Research on Alley Cropping Technology on Sloping Land of Guizhou Province

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Abstract: The Alley cropping technology is special technology of the agro-forest system. Since 80's long-term international cooperation on sloping land, conducted in Asia and Africa, showed good results on soil erosion and runoff control, which provided an alternative technology and system for management for sustainable agriculture. Under the support of Swiss Agency of Development and Cooperation, the International Water Management Institute nine-years data were collected from the long-term soil conservation experiment site since 1992, locates in Bianyang township of Luodian county of Guizhou province. The results showed alley cropping technology had significant impact on soil and water conservation. The average annual quantity of soil erosion declined from 43.2 t/hm^2 in traditional farming to 4 t/hm^2 in this technology on sloping land, and capacity of water holding increased 360 m^3/hm^2 yr. By the significant control of soil erosion and runoff farmers were encouraged to increasing input that coursed to maintain or increase soil fertility. Crop yield and farmers income also increased gradually. The experiment also showed that the slope gradient decreased 1.1º per year and earth ladder of 17.1cm—20.0cm high formatted along the hedgerows per year in average to gradually form terracing land with high and stable yield. This technology had the advances on saving time, saving money, saving manpower, and easy to be implemented and managed, so it is suitable to be extended in proper mountainous and hilly areas.
Keywords: sloping upland, soil and water conservation, alley cropping, terracing sloping land

Alley cropping technology is special one of agro-forest system. It means to plant suitable grass, shrubs or trees or mixed them in proper intervals along contour as hedgerows on sloping farmland. When the hedgerow plants grown well, there are barrieing runoff, decreasing erosion, slow declining slopes, formatting terraces at last for sustainable use of sloping farmland.

Guizhou is a mountainous province in China. According to the Second soil survey of Guizhou province, 84% of upland was over 5 degree on the slope gradient and over 25% of upland was over 25 degree, which need to be afforestation or back to grass land. Only 10%—20% of upland had been controlled by conservation measures on slope farmland in Guizhou. Alley cropping technology provided a proper and effective technology for erosion control on upland, and showed broad extension potencies in mountainous areas in South China.

1 Materials and methods

Since 1991 an experiment side for soil erosion control was set up in a valley of Sangchahe River, Xinglong Township (latter merged into Bianyang township). Four treatments are: T1 hillside ditches: the ditches along contour with 1 meter width and 0.5 meter depth, Banana and Amomum Xanthioides were planted in the ridges or slope of ditches, corn and following legume (as green manure) planted between ditches. T2: Farmers' Practice: cropping system was corn and green legume like local farmers doing without conservation measure. T3 alley cropping: four hedgerows plants in it, witch was Tephrosia Candida plus Coronilla varia in the beginning of five or six yeas and then gradually changed to vertivergrass because the Tephrosia Candida dead as it was not very suitable in winter condition in the

areas. Corn and green legume crops planted between hedgerows. T4 was bare land: in it no crop planted and keeping the soil exposed to rains whole year round.

Each plot size (projection size) was 16m×25m, no replication, segregated by cement boards, cement tank in the bottom of each plot for water and soil erosion collecting with three steps of water collectors for measure diffluent runoff and soil loss. A rain gauge, an automatic rain gauge and an automatic weather recorder were installed in the site.

Cropping system was corn and winter legume rotation in the plots except bare land treatment, so the crop managements, growing stages, yield and economic input and output at ct were carefully recorded. For corn growing N 100 kg/hm^2—150kg/hm^2, P_2O_5 75 kg/hm^2—95kg/hm^2, organic manure 10t/hm^2—15t/hm^2 were applied in the plot annually.

From April 1 to September 30 in nine years of 1992—2000, data of every event of rains, runoff and soil loss were collected. Several eroded soil and runoff water were sampled and analyzed for N, P and K. In the plots top soils sampled twice before corn seeding and after corn harvesting for analyses of soil organic matter, pH (water), total and available N,P,K. the trimming residue of hedgerow crops also were collected annually. All the samples were analyses by Soil and Plant Analysis Laboratory of Soil and Fertilizer Institute of Guizhou Academy of Agricultural Sciences.

Testing soil is hapludult (Ustisol), developed by shale, sloping gradient was 40 % (or 21.8 degree) soil was loose, nutrient was lower and fertility was lower. The basic analysis of soil nutrient contents was in Table 1 below.

Table 1 Soil nutrient contents in experiment site of Guizhou province in 1991

Items	Total N %	Ava-N mg/kg	T-P %	T-K %	Ava-P mg/kg	Ava-K mg/kg	OM %	pH	Water Salt %
0cm—20cm	0.171	83.6	0.087	1.72	1.53	119.7	2.96	6.31	5.83

2 Results and discussion

2.1 Precipitation and runoff

(1) The average precipitation from April to September (see Table 2) in the period was 908 mm from the site records, a little different from the data (972.7mm) collected by the County Weather Station (28 km away from the site) in over 20 years in average. It is 81.2 % of the total rains, that courses significant two seasons i e., drain and raining seasons in the area.

Table 2 Runoff and soil loss in the site of Guizhou province from 1992—2000

Years	Rains April —September(mm)	Runoff(10^3/hm^2)				Soil loss(t/hm^2)			
		T1	T2	T3	T4	T1	T2	T3	T4
1992	585	12	90	23	217	2	4	1	81
1993	1,180	77	321	202	645	62	112	57	342
1994	684	92	142	147	307	1	1	0	108
1995	979	164	218	204	454	5	17	0	98
1996	892	282	287	255	513	5	12	0	65
1997	896	116	115	106	245	3	2	0	29
1998	710	84	90	72	185	2	3	1	26
1999	1,266	205	330	284	669	5	85	10	631
2000	972	186	207	185	552	33	153	17	335
平均	907	135	200	164	421	13	43	10	190

Notes：* T1 is hillside ditches, T2 is farmers' practice, T3 is alley cropping and T4 is bare land

(2) The average runoff amount were 1,350（hillside ditches）—4200 m^3/hm^2（Bare land）and its rate was 14.9%—46.3% of total precipitation.

(3) The annual average runoff in alley cropping treatment was 1,640m^3/hm^2 with runoff rate of 18%. It was only 82 % of that in farmers' practice and increasing 360m^3/ hm^2 of water holding in the plot soil than that in farmers' practice and 2,560m^3/ hm^2 than that in bare land.

(4) The same effect could be found in hillside ditches treatment. Its annual average runoff was 1,350m^3/ hm^2, only equated 67.5 % of that in farmers' practice, increased 650 m^3/ hm^2 of water holding than that in farmers' practice and 2,850m^3/ hm^2 than that in Bare land.

Obviously, taking some conservation measures can decrease runoff and increase amount of soil water holding in the site research.

Table 3 Effects of runoff and soil loss by storm in the site of Guizhou province

Event	Rains	Density of rain (mm/h)		Runoff ($m^3/hm^{2)}$)				Ratio of rain %				Soil loss (t/hm^2)			
Y/M/D	mm	5min	30min	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
1993/ 4/ 26—27	37	135.6	61.6	108	131	118	132	29	35	32	36	14.6	27.4	11.7	40.8
1993/ 5 /13—14	75.4	119.8	78.5	285	336	332	477	38	45	44	63	41.6	59.1	42.6	108.7
1999 /4 /24	106	105.6	54.0	113	146	179	841	5	11	14	17	1.47	51.5	7.4	74.8
2000 /5/8	60.7	104.4	53.4	27	37	36	484	4	6	6	79	0.93	4.20	0.4	54.4
2000/6/6	152.9	105.6	55.0	538	498	501	1,382	35	33	33	90	28.0	139.2	11.6	108.8
2000/6/24—25	147.9	75.6	35.0	970	1,121	954	1,292	66	76	64	87	1.84	4.1	3.5	77.5

Note: * T1 is hillside ditches, T2 is farmers' practice, T3 is alley cropping and T4 is bare land

2.2 Soil erosion (see Table 2, 3)

(1) In bear land the topsoil exposed in rains without any conservation measure and plant cover the soil loss was very heavy. Annual average soil loss was high to 190.4 t/hm^2, equating to 15.1mm topsoil eroded. If the topsoil is 150 mm on sloping land that means all the topsoil already eroded and soil fertility and productivity was totally lost in nine years in the site.

(2) In farmers' practice the soil loss was 43.2 t/hm^2, equating to 3.4mm of topsoil eroded. The topsoil will be total lost in 44 years, such a heavy soil loss is the crucial reason of soil fertility and productivity degradation on sloping lands.

(3) In hillside ditches the annual soil loss was 13 t/hm^2, 1.0 mm soil was lost annually, equating to the soil formation rate in shale area, so that could keep the top soil for sustainable agricultural use.

(4) In alley cropping the annual soil loss was lower to 9.6 t/hm^2 or 0.8 mm of topsoil lost annually, that was under the soil formation ratio. It means that soil would be thickening in shale area for sustainable land use. In Table 2 it showed the large soil loss were found in first or second year after the hedgerow crops planted. It is easy to understand that in the beginning the plant fences are not formatted well, so they are not strong to hold soil than later. After 2 years it is growing well to effectively conserve soil loss. If calculating data from 1994—2000, the annual soil loss was only 4 t/hm^2, that could wholly meet the sustainable need.

(5) Data from long observation showed that heave rains, heave storms and lower plant coverage were the main reasons on soil erosion. In Table 3 the effect of several heaver rains listed. In bare land because of not any plant cover heaver rains straightly attack the topsoil and make heaviest soil loss. In alley cropping treatment it was found that in the beginning (1992—1993) the soil loss almost equated with farmers' practice, but after 1993 the soil erosion significantly decreased for the plant fences strong to against to storms. Heaver storm significantly affected and damaged the sloping land soil, for example in June 6, 2000, one event of heavy storm (157mm rain) soil loss was 139 t/hm^2 or 11 mm of top soil loss in farmers' practice, but only 11 t/hm^2 in alley cropping. Only over 10 events of such storm the topsoil would be totally lost in farmers' sloping land. This was the reason that sloping farmland easy to be

changed to barren land. Sloping land without conservation measure would quickly lost the fertility and productivity. The heaver loss was also being found in April-June when the sloping farmland just ploughed and crop in seedling stage where soil coverage was lower in raining reason in the area.

2.3 Effect of sloping gradient by alley cropping technology

Planting hedgerows in 6 meter intervals and check the gradient change after 7 years, because of the plough along contour making soil move to lower and plant fences holding soil eroded from the topper, the sloping gradient changed from 21.8 degree to 14.3 degree. In average annual change was 1.1 degree of sloping gradient. Along the plant fences, 1.2 meter—1.4 meter ladders were formatted with the annual rate of 17.1cm—20.0cm. In the beginning the terracing speed was fast for the loose topsoil moving, but latter slowly for the parent soil moving. It is estimated that need almost 20 years to formatting terracing lands in water level in general.

2.4 Effect to crop yield in different treatments (see Table 4)

Width of plant fences increased from about 0.9m to 1.2m follow the hedgerow crop growing and unused land increased from 15% to 20% of total, but the corn yield still trained to increasing, comparison with the farmers' practice.

(1) In average in nine years and in the same level of crop management, corn yield in alley cropping increased 0.29 t/ha or 8.26% of increasing ratio, comparison with that in farmers' practice. We could not have good yield in hillside ditches treatment because of the ditches and ridges occupied almost 60 % place of the upland.

(2) Table 4 showed in first five years little less or same corn yield harvested in alley cropping and farmers practice, but after that the yield trended to increasing in alley cropping due to the erosion control. In farmers' practice the total soil erosion was 388.8/hm^2, equation of 30.8mm topsoil eroded, but in alley cropping treatment soil erosion had be well-controlled, increased holding water and fertility capability, that obviously affected crop yield.

(3) In hillside ditches the corn yield decreased, but planted banana and at ridges, that was cash crops for economic return. We had still had lower income in the plot due to the un-appropriated choose of those cash crops in the site. Banana damaged by the cold temperature and dry weather in winter season, and need high fertility soil and density moisture that could not to be provided on the slopes. So appropriate selection of suitable ridge cash crops for high income is crucial in this technology.

Table 4 Corn yield from 1992 to 2000 at Luodian experiment site of Guizhou province

Years	Alley cropping	Treatments (t/hm^2) farmers' practice	Hillside ditches
1992	1.73	1.33	1.33
1993	2.84	3.05	2.02
1994	3.86	4.02	2.53
1995	3.50	2.88	2.43
1996	4.00	4.05	2.43
1997	3.78	3.34	1.07
1998	4.64	4.31	1.84
1999	5.18	4.58	2.60
2000	4.95	4.02	2.53
Av	3.80	3.51	1.98
Yield increasing t/ha	0.29	0	–1.53
Yield increasing %	8.26	0	– 43.59

2.5 Preliminary analyses of principle of erosion control by alley cropping

The principle of the technology for soil control is integrated many factors, such as increasing vegetation coverage, decreasing slope gradient, improving soil texture, shorting the length of slope and the mechanic blocking off runoff. The Geographic Institute of China Academy of Science set up an experiment site in Hubei province and the results of three years researches on alley cropping concluded that soil erosion significantly changed not by increasing vegetation coverage. Only 2 or 3 degree of slope gradient changed in two or three years which is not very effective on soil erosion, soil texture was not change so much and the runoff still nearly keep in same level. The main factor is mechanic blocking off runoff. When runoff water reaches the barriers of plant hedgerow, slows down runoff speed, soil sediment in the upper of the plant fences. Many observations showed that rill erosion stopped in hedgerows. In the middle stage after three or four years terracing formation continues, slope gradient is significantly changed, such as in the site slope gradient decreased 8degrees and 1.2m—1.4m soil ladders formatted. Long slope has been cut to 5m—10m length of discontinuous slope, and the mechanic blocking. So the three main factors mixed together for decreasing soil erosion significantly. In the last stage or third stage of the technology or after 15 years, terraced land formatted and it could effectively control erosion as many research already approved, the hedgerow plants would be functioned as a protection crops grown on the edge of almost terraced land.

2.6 Input of alley cropping technology

It is popular to use the stonewall or soil wall technology for terracing land in Guizhou province. For construction of stone wall it is need a huge input of fund and labor power, stone wall and soil wall are easy to be destroyed by rains, soil layer disturbed that need many years to returning to normal. Main advantages of alley cropping technology are saving fund, saving labor and easy to be extended. The main input is seeds or seedlings, for example, if planting vertivgrass or Amorpha Flutisoca, seedling charge will be 750 yuan/ha, 30 labor powers, totally 900 yuan/ha. If planting fruit trees, tea tree, medicine crop, day lily the input will be higher. Hedgerow crop management is relatively easy, trimming residue could be used as fertilizer or forages, and not very affects crop yield in short-term. So it is easy to be accepted by farmers.

3 Conclusions

(1) Alley cropping technology had significant effect on erosion control. Experiment approved that soil erosion decreased from 43.2 t/hm^2 to 4 t/hm^2 or less, rainwater storage increased 360 m^3/hm^2.

(2) Alley cropping technology had the advantage for terracing sloping land. Research result showed that the slope gradient decreased 1.1 degree and 17.1cm—20.0cm of soil ladder formatted annually in general.

(3) Alley cropping technology not only conserves water and soil but also increases crop yield and income. Research results showed that in the same management average corn yield increased 0.29t/hm^2, or 8.26 %, comparison with farmers' practice.

(4) Alley cropping technology has advantage of saving time, saving fund and labor power, easy to be implemented and managed, so it is easy to be expanded to large areas.

Alley cropping technology provided a new way in earth mountain areas or stone mountain areas with thick soil layer areas for sustainable agriculture on sloping upland, especially in southern mountainous areas. At present this technology has been expanded about 670 hm^2, and continue to expanding to the appropriate areas in Guizhou province.

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