The Influence of Typical Forest Types on Soil Erosion Resistance in the Water Source Areas of Central Yunnan

Yangyi ZHAO * **, Xu DUAN, Shumiao SHU**

College of Environment Science and Engineering, Southwest Forestry University, Kunming 650224, China

Abstract In order to clarify the influence of different forest types on soil erosion resistance in water source area of Central Yunnan, with the soils under three different kinds of typical forest in Yizhe watershed as the research object, this paper uses field simulation method and principal component analysis to analyze the soil erosion resistance of three kinds of soils. The results show that there is a significant difference in the shear strength of soil among three types of typical forest, and the size of soil shear strength is in the order of *Pinus yunnanensis* forest land > mixed broadleaf-conifer forest land > eucalyptus forest land. The difference in the soil erosion coefficient among different forests is not significant, and the soil erosion resistance is highest in mixed broadleaf-conifer forest land (39.0%), followed by eucalyptus woodland (37.0%) and *Pinus yunnanensis* forest land (24.0%). Under heavy rain intensity and long duration of rainfall, the ability of soil under eucalyptus × *Pinus yunnanensis* mixed forests to resist disintegration is more obvious. Using principal component analysis to analyze soil erosion resistance of soils under three different forests, we get the comprehensive evaluation model for soil erosion resistance: $Y = 0.763Y_1 + 0.236Y_2$. The soil erosion resistance is in the order of mixed broadleaf-conifer forest land (0.150) > eucalyptus forest land (0.127) > *Pinus yunnanensis* forest land (−0.079), indicating that the mixed forests have better water loss and soil erosion control effect than pure forests.

Key words Mixed broadleaf-conifer forest, Eucalyptus forest, *Pinus yunnanensis* forest, Soil erosion resistance, Small watershed

1 Introduction

Soil erosion is a major environmental hazard issue of common concern in the world today[1-2], and it can cause decline in land productivity. The eroded sediment would cause silting of downstream rivers, reservoirs and estuaries. Meanwhile, the sediment adsorbs the organic and inorganic pollutants, polluting the downstream water body[3-4]; there will be more serious consequences if soil erosion occurs in the water source areas. Yunnan Province is located in the southwestern mountainous areas, where farmers survive by deforestation and expansion of arable land. The sloping land is difficult to retain water, soil and fertilizer, resulting in low yields and economic poverty, thereby exacerbating the water loss and soil erosion. According to studies[5-6], more than 70% of sediment in the Songhuaba reservoir area in Kunming City is from the arable land reclaimed from the steep slope. Thus, the vegetation protection in water source areas is particularly important. Based on the special soil erosion in water source areas of Kunming, the vegetation construction has become the key to further improving water retention and soil conservation effect and thus indirectly promoting regional agricultural development, so the study of the influence of typical forest types on soil erosion resistance is of great significance to regional soil and water conservation. This paper studies the erosion resistance of soil under three typical forest types within Yizhe small watershed in Kunming City, and explores the influence of different forest types on soil shear resistance, scourability resistance and erosion resistance, in order to provide a basis for the prevention and control of regional water loss and soil erosion.

Received: April 20, 2015 Accepted: June 22, 2015

Supported by Research Project of Yunnan Provincial Department of Education (2013Y114); Applied Basic Research Projects of Yunnan Province (2012FD028); Key Disciplines (Ecology) Project of Yunnan Education Department (05000511311); Research Starting Capital Project of Southwest Forestry University (111168).

* Corresponding author. E-mail: yyz301@foxmail.com

2 Materials and methods

2.1 Overview of the study area The study area is in Yizhe small watershed in Central Yunnan (102°45′E, 25°08′N), with elevation of 1985 – 2200 m. It features a low-latitude plateau and mountain monsoon climate, with the annual average temperature of 15 ℃. The annual precipitation is about 1031 mm, and the relative humidity is 74%; the average annual sunshine is 2200 h, and the annual frost-free period in recent years averages above 240 d. There are many sunny days throughout the year, and the sunshine rate is 56%. The soil is mainly yellow loam soil. The main forest types include three: evergreen broadleaf forest; mixed broadleaf-conifer forest; coniferous forest. The forest age is 15 years. The evergreen broadleaf forest is dominated by eucalyptus. The eucalyptus species is *Eucalyptus maideni*, and the average tree height is 15.6 – 28.8 m; the shrub is dominated by *Myrsine Africana* and *Lysidice rhodostegia*, and the average height is 0.3 – 1.5 m and 0.4 – 2.7 m, respectively; the herb is dominated by *Eupatorium adenophorum*. The canopy density is about 0.55 to 0.75, and the cover degree is about 35% to 50%. The mixed broadleaf-conifer forest is mainly the mixed forest of eucalyptus and *Pinus yunnanensis*. The canopy density is about 0.65 – 0.80, and the cover degree is 65% – 75%. The shrub is dominated by *Myrsine Africana* and the herb is dominated by *Eupatorium adenophorum*. The coniferous forest is dominated by *Pinus yunnanensis*. The canopy density is about 0.85 – 0.90, and the cover degree is about 90%.

The shrub is dominated by *Myrsine Africana*, and the herb is dominated by *Eupatorium adenophorum*.

Table 1 Tree species composition and characteristics of plot

Plot	Average DBH//cm	Average tree height//m	Canopy density	Stand density trees · hm^2	Altitude m	Slope °	Slope direction
Mixed broadleaf-conifer forest (*Pinus yunnanensis* × eucalyptus)	13.22	18.74	0.7	1350	2008	25	West
Eucalyptus forest	9.78	20.55	0.6	1270	1995	21	Northwest
Pinus yunnanensis	11.59	16.35	0.7	1130	2030	24	Northwest

2.2 Research methods

2.2.1 Determination of soil physical properties. In July 2013, we set the standard plots (20m × 20m) in the typical places with similar elevation and slope within the study area, and conducted stand survey. We measured the density of trees, average height, average DBH and other stand characteristics within plots, and the basic information of plots is shown in Table 1. Using 5-point method, we collect soil samples at 0 – 20cm and 20 – 40cm, and the test soil is yellow loam. The soil samples are packed and brought back to laboratory to be air-dried, ground and sieved for analysis. The cutting ring method is used for soil bulk density, porosity and other indicators, and the oven drying method is used for soil moisture content[7–8]. Soil shear strength is measured using the portable shear produced by EIJkelkamp Company, and three replications are set for each sample.

2.2.2 Determination of soil anti-scouribility. Using the undisturbed soil scouring flume and experimental method designed by Jiang Dingsheng[9–10], we take 15 × 10 × 10 cm undisturbed soil samples from the soil surface layer by self-made soil sampler and soak the undisturbed soil samples prior to testing for 24 h. The soil samples are kept still for 1 min and weighed after removing the gravitational water. They are placed in 50 × 10 × 10 cm scouring flume, and the slope is set at 20° for purposes of comparison. Scouring time is fixed at 10 min. The soil washed away is filtered and weighed after scouring, to calculate the impact factor. Anti-scourability of soil (C) is used to evaluate the soil erosion resistance, defined as the product of the amount of water (Q/L) needed to wash away 1 g of soil and time (t/min).

$$C = Q \cdot t / w$$

where C is anti-scourability of soil and w is the weight of soil washed away (g).

2.2.3 Determination of soil erosion resistance index. We use a sieve with aperture diameter of 5mm to select 75 5 – 7 mm soil aggregates and put them on the sieve with aperture diameter of 5mm to be immersed in water, 25 each time. The number of soil particles collapsed is recorded every 1 min, and it is recorded continuously for 10 min. The process is repeated three times, and it is averaged to calculate erosion resistance index. The specific formula[11] is as follows:

Erosion resistance index = (total number of soil particles-number of soil particles disintegrated)/total number of soil particles.

3 Results and analysis

3.1 Soil physical properties of different types of forest land

We perform the analysis of soil physical properties under three typical forest types (Table 2). For the same layer of soil in three plots, in the 0 – 20cm soil, *Pinus yunnanensis* forest land has the highest soil bulk density (1.57 g/cm^3); mixed broadleaf-conifer forest land has the lowest soil bulk density (1.30 g/cm^3); mixed broadleaf-conifer forest land has the highest total soil porosity, capillary porosity and non-capillary porosity (51.07%, 36.89% and 14.18%, respectively). In the 20 – 40 cm soil, mixed broadleaf-conifer forest land has the highest soil bulk density (1.65 g/cm^3); eucalyptus forest land has the highest total soil porosity (44.65%); *Pinus yunnanensis* forest land has the highest soil capillary porosity (42.21%); eucalyptus forest land has the highest non-capillary porosity (12.14%). For different layers of soil in the same plot, the soil bulk density of mixed broadleaf-conifer forest land increases with increasing soil depth while the soil bulk density of eucalyptus forest land and *Pinus yunnanensis* forest land will decrease with increasing soil depth, mainly because of frequent human disturbance; the soil capillary porosity of mixed broadleaf-conifer forest land and *Pinus yunnanensis* forest land decreases with increasing soil depth while it increases for eucalyptus forest land. It can be found that the mixed broadleaf-conifer forest land plays a more significant role in improving soil structure, protecting soil texture, increasing infiltration, reducing runoff and lowering water loss and soil erosion, followed by eucalyptus forest land and *Pinus yunnanensis* forest land; mixed forest land plays a better role in improving soil structure than pure forest land.

3.2 Analysis of soil shear strength of different forest land types Table 3 shows that there are significant differences in the shear strength values of soil in the same layer for eucalyptus forest, mixed broadleaf-conifer forest and *Pinus yunnanensis* forest land, and it shows an increasing trend. The shear strength values of soil in 0 – 20 cm layer is smaller than in 20 – 40 cm layer, possibly because the forest land subsurface soil is more stable than the topsoil under root retaining effect. The soil shear strength of three typical plots is in the order of *Pinus yunnanensis* forest land > mixed broadleaf-conifer forest land > eucalyptus forest land, indicating that *Pinus yunnanensis* forest land has better soil shear strength than the other two types of forest land.

Table 2 Physical properties of soil under different forest types

Forest types	Soil layer cm	Soil bulk density g/cm³	Total porosity %	Capillary porosity %	Non-capillary porosity//%
Eucalyptus forest	0 – 20 cm	1.56 ± 0.16	41.26 ± 6.110	30.33 ± 15.14	10.93 ± 9.530
	20 – 40 cm	1.47 ± 0.16	44.65 ± 5.890	32.51 ± 3.200	12.14 ± 4.640
	Mean	1.52 ± 0.10	42.95 ± 3.820	31.42 ± 8.980	11.54 ± 7.960
Mixed broadleaf-conifer forest	0 – 20 cm	1.30 ± 0.12	51.07 ± 4.530	36.89 ± 17.25	14.18 ± 12.90
	20 – 40 cm	1.65 ± 0.06	37.61 ± 2.430	25.53 ± 2.870	12.08 ± 4.280
	Mean	1.48 ± 0.21	44.34 ± 1.470	31.21 ± 9.600	13.13 ± 8.460
Pinus yunnanensis	0 – 20cm	1.57 ± 0.29	40.63 ± 10.95	34.27 ± 12.55	6.36 ± 2.620
	20 – 40 cm	1.37 ± 0.14	48.18 ± 5.460	42.21 ± 10.45	5.97 ± 5.010
	Mean	1.47 ± 0.21	44.41 ± 8.000	38.24 ± 10.99	6.17 ± 3.050

Table 3 Soil shear strength values of different forest land types

Forest types	Soil layers//cm	Soil shear strength kg · m²
Eucalyptus forest	0 – 20	2090.83 ± 53.03a
	20 – 40	2815.00 ± 282.84d
Mixed broadleaf-conifer forest	0 – 20	2349.17 ± 288.73b
	20 – 40	2775.84 ± 312.31e
Pinus yunnanensis	0 – 20	2593.33 ± 502.05c
	20 – 40	2988.34 ± 377.12f

Note: The letter after numbers indicates the multiple comparisons of shear strength for the same soil layer, and the different letters mean significant differences while the same letters mean unobvious differences, the same below.

3.3 Soil anti-scourability and erosion resistance of different forest land types

3.3.1 The changes in soil anti-scouribility with slope. The anti-scourability to a certain extent reflects the ability of soil to resist runoff erosion. As can be seen from Table 4, the average anti-scourability of soil for various forest types is in the order of eucalyptus × *Pinus yunnanensis* mixed forests > *Pinus yunnanensis* pure forest. Except *Pinus yunnanensis* forest land, the anti-scouribility coefficient in the 0 – 20 cm soil is greater than in the 20 – 40 cm soil; with the increase of slope, the anti-scourability shows a decreasing trend. The significance analysis shows that the anti-scouribility coefficient of soil under different vegetation types at the same slope is significantly different, and with the increase of slope, the significant difference is also increasing. In the 0 – 20 cm soil layer (Table 4), the anti-scourability of soil under mixed broadleaf-conifer forest at slope of 10° is 1.08 and 1.25 times as high as that of soil under eucalyptus forest and *Pinus yunnanensis forest*, respectively; when the slope becomes 25°, it is 1.09 and 1.26 times as high as that of soil under eucalyptus forest and *Pinus yunnanensis* forest, respectively; when the slope becomes 30°, the anti-scouribility coefficient of soil under mixed broadleaf-conifer forest is 1.70 and 1.49 times as high as that of soil under the other forest types. The variation in the 20 – 40 cm soil layer is consistent with that in the topsoil under three degrees of slope. From the overall slope change in the 0 – 40 cm soil, when the slope is 10°, the anti-scourability of soil under mixed forest is 12.52% and 18.43% higher than under eucalyptus forest and *Pinus yunnanensis* forest, respectively; when the slope is 30°, it is 64.24 % and 28.25 % higher than under eucalyptus forest and *Pinus yunnanensis* forest, respectively. The above conclusion suggests that with increase of slope, mixed forest plays a better role than pure forest in improving the anti-scouribility of soil.

Table 4 Soil anti-scourability of typical forest land

Soil layer cm	Plot type	Anti-scouribility coefficient//L · min · g⁻¹			
		10°	25°	30°	Mean
0 – 20	Mixed broadleaf-conifer forest	7.09	5.41	4.90	5.80
	Eucalyptus forest	6.54	4.97	2.88	4.80
	Pinus yunnanensis	5.69	4.31	3.28	4.43
	F value	8.96**	15.67**	19.22**	–
20 – 40	Mixed broadleaf-conifer forest	4.41	3.64	2.99	3.68
	Eucalyptus forest	3.68	3.01	1.93	2.87
	Pinus yunnanensis	4.02	3.83	2.88	3.58
	F value	4.03*	6.78**	9.29**	–

Note: * means that the difference is significant at significance level of 0.05; ** means that the difference is highly significant at significance level of 0.01.

3.3.2 Analysis of soil erosion resistance under different forest types. Table 5 shows that mixed broadleaf-conifer forest has the highest soil erosion resistance index (39.0%), followed by eucalyptus forest (37.0%) and *Pinus yunnanensis* forest (24.0%); there is a small difference in the soil erosion resistance index between eucalyptus forest and mixed broadleaf-conifer forest (2%), while there is a large difference in the soil erosion resistance index between *Pinus yunnanensis* forest and eucalyptus forest, between *Pinus yunnanensis* forest and mixed broadleaf-conifer forest (13% and 15%, respectively). There are significant differences in the soil erosion resistance index between different soil layers in the same plot, and the soil erosion resistance index decreases with increasing soil depth; there are no significant differences in soil erosion resistance index in the 0 – 20cm layer in different plots between eucalyptus forest and mixed broadleaf-conifer forest, while there are highly significant differences in soil erosion resistance index between *Pinus yunnanensis* forest and the other two forest types; in the 20 – 40cm layer, there are significant differences in erosion resistance index among three forest types, indicating that the mixed eucalyptus and *Pinus yunnanensis* forest plays a better role than pure forest in improving soil erosion resistance.

Table 5 The soil erosion resistance index for different forest types

Forest types	Soil layer//cm	Erosion resistance index//%
Eucalyptus forest	0 – 20	43.2a
	20 – 40	28.8c
	Mean	37
Mixed broadleaf-conifer forest	0 – 20	44.8a
	20 – 40	33.2d
	Mean	39
Pinus yunnanensis forest	0 – 20	24.4b
	20 – 40	23.6e
	Mean	24

Fig. 1 shows the changes in soil erosion resistance index in 0 – 20 cm and 20 – 40 cm soil layers for different forest land types within ten minutes. It can be found that within ten minutes, the soil particles of two layers in three plots disintegrate completely, and the soil erosion resistance index is zero at the tenth minute. The soil particles of Pinus yunnanensis forest land disintegrate rapidly, and the soil erosion resistance index is relatively small and turns to 0 within five to seven minutes for two soil layers. The soil particles of mixed broadleaf-conifer forest land and eucalyptus forest land disintegrate slowly, and the soil erosion resistance index gradually decreases to 0 after eight to nine minutes. The soil anti-disintegration property of *Pinus yunnanensis* forest land is poor, while the soil anti-disintegration property of mixed broadleaf-conifer forest land and eucalyptus forest land is a little better, indicating that during the actual rainfall, the soil disintegration and loss are not serious in the early rainfall for eucalyptus forest and *Pinus yunnanensis* × eucalyptus mixed forest land, but with the increase of rainfall, the probability of water loss and soil erosion is gradually increased for eucalyptus forest, and *Pinus yunnanensis* and eucalyptus mixed forest can significantly improve the erosion resistance of soil underneath.

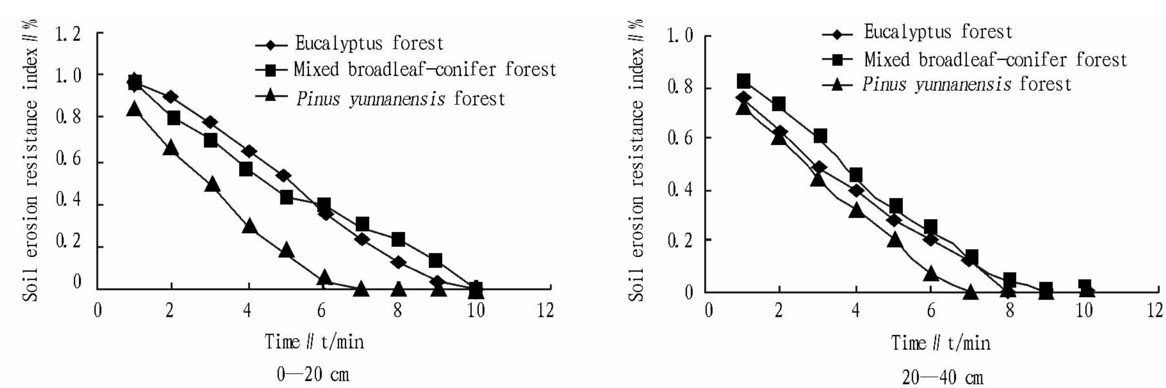

Fig. 1 The changes in soil erosion resistance index in different soil layers over time

3.4 Comprehensive evaluation of erosion resistance of soil under different forests

3.4.1 Selection of soil erosion indicators. This paper selects seven indicators commonly used for the study of soil erosion resistance at home and abroad, namely soil bulk density (X_1), total porosity (X_2), capillary porosity (X_3), non-capillary porosity (X_4), anti-scourability of soil (X_5), soil erosion resistance index (X_6) and soil shear strength (X_7). The above indicator system is comprehensive, but it is burdensome and complex and the information of some indicators overlaps with each other. Therefore, we can use fewer new indicators to replace the original indicators and save the information of the original indicators as much as possible. Here we use principal component analysis to determine the soil erosion resistance of three forest land types, and grasp the influence of three forest types on soil erosion resistance.

3.4.2 Principal component of soil erosion resistance and modeling. Table 6 is the result of component extraction after the principal component analysis. The characteristic root and contribution rate of component are the basis of selecting the common components, and the seven original variables of erosion resistance are transformed into seven components. It can be seen that the characteristic root of the first principal component is 5.35, indicating that the first principal component describes 5.35 of total variance of the original variables, and the variance contribution rate is 76.42%, representing 76.42% of information of all components, so it is the most important component; the characteristic root of the second component is 1.65, representing 23.575% of information of all components, second only to the first one; the contribution rates of other components descend one by one. The cumulative contribution rate of the first two components reaches 100%, indicating that the first two components have reflected all information of erosion resistance factors, so we can select the first two components as the comprehensive factors for erosion resistance evaluation. From Table 6, 7, it can be found that for the first principal component, seven factors such as soil bulk density have great load; for the second principal component, except soil shear strength, all factors have great load. According to the load of factors in the two principal components, we can establish the principal component model of soil erosion resistance for different forest land as follows:

$Y_1 = 0.856x_1 - 0.822x_2 + 0.812x_3 - 0.910x_4 + 0.843x_5 + 0.865x_6 - 0.997x_7$;

$Y_2 = -0.517x_1 + 0.569x_2 + 0.583x_3 - 0.415x_4 - 0.537x_5 + 0.501x_6 - 0.079x_7$.

Table 6 All explanatory variables

Component	Initial eigenvalues			Extraction results		
	Eigenvalues	Variance contribution rate // %	Cumulative contribution rate // %	Principal component eigenvalues	Variance contribution rate // %	Cumulative contribution rate // %
1	5.35	76.425	76.425	5.35	76.425	76.425
2	1.65	23.575	100.00	1.65	23.575	100.00
3	3.46E-16	4.95E-15	100.00	-	-	-
4	2.28E-16	3.26E-15	100.00	-	-	-
5	1.46E-16	2.09E-15	100.00	-	-	-
6	-1.39E-17	-1.99E-16	100.00	-	-	-
7	-2.05E-16	-2.93E-15	100.00	-	-	-

Table 7 Principal component analysis of soil erosion resistance indicators for different forest land types

Factors	Principal component	
	1	2
Soil bulk density // g/cm^3	0.856	-0.517
Total porosity // %	-0.822	0.569
Capillary porosity // %	0.812	0.583
Non-capillary porosity // %	-0.910	-0.415
Anti-scourability of soil // L · s/g	0.843	-0.537
Soil erosion resistance index // %	0.865	0.501
Soil shear strength // $kg \cdot m^2$	-0.997	-0.079

3.4.3 Comprehensive evaluation of soil erosion resistance for different forest land types. The results of principal component analysis not only give the principal component model of soil erosion resistance for different forest land types, but also derive the correlation coefficients between variables and factors. These correlation coefficients constitute the factor structure. Based on the weight of amount of information provided by the principal component, we calculate the composite scores of principal component[12-13] to evaluate the soil erosion resistance of different forest land types. The specific formula is as follows:

$Y = 0.763\ Y_1 + 0.236\ Y_2$.

Using the score function of two principal components and composite score formula of principal components, we calculate the composite score of soil erosion resistance for three different forest land types. The comparison of soil erosion resistance is shown in Fig. 2. The higher the comprehensive evaluation score, the stronger the soil erosion resistance. It can be found from Fig. 2 that the soil erosion resistance of mixed broadleaf-conifer forest land is strongest, and the comprehensive evaluation score is 0.150, while the soil erosion resistance of *Pinus yunnanensis* forest land is weakest, and the comprehensive evaluation score is negative (-0.0792). The soil erosion resistance for three different forest land types is in the order of mixed broadleaf-conifer forest land > eucalyptus forest land > *Pinus yunnanensis* forest land. The single forest type plays a limited role in improving physical and chemical properties of soil, soil structure, soil texture and soil erosion resistance, and its role in soil and water conservation is not significant.

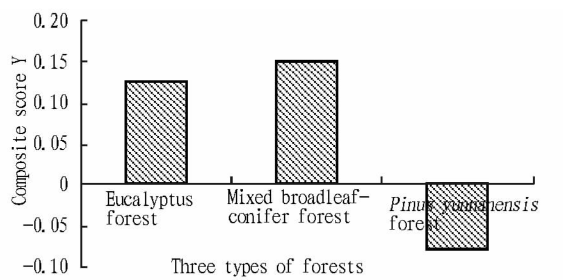

Fig. 2 Comprehensive index of soil erosion resistance for different forest types

4 Conclusions

In this paper, we study the influence of three types of typical forest on soil erosion resistance in water source area of Central Yunnan. The results show that there are significant differences in the shear strength values of soil in the same layer for eucalyptus forest, mixed broadleaf-conifer forest and *Pinus yunnanensis* forest land, and it shows an increasing trend. The shear strength values of soil in 0-20 cm layer is smaller than in 20-40 cm layer, possibly because the forest land subsurface soil is more stable than the topsoil under root retaining effect. The soil shear strength of three typical plots is in the order of *Pinus yunnanensis* forest land > mixed broadleaf-conifer forest land > eucalyptus forest land, indicating that *Pinus yunnanensis* forest land has better soil shear strength than the other two types of forest land. There are no significant differences in the anti-scourability of soil for three different forest land types, and mixed broadleaf-conifer forest has the highest soil erosion resistance index (39.0%), followed by eucalyptus forest (37.0%) and *Pinus yunnanensis* forest (24.0%). In the context of heavy rain and long duration rainfall, the soil under mixed eucalyptus × *Pinus yunnanensis* forests plays a more significant role in resisting disintegration, that is, the erosion resistance is stronger. Using principal component analysis, we analyze the erosion resistance of soil under three types of forest land, and get principal component analysis model of soil erosion resistance for three types of forest land:

$Y_1 = 0.160x_1 - 0.154x_2 + 0.152x_3 - 0.170x_4 + 0.158x_5 + 0.162x_6 - 0.186x_7$;

$Y_2 = -0.313x_1 + 0.345x_2 + 0.353x_3 - 0.252x_4 - 0.326x_5 + 0.304x_6 - 0.048x_7$.

Based on the weight of amount of information provided by the principal component, we calculate the composite scores of principal component and get the comprehensive evaluation function: $Y = 0.763Y_1 + 0.236Y_2$. It can be found that in terms of soil erosion resistance, the different types of forest land are sequenced in descending order of mixed broadleaf-conifer forest land (0.150) > eucalyptus forest land (0.127) > *Pinus yunnanensis* forest land (-0.0790), which further indicates that the mixed forests have better water loss and soil erosion control effect than pure forests.

References

[1] MORGAN RPC. Soil erosion and conservation[M]. London: Longman Essex, 1995: 3.
[2] NIU DK, GUO XM. The current situation and future advances of research on soil erodibility[J]. Acta Agriculturae Universitis Jiangxiensis, 2004, 26(6): 936-940. (in Chinese).
[3] WANG LX, BI HX. Present situation and control measures of soil and water loss in China[C]. China Association for Science and Technology, 1999: 62-65. (in Chinese).
[4] LI P, LI ZB, ZHENG LY. Hydrodynamics process of soil erosion and sediment yield by runoff on Loess Slope[J]. Advances in Water Science, 2006, 17(4): 444-449. (in Chinese).
[5] CHEN QX. Situation of soil and water conservation - based eco - environment and sustainable development of society and economy[J]. Bulletin of Soil and Water Conservation, 2000, 20(3): 1-4. (in Chinese).
[6] Water Resources Department of Yunnan Province. Announcement of soil and water loss and its prevention in Yunnan Province[N]. Yunnan Daily Press, 2009-02-21. (in Chinese).
[7] Institute of Soil Science, Chinese Academy of Sciences. Analysis of soil physico-chemical properties[M]. Shanghai: Shanghai Science and Technique Publishing House, 1978. (in Chinese).
[8] ZHANG WR, XU BT. Study on forest soil positioning[M]. Beijing: China Forestry Publishing House, 1986: 30-36. (in Chinese).
[9] JIANG DS, LI XH. Discussion on soil anti-scourability and soil and water conservation measures system in the contiguous area of Shanxi and Shanxi province as well as Inner Mongolia[J]. Journal of Soil and Water Conservation, 1995, 9(1): 15-18. (in Chinese).
[10] LIU BB, ZHANG GH. A comparative analysis on soil wash - resistance using undisturbed soil sample washing method and artificial simulationof rainfall method[J]. Bulletin of Soil and Water Conservation, 1996, 16(2): 32-37. (in Chinese).
[11] ZHOU LJ, QI S, WANG YQ. Research on forest soil anti-erosion and anti-scour of typical forests in Three Gorges Reservoir Areas[J]. Research of Soil and Water Conservation, 2006, 13(1): 186-188. (in Chinese).
[12] HU JZ, FAN XL, WANG YC, *et al*. Soil anti-erodibility indexes of hippophae rhamnoides forest in Loess Plateau[J]. Bulletin of Soil and Water Conservation, 1998, 18(2): 25-30. (in Chinese).
[13] WANG YQ, WANG YJ, ZHU JZ. Anti-erodibility analysis in forest soil of typical forests in Jinyun Mountain in Chongqing City[J]. Resources and Environment in the Yangtza Basin, 2005, 14(6): 775-780. (in Chinese).

(From page 34)

e-commerce platform. It is necessary to maintain the marketing capacity and production and processing capacity in order to play market-oriented effects. On the basis of store marketing, it is necessary to focus on developing e-commerce platform, implement online trading, and use television, newspapers, the Internet and other news media to improve the Jiangtou tribute tea brand awareness. There is also a need to develop the logistics platform and increase storage capacity. (vii) Building standard improved seed nursery. On the basis of tea varieties with the unique local characteristics, the new tea plantations in the city should increase the area of improved tea nursery and augment the annual output to meet the new seedling needs. (viii) Strengthening the organization and leadership. It is necessary to set up the Municipal Tea Industry Office which develops industry development plan and urges all relevant departments and township offices to carry out the work. It is necessary to support tea processing enterprises and supervise and assess the township tea industry office. (ix) Strengthening supportive policies. It is necessary to offer financial awards and discount loans for the links that can promote processing capacity, product design and brand building; conduct tea policy insurance pilot work to encourage businesses and households to participate in agricultural insurance and support the development of tea industry; accelerate the pace of certification and provide preferential tax policies to optimize the investment environment of tea industry. (x) Strengthening safety supervision. It is necessary to regularly carry out the city's tea testing, establish quality tracing files to strengthen quality and safety supervision, and publicize the testing results to ensure the city's tea production safety.

References

[1] LIU JP. On the current situation of tea garden management in Jingning County and the countermeasures[J]. Tea Science and Technology, 2008(4): 25-27. (in Chinese).
[2] LI YX. Current situation of tea development and its countermeasures in Guizhou[J]. Guizhou Agricultural Sciences, 2008, 36(1): 142-144. (in Chinese).
[3] HU SD, WEI ZL, LI YY. On the problems in tea development in Lingshou County of Hebei and the countermeasures[J]. Auhui Agricultural Science Bulletin, 2011, 17(7): 84-85. (in Chinese).
[4] DING ML, ZHANG N, ZHAO J, *et al*. On current situation of tea development in Lanshan District of Rizhao City and the measures[J]. Journal of Tea Business, 2009, 31(2): 91-94. (in Chinese).
[5] XU YS, LEI YH. Discussion on accelerating the development of tea processing industry and propelling tea industrialization process[J]. Journal of Tea, 2007, 33(1): 48-49. (in Chinese).
[6] YE HX, HE XM, ZHANG LF, *et al*. The countermeasures of sustainable development of Songyang tea industry[J]. China Tea, 2010(2): 14-16. (in Chinese).