y=-0.2101x+0.361
R²=0.033

y=-0.0918x+0.3588
R²=0.3002

y=0.3337x+0.3277
R²=0.0772

y=-0.4079x+0.4094
R²=0.413

y=-0.1198x+0.3643
R²=0.359
The results show that in the interval of the 500-600mm. The value of soil average physical sand is larger and the physical clay value is smaller. This situation will diminish the K value. In the interval that the annual rainfall exceeds 600mm, there is the high organic matter content. It’s may be the reason for the transformation law of K value is different from another intervals.

3.4.3 Topographical factors
In this paper, the slope and elevation data extracted from the Gansu Province Digital Elevation Model (DEM) map for researched topographical factors. As is shown the Figure 5 and Figure 6: the slope and elevation have the law of inverted U-shaped distribution with the K value. Besides, there is the specific interval of slope and elevation. the K value is the maximum. K value is gradually decreasing on both sides of this interval.
4. Conclusion
1. The EPIC model can accurately count the K value of Gansu province.
2. The soil of Gansu Province is weakly alkaline, and the organic matter content is greatly discrepant across the province.
3. The great mass of area is moderately high and high erosion areas on Gansu Province. The soil loss risk is higher other area.
4. The soil erodibility K value was affected by factors, such as rainfall, organic matter content, slope and elevation. The rainfall and organic matter content are negatively correlated with the K value. the slope and elevation have the law of inverted U-shaped distribution with the K value.

5. References
[1] Yao J Z 2015 Thoughts on Soil and Water Conservation Work in Gansu Province Soil and Water Conservation in China (Gansu: Gansu Provincial Water Resources Department) chapter 3 pp 1-2, 11.
[2] Wang B and Zheng F L 2015 Soil Erodibility for Water Erosion: A Review Research of Soil and Water Conservation (Yangling: Northwest A&F University) chapter 20 pp 277-286.
[3] WILLIAMS J R. 1983 EPIC- a New Method for assessing erosion' s effect on soil productivity Journal of Soil and Water Conservation, chapter 38 pp 381 - 383.
[4] Yan R and Yan S J 2013 The Accuracy Verification of the Different Soil Texture Transformation Models in Cha-kou Watershed Journal of Shanxi Agricultural University (Taigu: Shanxi Agricultural University) chapter 33 pp 109-113.
[5] Shi Z and Li Y 2006 Application of geostatistics in soil science Beijing (China Agriculture Press)
[6] Jin S S and Zhang R H 2017 Spatial Variability on K Value of Soil Erodibility in Typical County of Yimeng Mountain Area Chinese Journal of Soil Science (Taian: Sandong Agricultural University) chapter 48 pp 278-284.
[7] Bu Z L and Yang L Z 2002 Soil erodibility (K) value and its application in Taihu lake catchment Acta Pedologica Sinica (Nanjing: Institute of soil science) chapter 39 pp 296-300.
[8] Liu B T and Tao H P 2014 Spatial distribution characteristics of soil erodibility K Value in Qinghai-Tibet Plateau Bulletin of Soil and Water Conservation (Chengdu: Institute of Mountain Hazards and Environment) chapter 34 pp 11-16.
[9] Liu J F and Li S J 2006 Soil erodiable K in the catchment of Qinghai lake Arid Land Geography (Nanjing: Nanjing Institute Of Geography & Limnology CAS) chapter 29 pp 321-326.
[10] Yang C M 2008 Quantitative Study on the Relation of Soil Organic Content and Soil and Water Losses Research of Soil and Water Conservation (Taiyuan: Institute of Soil and Water convention of Shanxi) chapter 15 pp 177-179.
[11] Sun D F and Wang L 2007 Effects of farmlands’ soil erosion under different intensities of rainfall in loess hilly regions Research of Soil and Water Conservation (Lanzhou: Gansu Agricultural University) chapter 14 pp 16-18.

Acknowledgments
The National Natural Science Foundation of China (51068025), Gansu Natural Science Foundation Project (1308RJZA302), Gansu Provincial Key Laboratory of Oil and Gas Resources Research Open Fund (SZDKFJJ20150606) and Gansu Provincial Key Science Ecological Science Funding.