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Ecology of the rehabilitation of vegetation on tropical coastal eroded land in Guangdong, China

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Abstract—It is widely promoted that tropical forest is irreversible if it is destroyed. However, a broad - leaf mixed forest was artificially established on the barren land degraded from cutting tropical forest in Xiaoliang, China. The results of the studies in 30 years showed: (1) The tropical forest can be rehabilitated artificially after disturbance; (2) The stability of the ecosystem was led by the diversity of the organisms, and the diversity of plants was the basis of the stability of the man - made forest ecosystem; (3) The change of the forest structure led to the alternation of the function of the ecosystem. The good function occurred in the good structure; (4) The essential reason for the lowering of ground water in eucalypt forest was the removal of undergrowth and litter. Therefore, in order to elevate the hydrological effect of the forest, the litter in the forest must be protected.

Keywords: tropics; eroded land; ecology of vegetation recovery.

In 1959, the survey showed that barren land in Xiaoliang resulted from the destruction of forest and drought became the crucial limiting factor to forest rehabilitation. However, high temperature, high precipitation and high humidity were favorable to plant growth and vegetation recovery. A research on time - spatial plantation composition was implemented in the light of relationship between species, and between plant and environment. The aims were to search the effective method of reforestation and to study the inter - relationship between the diversity and stability, and the structure and function of man - made forest ecosystem.

1 The physical features of experimental area

The experimental area was situated in the coastal terrace in Dianbai County, Guangdong Province, China, where was the northern boundary of tropics, 110°54′18″ E and 21°27′49″ N. The mean annual temperature was 23℃, maximum 36.5℃, minimum 4.7℃. The annual precipitation ranged from 1400 to 1700 mm and was distributed unevenly. There was a distinct alternation of humid and dry seasons, and the duration of dry season was half a year or more.

The soil was tropical laterite derived from granite. Most of the top soil has been washed by severe erosion. The subsoil was exposed and the ground surface was bare. The fertility of such eroded soil was very low. The content of organic matter was less than 0.63%. The total nitrogen was merely 0.03%. The physical character was very bad. The content of soil moisture in 30—40 cm was below the wilting point (Tu, 1983).

The climatic climax was tropical monsoon forest. By reason of human activities, the primary forest had been destroyed entirely. The standing vegetation was the sparse tufts of low grass on the barren land. But there were still small remaining forests conserved by the villagers near the villages. According to the exploration in 1959, there were 293 species of higher plants belonging to 243 genera and 87 families. This remained forests were the suggestion and theoretical for the project of reforestation.

2 Stages and method

With the dilemma of serious erosion, poor soil and its low productivity, the only alternative was to introduce pioneer community to control erosion and improve soil. As a consequence of the fact that broad - leaf mixed forests composed of native species and having comprehensive effects could only grow on better soil, they had to be planted on the site having previous pioneer plantation. In terms of the rule of succession and structure diversity in natural forest, the experiments were divided into three stages (Yu, 1988).

2.1 Plantation of pioneer arborous communities, 1959—1973

The integrated methods of biology and engineering were used. Eucalypt and pine which were grew fast and had the abilities of drought and sterility resistance were selected to plant the pioneer forests. The aim was to improve the unfavorable environment and to create suitable conditions for other plants. The forests of *Pinus massoniana*, *Eucalyptus exserta* and *Acacia confusa* in 400 ha were planted on eroded land till 1964 in good condition (Guangdong Institute of Botany, 1976).

2.2 Plantation of mixed broad - leaf forests and economical crops, 1974—1980

After the harvest of pioneer trees the mixed broad - leaf forests have been planted. In worse habitat the legume plants having tolerance to drought and sterility were planted for the improvement of the environment. In better habitat the economic plants were selected for the purpose of utilization. The tropical crops and fruit trees were planted simultaneously (Yu, 1985).

2.3 The multi - disciplinary studies of man - made forest ecosystems, 1980—1990

Permanent plots to study the components of micro - climate, soil, hydrology, microbiology, botany, zoology, forest ecology and ecophysiology in man - made forest ecosystems were established on a barren slope, in pure eucalypt forest and in broad - leaf mixed forest on sites with similar conditions of geomorphology, geology and pedology. The biological and ecological effects of species richness and of the abundance and of species diversity, soil flora and fauna were studied simultaneously.

3 Results and discussions

3.1 The biological effects in recovery of vegetation

The animal community developed from low level to high level during the succession of plant community from simple stage to complex stage. There was close relation between plant community and animal community. For example, before 1973 pure pine forest and eucalypt forest were planted in most part of the experimental area. In this period both plant species and animal species were few. Since 1974 the broad - leaf mixed forest was cultivated and extended, the number of plant species increased and the inter - relation of living organism changed. There were three stages in the development of plant community.

3.1.1 The constraint of growth of constructive species, 1974—1978

In the early stage of the planting of broad - leaf species there was rare insect damage. With the gradual growing of the plants the insects began to attack the leaves of the plants. In some cases one kind of plant was damaged by many insect species. In the investigation of June 1976, there were more than 20 herbivorous insects in the experimental plot of 1 ha. The most sever damage was caused by *Eligma narcissus*, *Anoplophora chinensis* and *Catopsilia crocale*. The *Ailanthus malabaricus*, which was native to Xishuangbanna, Yunnan Province, was planted in 1974 and grew well in early stage, but most were killed by *Eligma narcissus* during 1976—1977. The *Chukrasia tabularis* was planted in 1974, and all the individuals grew badly in 1978 caused by the impact of *Anoplophora chinensis*.

3.1.2 The recovery of growth of plant communities, 1979—1982

During the increase of damage by insects in broad - leaf mixed forest, the carnivorous animals developed simultaneously. There were very few birds in the early stage of reforestation, but more than 20 species of birds were found in 1983, the common birds were *Pycnonotus sinensis*, *P. aurigaster* and *Parus major* (Chen, 1984). The common carnivorous vertebrate were *Rhacophorus leucomystax* and *Calotes versicolor*. The common carnivorous or parasitic insects in the mixed forest were *Vespidae*, *Sphecidae*, *Lanvaevoridae* and *Mantidae* (Xie, 1984). A good example of the biological effect was the spider, *Nephila imperialis*. This spider was found firstly in August 1978 in very low population. It became the dominant species of web spider and during 1980—1981 was the chief predator of harmful insects, e. g. butterfly, termite, cicada, moth and locust. In 1982 the biomass of this spider was 5.46 kg/ha and the insects of 36 kg/ha were predated yearly by the spiders (Liao, 1984). The secondary consumer protected the producer from the harmful insects in the forest ecosystem. The growth of *Ailanthus malabaricus* and *Chukrasia tabularis* was recovered.

3.1.3 The stabilization of plant communities from 1983

During the development of carnivorous animals, e. g. birds, frogs, lizards and spiders, the damage of insects was controlled and the plant communities were developed stably. In 1984 high population of the tree rat, *Rattus rattus slandeni* occurred. The foods of the rat were fruits, seeds, locusts, birds and lizards. The rat was both primary consumer and secondary consumer in the food web and regulated the energy flow in the ecosystem (Liao, 1985), and complicated the food web in the mixed forest (Liao, 1986).

In Fig. 1 the nutritive relationship between living organisms was shown. The simple linear structure of food chain (barren land) was transited gradually into the complex structure of food web (mixed forest). The three paths of energy flow (eucalypt forest) between producer and secondary consumer were increased to six paths. The tropical man - made forest ecosystem was transferred from the unstable juvenescence to the stable maturity (Liao, 1985).

3.2 The edaphic effects on recovery of vegetation

The nutrient of tropical soil was commonly insufficient in the conditions of high temperature and precipitation. The soil nutrient was a limit factor to the growth rate of plants and especially in eroded land. Therefore the recovery of land fertility was an important procedure in the rehabilitation of degraded ecosystems. The recovery of soil fertility was the important index for the rehabilitation of degraded ecosystem. For the investigation of the ecological effect of soil during the reforestation, the permanent sampling plots for soil survey were set up in barren land, eucalypt forest and mixed forest respectively. Periodical soil samplings had been done for the analyses of organic matter, total nitrogen, total phosphorus and available phosphorus.

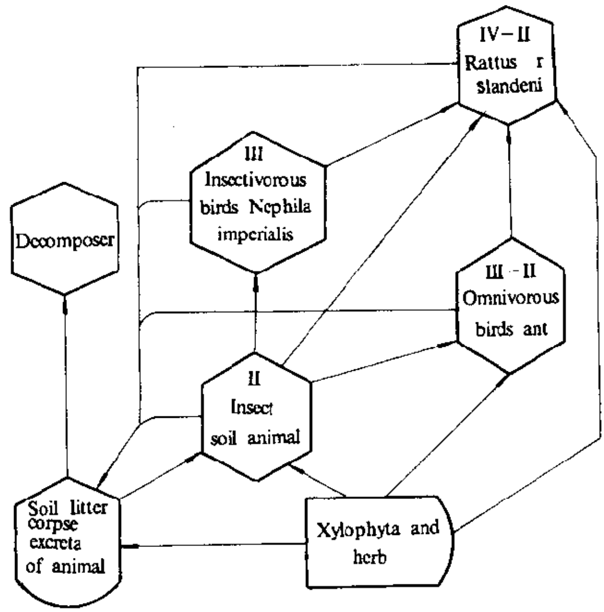

Fig. 1 A simplified model of food web

I: producers II: primary consumers III: secondary consumers IV—II & III—II: mixed consumers

3. 2. 1 The comparison of soil fertility in different vegetation

The experimental results were shown in Table 1.

Table 1 The development of soil fertility in different forest types

Vegetation		Index of soil fertility	1979 (0—15cm)	1985 (3—15cm)	1989 (0—20cm)	Increment	Annual mean litter
Bare land		Organic mat., %	0.64	0.47	0.45	—0.19	
		Total N, %	0.031	0.019	0.028	—0.003	——
		Total P, %	0.006	0.004	0.007	0.001	
Eucalypt forest		Organic mat., %	1.03	1.26	1.06	0.03	
		Total N, %	0.050	0.046	0.050	0	——
		Total P, %	0.022	0.016	0.014	—0.008	
Broad-leaf mixed forest	Non—legumes mixed forest	Organic mat., %	1.20	1.30	1.47	0.27	
		Total N, %	0.065	0.024	0.070	0.005	3.61
		Total P, %	0.010	0.018	0.017	0.007	
	Legumes mixed forest	Organic mat., %	1.30	1.32	1.82	0.52	
		Total N, %	0.068	0.060	0.099	0.031	5.47
		Total P, %	0.026	0.043	0.052	0.026	

(a) Soil erosion was occurred continually in barren land because there was no cover of vegetation and the ground surface was bare. The soil fertility decreased year by year from 1979—1981. Organic matter declined from 0.64% to 0.45%, and the total nitrogen from 0.06% to 0.028%. The soil was degraded continually.

(b) Eucalypt forest was the pioneer and an intermedium between barren land and broad-leaf mixed forest. Although the litter was moved by the local people, but the forest still reserved the soil fertility and created a better soil condition for the planting of mixed forest.

(c) The soil fertility was increased year by year in broad-leaf mixed forest. There was the best effect on soil improvement in the mixed forest dominated by leguminous plants. This forest had high diversity of species, complex structure and plentiful litter. For example, from 1979 to 1989 the organic matter was raised from 1.30% to 1.82%, the mean annual increment was 0.052%; the total nitrogen was increased from 0.068% to 0.099%, the mean annual increment was 0.003%.

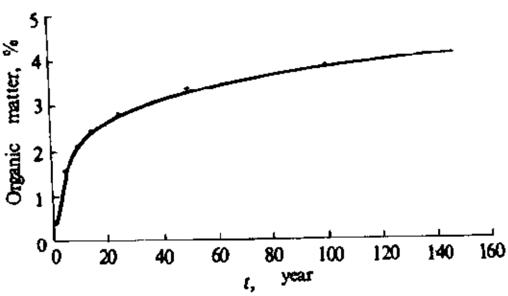

Fig. 2 The regression curve of soil organic matter against time

3.2.2 The trend and prediction of soil fertility in recovery of vegetation

Table 2 indicates that the soil fertility was improved continually and stably during the growth of the forest. For example, in the man-made mixed forest from 5 years to 25 years old, the soil organic matter was raised from 1.34% to 2.68%, the mean annual increment was 0.067%; the total nitrogen was increased from 0.076% to 0.135%, the mean annual increment was 0.003%. The following regression equation was made according to the investigation of organic matter for many years in Table 2:

$$y=0.347+0.767\ln x \quad (r = 0.976;\ df = 4),$$

where, r is the relative coefficient of 2 variables after linear measure of the data, the relation was very prominent ($r_{0.01}=0.917$). In the result of simulation in Fig. 2, it was shown that it will be needed 148 years for the restoration of soil organic matter similar to the soil of the remain natural forest.

Table 2 The trend of soil fertility in broad-leaf mixed forest

Index of soil fertility	Bare land	MMF of 5 years	MMF of 8 years	MMF of 15 years	MMF of 25 years	NSF of 100 or more years
Organic matter, %	0.64	1.34	2.07	2.40	2.68	4.18
Total N, %	0.031	0.076	0.109	0.141	0.135	0.215
Total P, %	0.006	0.012	0.020	0.033	0.022	0.054
Available P, mg/100g	Trace	0.11	0.10	0.13	0.16	0.78

Note: MMF—Man-made forest; NSF—Natural secondary forest

3.3 The hydrological effects on recovery of vegetation

Three tanks for the survey of run off were set up on the outlets of watersheds in barren land, eucalypt forest and mixed forest respectively in 1980. The area of watershed in barren land was 3.7 ha, the place was the eroded land with bare ground surface and many eroded furrows. The area of watershed on eucalypt forest was 3.8 ha, the forest was planted in 1960 and was a sprout land in the crown density of 70% after the logging in 1976 without undergrowth. The broad - leaf mixed forest of multi - layers was cultivated during 1973—1976. The crown density of the mixed forest was 70%. There were shrubs, herbs and litter under the mixed forest. The volumes of rainfall, run off and erosion were examined. The data are shown in Table 3.

Table 3 The comparison of hydrological effects in different vegetation types

Year	Bare land			Eucalypt forest			Mixed forest		
	Rainfall volume, mm	Run off volume, m^3/ha	Brosion volume of soil, t/ha	Rainfall volume, mm	Run off volume, m^3/ha	Brosion volume of soil, t/ha	Rainfall volume, mm	Run off volume, m^3/ha	Brosion volume of soil, t/ha
1983	1560	3567.43	29.36	1658	6666.18	6.30	1494	43.30	0.03
1984	1962	6022.75	44.31	2013	10041.92	12.41	2040	1728.24	0.98
1985	2369	5920.55	66.24	2415	12808.81	21.18	2431	1641.21	0.29
1986	1402	2908.05	58.85	1394	5220.64	12.00	1400	3.16	0
1987	1348	2946.17	71.04	1352	6374.56	11.29	1368	5.80	0
1988	1289	2567.11	46.11	1285	1913.77	4.29	1313	4.51	0
1989	1255	2592.88	50.23	1285	5273.37	8.03	1257	2.18	0
Total volume	11185	26524.94	366.21	11402	49299.25	75.50	11303	3428.40	1.30
Annual average	1598	3789.28	52.32	1629	7042.75	10.79	1615	489.77	0.18

3.3.1 Volume of run off

The highest volume was 7042.8 m^3/ha.a in eucalypt forest; the lesser volume was 3789.3 m^3/ha.a in barren land and the lowest volume was 489.8 m^3/ha.a in mixed forest.

3.3.2 Volume of erosion

The highest volume was 52.32 t/ha.a in barren land; the lesser volume was 10.79 t/ha.a in eucalypt forest and the lowest volume was 0.18 t/ha.a in mixed forest. In comparison to other regions, the volume of erosion was 2.22 t/ha.a in bare land and 0.05 t/ha.a in forest in Switzerland; 69 t/ha.a in bare land and 0.02 t/ha.a in forest in U.S.A.; 32.08 t/ha.a in bare land after shifting cultivation and 0.05 t/ha.a in natural tropical montane rain forest in Hainan, China (Lu, 1982). The effect of water and soil conservation in the cultivated broad - leaf mixed forest was nearly similar to the natural mixed forest.

3.3.3 Ground water

Since 1980 three cylinders were put in the outlets of the mentioned watersheds respectively.

No. 1 in the depth of 18.4 m was in the mixed forest at the site of 33.2 m above the sea level. No. 2 in the depth of 22.8 m was in the eucalypt forest at the site of 33.2 m above the sea level. No. 3 in the depth of 13.6 m was in the barren land at the site of 30.6 m above the sea level. The levels of ground water were surveyed simultaneously every five days. The data was indicated in Table 4.

(a) The variation of ground water level in a year

There was distinct seasonal variation of ground water level which was influenced by the precipitation. The level was highest from May to September during the period of typhoon and storm. The level declined in October and November. The level was lowest from December to March next year during the dryer season.

Table 4 The comparison of ground water in different vegetation types Unit: m

Vegetation		1	2	3	4	5	6	7	8	9	10	11	12	Average
Mixed forest	1980	4.15	4.68	5.01	4.14	3.92	2.11	2.29	1.87	0.10	0.43	0.98	1.93	2.64
	1981	2.74	3.39	3.89	4.08	2.88	1.24	1.75	2.13	2.20	0.25	1.34	2.23	2.34
	1982	2.81	3.64	4.01	4.19	2.81	3.04	2.73	2.21	2.67	3.24	3.91	4.32	3.30
	1983	4.37	4.14	1.81	1.06	0.93	1.13	2.27	3.02	3.37	3.60	4.25	4.81	2.90
	1984	5.12	5.26	5.52	5.05	2.95	1.78	0.10	0.09	0.48	1.51	2.46	3.20	2.79
	1985	3.77	3.95	3.68	1.47	1.67	1.28	0.73	0.51	0.07	0.72	1.34	2.19	1.78
	1986	2.89	3.39	3.69	4.11	4.05	3.59	2.37	2.55	2.90	3.44	3.54	40.9	3.38
	1987	4.59	4.96	5.17	5.22	5.33	2.91	2.79	2.11	2.59	2.66	3.36	4.03	3.81
	1988	4.57	5.00	5.23	5.45	5.09	4.60	5.03	3.12	3.36	4.24	4.44	4.56	4.56
	1989	4.81	4.92	5.36	5.40	5.10	4.20	4.39	4.18	3.90	3.34	4.08	4.81	4.54
	Av.	3.98	4.33	4.34	4.02	3.47	2.59	2.45	2.18	2.16	2.34	2.97	3.62	3.20
Eucalypt forest	1980	9.27	9.55	9.83	9.71	9.44	9.41	9.30	8.74	6.70	7.50	8.23	9.16	8.90
	1981	9.97	10.46	10.76	11.00	10.59	9.66	9.37	9.79	9.55	8.81	9.29	9.93	9.93
	1982	10.65	11.20	11.42	11.58	11.21	11.19	10.63	9.84	10.48	10.99	11.51	11.56	11.02
	1983	11.57	11.16	9.70	9.36	8.99	8.80	9.64	10.12	10.07	9.86	10.77	11.65	10.14
	1984	12.21	12.54	12.77	12.73	11.91	10.49	8.62	8.29	8.20	9.30	10.32	11.23	10.71
	1985	12.12	12.30	11.71	10.27	9.94	9.27	8.91	8.90	6.85	7.83	8.36	9.11	9.63
	1986	9.89	10.47	10.64	11.00	10.93	10.16	9.48	9.36	9.36	10.13	10.26	10.91	10.22
	1987	11.45	11.98	12.40	12.62	12.77	11.25	10.61	9.79	10.05	10.52	11.36	12.11	11.41
	1988	12.73	13.08	13.34	13.40	13.54	13.28	13.28	11.88	11.68	12.72	12.06	12.84	12.89
	1989	13.27	13.32	13.50	13.66	13.41	12.56	12.05	12.60	12.60	12.23	13.04	13.71	13.07
	Av.	11.31	11.61	11.61	11.53	11.27	10.61	10.28	9.93	9.55	9.99	10.61	11.22	10.79
Bare* land	1980	4.87	5.10	5.22	4.81	4.09	3.69	3.36	3.33	2.11	2.65	3.34	3.92	3.87
	1981	4.34	4.62	4.75	4.63	3.84	3.28	3.20	3.75	3.47	2.46	3.38	3.95	3.81
	1982	4.32	4.53	4.62	4.24	3.74	3.92	3.41	3.33	3.89	4.12	4.39	4.26	4.06
	1983	4.12	3.69	2.78	3.03	2.90	3.26	3.72	3.52	3.72	3.64	4.30	4.60	3.61
	1984	——	——	——	4.25	3.70	2.97	2.29	2.32	2.75	3.58	4.11	4.51	
	1985	——	4.16	4.04	2.77	3.13	2.95	3.21	2.62	1.86	2.76	3.23	3.82	
	1986	4.26	4.38	4.53	——	4.11	3.66	3.48	3.57	3.71	3.84	4.24	4.59	
	1987	——	——	——	——	4.32	3.37	3.28	2.98	3.51	4.05	4.48	——	
	1988	——	——	——	——	4.02	——	4.19	3.17	4.08	4.41	4.05	4.50	
	1989	——	——	——	——	4.39	4.12	4.05	3.93	3.97	4.17	——	——	
	Av.	4.41	4.49	4.34	4.18	3.64	3.54	3.42	3.48	3.30	3.22	3.85	4.18	3.84

* The data of ground water below 4.60 m have not been measured since 1984 because the tube was stopped; the average was measured from the data 1980—1983.

(b) The variation of ground water level between years was related closely to the precipitation. High ground water levels occurred in the years of plentiful rainfall. For example, the high ground water level was 1. 78m in mixed forest and 9. 63 m in eucalypt forest when the annual precipitation was 2400 mm in 1985 (Table 3); and the low ground water level was 4. 54 m in mixed forest and 13. 07 m in eucalypt forest when the annual precipitation was 1200 mm in 1989.

3. 4 The effects of temperature and humidity on recovery of vegetation

Before the recovery of vegetation, a meteorological station was set up on the barren land. Since 1980 three stations for the survey of microclimate were built on the watersheds of barren land, eucalypt forest and mixed forest respectively. The underground temperature (5, 10, 15 and 20 cm), ground surface temperature (maximum and minimum), air temperature (20, 50 and 150 cm), relative humidity (20, 50 and 150 cm), precipitation and evaporation have been explored.

3. 4. 1 The comparison of temperature before and after afforestation

1958—1959 before afforestation, the mean monthly temperature of the experimental site was higher than The Meteorological Station of Dianbai County in the distance of 13 km except January to March. 1988—1989 after afforestation, in the effect of the forest the mean monthly temperature of the site was lower than the mentioned station (Fig. 3). 1958—1989 the mean annual temperature in thirty years was 23. 2℃, and 1988—1989 in two years was 22. 6℃ with the difference of 0. 6℃. The annual amplitude of temperature was 14. 4℃ before afforestation in 1958—1959, and was 12. 2℃ after afforestation in 1988—1989 with the difference of 2. 2℃ (Table 5).

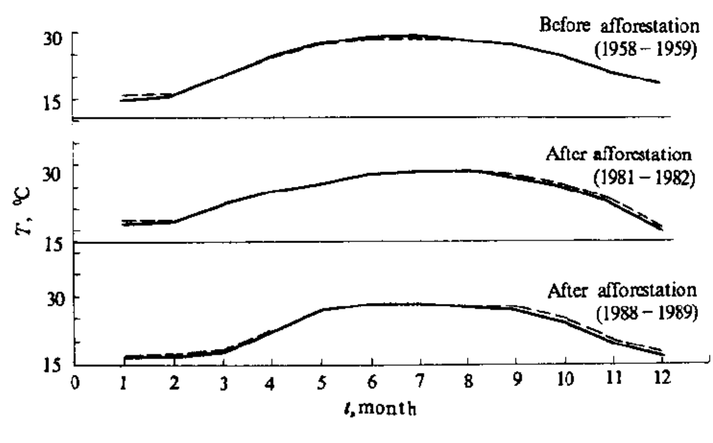

Fig. 3 The mean temperature before and after afforestation

——— the temperature in Xiaoliang Station

- - - - the temperature in Dianbai Meteorological Station

3. 4. 2 The comparison on the gradient of temperature in different vegetation types

In Table 6 the following points are shown.

(a) The gradient of mean annual temperature in mixed forest was lower than any other vegetation types. For example, the temperature at 50 cm was 22.7℃ in mixed forest, 23.0℃ in eucalypt forest and 23.5℃ in barren land.

Table 5 The mean annual temperature and its annual amplitude before and after afforestation in Xiaoliang

Stages		Annual average, ℃	Annual amplitude, ℃
Before afforestation	1958—1959	23.2	14.4
After afforestation	1981—1982	23.0	13.6
	1988—1989	22.6	12.2

Table 6 The comparison on the gradient of temperature in different types of vegetation (1981—1989) **Unit: ℃**

Types	Gradient, cm	1	2	3	4	5	6	7	8	9	10	11	12	Annual average	Annual amplitude
Barren land	150	15.6	16.3	18.9	22.8	26.3	28.0	28.6	28.3	27.3	25.0	20.9	16.4	22.9	13.0
	50	16.2	16.8	19.4	23.3	26.9	28.7	29.3	29.0	28.1	25.8	21.7	17.1	23.5	13.1
	20	16.3	16.9	19.5	23.5	27.0	28.8	29.6	29.2	28.5	26.0	21.9	17.2	23.7	13.3
Eucalypt forest	150	15.7	16.5	19.1	22.9	26.3	27.9	28.5	28.1	27.2	24.9	20.9	16.3	22.9	12.8
	50	15.8	16.5	19.2	23.2	26.4	28.1	28.8	28.3	27.3	25.0	21.0	16.4	23.0	13.0
	20	15.8	16.6	19.2	23.2	26.5	28.2	28.9	28.4	27.4	25.0	21.0	16.4	23.1	13.1
Mixed forest	150	15.6	16.4	19.0	22.9	26.4	28.0	28.6	28.1	27.0	24.6	20.6	16.0	22.8	13.0
	50	15.6	16.4	19.1	22.9	26.3	27.9	28.4	27.9	26.9	24.6	20.5	15.9	22.7	12.8
	20	15.8	16.7	19.4	23.3	26.7	28.3	28.7	28.2	27.2	24.9	20.7	16.2	23.0	12.9

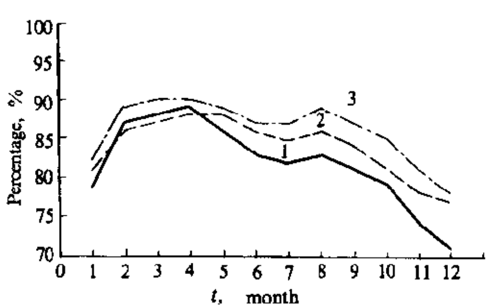

Fig. 4 The comparison of relative humidity in different vegetation types (150 cm)
1: bare land 2: eucalypt forest 3: mixed forest

(b) The gradient of temperature in every vegetation type was declined during the increasing of height from 20 cm to 150 cm. The biggest amplitude was 0.8℃ in barren land and the smallest one was 0.2℃ in mixed forest.

(c) The order of the annual amplitude of temperature in the vegetation types was barren land > eucalypt forest > mixed forest.

3.4.3 The comparison of relative humidity in different vegetation types

According to the data of 1981—1989, the order of mean annual relative humidity was 86% in mixed forest > 84% in eucalypt forest > 82% in barren land. In Fig. 4 the highest mean monthly relative humidity was 88%—90% at April in all vegetation types and the lowest one was 71%—78% in December.

4 Conclusions

On the whole, the rehabilitation of forest vegetation was initiated from the barren land transited by the pure forest of *Eucalyptus exserta* and achieved in the broad - leaf mixed forest of several storeys and many species. During the succession of the plant communities, the complex food web occurred and the environmental condition was improved gradually. The ecosystem was changed from the unstable phase to the stable stage. During the experiment of thirty years the conclusions were indicated as follows:

4.1 In the rule of the succession of vegetation, the tropical forest can be rehabilitated after it has been destroyed. Hundred years ago the experimental region was covered with natural tropical monsoon forest. With the impacts of men the virgin forest had been disappeared. Therefore, the small remain natural forests protected by men near the villages were the sample for the rehabilitation of forest vegetation in the project. In the final stage of the experiment, the man - made broad - leaf mixed forest, which was composed of 320 species of plant and had several storeys, has been achieved. The floristic composition and structure of the mixed forest was similar to the mentioned sample (Liao, 1985). According to the estimation it will be needed 148 years for the restoration of soil organic matter similar to the soil of the remain natural forest.

4.2 The stability of the ecosystem was led by the diversity of the creature

The diversity of the creature of the tropical man - made forest in Xiaoliang was initiated by the diversity of plant. The diversity of floristic composition and structure contributed the feeding and living place to insects, birds and mammals, so the diversity of animal was promoted. On the other hand, the organic matter in the soil was enriched by the forest litter and root secretion , then, the suitable condition for the development of soil animals and soil microorganisms was created, and the diversity of soil creature was achieved (Yu, 1988; Liao, 1984; Insam, 1990). A complex food web both above and under ground in the forest was formed after the occurrence of the diversity of the creature, and the stability of the ecosystem was led finally.

4.3 The high function was based on the rational structure of the ecosystem

In the succession of the man - made forest in Xiaoliang, the structure of the ecosystem was transited from simple to complex. The function of the ecosystem was enhanced in the change of the structure. For example, the structure of the eucalypt forest was very simple which was a pure forest of only one tree storey dominated by *Eucalyptus exserta*; the structure of the mixed forest was more complex and constructed by the storeys of tree, shrub and herb, which was composed of 320 plant species. The function of water and soil conservation was different in these forests which had different structures. The mean annual run off in eucalypt forest was 7042.75 m^3/ha.a and was merely 489.77 m^3/ha.a in mixed forest; the mean annual loss of soil was 10.79 t/ha.a in the former and 0.18 t/ha.a in the latter. It was clear that the changes of input, storage and output in the ecosystem was caused by the transformation of the structure of the forest.

4.4 Besides some other reasons, the removing of the litter by the local people was the chief cause for the lowering of ground water in eucalypt forest. Therefore, in order to raise the effect of water and soil conservation and the improvement of soil by the forest, it is necessary to protect the undergrowth and litter of the forest.

References

Chen Maoqian, Liao Chonghui. Tropical and Subtropical Forest Ecosystem, 1984; 2:202

Guangdong Institute of Botany. The vegetation of Guangdong. The Sciences Press, 1976

Huang Luji, Li Guoshen, Zhan Shaoxian, Yu Zuoyue. Tropical and Subtropical Forest Ecosystem, 1984; 2:114

Insam H, Gabriele Walenzik, Vera Weihs, Domsch KH, Yang Jiacheng. Tropical and Subtropical Forest Ecosystem, 1990; 6:135

Laboratory of Geobotany, Guangdong Institute of Botany. Acta Botanica, 1977; 19(3):182

Liao Chonghui, Chen Maoqian. Tropical and Subtropical Forest Ecosystem, 1984; 2:190

Liao Chonghui, Chen Maoqian, Xie Yingshu. Tropical and Subtropical Forest Ecosystem, 1984; 2:214

Liao Chonghui. Tropical and Subtropical Forest Ecosystem, 1985; 3:139

Liao Chonghui, Chen Maoqian. Tropical and Subtropical Forest Ecosystem, 1986; 4:93

Lu Junpei, Li Yanmin. Sciences and Technology in Tropical Forestry, 1982; 1:13

Tu Mengzhao, Yao Wenhua. Acta Botanica Austro Sinica, 1983; 1:95

Yao Qingyin, Zheng Liangwen, Huang Shaohui. Tropical and Subtropical Forest Ecosystem, 1984; 2:91

Yi Weimin, Ding Mingmao, Liao Lanyu, Chen Taixiong. Tropical and Subtropical Forest Ecosystem, 1984; 2:59

Yu Zuoyue, Pi Yongfeng. Tropical and Subtropical Forest Ecosystem, 1985; 3:97

Yu Zuoyue, Wang Zhuhao. Proceedings of Regional Workshop on Ecodevelopment Process for Degraded Land Resources in Southeast Asia, 1988:1

Xie Yingshu, Liao Chonghui. Tropical and Subtropical Forest Ecosystem, 1984; 2:173

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