Development of Sustainable Agriculture on Sloping Lands in China

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Abstract: When farming on sloping lands in China, farmers generally plant their crops up-and-down the slope and cultivate their land with minimal concern for soil erosion. This causes loss of not only topsoil but also plant nutrients. Since sloping lands cover vast areas in China and are being encroached upon and cultivated every year, it is imperative that appropriate technologies for managing these lands be introduced to farmers to minimize damage to the lowland areas and avoid farmers slipping into poverty because of degraded soils. As a model for development of sustainable agriculture on sloping lands in China, on-farm trials, funded by the Potash and Phosphate Institute of Canada (PPIC), were conducted in farmers' fields in Sichuan, Guizhou, and Yunnan provinces.

In the trials, alley cropping and application of balanced fertilizer were employed as the technology to reduce soil erosion and increase crop yields, in comparison with the farmers' practice. Day lily, pears, and Chinese prickly ash were used as hedgerow crops and corn, soybean, and sweet potatoes as alley crops in the alley cropping technique whereas K application was emphasized in the balanced fertilizer treatment.

Results showed that K increased crop yields significantly when compared with the farmers' practice, which received no K. Increase in corn yield as high as 13% and wheat + barley yield as high as 31% was obtained from K application. With proper plant population density, K plus dolomite and B increased corn yield at the Yunnan site by 115% when compared with the farmers' practice. Soil loss was greatly reduced by alley cropping, ranging from 60%—80%, Economic analysis indicated higher net return from the application of K and alley cropping than that of the farmers' practice. Currently, the project is extending this technology to farmers. Responses to the extension are positive from both farmers and government officials.

Keywords: alley cropping, balanced fertilizer, soil loss, crop yield, economic analysis, participatory approach

1 Introduction

When farming on sloping lands in China, farmers generally plant their crops up-and-down the slope and cultivate their land with minimal concern for soil erosion. This causes loss of not only topsoil but also plant nutrients. In addition, this causes siltation of valleys, rivers and dams, resulting in down stream flooding and threatens the environment of the area. With serious soil erosion, the soil could quickly lose its productivity to the point where it can no longer sustain crop growth. Since sloping lands cover vast areas in China and are being encroached upon and cultivated every year, it is imperative that appropriate technologies for managing these lands be introduced to farmers to minimize damage to the lowland areas and avoid farmers slipping into poverty because of degraded soils. Sustainable agriculture on sloping lands can eventually be achieved. As a model for development of sustainable agriculture on sloping lands in China, on-farm trials, funded by the Potash and Phosphate Institute of Canada (PPIC), were conducted in farmers' fields in Sichuan, Guizhou, and Yunnan provinces.

The Sichuan Basin, with an area of 12,100,000 ha, a population of 68 million ha and 244,000 ha of arable land, is the main agricultural production area of Sichuan Province. Its output accounts for 60%—80% of the total production of Sichuan Province and Chongqing city. This area of only 3.8% of the national arable land produces 6.4%, 11.4% and 25%, of the national total grain , pork and cocoon silk, respectively. The land of the area is hilly, with steep slopes and erosive rainfall, so soil erosion is serious. In some area, an annual soil loss can be as high as 10,000 t ha^{-1}.Guizhou Province is in the center of southwestern China, where karst landforms are common. The province has a total area of 176,000 km^2, of which 129,600 km^2 are karst. Within the territory, the landform is complex and the earth surface is sharply dissected. Mountains and hills constitute 92.31% of the total area, the rest (7.96%) are lowlands and valley plain. Due to the lack of arable land and the rapid increase of population, the steep sloping lands are encroached for cultivation. Farmers cultivate these lands without appropriate technologies for soil and water conservation (Zhu, 1994).

Yunnan is a hilly mountainous province. Its topography consists of 84% hills and mountains, 10% undulating land, and 6% flat lands and valleys. Soil loss is a widespread problem in Yunnan and has notorious character with big amount and large range occurrence. An average of 1.08 mm of topsoil has been eroded away every year in the whole land, and 38% of the total area in Yunnan has soil erosion problem (District Planting Scheme of Yunnan Province, 1992)

2 Objectives

The main objective of this trial is to conserve the soil resources on sloping lands with the aim to have a sustainable form of agriculture. Specifically, the objectives of the trial are

- To validate the effectiveness of alley cropping and balanced fertilizer in reducing soil loss and runoff and increasing crop yield,
- To evaluate economic returns under various treatments, and
- To establish demonstration sites, dealing with sustainable agriculture on sloping lands.

3 Materials and methods

Three field trials were conducted in farmers' fields in Fuming, Yunnan Province, Luodian, Guizhou Province, and in Jianyang, Sichuan Province. Treatments evaluated in the trial included alley cropping, an improved soil conservation technology, balanced fertilizer application, and the farmers' practice. The detail of treatments and fertilizer applications employed in the different sites was described below.

The jianyang site, Sichuan province

Three treatments were validated as follows:

T1: Farmers' practice, crops planted up-and-down slope

T2: Alley cropping using pears and day lily as hedgerows, crops planted across slope

T3: same as T2 plus K application

The cropping system employed for T1 and T2 was wheat/corn/sweet potatoes and for T3 was wheat + barley/corn + soybean/sweet potatoes.

Table 1 shows the detail of various fertilizer application rates for different treatments.

Table 1 Fertilizer application (kg· ha^{-1}) for different treatments and crops in Jianyang, Sichuan Province

Crop	Farmers' practice				Alley cropping 1				Alley cropping 2			
	N	P_2O_5	K_2O	Manure	N	P_2O_5	K_2O	Manure	N	P_2O_5	K_2O	Manure
Corn	160	120	—	3,000	160	120	—	3,000	160	120	150	3,000
Potatoes	60	60	—	—	60	60	—	—	60	60	65	1,500
Wheat +barley	150	75	—	3,000	150	75	—	3,000	150	75	120	3,000

The luodian site, Guizhou province

Treatments validated at this site included:

T1: Farmers' practice, crops planted up-and-down slope

T2: Bench terrace

T3: Contour planting

T4: Alley cropping 1 using polygonum and pears as hedgerows

T5: Alley cropping 2 using Chinese prickly ash and day lily as hedgerows

Details of the fertilizer application rate under different treatments are shown in Table 2.

Table 2 Fertilizer application for different treatments in Luodian, Guizhou Province

Treatment	Fertilizer application (kg· ha^{-1})					
	N	P_2O_5	K_2O	Lime	Manure	$ZnSO_4$
Farmers' practice	270	150	0	0	18,000	0
Bench terrace	270	105	105	1,950	18,000	6
Contour planting	270	105	105	1,950	18,000	6
Alley cropping 1	270	105	105	1,950	18,000	6
Alley cropping 2	270	105	105	1,950	18,000	6

The fuming site, Yunnan province

Five treatments were validated at this site as follows:

T1: Farmers' practice (FP), crops planted up-and-down slope plus fertilizer rate used by farmers

T2: Farmers' practice (FP), crops planted up-and-down slope plus balanced fertilizer

T3: FP plus alley cropping (AC)

T4: Contour planting

T5: Alley cropping using Chinese prickly ash and day lily as hedgerows (AC)

Details of various fertilizer application rates for different treatments are shown in Table 3.

Table 3 Fertilizer application for different treatments in Fuming, Yunnan Province

Treatment	Fertilizer application (kg· ha^{-1})				
	N	P_2O_5	K_2O	B	Dolomite
T1: Farmers' practice (FP)	251.0	46.2	—	—	—
T2: FP + Balanced fertilizer (BF)	197.0	124.0	60.0	1.5	3,570
T3: FP + Alley cropping (AC)	197.0	124.0	60.0	1.5	3,570
T4: Contour planting	197.0	124.0	60.0	1.5	3,570
T5: BF + AC	197.0	124.0	60.0	1.5	3,570

4 Main outcomes

Effect of soil conservation measures on soil loss and runoff

Effects of different technologies on soil loss and runoff at the Luodian site are presented in Table 4. In both years, soil loss under the farmers' practice was significantly higher than that under the other technologies. The effectiveness of alley cropping in reducing soil loss was as good as that of bench terrace. Contour planting was also effective in conserving the soil. When compared with the farmers' practice, the reduction in soil loss ranged from 53% to 93% under alley cropping, from 62% to 65% under bench terrace, and from 48% to 58% under contour planting. The response from runoff under these treatments was similar to soil loss, i.e. the highest runoff occurred with the farmers' practice.

It was observed that rill erosion was serious on the plot which had no soil conservation measure (the farmers' practice). Under the farmers' practice most of the surface soil on the upslope was eroded and deposited at the downslope. It was also observed that, due to the filtration out and accumulation of runoff sediment, small terraces were formed along the hedgerows of the alley cropping treatment.

Table 4 Soil loss and runoff at the Loudian site, Guizhou Province

Treatment	Runoff (mm)		Soil loss (t· ha^{-1})	
	Year 1	Year 2	Year 1	Year 2
Farmers' practice	316.7	58.8	102.3	2.9
Alley cropping 1	178.1	44.3	35.2	0.2
Alley cropping 2	189.0	37.3	47.5	0.2
Bench terrace	206.3	49.4	38.0	1.0
Contour planting	245.6	52.6	53.5	1.2

Effect of K on crop yield

The effect of K on corn, sweet potatoes, and wheat + barley yields at the Jianyang site, Sichuan Province is shown in Table 5. Potassium increased the yield of corn by 13%, of sweet potatoes by 19%, and of wheat + barley by 32%, when compared between the two alley cropping treatments. In comparison with the farmers' practice, potassium increased the yield of sweet potato and wheat + barley yields, respectively, by 3% and 53%. Corn yield of the farmers' practice was as high as the alley cropping + K treatment, may be due to higher population density of the corn in the former than the latter.

Table 5 Effect of K on crop yields (average of 1997 — 2000) in Jianyang, Sichuan Province

Crop	Yield (t· ha^{-1})		
	Farmers' practice	Alley cropping	Alley cropping + K
Corn	5.07	4.27	4.83
Sweet potatoes	11.37	9.80	11.71
Wheat + barley	2.17	2.53	3.33

Yield and plant biomass as affected by balanced fertilizer

The difference between the fertilizers used by the farmers and the balanced fertilizer in Guizhou was that K, lime, and Zn was added to the latter (Table 2). The effect of the balanced fertilizer and that of the farmers' on corn yield and biomass is presented in Table 6. In all treatments, except bench terrace, corn yield and biomass were increased by the combination effect of K plus lime and Zn. The increase of corn yield over the farmers' practice was 36%, 35%, and 35%, respectively, under contour planting, alley cropping 1, and alley cropping 2. Bench terrace appeared to give negative effect on the corn yield and biomass. The result also showed a positive relationship between yield and biomass.

Table 6 Effect of balanced fertilizer on corn yield and biomass in Luodian, Guizhou Province

Treatment	Weight (t· ha^{-1})	
	Biomass	Yield
Farmers' practice	3.75	3.59
Contour planting	5.66	4.87
Alley cropping 1 (Pears)	5.81	4.85
Alley cropping 2 (Day lily)	6.08	4.84
Bench terrace	4.50	3.98

The positive effect of balanced fertilizer on corn yield was also obtained at the Fuming site, Yunnan Province (Table 7). The combination effect of K plus dolomite and B increased the yield by 26% when compared with the farmers' practice (6.01t ha^{-1} vs 4.76 t ha^{-1}). The increase was as high as 115% when the balanced fertilizer was used with higher population density (67,800 plant· ha^{-1}).

Table 7 Effect of balanced fertilizer (K + dolomite + B) on corn yield at the Fuming site, Yunnan Province

Treatment	Corn	
	Pop. Density (no. plant· ha^{-1})	Yield (t· ha^{-1})
Farmers' practice (FP)	36,700	4.76
FP + Balanced fertilizer (BF)	36,300	6.01
FP + Alley cropping (AC)	34,500	5.46
Contour planting	67,800	10.25
BF + AC	63,400	9.84

Economic analysis

A simple cost and return analysis was done to evaluate the benefit obtained under different treatments. Items included as cost were expenses for labor and materials whereas total revenue (return) was the product of yield and its unit price. Net returns were calculated as the difference between the return and the cost. Tables 8 and 9 present an economic analysis of the site in Jianyang and Luodian , respectively. Table 8 shows that, in the first year, the net return under alley cropping was lower than the farmers' practice. The low return under the alley cropping was due mainly to the additional cost of establishing hedgerows.

Table 8 Cost and return analysis (US$ ha^{-1}) of the Jianyang site, Sichuan Province, in different years

Item	Farmers' practice	Alley cropping 1	Alley cropping 2
1997			
Cost	670.8	1,509.8	1,687.1
Return	1,106.5	972.8	1,138.4
Net return	435.7	–537.0	-548.7
1998			
Cost	918.7	1,069.3	1,244.9
Return	2,034.5	1,883.1	2,272.1
Net return	1,115.5	813.8	1,027.2
1999			
Cost	881.5	1,044.9	1,220.6
Return	1,615.9	1,924.4	2,213.8
Net return	734.4	879.5	993.2
2000			
Cost	881.5	1,044.9	1,220.6
Return	1,550.6	1,912.4	2,213.9
Net return	669.1	867.5	993.3

In the second year, some yield was obtained from the day lily (hedgerow crop), generating additional income for the alley cropping. As a result the net return of the two alley cropping treatments was close to the farmers' practice. The net return from the alley cropping was higher than the farmers' practice from year 3 and onwards, when more additional income from the pears and daylily was generated. The result

was more striking from alley cropping 2 than alley cropping 1, due to the effect of K. Table 9 also shows the positive economic benefit obtained from alley cropping and the application of balanced fertilizer in Luodian.

Table 9 Cost and return analysis (US$ ha^{-1}) of the Luodian site, Guizhou Province, in 2001

Item	Farmers' practice	Bench Terrace	Contour planting	Alley Cropping 1	Alley Cropping 2
Cost	537.2	570.1	565.6	560.9	560.9
Return	586.5	607.1	705.6	844.5	1,167.6
Net return	49.3	37.0	140.0	283.6	606.7

5 Extension plan

Sustainable agriculture on sloping lands can not be achieved if farmers continue doing their current cultural practice without the concern for soil erosion. In its program, this project has planned to introduce alley cropping and the application of balanced fertilizer to farmers. It is expected that fully-fledged extension program will be established with financial assistance from the governments.

Up to the present time, many field days and workshops were organized for farmers, researchers and extensionists, and government officials at the three sites. The main objective of the field days and workshops was to convince and encourage the farmers for their adoption of the technology, to get more support from the governments, and to prepare personnel to be ready for large extension programs after more financial support from the governments is obtained. Although the fully-fledged extension program has not occurred yet, a significant number of farmers in Jianyang adopted and practiced our technology on their farms, currently.

6 Summary

The limited availability of arable lands has forced farmers in China to encroach and cultivate sloping lands to meet food demand. In general, the farmers cultivate these lands with minimal concern for soil erosion, resulting in unsustainableagriculture. Two main measures, i.e. alley cropping and balanced fertilizer application, were used by this project to assist farmers to obtain a sustainable form of agriculture on sloping lands. While alley cropping can protect the soil, reduce soil erosion, and give additional income from hedgerows, balanced fertilizer application will increase crop yields. Under this circumstance, certainly, the quality of the environment of the surrounding areas will be preserved/enhanced and the income of the farmers can be increased.

Results showed that soil loss and runoff were greatly reduced by alley cropping. The day lily and pears, which were used as hedgerows for the alley cropping treatment, generated additional income for farmers. Natural terraces were formed by alley cropping. Balanced fertilizer application remarkably increased crop yield over the farmers' practice and the role of K was significant.

Field days and workshops were organized for farmers, researchers/extensionists, and government officials. It is hoped that, after all these activities, more support from the governments can be obtained and the technology is adopted and practiced by farmers. This project can serve as model for developing sustainable agriculture on sloping lands in other similar areas in China.

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