The Preliminary Study on Conservation Effects of Different Methods Treated to Orchard Slopes of Red Soil

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Abstract: Soil and water losses from red soil orchard slopes that treated with eight different conservation measures were assessed. There were significant different effects among treatments. Planting Bahia grass on level bench terrace riser was the most effective method to conserve soil and water. Other methods also resulted in positive effects. It is suggested that growing Bahia grass on orchard slopes will improve vegetation coverage and soil conservation.
Keywords: soil and water conservation, bahia grass, runoff ratio, soil losses, vegetative coverage

1 Introduction

Red soil in China is mainly distributed in upland areas south of Yangtze River. Serious leaching has caused the loss of organic materials and nutrients and acidified the surface layer. Together with high temperature and strong torrential rain that help accelerate the decomposition of organic matters, soil erosion has become severe, which greatly degraded the soil texture and resulted in high clay content that approaching 40%. Soil surface becomes less permeable, from time to time; surface crust can be easily identified on-site with apparent cracks. The dramatic geographic settings even facilitate the loss of soil layer whenever a heavy rain occurs. Draught forms easily. A serious case of erosion may lead to environment pollution, deterioration of water quality, flash flood, and sediment damages. Roads, bridges, farming lands, and other facilities are often destroyed; not to mention the threat on lives and properties of the local residents.

The red soil in Jian-Si Province covers about 55.8% of the total land areas. The principal makeup of the soil is by Quaternary Period red soil. Social and economic development has increased the level of urbanization and industrialization. Land use has gradually transformed for other purposes, agricultural lands move towards the hill slope upland areas. In the process of hill cultivation, the locals pursuit short term benefit and labor intensive crops in order to increase revenue [17,20]. The continuity of land usage is ignored which lowering the land productivity but increasing severity of soil loss.

The climate conditions and geology environment in Taiwan is similar to that in Jian-Si Province [16]. Ever since the 1950s[8,9,13], researches have begun in soil and water conservation. After a series of research, it was discovered that hillside ditch combined with vegetation cover is the most economic and effective methods among all [4,11,15]. Not only soil losses can be effectively controlled, organic matter and porosity of the soil can be raised, crops' growing environment can be improved, but also the quality and quantity of fruit and vegetable crops can be increased eventually [1,2,3,6,14,19,21,22, 23]. The method can also offer limited protection to public facilities, increase and purify water resources, and decrease and delay the peak time of floods and the peak discharge to prevent mud flow [12,15,18].

In order to prevent soil loss, to protect the sloped upland areas, and to improve economic development, soil and water conservation technology that Taiwan employs for sloped upland cultivation can be imported to Jian-Si Province for modification and localization. This will be a new path of research in the southern red soil sloped upland areas for better land protection, modernized sloped upland farming, and continuous agricultural development.

2 Materials and methods

2.1 Experiment design

The experiment area is located in Nanchang, where rough grained red soil can be found to represent the poorer red soil hills. The experiment area is divided into 8 smaller plot areas with the slope length of each area in reference to interval of hillside ditch of 25m, width of 5m, slope of 25 degrees, and total plot area of 125m^2. Physical and chemical characteristics of the soil are shown in Table 1.

Table 1 Physical-chemical properties of experimental field

Organic matter (kg/kg)	Total nitrogen (kg/kg)	Available phosphorus (kg/kg)	Available potassium (kg/kg)	pH value (H_2O)
7.1×10^{-3}	5.1×10^{-4}	2.15×10^{-4}	4.13×10^{-3}	5.30

From early experiment results of Taiwan, it was known that if the wall of ridge terrace remained un-vegetated, the outside ridge wall would not only generate soil loss, but also threaten terrace structure easily [5,7]. After planting grass on the riser, not only erosion can be decreased, but also traditional farming method can be improved. Therefore, total of eight treatments was implemented as follows. They were:

(1) Level terrace planting grass on the riser.

(2) Level terrace with terrace riser uncovered. This method can be taken as the representative of traditional farming methods [10]. The width of the bench terrace is 4m, and the sloped of the terrace riser is 1∶0.5.

(3) Entire plot is planted with Bahia grass except the 0.30m radius area at the root of the main crop of which crops are planted 0.20m×0.20m apart.

(4) Bahia grass strip interplanted with soybean. The width of the grass strip is 0.50m. The idea of having grass strip interplanted with soybean is to increase farming revenue and also reduce overland velocity, filter the eroded soil, and form a bench terrace eventually.

(5) Similar to Treatment #3 except using Bahia grass residue as mulch under the crop's canopy.

(6) Similar to Treatment #3 except using centipede grass instead.

(7) Similar to Treatment #4 except replace Bahia grass with vetiver grass and peanuts with soybean.

(8) Plant only main crops (peach trees) in the area with neither vegetation nor mulching for comparison.

2.2 Observation method

The boundaries of each plot are isolated with cement walls to keep runoff from entering the plot. One set of observation pools in which soil loss as well as runoff was measured was constructed at the lower boundary of the plot. Observation pools consisted of A pool and B pool; of which A pool measured 1.5m in length, 1.0m in width, and 1m in depth. B pool had the same dimensions except it only measured 0.9m in depth. A pair of stainless steel triangle weirs was installed at the rim of A pool. This pair of triangle weirs split the runoff into two uneven proportions; 5/6 of the exceeding runoff was discarded and 1/6 of which was kept in B pool.

Runoff and soil loss were measured by storm basis. Two gate valves were installed on each pool respectively; one located at the bottom of the pool, and the other locates 0.50m above the bottom. Whenever the storage level of the runoff exceeds 0.50m, the surplus runoff will be drained through the upper valve. The remaining runoff and sediment will then be fully stirred before samples are taken. Samples are taken at the bottom, center, and the top levels of the runoff sediment mixture. They are then weighted and oven dried to calculate the average soil loss for each treatment.

After the construction of experiment plots and observation pools, pre-selected vegetation as well as peach trees were planted in March the next year. Field data collections were formally initiated in April. Due to proper design of the observation pools, all valid data were collected successfully. Runoff volume and amount of soil loss from each treatment was used later on to calculate runoff ratio and total soil loss.

3 Results and discussion

During the period of experiment, total of 31 runoff ratios and soil losses were obtained. The results are summarized in Table 2.

Table 2 Runoff ratio and soil loss from each treatment

Year	Annual precipita-tion (mm)	Treatment	Level terrace planting grass on the riser	Level terrace uncover the riser	Cover with Bahia grass	Bahia grass strip intercropped with soybeans	Cover and mulching with Bahia grass	Cover with Centipede grass	Vetiver grass intercropped with peanuts	Bare (CK)
1998	1,237.3	Average runoff ratio %	4.76	16.48	22.39	20.61	22.22	25.72	21.21	32.14
		Average soil loss capacity kg/125m^2	16.81	154.05	153.94	433.11	292.59	182.73	565.57	1,642.70
1999	1,432.1	Average runoff ratio %	1.15	19.90	3.25	5.13	3.69	6.37	7.49	40.26
		Average soil loss capacity kg/125m^2	0.00	70.09	0.00	1.91	0.00	1.25	10.18	171.25

As shown in Table 2 and Figures 1 and 2, in the first year of the newly cultivated orchard, all treatments can decrease the surface runoff and soil loss in the first year of newly cultivated orchards. The greater the amount of rainfall is, the more obvious the effectiveness of soil and water conservation treatment appears. The results from variance analysis also indicate that the runoff ratio and soil loss from different treatments achieve F values of 5.636 and 3.771 respectively. Both F values exceeds the theoretic value $F_{0.01(7.136)}$=2.792, and achieve the extreme significance level. Same set of data was again analyzed with Duncan analysis, and the results are shown in Table 3.

Table 3 Analysis of Duncan's MRT test of treatment of runoff ratio and soil loss

Treatment	Year 1998	
	Average runoff ratio (%)	Average soil loss (kg)
Level terrace planting grass on the riser	4.76^{a}	0.93^{a}
Level terrace uncover the riser	16.48^{b}	8.56^{a}
Cover with Bahia grass	22.39b^{c}	8.55^{a}
Bahia grass strip intercropped with soybeans	20.16^{b}	24.06^{a}
Cover and mulching with Bahia grass	22.22^{bc}	16.26^{a}
Cover with centipede grass	25.72^{bc}	10.15^{a}
Vetiver grass intercropped with peanuts	21.21^{bc}	31.42^{ab}
Bare (CK)	32.14^{c}	81.26^{b}

Remark: Numbers with same superscript does not exceed 5% significance level

In the first year of newly cultivated orchard, the soil was often plowed for planting that often leaves soil surface uncovered. Therefore, all treatments excluding the terrace can effectively reduce surface runoff ratio to 20% as compared to the check plot. As for soil loss control, all treatments has reached the same level of control as terrace except the treatment using vitiver grass. Vetiver is a straight and shrubbery plant, hence, it provides less ground cover in a relatively short period. It is also less effective either stopping or filtering the soil in runoff and fails to achieve the significance level.

In the second year (the year of 1999) of the experiment, besides the centipede grass that only provided 60% ground cover, the rest of vegetation plants showed signs of good growth with over 95% ground coverage. Also, from the single factor variance analysis of runoff ratio and soil loss, $F_{0.01(7.96)}$=2.86 value of 29.23 and 7.32 were achieved; respectively, both higher than the theoretic value and achieving the extreme significance level. Duncan analysis was again employed and the results are shown in Table 4.

The runoff ratio and soil loss from all treatment; except the treatments of terrace with riser bared and check plot has decreased apparently. The effectiveness of soil and water conservation measures was very obvious. The results suggest that labor saving plantation method together with hillside ditches can achieve same degrees of coil and water conservation effect as terraces. In order to understand the variation of effectiveness for each treatment in two consecutive years, results are further arranged in Table 5.

Table 4 Analysis of Duncan's MRT test of treatment of runoff ratio and soil loss

Treatment	Year 1999	
	Average runoff ratio (%)	Average soil loss (kg)
Level terrace planting grass on the riser	1.15[a]	0.00[a]
Level terrace uncover the riser	19.90[b]	5.39[b]
Cover with Bahia grass	3.25[a]	0.00[a]
Bahia grass strip intercropped with soybeans	5.13[a]	0.15[a]
Cover and mulching with Bahia grass	3.69[a]	0.00[a]
Cover with centipede grass	6.37[a]	0.10[a]
Vetiver grass intercropped with peanuts	7.49[a]	0.78[b]
Bare (CK)	40.26[c]	13.17[c]

Remark: Numbers with same superscript does not exceed 5% significance level

Table 5 Comparison of runoff ratio and soil loss in each treatment

		Treatment							
Results	Observation Year	Level terrace planting grass on the riser	Level terrace uncover the riser	Cover with Bahia grass	Bahis grass strip intercropped with soybeans	Cover and mulching with Bahia grass	Cover with Centipede grass	Vetiver grass intercropped with peanuts	Bare (CK)
Average runoff ratio(%)	1998	4.76	16.48	22.39	20.61	22.22	25.72	21.21	32.14
	1999	1.15	19.90	3.25	5.13	3.69	6.37	7.49	40.26
	Percent of reduction w.r.t. 1998 (%)	75.84	–20.75	85.48	75.11	83.39	75.23	64.69	–25.26
Average soil loss (kg/ 125 m^2)	1998	16.81	154.05	153.94	433.11	292.59	182.73	565.57	1,462.70
	1999	0.00	70.09	0.00	1.91	0.00	1.25	10.18	171.25
	Percent of reduction w.r.t. 1998 (%)	100.00	54.50	100.00	99.56	100.00	99.32	98.20	88.29

When the ground cover rate increased, runoff rate and soil loss decreased obviously as compared to that from year 1998; particularly the average soil loss from certain treatments became untraceable. The main reason is that when the root system of the Bahia grass decays and decomposes it increases the soil porosity, permeability rate, and the organic matter. After harvesting the grass, grass residue turns into the mulching material. The grass residue not only serves as nutrient source, but also helps improve soil's anti-erosion ability.

As for the treatment of terrace with riser uncover and the check plot is concerned, the decrease of soil loss in the second year is because of the surface crusting. Even though soil loss decreases, runoff ratio increases. After the ground surface hardens, water permeability is impeded, ventilation in soil matrix decreases, the growth of grass and the activities of the microorganisms is therefore blocked, and eventually the deterioration of the soil quality accelerates.

Bench terrace is among the main farming methods implemented in upland agriculture in China. Farmers often leave the terrace riser un-vegetated. A period of intense storm can easily damage the terrace riser by erosion that makes bench terrace difficult to maintain. If Bahia grass is planted on terrace riser, not only the runoff ratio can be decreased by more than 97%, but also the soil loss can be greatly reduced to null [5]. The terrace riser or the slope upland together with good ground vegetation can improve the soil environment, modify soil temperature, and facilitates the growth of rooted plants and microorganisms. Bahia grass residue covering the base of the root can decrease water evaporation and improve the water quantity in the soil. After mulching residue decomposes, the organic matter in the soil can be increased, soil structure can be improved, and the anti-erosion ability of the soil also improves.

The field observations of this study clearly show that level terrace planting grass on the riser is the best, with the lowest runoff rate and soil losses; whereas, leaving the soil surface bared produces the highest runoff rate and soil losses. The results also suggest that Bahia grass is the best vegetation to choose for red soil upland and orchard with serious soil loss.

4 Conclusion

The overall results of this preliminary study indicate that both runoff ratio and soil loss can be effectively decreased in the first year of planting Bahia grass, and the effectiveness continues to improve with the increase in ground coverage. Bahia grass has proved itself to be one of the best ground vegetation for the red soil. The riser of bench terrace must be planted with vegetation to decrease erosion, and to reduce the maintenance period and costs. If the orchard can be fully vegetated together with hillside ditches, not only the physical and chemical characteristics of the red soil can be improved gradually, the quality and quantity of the crop can increase, but also the soil permeability can be enhanced so that time of concentration and peak flow from upland areas can be delayed and reduced.

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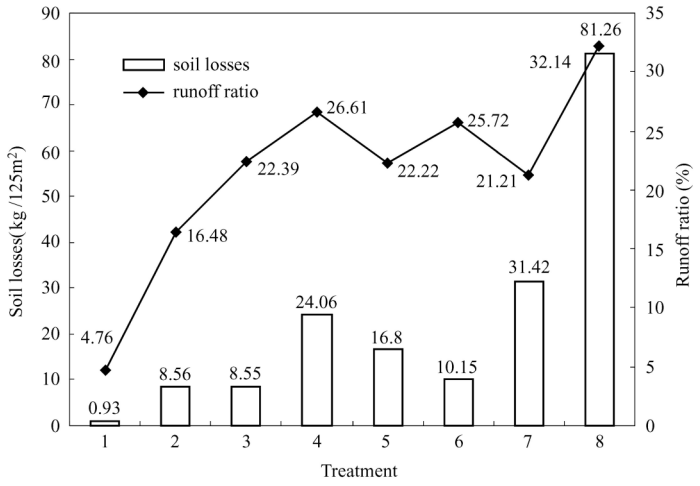

Fig. 1 Runoff ratio and soil loss from each treatment in 1998

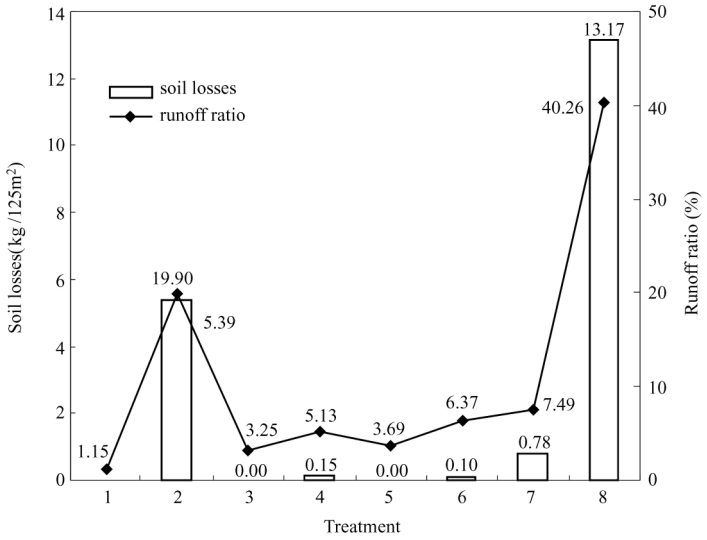

Fig. 2 Runoff ratio and soil loss from each treatment in 1999