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An evaluation of the initial stages of natural succession on abandoned land in mountain areas

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Abstract When the cultivation of slope land ceased for three years, the plant communities changed from a primarily annual and perennial herb community to one of perennial herbs and shrubs. The number of *xylophyta* species increased from 2 to 14, and the biomass increased from 1.411 to 15.830 t ha^{-1}. The mean erosion index decreased 6.4-8.6 times compared to the control plots, resulting in erosion rates 19.07 t km^{-2} $year^{-1}$ greater than the permitted amount, and decreased 30.1 times in rainstorms. The physical properties of the abandoned soil benefit from increased permeability, and soil nutrients are available for plant succession. The microbial numbers in the abandoned land are less than in the shrubgrass.

INTRODUCTION

The economy of the mountain areas of Guizhou is restricted because slope land accounts for 80% of the cultivated land in the middle and lower areas. It has been shown that the slope land is the main area of soil loss in mountain areas, and that it is an important source of ecological and economic problems. Cultivation of land with slopes above 25° will cease and the natural forest and grass will be gradually restored (Qian Zhengyuan, 1991; Zhao Xiejing *et al.*, 1990). Studies of the abandoned land (cf. Zhen Dahao *et al.*, 1991) have investigated the economic effects of stopping cultivation and restoring the forest, and Lu Junpei & Zeng Qingbo (1981) have made preliminary observations on the ecological consequences of "slash and burn cultivation", Zhang Dayong *et al.* (1988) have reported quantitative analyses of vegetation succession on the abandoned land of the subalpine meadows.

METHODS

In the present report, the natural succession of abandoned land on subtropical purple soils is evaluated. The experimental areas are located along the Banqiao River of Dejiang County, in the northeast region of Guizhou Province. The

climate is subtropical and humid temperate monsoon. The average annual precipitation is 1180 mm, the relative humidity averages 81% and the average temperature is 16°C.

The area of the abandoned land that ceased to be cultivated in 1989 is 0.3 ha. It is surrounded by shrub-grassland and has a slope of 18-35° and a southerly aspect. Eight 1.0 × 1.0 m permanent plots have been set up for surveying the natural succession of plants in July and November each year. An additional two temporary plots on abandoned shrubgrass and China fir (Chinese fir) have also been set up. The plots are used to survey plant and soil conditions and to analyse the physical, chemical and microbial properties of the soils.

Individual 5.0 × 20.0 m runoff plots have been set up on the ploughed, abandoned, shrubgrass and China fir land, in 1989 (see Table 1). The conditions associated with these runoff plots are basically the same except for the vegetation cover. Shrubgrass and China fir are widely distributed over this region, and are a typical vegetation cover. Maize and soybean are cultivated on the ploughland from March to August and the land is fallow from September to February the next year. In addition, a precipitation station has been set up for measuring precipitation in this area. All the plots were contained within an area of 0.7 km^2.

Table 1 The characteristics of the runoff plots.

Runoff plot	Altitude (m)	Slope	Aspect	Soil texture	Soil depth (cm)
Ploughland	780	27°	southeast	Sand-loam	35
Abandoned	675	28°	southeast	Sand-loam	30
Shrubgrass	675	28°	southeast	Sand-loam	30
China fir	775	27°	east	Sand-loam	30

RESULTS AND ANALYSES

Plant succession on abandoned land There are two or three common weeds in the ploughlands, but the natural vegetation was restored rapidly after cultivation ceased (see Table 2). Between the first and second year after cultivation ceased, the vegetation changed from an annual and perennial herb community to one of perennial herbs and shrubs, and tree species appeared. In the first year, the plant cover amounted to 71.8% in July and litter accumulated

Table 2 Change of species numbers and coverage on abandoned land.

Survey time	*H*	Coverage (%):		Species numbers (%):				
	(cm)	Plant	Litter	Total	Annual	Perennial	Shrub	Tree
23 July 1989	42.6	71.8		14(100)	7(50)	5(36)	2(14)	
28 Nov. 1989	67.6	90.0	6.9					
18 July 1990	56.1	92.5	8.8	21(100)	4(19)	9(42)	7(34)	1(15)
30 Oct. 1990	66.1	81.3	31.9					
20 July 1991	62.2	92.9	46.9	33(100)	4(12)	15(46)	10(30)	4(12)

in the winter. In the third year, the number of plant species was 19 greater than in the first year, amounting to 33 species, and the proportion of tree species increased to 12%. The coverage of plant and litter is very important for controlling water and soil loss. The plant community three years after cultivation ceased is a typical *xerophyte heliophyte* shrubgrass. According to the surveys (see Table 3), in the third year the biomass (dry weight) was 10.2 times greater than in the first year, representing 73.9% of that of the shrubgrass and 37.1% of that of the China fir. The litter accounts for up to 57.1% of the biomass of the shrubgrass and 48.6% of the biomass of the China fir. This biomass is important for preventing surface flow, splash erosion and surface evaporation.

Table 3 The biomass (t ha^{-1}) of abandoned land in comparison to areas with shrubgrass and China fir.

Items	Abandoned land:			Shrubgrass	China fir
	First year	Second year	Third year		
Aboveground	0.903	3.361	10.108	9.772	30.616
Underground	0.508	1.857	3.296	7.406	7.064
Litter		1.152	2.426	4.248	4.990
Total	1.411	6.370	15.830	21.426	42.670

Water and soil loss from the abandoned land The average depth of runoff (R) from the ploughed plot is 2.3 times greater than that from the abandoned land, and the average erosion index (Q) of the ploughed land is 8.0, 6.4 and 8.6 times greater than that of the abandoned land, the shrubgrass and the China fir plots respectively (see Table 4). During a rainstorm which occurred on 18-19 June 1991 with a total precipitation of 89.4 mm and an intensity of 7.37 mm h^{-1}, the runoff depth from the ploughed plot was the largest of the four plots and it was 1.4 times greater than that of the abandoned plot. Soil loss from the ploughed plot was 30.1 times greater than that from the abandoned plot. Based on a soil loss tolerance of 180 t km^{-2} $year^{-1}$ (Zhu Anguo, 1985), the average erosion index of the ploughed plot is 8.9 times greater than the permissible loss, whereas on the abandoned land the soil loss is only 1.1 times greater than the permitted loss. Based on these findings, if cultivation of the slope land ceases, water and soil loss will be controlled. The reasons are that: (a) the plant cover will increase rapidly after cultivation ceases and splash erosion is restricted; (b) In the initial stages after abandoning cultivation the soil structure remains loose. Even during a rainstorm, the water can penetrate into the soil and surface flow

Table 4 Water and soil loss from runoff plots.

Runoff plots	Average loss:		Rainstorm:	
	R (mm)	Q (t km^{-2} $year^{-1}$)	R (mm)	Soil loss (g m^{-2})
Ploughed	38.75	1784.76	2.28	149.50
Abandoned	11.64	199.07	1.20	4.81
Shrubgrass	19.39	242.50	0.78	3.15
China fir	12.66	186.70	0.20	4.10

is decreased: (c) The heliophytes spread on the abandoned land and grew rapidly. Their roots formed a dense network within the upper 30 cm of the soil (see Table 5). Under the same soil conditions, the roots of the shrubgrass and China fir land penetrate deeper than those in the abandoned land, but there are less 0.1 mm (diameter) rootlets and these amounted to only 65.9% and 54.4% of the numbers on the abandoned land, respectively. Most rootlets in the soils of the abandoned land are distributed within the upper 30 cm, and they are important in preventing surface and rill erosion.

Table 5 The rootlet numbers in a 1.0 m soil profile.

Horizon	Abandoned:		Shrubgrass:		China fir:	
(cm)	$D <$ 1.0 mm	$D >$ 1.0 mm	$D <$ 1.0 mm	$D >$ 1.0 mm	$D <$ 1.0 mm	$D >$ 1.0 mm
0-10	988	46	536	84	310	47
10-20	441	13	317	36	239	56
20-30	184	7	147	22	232	33
30-40			63	10	89	14
40-50					8	4
Total	1613	66	1063	151	878	156

The physical, chemical, microbial properties of soils on abandoned land After cultivation ceases, the soil of the slope land changes in response to the vegetation recovery, but the soil still retains a few properties of the ploughed soil. The physical properties of the soil in the first year are listed in Table 6. The gravel content is 45% and considerably more than that of the shrubgrass and China fir land, because fine soil has been eroded during cultivation. Therefore the physical properties of the soils from the abandoned land differ from those of the other soils. The rapid water penetration and the greater moisture capacity of the abandoned land soils are beneficial in decreasing water and soil loss. On the other hand (see Table 7), in the first year after cultivation ceased, the chemical properties when compared with the shrubgrass demonstrate a 26.3% lower organic matter content, an equal content of easily soluble potassium, a 17.4% greater total nitrogen content, a 84.4% increase in total phosphorus, a 4033.3% increase in easily soluble phosphorus, a 282.3% increase in exchangeable calcium, a 381.8% increase in exchangeable magnesium, and a 223.7% increase in base saturation degree. Because of the application of fertilizer and manure to ploughed land, the soil nutrient content of abandoned land assists the rapid restoration of the vegetation. After cultivation ceased in the first year, the numbers of bacteria,

Table 6 The physical properties of soils on various lands.

Land	Structure	Compactness	Moisture	Gravel (%)	Maximum moisture capacity (%)	Penetration (mm min^{-1})
Abandoned	Granular	Loose	Dry	45	43.07	13.806
Shrubgrass	Granular	Moderate	Humid	37	39.25	5.353
China fir	Granular	Moderate	Humid	20	39.76	8.212

Table 7 The chemical properties of soil from abandoned land during the first year after cultivation ceased and of shrubgrass soil.

Soils	Organic matter (%)	Total nitrogen (%)	Total phosphorus (%)	Easily soluble phosphorus (ppm)	Easily soluble potassium (ppm)	Exchanged calcium (mg 100 g^{-1})	Exchanged magnesium (mg 100 g^{-1})	Base saturation degree (%)
Abandoned	1.46	0.101	0.083	24.8	80	5.62	1.59	56.04
Shrubgrass	1.98	0.086	0.045	0.6	80	1.47	0.33	17.31

actinomycetes and fungi in the abandoned land were 84.5%, 67.8% and 82.9% of those in the shrubgrass land. This is because the soils of abandoned land are dryer than those of the shrubgrass and the organic matter content is lower.

DISCUSSION

The results obtained from this study show that, under conditions of natural recovery, on a slope of 28°, the erosion index of the abandoned land was reduced from 1784.67 t km^{-2} $year^{-1}$ to 199.07 t m^{-2} $year^{-1}$. In protecting the abandoned land it is important to exclude the various activities of people and livestock, otherwise the recovery of the vegetation will be restricted, the water and soil loss will remain high and the soil nutrient content will be depleted. In the experimental area, on the basis of preliminary observations, the vegetation was seen to succeed to brush five years after cultivation ceased. If seed bearers (e.g. Masson's pine) are growing near the abandoned land, it is easy for them to colonize the land.

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