Effects of Rehabilitation Measures on Properties of the Severely Eroded Lateritic Red Soil in Southeastern Fujian, China

Yang Yusheng, Xie Jingsheng, Jiang Miaohua and ***Chen Guangshui***

Forestry College, Fujian Agriculture and Forestry University, Nanping 353001, P.R. China
E-mail: ffcyys@public.npptt.fj.cn

Abstract: In the southeastern Fuian, China, deforestation has led to serious soil erosion and degradation, which troubled the rehabilitation and reconstruction of the degraded ecosystem very much. This paper studied the effects of several rehabilitation measurements on the soil characteristics of this severely eroded lateritic red soil. Under taking the harness measures, the soil antierodibility has been strengthened, the soil structure and the moisture condition have been improved, the soil organic matter content has been increased, the quality of soil humus has been improved, the soil nutrient availabilities and nutrient pools has been increased obviously. Also, the amount of soil microorganism has been increased sharply, the soil respiration and enzyme activity has been intensified and the soil fertility was in recovering. It suggested that adopting leguminous tree species such as *Acacia auriculae formis* instead of solely planting fruit trees is advantageous to soil fertility. Also, it suggest that increasing ground mulch such as introducing leguminous plants to orchard is an important technical measure for controlling soil erosion and improving soil fertility.

1 Introduction

In the coastland of southeastern Fujian, China, deforestation is very common for a long history due to only a small portion of plowland for a large population. Thus, the antierodibility of the lateritic red soil declined sharply under the condition of losing the shielding of ground vegetation, resulting in very severe soil erosion. The degrees of erosion under various land use rank the first in Fujian province. Under the guidance of local authority related, the native had launch a program to harness the degraded soil and had found some successful ways matching different regions, especially those of planting tropical or southern subtropical fruiters (e.g., litchi, longan), which has exhibited a good economic benefit as well as an good ecological efficiency. With the increasing of the orchard area, people now have to focus on a new problem: the increase of soil erosion and fertility deterioration in the orchards. We attempt to propose a principle for preventing soil erosion, improving soil fertility and enhancing the integrative benefit of harness through an investigate on soil fertility under several harness measures of soil erosion this area.

2 Materials and methods

The study was conducted in Guanpo Town, Zhao'an County, and Nan'an State-own Forest Farm, both in southeastern Fujian, China. The area is characterized by a south subtropical oceanic monsoon climate, with an annual mean temperature of 20℃—21℃. There occurs only two seasons over the year, without a period of winter. The warm climate is suited for the tropical and subtropical economic crops and fruiters such as longan and lichee. The annual mean precipitation is between 1,000 mm and 1,600 mm. This area is often subjected from typhoon by the frequency and intensity rainstorm during typhoon season. The soil is lateritic red soil derived from coarse granite. The soil configuration is B-C type. The soil is seriously degraded, with an organic matter content less than 1%. The anthropic deforestation has led to serious soil erosion. The land is barren, featured by an undeveloped soil profile and a bared illuvium horizon.

From 1991 to 1994, the growth status of plant vegetation（average diameter at breast high or at base trunk (D), average tree high(H), density, cover-degree, crown density）and the rehabilitation status of subsoil in some major biological harness measures this area were investigated. Some site characteristics and plant growth status under these harness measures are listed in Table 1.

Table 1 Site characteristics and plant growth status under different harness measures

Sites	Treatment	Slope	Biological measures	Engineering measures	Age	Stem density (Stem hm^{-2})	Tree height (m)	Crown length (m)	Crown density	DBH (cm)	Undergrowth coverage (%)
Zhaoan	CK_{10}	20	Barren land								
	T_{11}	18	planting litchi	dig holes	6	750	2.8	2.85	0.58		Sparse
	T_{12}	21	planting Acacia auriculae formis	dig holes	6	2,710	5.4	1.96	0.9		30
Nanan	CK_{20}	16	Planting Masson Pines	dig holes	29	1,726	3.27		0.4	4.8	15
	T_{21}	15	planting litchi	Terrace, dig hole	29	200	5.7	7.1	0.7		60
	T_{22}	17	planting longan	Terrace, dig hole	29	150	4.8	8.0	0.85		30
	T_{23}	16	planting waxberry	small platform	28	150	5.1	6.4	0.4		70

Five soil samples were collected following a sigmoid route in each treatment. Only the subsoil (0cm—20cm) is considered here. Laboratory analyses were carried out to determine the soil antierodibility, chemical properties, physical structure and biological activity [1—4]. Data presented in this study were the averages of five samples.

3 Results

3.1 Soil antierodibility

Soil antierodibility is defined as the capability of soil to resist to be separated and suspended against water; it is an important factor affecting soil erosion. It is so complex that no general applicable index has been adopted worldwide [1, 5—9], because the soil antierodibility is substantially affected by factors such as soil, vegetation and human being.

Table 2 Indices of soil antierodibility under different biological treatments

Treatment	Microaggregate (mm)		Macro-aggregate (mm)	aggregation state (g • kg^{-1})	Aggregation rate (%)	Dispersion degree (%)	Moisture Equivalent (g • kg^{-1})	Erosion ratio (%)	E_{VA}	Destroyed rate of ped	E_{MWD} (mm)
	<0.001	>0.05	>0.25								
CK_{10}	$\frac{0.14}{28.18}$	$\frac{48.52}{41.72}$	$\frac{93.93}{21.13}$	6.80	14.01	88.33	21.33	66.86	32.48	77.50	0.21
T_{11}	$\frac{4.48}{32.64}$	$\frac{50.64}{36.06}$	$\frac{93.83}{30.06}$	14.58	28.79	78.42	24.62	59.15	18.12	67.96	0.38
T_{12}	$\frac{11.86}{38.41}$	$\frac{45.31}{28.71}$	$\frac{93.62}{48.21}$	16.60	36.64	76.71	31.81	63.53	6.32	48.50	1.15
CK_{20}	$\frac{3.58}{26.68}$	$\frac{52.71}{42.21}$	$\frac{93.05}{24.17}$	10.50	19.37	81.72	22.78	69.74	23.36	74.02	0.27
T_{21}	$\frac{13.48}{37.88}$	$\frac{55.01}{32.69}$	$\frac{94.63}{40.31}$	22.32	40.57	65.35	25.74	44.41	9.28	57.40	0.77
T_{22}	$\frac{12.32}{38.28}$	$\frac{54.07}{33.45}$	$\frac{92.51}{36.36}$	20.62	38.14	69.02	24.93	44.95	11.07	60.70	0.69
T_{23}	$\frac{8.32}{32.18}$	$\frac{54.30}{38.71}$	$\frac{96.04}{51.49}$	15.59	28.71	74.56	29.31	67.91	6.26	46.39	1.23

It can be seen from Table 2 that there are more content of microaggregate >0.01mm in size than that <0.01mm in size in soils of the controls, especially in CK_{10}, indicating the typical characteristic of severely eroded lateritic red soil. The values of dispersion degree, erosion ratio and E_{VA} were relatively high and the levels of aggregation state and aggregation degree were relatively low in the soils. Under different treatments, benefited from the good effects of vegetation, soil erosion had been controlled more or less, the values of soil dispersion degree, erosion rate and E_{VA} had been decreased obviously, and the contents of clays (<0.001mm in size) and the values of aggregate degree had been increased.

In soils of the two controls, the content of waterstable aggregate >0.25mm in size were 21.13% and 24.17%, respectively. The destroy rates of aggregate were all above 70%, and the mean weight diameters (E_{MWD}) of aggregate were all less than 0.3mm. It indicated that the aggregate structure of the severely eroded lateritic red soil was very poor. Under taking different treatments, the content of soil organic matter has been improved, the total content of >1mm waterstable aggregate and E_{MWD} has been improved, the destroyed rate of ped has been decreased, and the structure capacity has been ameliorated.

3.2 Nutrition status and humus composition

Nutrition conditions of the severely eroded lateritic red soil were very poor due to long period of erosion. Contents of organic matter, total N, total P, available nutrients, base and CEC in soils of CK_{10} and CK_{20} were very low. The soil base was highly unsaturated, and soil acidity was very high. Under different treatments, the contents of soil organic matter, total N and total P had been improved obviously. The contents of available nutrients had been increased. For instance, the contents of soil hydrolytic N in T_{12} and T_{22} were 2.08 and 2.90 times higher than those in CK_{10} and CK_{20}, respectively; the contents of available P and available K had the same tendency (Table 3). Soil nutrient conserving capacity and nutrient buffer capacity were both increased. For example, the soil cation exchange capacity and base content in T_{12} were 1.84 and 3.2 times as high as those in CK_{10}, separately, and the degree of base saturation was increased by 11.8% (Table 3). Soil pH values had been increased by 1.4—1.9 compared with those in controls.

Under different measures, the degree of humification had been improved obviously. The ratios of HA/FA were also increased. The degree of humification and the ratio of HA/FA of soils in T_{12} were 7.71 and 4.67 times as high as those in CK_{10}. It showed that the proportions of humic-C in total soil C, the molecular weights of humus, the complexicity of humin, the granulation increased, and the humus qualities were improved after adopting different harness measures [7].

Table 3 Nutrient contents and humus composition of latertic red soil under different treatments

Harness measures	Organic matter	Total-N	Total-P	Hydrolyzable N	Available P	Available K	Total amount of CEC		Percent Saturation of base (%)	pH	Humus composition		
	(g/kg)				(mg/kg)		cmol(+)/kg				HA	FA	HA/FA
CK_{10}	3.160	0.14	0.0164	19.1	0.6	29.4	2.21	0.35	15.8	4.2	0.31	10.35	0.03
T_{11}	5.890	0.23	0.0216	36.4	1.4	36.4	3.18	0.69	21.6	5.6	1.48	16.48	0.09
T_{12}	14.140	0.52	0.0236	58.9	4.2	50.6	4.06	1.12	27.6	5.9	2.39	17.10	0.14
CK_{20}	4.880	0.18	0.0112	20.4	0.3	26.4	2.02	0.34	16.7	4.3	0.79	13.14	0.06
T_{21}	11.120	0.42	0.0184	67.9	3.7	55.6	4.48	1.37	30.6	6.1	3.65	19.20	0.19
T_{22}	9.640	0.40	0.0172	79.6	2.4	57.3	4.21	1.32	31.4	6.0	3.37	18.74	0.18
T_{23}	13.340	0.46	0.0132	58.9	1.7	48.4	4.53	1.68	34.8	6.2	3.10	19.35	0.16

3.3 Amount of soil microbes

The amounts of total microorganism in soils of T_{11} and T_{12} were 3.2 and 11.9 times as high as those in CK_{10}, and those in T_{21}, T_{22} and T_{23} were 14.7, 14.0 and 18.6 times as high as those in CK_{20}, respectively. There are some differences in microflora between soils of harness measures and controls. In soils of controls, fungi dominated the total soil microbes, accounted for over 50% of the total amounts, followed by bacteria. While in soils of different measures, the proportion of bacteria increased, e.g., the proportions of bacteria in soils of T_{12} and T_{23} accounted for over 80% of the soil microbe amounts, and that of fungi decreased to below 10% (Table 4). The intensity of soil respiration of the severely eroded lateritic red soil was very weak. Under taking harness measures, soil respirations were more strengthened than those in controls, due to an increase in soil microorganism quantity and enhanced activities of roots and soil fauna. It can be Seen from Table 4 that the intensities of soil respiration in T_{11} and T_{12} were 6.6 and 10.7 times as high as that in CK_{10}, and that in T_{21},T_{22} and T_{23} were 8.8, 9.5 and 7.6 times as high as that in CK_{20}, respectively.

Table 4 The amounts of soil microbes and activities of enzymes in latertic red soils under different harness measures

Harness measures	Bacteria	Fungi	Actino-myces	Total microbes	Respiratory intensity (mg CO_2/20g soil 24hr)	Invertase Urease(0.1N $Na_2S_2O_3$ ml)	Urease (mg/g)	Acid phosphotase (mg/100g)	Catalase (0.1 N $KMnO_4$ ml/g)	Peroxidase (mg/g)
CK_{10}	17.45	53.00	10.35	80.80	0.021	0.114	0.81	0.11	11.2	6.32
T_{11}	146.60	39.56	72.40	258.56	0.138	0.344	0.92	0.23	23.5	9.88
T_{12}	787.48	53.85	120.90	962.23	0.224	0.837	1.26	0.31	38.6	12.55
CK_{20}	39.29	63.04	18.20	120.53	0.031	0.128	0.98	0.16	13.4	7.24
T_{21}	1,261.51	143.69	366.59	1,771.79	0.274	0.886	1.53	0.43	37.4	13.38
T_{22}	1,183.86	150.30	354.65	1,688.81	0.295	0.794	1.64	0.42	39.3	12.67
T_{23}	1,922.11	101.05	222.30	2,245.46	0.235	0.894	1.36	0.28	36.4	12.48

* The unit of soil microbes quantity: （10^3 / g dry soil）

3.4 Soil enzyme activity

The results showed that the activities of soil invertase and urease in different harness measures were more strengthen than controls, for example, those in T_{12} were 7.3 and 1.6 times as high as those in CK_{10}, respectively. It indicated that both invertase and urease indicated that the intensities of both C and N cycling in soil had been highly improved. Under taking harness measures, the activities of soil acidic phosphatase had been improved obviously, e.g., that in T_{12} was 2.8 times as high as that in CK_{10}, which was propitious to improve soil P availability in the lateritic red soil (Table 4). Under taking harness measures, the activities of both soil hydrogen peroxidase and peroxidase had been enhanced (Table 4). It concluded that, compared with the controls, the activities of both oxido-reductase and hydrolase in soils of harness measures were enhanced and the rates of decomposition of soil organic detritus and resynthesis of humus had been increased, indicating that soil fertility in harness measures were recovering progressively [10].

4 Discussion

4.1 Development harness: suited for controlling soil erosion

Poverty is not only the consequence of soil erosion but also the cause of accelerated soil erosion in the severely eroded lateritic red soil region in Southeastern Fujian. For a long history, the attempts on erosion controlling have been mainly focused on the conservation of soil and water resources, especially on the profits of soil and water conservation, and rarely on the economic profits. The accumulated experiences have tell us that this pattern would come to fail because that the mass could not be able to benefit from this practice to improve their lives. For example, in coastland of Fujian, there had launch a program to erosion controlling in 1950s and 1960s; whereas, by far today there only left the harness meaures of planting waxberry, longan and litchi, which were directly related to the economic profits of the mass. The others had been destroyed, and the soil erosion in this region is still very intensive.

In subtropical China, the amicable natural conditions, such as the plenty of rain and heat, the complexity of terrain, and the abundance of plant species and soil types, protect a superior position for the economical fruiters of southern subtropics to grow, such as for longan, litchi, banana, neflier, orange, waxberry, olive. These economical fruiters have a large potential market and a high economic profit, providing a base for the development harness in this region. So the development harness has the strong vitality in the coastland of Fujian and even in southern subtropical China. Though there are differences in regional economic and natural conditions, there exist regional advantages and features. Through market survey and argument, a development harness patter suited for a specific region is certainly welcomed to local farmers.

4.2 Importance of soil rehabilitation

If the ecologic degraded process includes only the vegetation retrogression, then after the elimination of external disturbance, the ecosystems would soon be rehabilitated through secondary succession, during which the vegetations could renew to be established through buried seeds, old root system and other propagation materials. Soil is one of the most important ecofactor in ecosystems. Ecological degradation is often coupled with soil erosion. Soils with low intensity of erosion can still support most part of the vegetation, and the secondary succession will still progress steadily. If soil erosion is very severe and cause severe soil degradation, the ecological degradation is irreversible and the rehabilitation of vegetation through natural processes is impossible, such as for CK_{20} in this study, though the time of planting *Masson pine* as early as in 1964, there was no difference in obvious improvement in soils compared with those of the controls.

4.3 Difficulties in soil rehabilitation

The soil conditions in such severely degraded lateritic red soil is very strict for plant grow, e.g., loss of surface soil layer (A or A+AB layer), low OM content and nutrient availabilities, seriously degraded fertility, poor soil structure and moisture condition, and deadly high surface temperature in summer. Though *Pinus massonainia* is famous for high barren and drought endurance, it grows very poor on such soils, with an average tree height of 3.27 m and an average DBH of 4.8 cm at age 28 as in CK_{20}. Conversely, under taking the harness measures of planting longan, litchi, waxberry and *Acacia auriculae formis*, soil fertility had been improved more or less and soil were in a well circle of rehabilitation. Meanwhile, we must note that soil reconstruction is a process of long period, for example, though soil fertility had been recovered to a certain extent in the 6-year-old litchi site through digging holes and fertilizing with basal manure and after manure, it is still very poor. So is even for the 28-year-old litchi and longan sites and 27-year-old waxberry site, compared with that of soils in southern subtropical rain forest (OM 48.2g/kg, total N 1.9 g/kg, total P 0.67 g/kg). Yu *et al.* (1996) also pointed out that it need a relatively long period for the OM content in soils of plantations to recover to the levels of native forests [11].

4.4 Importance of introducing leguminous plants

Few tree species can be chosen as pioneer species due to the astringent condition of severely eroded lateritic red soil except for pinus and eucalypti because for their physiology characteristics of high barren and drought endurance. But pinus and eucalypti have their own limitations in soil amelioration. While introducing leguminous plants in forests of soil and water conservation can be a good alternative to improve soil fertility. For example, soil fertility in the 6-year-old *Acacia auriculae formis* site in Zhaoan was similar to those of 28-year-old- old litchi and longan sites and that of 27-year-old waxberry sites. It not only represents the function of leguminous plants in preventing soil erosion, but also indicates the limitation of the combination of engineering measures and planting fruiters in soil rehabilitation. Therefore, in the development harness of the severely eroded lateritic red soil, the key problem is how to introduce the leguminous plants into the orchards to increase ground mulch, to further control soil erosion and ameliorate soil fertility, to improve the fruiter growth and increase the yield, and whereby to improve the synthesis benefit, not only for the ecological environments, but also for a better lives of the farmers.

References

[1] Tian Jiying. 1964. Preliminary studies on soil physical properties and antierodibility in Lianjianbian, Ziwuling. Acta Pedologica Sinica, **12**(3): 280-296.

[2] Xu Guanghui. 1986. Handbook on mensurations of soil microbes. Beijing: Agriculture Press, pp102-228.

[3] Zheng H.Y., Zhou L.K and Zhang D.S. (Trans.); Ф.Х. Хазиев (ed.). 1980. ФЕРМЕНТИВНАЯ АКТИВНОСТЬ ПОЧВ. Science Press. Beijing. pp. 13-114.

[4] Institute of Soil Science , Chinese Academy of Sciences. 1978. Analytical Methods of Soil Physical and Chemical Properties. Shanghai Science and Technology Publishing House, Shanghai. pp. 137-456.

[5] Gao Weisheng. 1991. Regularity of soil antierodibility in forest land of mountainous loess region. Journal of Northwest Forestry College, **6**(3): 70-78.

[6] Yang Yusheng. 1992. Effects of different untilization manners on the antierodibility of purple soil. Journal of Soil and Water Conservation, **6**(3): 52-58.

[7] Yang Yusheng, He Zongming, Lin Guangyao and Luo Xuesheng. 1996. Effect of different control model on antierodibiloty of seriously deteriorated red soil. Journal of Soil Erosion and Soil and Water Conservation, **2**(2): 32-37.

[8] Yang Yusheng, He Zongming, Chen Guangshui. 1999. Effects of different biological harness measures on the antierodibility of lateritic red soil. Acta Pedologica Sinica, **36**(4): 528-535.

[9] Yang Yusheng, Chen Guangshui, Peng Jiacai and Qiu Renhui. 1999. The change in soil antierodibility in different Chinese fir Rotations. Journal of Mountain Science, **17**(2): 163-167.

[10] Yang Yusheng, He Zongming, Lin Guangyao and Yang Xuezhen. 1998. Effects of different harness measures on lateritic red soil fertility in Southeast coast of Fujian. Acta Phytoecologica Sinica, **22**(3): 281-288.

[11] Yu Zuoyue， Peng Shaoling. 1996. The study of vegetation restoration ecology of degraded ecosystem in tropics and subtropics. Guangzhou: Science Press of Guangdong.