Comparative Study of Guizhou Sloping Land Soil and Water Conservation Effect of the Three Cropping Patterns

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Abstract Surface cover degree, monthly variation of topsoil water content, loss of soil and nutrient in alfalfa-corn intercropping, strip rotation cropping and corn monoculture were studied in this paper. Then soil and water conservation effect of these planting modes were compared. Results showed that surface cover degree was high during the all rainy season in both alfalfa-corn intercropping and strip rotation cropping mode, with slope field covered by vegetation all the year round. Roots of alfalfa grew well, which not only improved the root biomass in 0 – 20cm layer, enhanced the capacity of the infiltration of rainwater to soil, protected biodiversity, but also reduced surface off and soil erosion of 39.3% and 59.3%. Strip rotation cropping could also reduce surface off and soil erosion of 10.4% and 21.3%. Both alfalfa-corn intercropping and strip rotation cropping increased soil moisture in rainy season and before rainy season, whilst reduced loss of organic matter (caused by soil erosion) of 29.9% – 52.4%, total N of 26.7% – 54.9%, total K of 27.3% – 70.9%, slow available K of 21.4% – 58.9%, increased corn production of 33.0% – 35.9%. Moreover, there was 13664kg/hm^2 in alfalfa-corn intercropping, which was 4.1 times higher than common mode. There was 12492 kg/hm^2 in strip rotation cropping which was 2.7 times higher than common mode.

Key words Slope field, Alfalfa-corn intercropping, Soil and water conservation

Guizhou is a mountainous province in southwest China and is one of the few places with Karst landscape in China. Besides, Guizhou is the only province in China that has no plain. The steep mountain and shallow soil have negative influence on human activity and lead to the serious loss of soil and water. The soil erosion takes account of 41.6% of the general land area[1]. There is 4770413 hm^2 of arable land in Guizhou, which takes account of 27.08% of the general land area. Besides, the gradient of arable land is between 6 and 25°, which indicate that it belongs to typical mountainous agriculture[2]. Traditional arable mode not only leads to serious water and soil erosion, but also grave nutrition loss[3]. Currently, there are many studies about the water and soil conservation of different modes of arable lands on the slopes. The study by Yuan Donghai *et al.*[4] suggested that the horizontal grassland can reduce the runoff loss by 32.33% and the sand loss by 45.88%. Li Xinping *et al.* compared beans with lily and grass and found that the runoff and erosion amount reduced by 4.67% and 37.82% if lily and grass were planted. Yi Dixin *et al.*[6] believed that the gradient technology of plants had significant water conservation effect, which can reduce the soil erosion from original annual 43.2 t/hm^2 to 4 t/hm^2, and can increase the annual conservation of moisture by 360 m^3/hm^2, which increased the crop output year by year. Alfalfa is the herb of beans genre[7]. Some experts have studied the function of alfalfa. Liu Zhongkuan *et al.* studied corn and alfalfa and found that different kinds of cultivation modes and different light intensity, penetration rate, nutrition in soil, corn yield, alfalfa output and net income per acre were studied. Li Wenrao *et al.*[9] compared the changes of germination of alfalfa and sorghum and its minimum requirement of water. Zou Yali *et al.*[10] studied the influence of temperature and humidity on the nitrogen in the soil of alfalfa. Li Yuan *et al.*[11] studied the tolerance of salt of alfalfa. Chu Jifang *et al.*[12] studied the saline experiment. The annual solid nitrogen in the root of alfalfa was up to 217 kg/hm^2, thus it would be a feasible way to increase production in agriculture[13]. The different strains, leaves and light properties of corn and beans increased the total density, reduced reflection, and enhanced light utilization rate[14]. Different distribution densities and depths of the roots of different crops varied, which increased the roots' assimilation of moisture in soil. The intercropping of corn and beans enhanced the layer of crops, enlarged the leaf area, increased the ground coverage, protected soil structure, decreased ground runoff, and enhanced the effectiveness of moisture[15]. Previous studies mainly concentrated on the increase of yield and land reform. Because there are few studies on the intercropping of corn and alfalfa in Guizhou, this project was carried out in the slope in Guizhou Province.

1 Materials and methods

1.1 General situation of the experimental field The experiment was carried out in the arable land in the mountainous Guizhou during 2005 and 2007. The elevation of the experiment area was 630 m and the gradient of slope was between 11.3° and

Received: January 11, 2013 Accepted: March 18, 2013

Supported by the Special Fund for the Scientific Research in the Commonweal Industry "Study and Demonstration of the Production and Utilization Technology of Green Crops" (200803029, 201103005); "Study and Demonstration of Cold Infusion Treatment Technology" (201003059); The Scientific Research Program of the International Plants Nutrition Research Bureau in Canada "Study on the Nutrition Management of Sustainable Development of Agriculture in Arid Slope in Guizhou" (BFDP. Guizhou. 200501); "Construction of Agricultural Resources and Environment Project Technological Research Center in Gruizhou" [G No. (2009)4001].

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24.3°. It is subtropical monsoon humid and semi-humid climate there. Annual average temperature was 19℃ and annual sunshine hours were 1 507.4 h. The annual precipitation was 12 mm and annual zero-frost period was 340 d. The rainy season lasted from April to September each year. More than 90% of the arable land was drought area. Corn, beans and potato were planted.

The soil in the tested area was loamy slime. The pH of physical property of soil was 4.7 and its organic material was 16.51 g/kg. The full N, P and K was 1.03, 0.25 and 22.19 g/kg. The alkaline hydrolysis N and available P and K was 47.00, 0.67 and 51.00 mg/kg. There was 207.67 mg/kg of slowly available potassium and 10.65 cmol/kg of CEC. The base saturation was 28.67%. According to the reference indicators of nutrition in soil in Guizhou Province[5], the full nitrogen in the soil was colorful and the amount of available K was low.

The field experiment was built in the observation point of runoff area according to State Hydraulic Department. There was automatic rainfall meter, automatic meteorological observing instrument. There were three treatments: alfalfa-corn, strip rotation plantation; habitual plantation of corn.

Fertilizer of field experiment: Manure 18000 (N 90.0, P 19.6, K 89.6) kg/hm^2; carbamide 587(N 270.0) kg/hm^2; superphosphate 656 (P 45.9) kg/hm^2; potassium chloride 175 (K 87.2) kg/hm^2. P, K and manure were used as the basic fertilizer and nitrogen was used as additional fertilizer.

Field corps: Corn was sowed in April and harvested in September. Farmers used to sow corn every 0.5 m × 0.75 m and 0.25 m × 0.5 m. Alfalfa was sowed in March in 2005 and harvested for twice every two to five months. Beans, potato and rape were planted every 0.25 m × 0.5 m. As for strip rotation plantation, firstly, two lines of corn was planted after two lines of beans; rape seeds were sowed after the harvest of corn in November; beans were sowed after the harvest of rape in April; potato was planted after the harvest of beans in July; then corn was planted again.

1.2 Sample collection and data determination The sand sample was collected every time there was soil erosion, so was the determination of sand amount and calculation of the general amount of sand in rainy season. The TST-55 soil penetration machine measured the penetration rate of moisture in the slope. The total nitrogen was measured by Kjeldahl method; P was measured by NaOH melting aluminum antimony resistance; and K was measured by NaOH melting flame photometry.

1.3 Field determination project and method Soil erosion: the silt was measured every time there was soil erosion. Silt was parched and weighed at 105 ℃ and 24 h. The soil erosion per acre and annual soil erosion were calculated.

Ground runoff: the runoff was measured every time there was one. 500 ml tube was taken to measure the runoff and soil erosion. The annual ground runoff also was calculated. Precipitation: ST automatic hyetometer was used to calculate the precipitation every time there was one. Annual precipitation also was calculated at the end. Moisture in the soil: Soil at the 0 – 10 cm, 10 – 20 cm, 20 – 30 cm and 30 – 40 cm were collected and parched at 105°for 24 h to measure the moisture in the soil on the 15th of each month from 2003 to 2006.

Land coverage: The land coverage was measured by sciagraphy in the middle from January in 2005 to December in 2006.

Root content: 10 kg soil was collected from the 0 – 20, 20 – 40 and below 40 cm in the middle of each field on March 15, 2006 to parch at 80 ℃ for 24 h. The root content in the soil per unit was calculated.

Moisture penetration in the soil: On September 15, 2006, after the harvest, double permeability ring method was applied in the center of each field after the harvest of crops. Biological types: On April 15, 2006, the types and number of species in each field was investigated.

Output: The plants were weighed after harvest. Samples were collected and parched to measure its moisture amount in order to calculate the output per acre.

1.4 Data processing All data were typed into Excel 2003. The root content, moisture penetration in soil, and biological types were one year data; the ground coverage was the mean value of two years while the other data were the mean value of three years.

2 Results and discussions

2.1 Influence of different modes on the land coverage The strip rotation mode increased from single crop to two to four crops. Meanwhile, the newly added alfalfa or beans have root rhizobium to promote the growth of corn and add land coverage effectively. In the original plantation mode, the earth was not used in winter for five months, and the coverage was also low in rainy season, yet it remained at high level during May and September before the coverage plummeted rapidly between September and October until the earth was fully exposed in the air. In the strip rotation mode, the earth was covered with crops all year long. Especially the alfalfa-corn mode, the land coverage was high from March to the entire rainy season (Fig. 1)

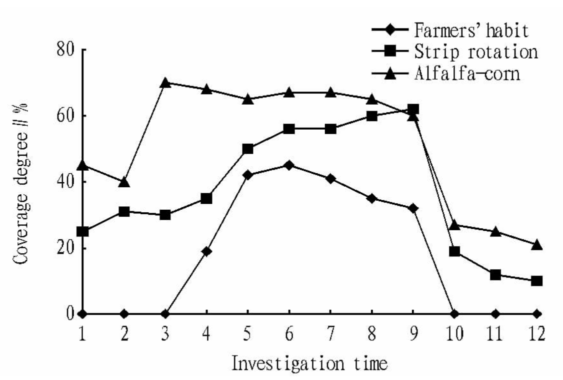

Fig. 1 Influence of different modes on the land coverage

2.2 Influence of different modes on the root of plants in the soil The alfalfa-corn strip rotation mode increased the number of root in the soil, especially the root in the soil of 0 – 20 cm (Table 1). The root of alfalfa was very advanced and the root amount was

9.0 g/cm^3, which was 7.5 times of that in the original cultivation mode, and 1.8 times of that in the strip rotation mode. The root at the soil between 20 and 40 cm and lower than 40 cm increased little.

Table 1 Influence of different modes on the root of plants in soil g/cm^3

Treatment	0 – 20 cm	20 – 40 cm	Under 40 cm
Alfalfa-corn	9.0	0.6	0.4
Crop rotating	5.0	0.8	0.2
Farmers habit	1.2	0.6	0.2

2.3 Influence of different modes on the moisture permeability in the arable land The strip rotation of alfalfa and corn improved the rainfall permeability in the soil. Within 30 min, the moisture permeability in the alfalfa-corn field increased by 54.2 % while within 60 min, the moisture permeability in the slope rose to 35.4%. However, to strip rotation cultivation, because of plenty activities and loose soil, the moisture permeability in the slope was larger, as it increased by 148% and 76.8% accordingly within 30 and 60 min.

Table 2 Influence of different modes on the penetration of water in the slope cm^3/min

Treatment	30 min		60 min	
	Penetration cm^3/min	%	Penetration cm^3/min	%
Alfalfa-corn	34.8	54.2	22.2	35.4
Crop rotation	55.8	148.0	29.0	76.8
Farmers habit	22.5	–	16.4	–

2.4 Influence of different modes on the biological diversity of arable land in the slope There was corn, herb, alfalfa, tarragon, chicory, cudweed in the strip rotation field, because the alfalfa was perennial plant, the land with alfalfa on didn't have to be cultivated, which was conductive to the growth of tarragon, chicory and cudweed. The plowing was bad to the growth of crops. The alfalfa-corn strip rotation was of great aid to the protection of biological diversity, which in return would conserve soil and water.

Table 3 Influence of different modes on the diversity of animals in the slope

Treatment	Variety of plant	Biological types
Alfalfa-corn	Corn, Herb, Alfalfa, Tarragon, Chicory, Cudweed	6
Rotation	Beans, wild daisy, corn	3
Farmers habit	Wild daisy, corn	2

2.5 Influence of different modes on the moisture in the soil in arable land in the slope In the 0 to 10 cm of soil layer, the soil moisture in February and May was significantly higher than that in the original plantation and reached the highest value in May before it reduced. The soil moisture differed between January and February before it increasing rapidly, which was higher than the original one, and the value reached the highest in May. However, the soil moisture only began to increase in April and reached the highest value from June to July. After July, the soil moisture decreased (Fig.3).

In 10 to 20 cm, the soil moisture in the original cultivation method began to increase in February and reached the highest value in May, kept at high level between May and July before decreased after July. However, the soil moisture in the strip rotation method began to increase in February, reached the highest value in May and then began to decrease after September (Fig.3).

In the 20 to 30 cm, the soil moisture began to increase in February and reached the highest value in June and July. The soil moisture in the strip rotation rose in February and achieved the highest value from May to July before it decreased. After September, the soil moisture in the three layers remained at low level (Fig.3).

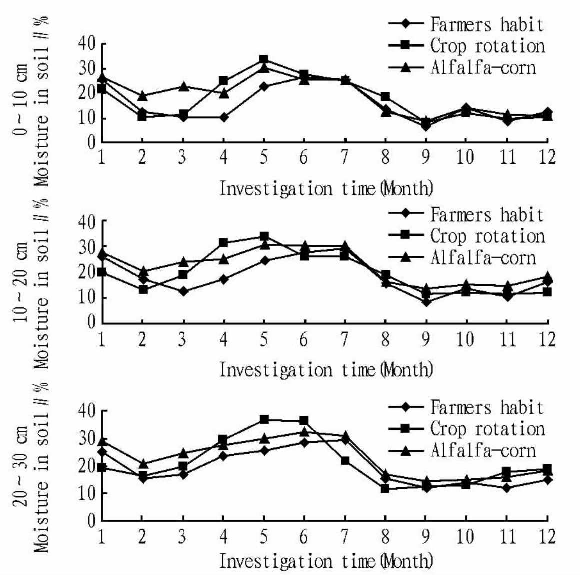

Fig.2 Influence of different modes on the moisture in the soil from 0 to 30 cm

2.6 Influence of different modes on the soil erosion in the arable land Precipitation was the direct reason of soil erosion in the slope. The annual precipitation reached 901 mm from 2005 to 2007. Precipitation was mainly during May and August and was up to 779 mm, which was about 86.5% of annual precipitation. The annual precipitation was in June and reached 363.85 mm, which was 40.4% of the general year. The soil erosion of different cultivation modes differed (Table 4). The soil erosion in the traditional cultivation method was large, as the mean soil erosion in three years reached 26.3 t/hm^2 and annual average ground runoff was 2659.7 t/hm^2. The erosion intensity reached the third grade according to the national erosion intensity standard. Both the alfalfa-corn mode and strip rotation mode can reduce much more soil erosion than the traditional method, since the ground runoff was decreased from 10.4% and 39.3%, and soil erosion was reduced from 21.3% to 59.3%. Therefore, the alfalfa-corn was a good way to conserve water and soil.

2.7 Influence of different modes on the nutrition erosion in the arable slope According to the analysis of runoff sample and soil erosion, and considering ground runoff and soil erosion, the nutrition in soil and water erosion was calculated. Results suggested that the alfalfa-corn and strip rotation can reduce the loss of organic materials by 29.9% and 52.4%, nitrogen by 26.7% and 54.9%, entire potassium by 27.3% and 70.9%, slowly available potassium by 21.4% and 58.9%. The alfalfa-corn method reduced 47.7% of available potassium more than the traditional method (Table 5).

Table 4 Influence of different modes on soil and water erosion

Treatment	Annual mean ground runoff t/hm^2	CK %	Annual mean soil erosion t/hm^2	CK %
Alfalfa-corn	1614.8	-39.3	10.7	-59.3
Crop rotation	2382.7	-10.4	20.7	-21.3
Farmers' habit	2659.7	- -	26.3	

Note: The data was the mean value in three years.

Table 5 Influences of different modes on the loss of nutrition in arable land

Project	Farmers habit kg/hm^2	Crop rotation		Alfalfa-corn	
		kg/hm^2	Compared with habit//%	kg/hm^2	Compared with habit//%
Organics	579.3	406.2	-29.9	275.7	-52.4
Full N	37.5	27.5	-26.7	16.9	-54.9
Full P	9.5	14.2	+49.5	4.9	-48.4
Full K	647.9	471.0	-27.3	188.6	-70.9
Available K	13.2	14.7	+11.4	6.9	-47.7
Slowly available K	5.6	4.4	-21.4	2.3	-58.9

2.8 Influence of crop output at different modes The alfalfa-corn method can increase the corn output by 33.0% and 35.9%, and the corn straw by 12.9% and 30.0%. Meanwhile, the alfalfa-corn can harvest 13664 kg/hn2 of dry alfalfa and the compound output was 19405 kg/hm^2, which was 4.1 times of traditional method. The strip rotation can harvest beans, potato and rape, etc. The compound output was 12492 kg/hm^2, which was 2.7 times of traditional method (Table 6).

Table 1 Influence of the output of crops at different modes kg/hm^2

Harvest	Farmers habit	Crop rotation	Alfalfa-corn
The seed of corn	2 142	2 911	2 850
The straw of corn	2 561	3 328	2 891
Bean		279	
Red potato vine		2 957	
Red potato		1 427	
Rape		1 592	
Alfalfa-corn			13 664
Compound output	4703	12 492	19 405

Note: The data was the mean value of three years.

3 Conclusions

Firstly, in the intercropping system, beans and herbs are one of the most successful combinations in the traditional agriculture[13, 16, 17]. Small producers in subtropical area produce lots of cereals and protein based on this intercropping method. Beans can hold nitrogen which was the necessary nutrition to keep the normal rotation of this system. Such combination was no doubt a sustainable production system in resources utilization and environment protection. Results indicated that the alfalfa in the corns can keep the land being covered all year long and would result in high land coverage during the entire rainy season. Compared with traditional method, the intercropping can increase the root in 0 to 20 cm and precipitation penetration, as well as the moisture in the soil from 0 to 30 cm. Such mode can increase biological diversity, reduce ground runoff by 39.3%, soil erosion by 59.3%, the loss of organic materials by 52.4%, the loss of nitrogen by 54.9%, the loss of potassium by 70.9% and the loss of available potassium by 58.9%. The intercropping of corn and alfalfa can enhance the corn output by 33.0% to 35.9% and would result in 13664 kg/hm^2 of dry alfalfa. The compound output was 19405 kg/hm^2, which was 4.1 times of the traditional method. In mountainous area in Guizhou, the intercropping of corn and alfalfa should be promoted as the essential way to ensure food safety and develop husbandry. Secondly, strip rotation is an essential reform in the cultivation policy in Guizhou. The comprehensive technology, with strip rotation in arid land can relieve the population pressure, enhance compound index and improve the output. It is an important way to the sustainable development of agriculture in arid land. Results suggested that cropping rotation can also keep the land being covered all year long and would result in high land coverage in the entire rainy season. However, the annual plowing requires lots of investment in labor force, which is bad to the protection of biological diversity. Thirdly, the traditional cultivation method is not suitable in Guizhou because it would result in large soil erosion, 26.3 t/hm^2 of mean soil erosion in three years, 2659.7 t/hm^2 of annual mean ground runoff, and moderate erosion. Fourthly, in Guizhou, corn is the staple crop, so the intercropping of corn and alfalfa and strip rotation methods are essential measures to ensure food safety, to develop husbandry and to realize the sustainable utilization of slope.

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