Soil Erodibility of Slope Farmland in Guizhou Mountain Areas

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Abstract This paper studied soil erodibility of slope farmland in Guizhou mountain areas by the plot runoff method, analysis and test. Results show that the variation coefficient of erodibility *K* value calculated according to formula introduced by Sharply is low and relatively stable and accurate, so it is a suitable method for calculating erodibility *K* value of slope farmland in Guizhou mountain areas. *K* value of layer A slope farmland decreases with increase of years. The erodibility of entire soil layer is high, and the erosion resistance is weak. From the influence of different planting system and use types in 4 years, *K* values of different soil layers decrease, average reduction of A, B and C layers reaches 3.17% - 11.64% (1.26% - 12.34% for layer A, 1.29% - 13.80% for layer B, and 1.26% - 10.80% for layer C). Except engineering terraced treatment, the decline of *K* value of grassland, zoning crop rotation, economic fruit forest, grain and grass intercropping, plant hedge, and mixed forest treatment is higher than farmers' treatment, and the decline level is grassland > zoning crop rotation > economic fruit forest > grain and grass intercropping > plant hedge > and mixed forest treatment. Planting grass and trees is favorable for lowering erodibility of slope farmland and improving farmland quality. Interplanting of corns with other plants can increase plant coverage and species, so it is favorable for improving erodibility of slope farmland.

Key words Slope farmland, Soil erodibility, *K* value

1 Introduction

Guizhou is a mountainous province in southwest China. Mountains and hills take up 97% of its land. According to Department of Land and Resources of Guizhou Province, Guizhou Province has 4.9035 million hm^2 farmland, accounting for 3.67% of national farmland, dry farmland accounts for 69.53% of total farmland, and 6 - 25° slope farmland takes up 61.17% of total farmland, indicating serious water loss and soil erosion (the area of water loss and soil erosion in the whole province takes up 41.6% of its total land). Therefore, Guizhou Province has carried out control and research of water loss and soil erosion in slope farmland, including loss of nutrient[1-2]. However, traditional plot runoff method consumes time and labor, and calculation result is generally water loss and soil erosion of a plot. Thus, it is impossible to make prediction of water loss and soil erosion of the whole province. Soil erodibility is an essential indicator for evaluating sensitivity of soil erosion and also an important parameter for predicting soil erosion[3]. About soil erodibility *K*[4], seasonal change of soil erodibility[5-6], the correlation between changes in soil erodibility *K* and rainfall erosivity[7], seasonal change of soil property erosivity[8], characteristics of spatial variation in soil erodibility *K*, both domestic and foreign scholars have made some researches, but the calculation methods are different, so the calculated soil erodibility is various. In line with slope farmland in Guizhou mountain areas, with the aid of calculation formula of Wischemeier and Williams, nomograph, *K* value of Universal Soil Loss Equation (USLE), we studied soil erodibility, in the hope of providing scientific basis for prediction and prevention and control of water loss and soil erosion in slope farmland of Guizhou mountain areas.

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2 Materials and methods

2.1 Overview of the study area The study area is Xinglong Township in Luodian County of Guizhou Province (106°08'10" - 106°37' 10" E, 35°33'10" - 35°34'50" N). The altitude is 600 - 630m and the slope is 11.3 - 34.7°.

2.2 Field experiment

2.2.1 Design of field experiment. In 2007, according to requirement of Test Specification of Soil and Water Conservation issued by Ministry of Water Resources, we established runoff plot observation site in dry farmland of west slope of Sanchahe River in Xinglong Township in Luodian County of Guizhou Province and monitored water loss and soil erosion situation of bare slope farmland. The plot slope is 21° and projected area is 105 m^2 (21 m × 5 m). The plot is separated by cement partition boards. 9 treatment zones are arranged: C1: mixed forest (eucalyptus interplanting with Vetiveria zizanioides and Amorpha fruticosa); C2: farmers' habit (planting corns along the slope); C3: zoning crop rotation (crop rotation of corns interplanting with Ipomoea batatas, soybean, and cross slope planting); C4: economic fruit trees (planting plum trees after terraced treatment); C5: engineering terraced treatment (planting corns after artificial terraced treatment); C6: grain-grass intercropping (corns intercropping with alfalfa); C7: plant hedge (day lily + corn); C8: grassland (planting witloof); C9: bare land (not planting crops).

2.2.2 Amount of fertilizer application in field experiment. Before sowing corns, we took phosphorus fertilizer, potash fertilizer and barnyard manure as base fertilizer, and took nitrogen fertilizer as additional fertilizer. Except C1 and C9, all farm works related to fertilizer application, irrigation, prevention and control of plant diseases and pests, and crop harvesting are the same. The amount of fertilizer application: barnyard manure 18 000 kg/hm^2, N 270.00 kg/hm^2, P 45.85 kg/hm^2, and K 87.17 kg/hm^2.

2.2.3 Crop of field experiment. Corns are directly sown in April and harvested in September. Apart from farmers' habitual 0.5m × 0.75m double-plant seedling, the spacing in the rows and spacing between rows are 0.25m × 0.5m single-plant seedling. The spacing in the rows and spacing between rows for soybean, rape and Ipomoea batatas are 0.25 m × 0.5 m single-plant seedling. Alfalfa is perennial plant was planted in March of 2008 by drilling method. It is planted in rows of corns. Day lily is perennial plant and was transplanted in March of 2008 with spacing in the rows and spacing between rows of 0.25 m × 0.32 m; double row is a plant hedge belt with spacing of 6 m. In April to June, it was harvested for 2 – 3 times. Witloof is also perennial plant and was planted in February of 2003. Plum trees were transplanted in March of 2008 with spacing in the rows and spacing between rows of 3 m × 4.2 m. For mixed forest, eucalyptus was planted in 1991. The major variety is plantation-grown eucalyptus with 1.5 m × 1.5 m spacing in the rows and spacing between rows in the first year and felling two rows every 4 rows in the second year. By 2008, eucalyptus was 11 years old and Vetiveria zizanioides and Amorpha fruticosa were 10 years old.

2.3 Collection of samples Soil samples were collected one time separately before sowing and harvesting corns every year. The collection was carried out at three levels in each plot. 3 samples were collected from each level as per the contour line. Each point was collected at layer A, B and C, and mixed samples were collected from points at different levels in each plot.

2.4 Measuring items and methods of field experiment Measuring items include soil organic matter, water-stable soil aggregates, soil micro-aggregate, and soil mechanical composition. Organic matter: potassium dichromate volumetric method with external heating method; water-stable soil aggregates: Yoder method; soil micro-aggregate: water sedimentation method; mechanical composition: pipette method.

2.5 Data analysis All data were analyzed with the aid of statistical software SPSS10.0 and Microsoft Excel 2003.

2.6 Determination and calculation of soil erodibility indicator

2.6.1 Formula method. Formula I: using algebraic expression introduced by Wischemeier *et al*[10]. $K = [2.1 \times 10-4\ (12-OM)M1.14 + 3.25(s-2) + 2.5(p-3)]/100$

where *OM* is content of organic matter (%), *M* is fraction of silt in soil (%) × (fraction of silt in soil % + fraction of sand in soil %), *s* is construction coefficient, and *p* is permeability class.

Formula II: adopting *K* value calculation equation proposed by Sharply *et al*[11] in EPIC model.

$$\{0.2 + 0.3\exp[0.0256S(1-0.01I)]\}[I/(L+I)]0.3\{1.0-0.25C/[C+\exp(3.72-2.95C)]\}\{1.0-0.7N/[N+\exp(-5.51+22.9N)]\}.$$

where S denotes the fraction of sand in soil (%), I is fraction of silt in soil (%), L is fraction of clay in soil (%), C is content of organic carbon in soil (%), $N = 1 - S/100$.

2.6.2 Nomograph method. On the basis of data of nearly 10000 plots by method of Wishmeier *et al*[10], we summarized nomograph of *K* value related to soil texture, structure, organic matter and permeability.

2.6.3 Look-up table method. We adopted the erodibility factor K in Universal Soil Loss Equation (USLE)[11-12] to look up values.

3 Results and analyses

3.1 Erodibility *K* value of slope farmland determined from different methods *K* values of bare slope farmland calculated by formula I, formula II, nomograph and look-up table methods: average value of K of layer A, B and C is 0.222 – 0.369, 0.329 – 0.413, 0.430 – 0.560 and 0.405 – 0.595 (as listed in Table 1). There is a great difference in *K* value calculated by different methods. *K* value is the highest from look-up table method, the next is nomograph and formula II, and the lowest is obtained from formula I. Besides, the coefficient of variation is also greatly different. From high to low coefficient of variation is formula I > look-up table method > nomograph > formula II. *K* value obtained from formula II is relatively stable and accurate.

For formula I, it is calculating soil erodibility *K* value through determining organic carbon, soil permeability, and mechanical composition, the method is simple and the data can basically reflect interannual changes and spatial changes of soil erodibility of slope farmland, but the coefficient of variation is higher.

As to formula II, it is calculating soil erodibility *K* value through determining mechanical composition and organic carbon, the method is slightly complex, but the data is more accurate and the variation coefficient of *K* value is lower, thus it can better reflect interannual changes and spatial changes of soil erodibility of slope farmland. For nomograph and look-up table methods, it can directly read out *K* value through observing nomograph and looking up table after determining mechanical composition and organic matter. These two methods are simple, but the data is not very accurate, and the variation coefficient of *K* value is low, thus the data fails to fully reflect interannual changes and spatial changes of soil erodibility of slope farmland. Comparing these methods, it can be known that formula II is the best method for calculating soil erodibility *K* value of slope farmland.

3.2 Laws of changes in soil erodibility *K* value of slope farmland

3.2.1 Laws of time changes in soil erodibility *K* value of slope farmland. The soil erodibility *K* value of bare slope farmland in 2007 – 2011 calculated by formula II is shown in Fig. 1. From Fig. 1, it can be known that *K* value of layer A of slope farmland declines with increase of years. In 4 years, the *K* value of soil layer A of slope farmland dropped 13.65% with annual drop up to 3.41%.

Table 1 Erodibility *K* value of bare slope farmland determined from different methods

Year	Soil layer	K_1	K_2	K_3	K_4
2007	A	0.227	0.381	0.430	0.560
	B	0.369	0.413	0.550	0.590
	C	0.226	0.407	0.560	0.595
2008	A	0.290	0.357	0.440	0.405
2009	A	0.271	0.339	0.430	0.405
2010	A	0.259	0.335	0.430	0.405
2011	A	0.222	0.329	0.430	0.560
	B	0.246	0.357	0.500	0.560
	C	0.247	0.395	0.550	0.595
Average	A	0.262	0.366	0.438	0.467
	B	0.308	0.376	0.525	0.578
	C	0.237	0.401	0.555	0.595
Overall average		0.266	0.376	0.483	0.520
Coefficient of variation // %		17.87	7.61	11.80	16.84

Note: K_1, K_2 and K_3 are obtained by formula I, formula II and nomograph respectively, and K_4 is obtained from looking up table in USLE.

3.2.2 Laws of changes in soil erodibility *K* value of different soil layers of slope farmland. *K* values of soil layer A, B and C in 2007 and 2008 are shown in Fig. 2. From Fig. 2, it can be known that *K* value of layer B and C is higher than that of layer A, separately higher for 8.39% - 8.51% and 6.82% - 20.61%. Layer A of red-yellow soil slope farmland is thin and easy to be eroded, while *K* value of layer B and C is higher, indicating that entire soil layer of slope farmland has higher erodibility and weak serosion resistance.

3.3 Characteristics of erodibility *K* value of slope farmland in different planting systems and use types For the erodibility *K* values of soil layer A, B and C of different planting systems and use types of slope farmland in 2008 and 2011 calculated by formula II, see Table 2. From Table 2, we can know that the erodibility *K* value of layer A in mixed forest in 2008 reduced about 11.84% compared with farmers' planting habits, while there is no big difference other treatment methods and farmers' planting habits. Also, there is no big difference in *K* value of layer B and C between different planting and use types of slope farmland. From the influence of different planting system and use types in 4 years, *K* values of different planting systems and use types of slope farmland decrease, average reduction of A, B and C layers reaches 3.17% - 11.64% (1.26% - 12.34% for layer A, 1.29% - 13.80% for layer B, and 1.26% - 10.82% for layer C).

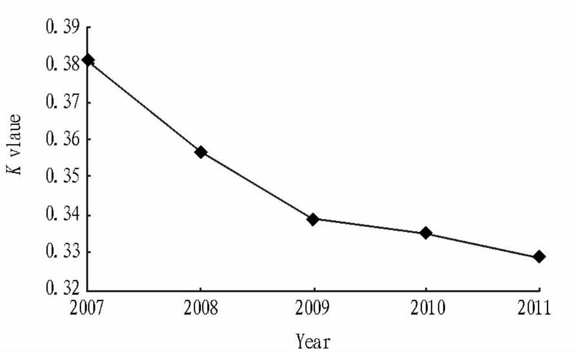

Fig. 1 Time changes in soil erodibility *K* value of topsoil

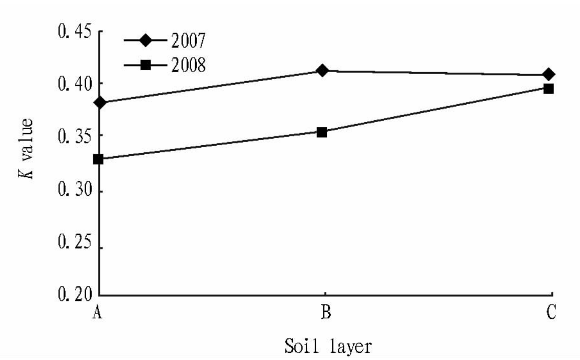

Fig. 2 Changes of erodibility *K* value of soil layers

Table 2 *K* value of slope farmland in different planting systems and use types

Year	Soil layer	Farmers' habit C2	Zoning crop rotation C3	Economic fruit trees C4	Engineering terraced C5	Grain and grass intercropping C6	Plant hedge C7	Grass land C8	Mixed forest C10
2008	A	0.380	0.393	0.391	0.398	0.371	0.373	0.389	0.335
	B	0.389	0.413	0.405	0.400	0.389	0.380	0.407	0.392
	C	0.397	0.411	0.426	0.400	0.391	0.450	0.408	0.394
2011	A	0.350	0.354	0.371	0.393	0.347	0.351	0.341	0.317
	B	0.384	0.356	0.378	0.386	0.362	0.367	0.353	0.367
	C	0.392	0.380	0.380	0.381	0.364	0.365	0.370	0.374
Decline in 4 years // %	A	7.89	9.92	5.12	1.26	6.47	5.90	12.34	5.37
	B	1.29	13.80	6.67	3.50	6.94	3.42	13.26	6.38
	C	1.26	7.54	10.82	4.75	6.91	9.88	9.31	5.08
	ABC	3.48	10.42	7.54	3.17	6.77	6.40	11.64	5.61

For different planting systems and use types of slope farmland, the decline of *K* value is varied. At layer A, only the decline of *K* value of zoning crop rotation and grassland treatment is higher than farmers' habitual treatment for 2.03% - 4.45%. For layer B and C, except engineering terraced treatment, the decline of *K* value for other ameliorative measures is higher than farmers' habitual treatment. The rank of decline is grassland > zoning crop rotation > economic fruit forests > grain and grass intercropping > plant hedge > mixed forests. For average result of layer A, B and C, except terraced treatment, the decline of *K* value of grassland, zoning crop rotation, economic fruit forest, grain and grass intercropping, plant hedge, and mixed forest treatment is higher than farmers' treatment, and the decline level is grassland > zoning crop rotation > economic fruit forest > grain and grass intercropping > plant hedge > and mixed forest treatment. These indicate that increasing biological diversity and increasing plant coverage are favorable for improving soil erodibility of slope farmland.

Mixed forests were already 12 years old when measured in 2008, the soil erodibility was improved to a certain extent and *K* value was low at the initial measurement, thus the decline of *K* value is not significant. When artificial measures disrupt soil layers and the initial value of soil erodibility *K* value is high, the decline of *K* value of economic fruit forests and engineering terraced treatment becomes greatly different, with a difference up to 3.86% –6.07%. The decline of *K* value of grassland is 8.16% higher than farmers' habitual treatment. Therefore, changing crops to trees and grass is also favorable for improving both soil erodibility and farmland quality.

4 Conclusions and discussions

Firstly, soil erodibility is an essential indicator for evaluating sensitivity of soil erosion and also an important parameter for predicting soil erosion[4]. From both domestic and foreign researches on soil erodibility, we can see that their calculation methods are different and the calculated soil erodibility is also various[5-7]. In line with slope farmland in Guizhou mountain areas, with the aid of calculation formula of Wischemeier and Williams, nomograph, *K* value of Universal Soil Loss Equation (USLE), we studied soil erodibility, in the hope of providing scientific basis for prediction and prevention and control of water loss and soil erosion in slope farmland of Guizhou mountain areas. There is a great gap between *K* values obtained from different methods, and the coefficient of variation is also high. Results indicate that variation coefficient of erodibility *K* value calculated according to formula introduced by Sharply is low and relatively stable and accurate, so it is a suitable method for calculating erodibility *K* value of slope farmland in Guizhou mountain areas.

Secondly, the erodibility *K* value of soil layer A, B and C in bare slope farmland is 0.329 – 0.381, 0.357 – 0.413, and 0.401 –0.407 respectively. The erodibility *K* value of entire soil layers of slope farmland is high and there is a decline trend with increase of years.

Thirdly, from the influence of different planting systems and use types in 4 years, *K* value of different soil layers decreases and the average reduction of layer A, B and C reaches 3.17 – 11.64%. The decline in *K* value is different for different planting systems and use types of slope farmland. Except engineering terraced treatment, the decline of *K* value of grassland, zoning crop rotation, economic fruit forest, grain and grass intercropping, plant hedge, and mixed forest treatment is higher than farmers' treatment, and the decline level is grassland > zoning crop rotation > economic fruit forest > grain and grass intercropping > plant hedge > and mixed forest.

Fourthly, it proves that increasing biological diversity and increasing plant coverage are favorable for improving soil erodibility of slope farmland in Guizhou mountain areas. In steep slope farmland with slope higher than 25 degrees, changing crops to grass and trees is favorable for improving soil erodibility and farmland quality; in gentle slope with slope lower than 25 degrees, interplanting corns with other plants can increase coverage and species. For example, grain and grain intercropping, plant hedge, and zoning crop rotation can improve soil erodibility of slope farmland. Engineering terraced treatment and farmers' habitual treatment, due to simply planting grain crops, have low coverage and are not favorable for improving soil erodibility of slope farmland and should be improved.

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