Preliminary Report on Technical Research for Soil and Water Conservation, Flood Control and Natural Disaster Reduction on Red-Soil Hilly and Sloping Lands

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Abstract: This paper describes the series of research we've conducted to cope with the soil erosion. Red-soil sloping lands in south China frequently suffer soil loss as well as drought and flood disasters. This report gives a detailed description of the contents and methods of the research. In particular, we have adopted for the first time the soil infiltration devices for quantitative observation and measurement in test plots. From which, we reach preliminary conclusions that the plot covered with Bahia grass is of the lowest surface runoff and underground runoff, where the soil and water conservation effect is good; whereas the plot mulched with Bahia grass is of the second lowest surface runoff and the highest underground runoff, where its capacity for flood control and natural disaster reduction is good; however, the bared check plot is of the highest surface runoff and the lowest underground runoff, where its capacity for soil and water conservation is fairly poor and it is in more serious danger of suffering from drought and flood disasters.
Keywords: red-soil sloping land, runoff, cover, mulch

1 Introduction

Red soil is widely distributed in south China while red and reddish yellow soils can be found everywhere in the 14 provinces and autonomous regions in south China, with a total area of 2,179,600 km^2 [1]. Among which, the red soil on hilly and sloping lands come to 1,060,000 km^2 [2], and only the area of lower hills is up to 430,000 km^2 [3]. South China is deemed as a major region for production of tropical cash crops and grain in China. As to the research on land resources of this region, many Chinese scholars have gained fruitful achievements in turns of land property and its spatial-time distribution, proper utilization of land resources based on quality improvement as well as the law governing land evolution, etc..[4] However, they failed to pay special emphasis on integration of land utilization with environment and social economy in viewing the situation as a whole, which results in serious soil erosion, water loss, soil degradation and gradual decline of biodiversity, thus affects the sustainable and stable development of agricultural production and social economy. In view of the above-mentioned facts, we initiated the cooperation with Chinese Soil and Water Conservation Society of Taiwan in 2000 and carried out the research in De'an County, Jiangxi Province, all in an attempt to seek out effective technologies for soil and water conservation, flood control and natural disaster reduction in red-soil hilly and sloping lands, and reliable technical support for the further development and utilization of red-soil land resources and proper control of soil erosion and water loss as well.

2 Background information of the research area

The research area is located within the boundaries of De'an County in northern Jiangxi Province, just at 115°42′ east longtitude and 29°17′ north latitude. It is on the western bank of Boyang River which belongs to the watershed of Poyang Lake. The soil-forming matrix in this area is adamic earth of the Quaternary period. In the research area, the topographic type is low hills, with an elevation of 30m—100m and a slope no more than 25°. It's typical red soil and a central area for red soil distribution in China. This area is situated within the subtropical monsoon climate zone, where the climate is warm, with plentiful rainfall. The annual average rainfall is 1,350mm or above, annual average air temperature 16.7°C, annual sunshine 1,650 h—2,100 h and annual average frost-free period 249 days.

Influenced by the local climate and other factors, the ground vegetation was mainly broadleaved evergreen forests. Due to long-term over-exploitation and improper utilization of land resources, the surface vegetation in this area has been destroyed to some extent, the biological environment degradation, soil erosion, and water loss become more and more serious. The land suffering from soil erosion and water loss accounts for 42.75 % of the total, in which over 80% is suffering from slight to moderate soil erosion, and the major type of soil erosion is water erosion.

The test area is chosen at the middle and lower parts of the hillside, where the soil thickness ranges from 0.5 m—1.5 m and the soil pH is 5.0, organic matter content 1.55%, total nitrogen content 0.08%, total phosphorous content 0.07%, C/N 7.5, but with low contents of various quick-acting nutrients. The local soil features such disadvantages like being acidic, cohesive, hardened and infertile in properties.

3 Methods

The research is rich in contents since it involves in a wide range of aspects. The major contents of this research is described in two parts as follows:

3.1 Fundamental research

3.1.1 Standard runoff plot

Total of 15 standard runoff plots of 5 m×20 m with the horizontal projected area of 100m^2 and the slope of 12° was established. To prevent the surface runoff from entering, the plots were specially enclosed with dykes. The dyke constructed with bricks and concrete structure is 30cm high above the surface and rooted into the ground by 45cm. At downslope end of each plot troughs were constructed to contain the runoff and sediment from the plots and lead them into the runoff pool. With full consideration of the maximum possible rainstorm volume and runoff in the local area, the runoff pool was composed of three square pools; respectively, namely Pool A, Pool B and Pool C, but all with the size of 1.0 m×1.2 m×1.2 m. In addition, 60° V-shape triangular diversion weirs were constructed on both rims of Pool A and Pool B. Four portions of runoff were discarded, one portion was discharged into Pool B. Similarly, one portion of runoff from Pool B was discharged into Pool C. Calibrations were conducted in all pools and the pool wall was equipped with an enamel water gauge. From the reading on which, we can calculate the surface runoff. Whenever there is runoff, we take the runoff sample and dry it for the measurement of soil erosion. Except for the check plot, each plot has planted with 12 three-year-age Penggan trees. (Penggan is a kind of mandarin orange.) The 15 plots were divided into 3 treatment groups: 7 plots (including one bared check plot) in forage grass group, 3 plots in farm cultivation group and 5 plots in terrace group. Other methods adopted were fully in conformity with the requirements as specified in “Standard for Soil and Water Conservation Test”.

3.1.2 Lysimeter

Lysimeter is for the first time used in soil and water conservation research in Mainland China. It consists of three small plots with treatments of grass-covered, grass-mulched, and bared check plot respectively. Original soil was first removed to form a 5m×15m×1.2m (W×L×H) soil pit. Soil was excavated at 40cm interval in depth and set aside sequentially in three separate piles. Steel-reinforced concrete was used to form sidewalls and bottom slab of the lysimeter. A retaining wall was built at the downslope end of the lysimeter with collecting troughs embedded. After the completion of boundary structures, previously excavated soils were then refilled in sequence to form a uniform slope of 14°.

Collecting troughs serve the purpose of sample collections which include surface runoff, soil loss, and infiltration discharges at the depth of 30cm, 60cm and 105cm respectively. Surface runoff and soil loss were routed to runoff pool similar to those previously described. As far as infiltration discharge is concerned, discharge from each depth was routed to a stilling tank equipped with 30° triangular weir and a floating-type gauging recorder.

To further investigate the dynamic variation of water content in the soil profile, a series of tensiometers was installed in each plot to the depth of 30cm 60cm and 105cm at three monitoring sections. The distances of the monitoring sections measure 3.5m 7.0m and 10.5m; respectively, from the top edge of the plot boundary. This integrated measurements covering surface runoff, soil loss, and infiltration were initiated one year after the construction to allow soil profile to become fully consolidated.

3.2 Applied research

3.2.1 Grassed waterway test

Irrigation and drainage system is absolutely necessary for farm cultivation in the vast hilly and sloping lands in south China. Most of the traditional irrigation and drainage system are usually built with mud, stone or concrete. But in this research, grassed waterway is adopted instead, namely, to plant Bahia grass and various other varieties of grass to protect the waterway from erosion. Rates of grass growth, water flow status, flow velocity, and the sustainability against erosion of the waterway was observed and recorded to identify the proper combination of irrigation, drainage system and grass species suitable for red-soil sloping lands.

3.2.2 Comparison of grass-planted farmroad and traditional farmroad

Farmroad is an important component in modern farms and orchards. Traditional farmroads are usually paved with gravel, cement or even left bare, which in turns raise maintenance costs, micro-climate, and soil loss. All these disadvantages can be overcome by grass-planted farmroads which serve less traffic volume and short-distance transportation. A comparative study of wheel pressure resistance, anti-slippery, and anti-erosion properties between grass-planted and traditional farmroad was conducted in this research to identify the economically feasible, durable, and beautiful in appearance grass-planted farmroad systems.

3.2.3 Collection and breeding of superior-quality plants suitable for soil and water conservation

Different species of superior-quality trees and grasses were collected and bred in this study. Plant growth, plant status as well as the capability of improving soil properties were carefully monitored to identify the suitable species for red-soil sloping lands. Once identified, the selected species will be implemented on those areas which have urgent needs of erosion control.

3.2.4 Labor-saving management and other tests

With constant social progress, modern agriculture is no long labor-intensive. Instead, it represents the general trend of mechanical operation and automatic irrigation. Hence, relevant researches including gully control, terrace wall planted with grasses and other technologies developed by Dr. Liao Mianjun; a famous Chinese expert in soil and water conservation were conducted.

Due to limited space of the paper, preliminary results related to surface runoff and soil loss observed from lysimeter were addressed in the following section.

4 Results and discussion

4.1 Analysis of runoff and infiltration acquired from lysimeter

Three treatments were implemented in lysimeter. They are plot planted with Bahia grass, plot mulched with Bahia grass residue, and bare check plot. The treatments thus implemented are denoted as Plot A, Plot B and Plot C respectively. Surface runoff as well as infiltration volume from various depths was monitored continuously throughout the rain season of year 2001. Data thus acquired were summarized in Table 1 in which subscript 0 represents surface runoff, subscript 1 represents infiltration volume from the depth of 30cm, subscript 2 represents that from depth 60cm and 3 from 105cm.

As shown in Table 1, surface runoff volumes keep the order of $A_0<B_0<C_0$, indicating that the plot covered with Bahia grass has better control of surface runoff as compared with plot mulched with Bahia grass residue. Whilst, the runoff volume from bare check plot is 6-fold or 7-fold more than that observed

from Plot A or Plot B. It becomes fairly obvious that lands covered or mulched with grass produce less runoff, which in turns produce less flood in the viewpoint of the watershed.

As to the infiltration or underground runoff, the monthly total infiltration volume from the bare check plot was the least among all treatments; whereas plot mulched with grass residue produces the greatest monthly total infiltration volume during the first half of rain season. The reason for Plot C having the least infiltration volume is because most precipitation leaving the bare check plot as surface runoff. At the meantime, plot mulched with grass residue maintains producing greatest volume of infiltration. The reason for such outcome is because mulch residue absorbs rainfall as sponge, which gradually release the water into soil profile. The mulch residue also protect soil surface from evaporation.

Table 1 surface and underground runoff acquired from lysimeter

time month/year		1/01	2/01	3/01	4/01	5/01	6/01	7/01	Total
Total rainfall（mm）		36.2	124.2	82.25	170.95	0	191.61	55.75	600.96
Plot cover-ed with Bahia grass (m^3)	A_0	0.08	0.19	0.14	0.03	0	0.22	0.05	0.71
	A_1	0.13	0.04	0.10	0.19	0.03	0.10	0.07	0.66
	A_2	0.15	0.04	0.12	0.23	0.02	0.10	0	0.66
	A_3	6.24	1.96	6.04	7.40	1.88	3.60	0.04	27.16
	Σ	6.61	2.23	6.40	7.85	1.93	4.02	0.16	29.19
Plot mul-ched with Bahia grass (m^3)	B_0	0.14	0.22	0.12	0.33	0	0.29	0.20	1.30
	B_1	0.30	0.09	0.17	0.40	0.11	0.17	0.03	1.27
	B_2	0.19	0.05	0.15	0.23	0.09	0.14	0.05	0.90
	B_3	6.79	2.25	6.44	11.10	5.09	7.83	3.78	43.28
	Σ	7.42	2.61	6.88	12.06	5.29	8.43	4.06	46.75
Bare ckeck plot (m^3)	C_0	0.25	0.61	0.75	2.47	0	1.95	1.66	7.69
	C_1	0.10	0.01	0.05	0.07	0.06	0.05	0	0.34
	C_2	0.09	0.01	0.06	0.08	0.05	0.06	0	0.35
	C_3	4.06	1.24	4.10	4.93	3.04	4.80	0.55	22.72
	Σ	4.50	1.87	4.96	7.55	3.15	6.86	2.21	31.10

As the observation goes into the second half of the rain season, the monthly infiltration volume from plot planted with Bahia grass (Plot A) becomes the least among all treatment; followed by bare check plot (Plot C) and plot mulched by grass residue (Plot B). The possible reason is due to the gradual growth of the grass and penetration of root system so that part of the infiltrated water is held by the vegetation.

The observed results listed in Table 1 with the subscript 3 represent the infiltration volume from the depth of 105cm below soil surface. This particular depth is just right above the lower physical boundary of the lysimeter. Due to the impermeability of the concrete slab, all infiltrated water eventually leaves the system. Since all three plots are similar in the aspects of area, surface gradient, slope orientations as well as rainfall and other climate factors, total infiltratin volume at this depth is founded in the order of $A_3<C_3<B_3$. Due to the transpiration of Bahia grass covered in Plot A, some of the soil water is lost and the runoff therefore becomes lower. According to a related report, during the vigorous growing period of Bahia grass, the daily transpiration volume can sum up to 4 —14 mm[5],which lead to a reduction of total runoff. Since Plot C is thoroughly exposed to the air, the total runoff is also reduced due to strong surface evaporation and serious rain loss. In Plot B where the surface is mulched with thick Bahia grass residue, the surface evaporation is effectively blocked and no water loss caused by plant transpiration, thus the underground runoff and total runoff become the highest.

4.2 Analysis of soil loss acquired from lysimeter

Soil loss from each treatment during the rain season of 2001 is listed storm by storm in Table 2. As shown in Table 2, the total soil loss of the season from the plot planted with Bahia grass (Plot A) is

12.119,6 t/km^2, the total soil loss from plot mulched with Bahia grass residue (Plot B) is 11.355,4 t/km^2; whereas, the total soil loss from the bare check plot (Plot C) reaches 12,556.53 t/km^2.

Table 2 Soil loss from each treatment

Time Year-Month-Day	Recorded rainfall（mm）	Plot covered with Bahia（t/km^2）	Plot mulched with Bahia(t/km^2)	Bare check plot(t/km^2)
01-1-7	22.3	0.2603	0.3412	1.1457
01-1-11	13.9	0.3808	0.6053	2.6320
01-2-7	79.4	1.5495	0.8326	1.4161
01-2-28	44.8	0.5358	0.4702	1.6758
01-3-11	8.5	0	0	0.2005
01-3-17	16.05	5.1152	3.3105	48.1712
01-3-25	57.7	1.0885	0.5237	38.6132
01-4-21	49.45	0.4048	0.2901	403.7131
01-4-30	121.5	1.7781	2.0225	1570.0600
01-6-1	78.7	0.0692	0.0682	0.5151
01-6-5	42.4	0.0309	0.0402	0.3293
01-6-14	40.4	0.3763	0.4748	3346.7110
01-6-27	30.11	0.0339	0.0973	4.0144
01-7-13	14.85	0.0322	0.1685	26.3654
01-7-15	40.9	0.4641	2.1103	7110.9680
Total	660.96	12.1196	11.3554	12556.5308

The reason for Plot B having the lowest total soil loss is because it is mulched with a thick layer of Bahia grass residue which effectively protect the soil from raindrop impact and runoff erosion. The total soil loss collected from Plot A reaches the second lowest among all treatments is due to 95% surface coverage by Bahia grass, which is slightly less than residue mulch. Therefore, the total soil loss is slightly increased accordingly. The total soil loss from Plot C is the highest among all, surpassing that from either Plot A or Plot B by thousand times. Furthermore, when hit by a heavy rain, the soil loss from Plot C can even reach several thousand tons per square kilometer. The results obtained from this field study clearly show that good soil and water conservation can be achieved by grass cover or residue mulch.

4.3 Conclusions

General speaking, field measurements of surface runoff, underground runoff, and soil loss of this study clearly indicate that the plot covered with Bahia grass features the merits of the lowest surface runoff, total runoff as well as comparative lower soil loss, showing its good effect in soil and water conservation. The plot mulched with Bahia grass is of the lowest soil loss and lower surface runoff, where good soil and water conservation effect is also achieved. In addition, the underground runoff and total runoff are the lowest among all treatments. The thick layer grass residue can effectively increase the infiltration volume, reduce the flood peak and increase the underground water volume, thus can be expected to provide good performance in flood control and natural disaster reduction.

The bare check plot; however, produces the highest surface runoff, extremely high soil loss but the lowest underground runoff, indicating that if a sloping land left in such a condition is not good for soil and water conservation, and it will lead to more serous drought and flood disasters. Therefore, it has an urgent need to put an end to such a condition with effective countermeasures to prevent any possible soil and water losses; especially on red-soil, so that agricultural production can become sustainable.

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