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The method on recovery of forest vegetation in degraded ecosystem in tropical and subtropical waste lowland in Guangdong

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Abstract—The aim of this paper is to discuss the reasonable method to set up the man-made ecosystem where the high productivity, high economic effects and ecological efficiencies, continual resources and suitable environment could be obtained.

Keywords: forest vegetation; degraded ecosystem; tropical waste lowland; South China.

INTRODUCTION

During the fast increase of population in the world, the economy is also developing quickly, people need richer resource and a more stable environment from nature. But some changes of ecological environment in big regions are occurring in the world for example deforestation of great area in the tropics, global degradation of land resource, global change in climate and the decrease of species. The appearance of global ecological problems may shake the basis of survival of mankind and may shadow the continual development of human economy. People will be afraid to foresee the situation of the world. "The Globe in 2000" was a report to the president of USA, the author indicated: "If the status is continued, in the year 2000 the world will be more crowded, polluted and more unstable in ecology. The heavy pressure of population, resource and environment will be more and more prominent. Although the substance and production are richer, there will be more poverty in many cases (Fransisco, 1985)."

Four pilot projects were focused to solve such problems in UNESCO, MAB program in recent decades.

1. Tropical humid and semi-humid regions where two billion people are living and with the pressure of shortage of energy.

2. Arid and semi-arid region and its marginal area where the problem of drought is rigorous day after day.

3. City ecosystem where the population in concentrated.

4. Problems of natural conservation.

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METHOD ON RECOVERY OF VEGETATION IN TROPICAL COASTAL ERODED AREAS

Since 1959, South China Institute of Botany, Academia Sinica cooperated with Xiaoliang Station of Water and Soil Conservation, Dianbai, Guangdong, on the project "Recovery of Vegetation" in the severe eroded areas. The aim of the project was to seek an available method to recover the tropical man-made forest vegetation and to study the inter-relationship between the diversity and stability of man-made plant communities.

Physical features of experimental plot

The experimental plot is situated in the terrace in Dianbai County, Guangdong Province where is the northern boundary of tropics, 110°54'18"E and 21°27'49"N(Fig. 1). The zonal soil is laterite. The climax is tropical monsoon forest. In the long-term influence of men activities, there is no more virgin forest. The history of soil erosion was more than hundred years. The average loss of surface soil is 1cm depth. 10000m^3 soil is removed per km^2 per year. The content of organic matter in soil declines from 4.0% to 0.6%. The degradation of environment has occurred.

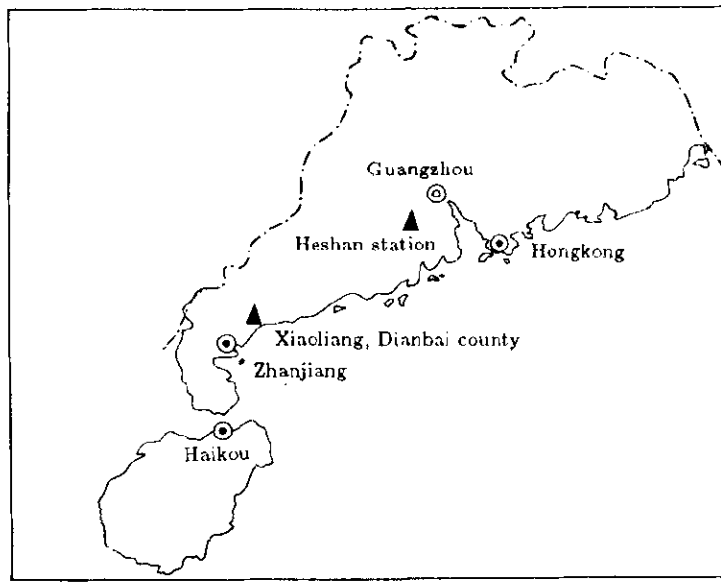


Fig. 1 The geographic Situation of Xiaoliang Station of Water and Soil Conservation & Heshan Downland Interdisciplinary Experimental Station, Academia Sinica

Climate

According to the data of the station from 1958 to 1965, the mean annual temperature is 23°C, maximum 36.5°C, minimum 4.7°C, annual range of temperature is 13.4°C. There are nine months in which the mean monthly temperature are above 18°C. On the whole, the condition

of temperature is suitable for the growth of plants. Owing to the bare surface of soil and the strong solar radiation, the range of variation in temperature 50cm above ground surface, may be more than 23°C. The maximum temperature on the ground surface may reach 55°C (Fig. 2). Such high temperature will cause burning of seedlings and decline the rate of survival in reforestation. The annual precipitation ranges from 1400 mm to 1700 mm and is distributed unevenly. The rain is concentrated from May to September, it is 75.8% of the total amount, the rain from October to next April is 24.2% in a year. There is distinct alternation of humid and dry seasons, and the duration of dry season is six months or more. The forms of rain are commonly downpour or rainstorm (rain in typhoon). The daily rainfall is high. Severe soil erosion occurred on the bare ground surface. For example, the rainfall in 22–23 June 1965 was 149.8mm. On 1000m^2 watershed in barren land, the total amount of runoff was 128.5m^3, the ratio of runoff was 85.8% and the earth washed out was 278.36 kg. In Table 1, the correlation between the amount of soil erosion and the intensity of rain is shown. Because large amount of rain is lost by runoff, drought could appear after rain. So there is a local idiom: "Little drought occurred in three rainless day, but big one in ten".

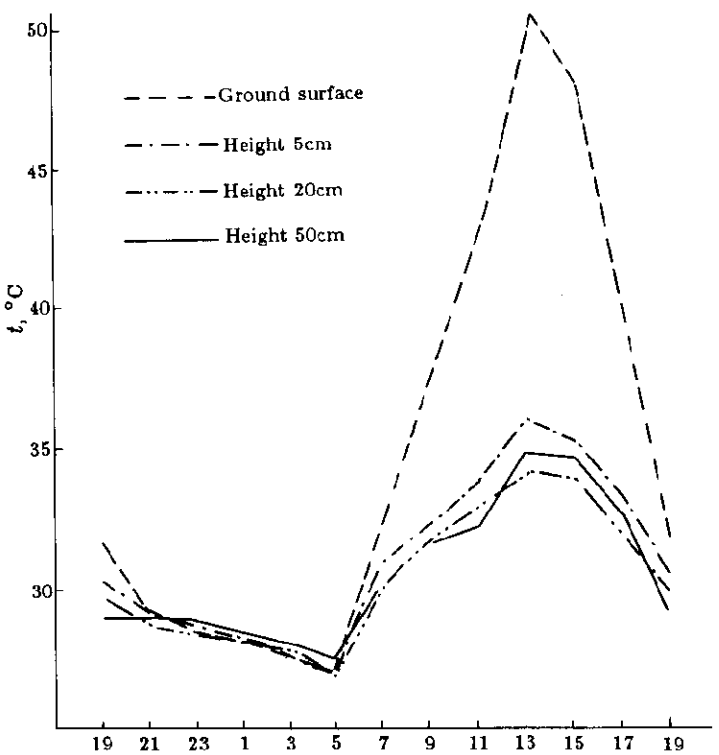


Fig. 2 Gradient variation of temperature on ES slope of barren land in Xiaoliang

Table 1 The content of eroded soil in the barren hill (May–August 1960)

Date, DD/MM	Precipitation, mm	Duration of rain, hour: minute	Intensity of rain, mm/h	Content of eroded soil, kg/ha
5/5	22.8	0:58	23.6	324.0
6/5	48.3	2:25	20.0	157.0
29/7	41.1	2:00	20.6	893.0
18/8	9.1	0:20	27.3	25.0
19/8	8.5	0:25	20.3	124.5
22/8	11.2	0:28	23.9	56.6
24/8	23.0	0:49	28.1	745.0
25/8	10.4	1:18	8.0	36.2

Soil

The soil is tropical laterite derived from granite. Most of the top soil has been washed by severe erosion. The depth of eroded top soil is above 100cm. The recent top soil is exactly the b layer former forest soil and is mostly semi-weathering layer. The subsoil is exposed. Most ground surface are bare and covered by ferro-manganese nuclei and quartz sand. The amount of humus and nutrient are very low in such eroded soil (Table 2). The physical character of this soil is very bad (Table 3), for example, low porosity, tight structure, rare capillarity and low water-holding capacity. The soil is very dry, even in the rainy season the content of soil moisture in 30–40cm is below the wilting point (Tu, 1983). It is unfavorable for the growth of plant and the recovery of forest vegetation on this soil.

Table 2 Content of humus and total nitrogen of eroded soil

Depth, cm	Bare land Humus, %	Bare land Nitrogen, %	Depth, cm	Secondary natural forest Humus, %	Secondary natural forest Nitrogen, %
0–7	0.63	0.03	1–7	4.14	0.212
30–40	0.37	—	10–20	2.09	0.120
100–110	0.35	—	35–45	1.55	0.078
			60–70	1.06	0.043

Vegetation

There was dense forest hundred years ago. But the primary forest has disappeared caused by long term activities of man. The standing vegetation is the sparse tufts of low grass on the barren land. The common grasses and herbs are *Eriachne pallescens, Aristida chinensis, Evolvulus alsinoides* and *Phyllanthus cochinchinensis, Clerodendrum fortunatum, Breynia fruticosa* and *Aporosa chinensis*. It is not easy to reforest in such poor vegetation. On the contrary, a small remaining forest conserved by the villagers near the experimental plot has been explored in 1959. There were 293 species of higher plants belonging to 243 genera and 87 families in this

forest which had 95 species of trees, 81 shrubs and 22 herbs. This remained forest was a model for the project on reforestation.

Table 3 The physical character of eroded soil

Depth, cm	Volume weight, g/cm^2	Maximum capillary moisture -holding capacity, %	Saturated moisture, %	Capillary porosity, %
0–10	2.11	18.40	18.66	38.82
10–20	2.08	16.90	17.24	35.15
20–30	2.04	17.13	17.40	34.95
30–40	2.03	20.11	20.41	40.82
40–50	1.94	21.32	21.13	41.36
50–60	1.93	21.60	21.84	30.98
60–70	1.87	24.67	25.09	46.13
70–80	1.82	26.35	26.63	47.96

Non-capillary porosity, %	Total porosity, %	Maximum moisture absorbing power, %	Wilting moisture content, %
0.55	39.37	4.46	9.68
0.71	35.86	—	—
0.55	35.50	—	—
0.61	41.43	6.42	9.65
0	41.36	—	—
0.46	31.35	—	—
0.79	46.92	5.46	8.18
0.51	48.47	—	—

Stages and method

The project on plant introduction and community designation, was referred to the rule of succession, composition of natural forest and character of structure. The experiment was arranged in three stages.

(1) Plantation of pioneer arborous communities

Eucalyptus and *pine* which are fast growing and have the abilities of drought and sterility resistance were selected, to plant the pioneer forests. The aim was the improvement of the unfavorable environment and creation of suitable conditions for other plants. The seedlings were densely transplanted in turfs from good nursery. *Pinus massoniana, Eucalyptus exserta* and *Acacia confusa* were planted in 400 ha from 1959 to 1964. They grew well in the early years, but the increment declined gradually after 8–10 years. The reason was, the pure stand was simple in composition and structure. In addition, the litter on the forest floor was taken

away by the villagers for fuel, therefore, the ground was still bare, and the soil erosion was still uncontrolled (GIB., 1977).

(2) Plantation of broad-leaf mixed forest of several storeys and species

Since 1973, the broad-leaf mixed forest has been planted after the harvest of pioneer trees. 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. In the combination of species for the construction of mixed forest, it was necessary to pay attention to the relation between sun plant and shade plant, deep root system and shallow root system, fast growing and slow growing, evergreen and deciduous, and legume and nonlegume. For the success on plantation of mixed forest on barren land, the nutritive cube for seedling, larger hole for transplantation and organic fertilizer have been used. The conservation of the young forest and the preservation of litter on the forest ground were also significant.

(3) Plantation of economic crops and fruit trees

After the environment has been improved by pioneer forest and mixed forest, the crops and fruit trees, for example, *Piper nigrum, Livistona chinensis, Litchi chinensis, Carica papaya, Averrhoa carambola, Artocarpus heterophyllus, Cocos nucifera* could be grown. A combination of conservation forest, fuel forest, timber forest and orchard has been established in the experimental plot.

Since 1980, the studies on man-made forest ecosystem was started. The biological and ecological efficiencies of the forests were surveyed. The comparison of climate, soil, hydrology, plant, animal, insect, soil animal and soil microbe in the barren land, pioneer forest and mixed forest has been studied simultaneously. Three small experimental water sheds, 0.037km^2 in barren land, 0.037km^2 in eucalyptus forest and 0.064km^2 in mixed forest, were built for the above surveys.

RESULTS

In 30 years, some fast growing plants which were suitable for growing in barren land have been screened, a sample of man-made mixed forest has been planted in 433 ha, the method and stages on the recovery of forest vegetation in waste area has been found (Yu, 1985). The results of the experiment are shown in Table 4.

1. Biological effects

The animal communities and microbe communities were succeeded from simple to complex during the succession of plant communities from barren land, pioneer forest to mixed forest. Before 1973, there were only pure stands of pine forest and eucalyptus forest, and the animal species was few. In 1974–1980, the area of mixed forest was increased from 1 ha to 20 ha, the plant species were raised from 10 to 320, the animal and microbe were in the similar conditions (Chen, 1984; Xie, 1984; Liao, 1984; Yi, 1984). The initial simple food chain was becoming a

more complex food web. Therefore, the basis of the stability of the man-made forest ecosystem was the diversity of the plant community.

Table 4 The comparison of biological and ecological effects in different vegetation types

Biological and ecological effects			Barren hill	*Eucalyptus* forest	Broad-leaf mixed forest
Biological groups	Plants	Higher plants	10	20	320
	Animals	Insects, estimated species	50	100	300
		Birds, number	93	22	144
		Soil animals, number/m^2	16	12	33
		Biomass of soil, animals, g/m^2	1.3171	6.2924	72.1763
	Soil microbe	Bacillus, mill./g	0.01	0.24	1.06
		Fungi, mill./g	0.29	1.96	0.65
		Actinomycetes, mill./g	0.06	1.35	3.03
Ecological environment	Climate	Annual temperature fluctuation, °C	14.3	14.0	13.0
		Relative humidity, %	83.2	85.5	87.3
	Soil	Organic matter, %	0.06	0.76	1.13
		pH, H_2O	4.5	4.9	5.7
	Hydrology	Annual loss of soil per unit area, kg/ha	19897.5	5677.5	3.0
		Soil moisture* content, %	9.8	11.9	13.2
		Depth of ground water, m	3–5	9–11	1–4

* Content of soil moisture in the 10 cm depth (January, 1982)

2. Ecological and environmental effects

The conditions of micro-climate, soil and water have been improved.

(1) Decrease in annual fluctuation range of temperature from 14.3°C in barren land to 13.0°C in mixed forest. Increase in relative humidity from 83.2% to 87.3% (Huang, 1984);

(2) Increase in soil organic matter from 0.06% in barren land to 1.70% in mixed forest, and pH from 4.5 to 5.7 (Tu, 1984);

(3) Decrease in amount of earth by runoff from 19897 kg/ha in barren land to 3 kg/ha in mixed forest (Yao, 1984);

(4) Increase in content of soil moisture in 10 cm depth from 9.8% in barren land to 13.2% in mixed forest (Fig. 3);

(5) Raise in ground water from 3–5m in barren land to 1–4m in mixed forest (Fig. 4).

3. Economic and social effects

During the experiment, the income of the station was increased from year to year, for example, 18440 yuan in 1960, 92521 yuan in 1970, 159240 yuan in 1980 and 188420 yuan in 1983. In 1987 the total income of production in the station was 2193967 yuan and the fixed capital was 1880000 yuan. In recent years, a sample on control and management of soil erosion and reforestation has been set up for the similar regions in the province. In Dianbai County, 369 km^2 of eroded area was controlled and improved. The annual production of rice was increased from 6.67 kg/ha to 40 kg/ha.

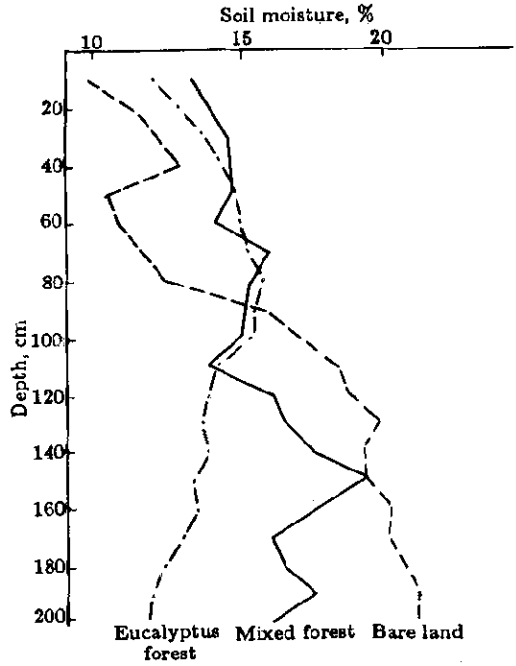


Fig. 3 The gradient variation of soil moisture in different forests (January, 1982)

CONCLUSION

In the above results, it was indicated that it is possible to reforest after the destruction of tropical forest, and the following points should be considered:

In the reforestation on barren land, two stages could be adopted: the pioneer forest and the mixed forest.

It was possible to plant a renewable man-made forest by planting legume trees which had the ability of nitrogen fixation. Since 1973, 75 species of legume plants have been planted, most of them showing such ability.

The diversity of tree species and types of forest was the basis for the resistance and stability of the man-made forest ecosystem. In the mono-culture of pine forest it was damaged severely

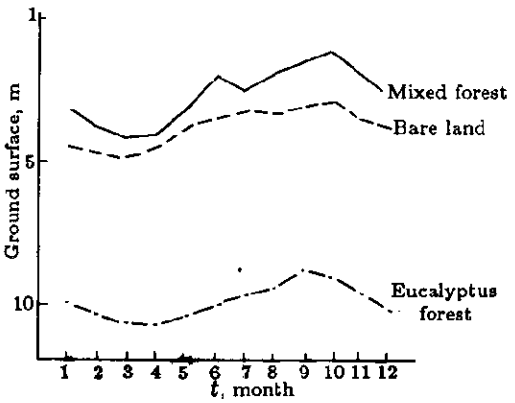


Fig. 4 The comparison of the depth of ground water in different forest (mean of 3 years)

by the insect pest. On the contrary, in 20 ha of mixed forest composed of 300 species, there was more complex food web and the damage from insect and disease was rare (Liao, 1985).

The construction of man-made forest of several species and storeys was effectuated for the utilization of solar energy and land resource and for the increase of productivity and economic efficiency. For example, the total amount of photosynthesis in the mixed forest of three storeys composed of *Aphanamixes polystachya, Calamus tetradactylus* and *Alpinia ozyphylla* was twice that of the mono-storey forest of *Aphanamixis polystachya* (Deng, 1985).

RECOVERY OF VEGETATION AND MODEL OF ECO-AGRICULTURE IN WASTE LOWLAND IN THE LOWER SUBTROPICS

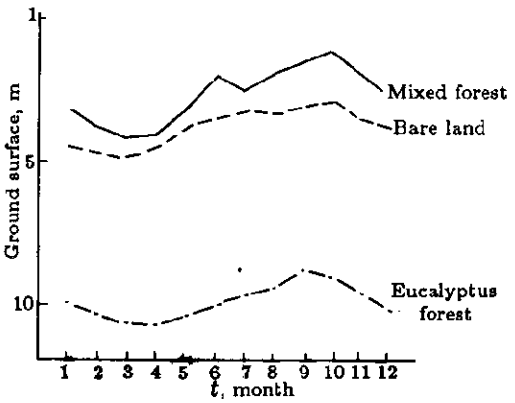
For the extension of the result and experience in above project, since 1984, He Shan Lowland Interdisciplinary Experimental Station, Academia Sinica was established and cooperated by South China Institute of Botany, Academia Sinica and He Shan Institute of Forestry. The project on "Recovery of vegetation and model of eco-agriculture in waste lowland in lower subtropics" was started. The aim was to set up a rational model having ecological, economic and social efficiencies for the utilization of land resource.

Physical features of experimental plot

The experimental plot in He Shan County, Guangdong Province is situated in the lower subtropics, 112°55'E and 22°40'N, 75 km from SW Guangzhou. It is an agricultural region of dense population and insufficiency of fuel, fodder and fertilizer.

1. Climate

It is warm, rainy and without snow in this area. The mean annual frostless season is 354 days. There is occasionally light frost in winter. The mean annual temperature is 21.7°C. The mean monthly temperature in the warmest month is 29.2°C and in the coldest month, 12.6°C. The mean annual hours of sunshine are 1797.8 hr. The mean annual solar radiation



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is 104.08 kcal/cm^2. The annual effective temperature summation 10°C is 7500–8000°C. The annual precipitation is 1990mm. There is distinct alternation of humid and dry seasons. The annual evaporation is 1679mm.

2. Soil

The soil is reddish red earth and is intermediate between laterite and red earth. Two subtypes of soil, reddish red earth derived from sandy shale on the slope and sandy earth on the ravine, are distinguished. The depth of organic matter of soil on the slope is not similar in different elevation, direction and declamation of the slope, it is thicker in shady slope and lower slope. The content of organic matter of soil in 70cm depth in a remain natural forest is 1.16–2.48%, but merely 0.56–1.64% in the waste land (Table 5). The activity of soil enzyme is low (Table 6). The amount of soil microbe is 2 million/g dry soil (Table 7).

Table 5 Chemical elements of soil in lowland experimental plot

Vegetation	Depth, m	pH, (H_2O)	Organic, %	Total N N%	Total P, P%	Available P, mg/100g	Quickly available, mg/100g
Secondary forest by village	1–3	4.4	2.48	0.122	0.038	Trace	6.4
	5–12	4.5	1.62	0.078	0.030	Trace	4.2
	15–30	4.7	1.16	0.048	0.028	Trace	2.8
	35–60	4.8	1.17	0.047	0.026	Trace	2.6
	70–100	5.0	0.78	0.034	0.031	Trace	2.6
Subtrop. grassland	5–15	4.5	1.64	0.066	0.016	0	4.4
	22-28	4.6	1.01	0.038	0.018	0	2.8
	35–50	4.8	0.64	0.035	0.020	Trace	3.1
	80-	5.0	0.56	0.028	0.022	Trace	1.5

Table 6 Activity of soil enzyme in lowland experimental plot

Item	Top	Middle slope	Bottom
Activity of urea enzyme, μg NH_3-N/g dry soil 48hr	780	880	920
Activity of reverse enzyme μg NH_3-N/g dry soil 48hr	850	820	780
Activity of contact enzyme μg NH_3-N/g dry soil 48hr	1.45	1.54	1.80
pH	4.37	4.38	4.41

Table 7 Amount of soil microbe in lowland experimental plot

Item	Result, million/g dry soil
Total amount	1.8–2.4
Bacteria	20.6–71.4
Fungi	9.4–25.7
Actinomycetes	10.3–67.2

3. Vegetation

In history, the climax plant community in the region was subtropical monsoon evergreen broad-leaf forest. Due to disturbance by activities of man, at present, the vegetation has reverted to grassland with sparse pine, over a large area. The common species on upper slopes are *Baeckea frutescens* and *Eriachne pallescens* and on lower slopes, *Rhodomyrtus tomentosa* and *Dicranopteris linearis*. Soil erosion occurred occasionally in the upper hill slopes.

Design of the ecological project

The principles on the design of the ecological project are the increase of the rate of utilization of solar energy and land resource, the increase of activity in nitrogen fixation, the promotion of the cycle and renewal of nutrient in the system, the rise of agricultural production, and the decrease of input on fuel, fodder, fertilizer and other raw materials. The aim of the project is to establish a rational model of eco-agriculture having the synthetic effects of ecology, environmental conservation, renewal of energy and economy.

In the utilization of barren hill, legume trees are planted at the top of the hill; mixed broad-leaf trees are grown in the middle part of the slope; fruit trees are cultivated in the lower slope; fishes are reared in the pond and reservoir.

For the purpose of raising the efficiency of solar energy, man-made forest of several storeys is planted, sun plants are planted in the upper tree storey; shade tolerant trees in the lower tree storey, and shade herbs in the undergrowth.

Set up the link of food chain from plant cultivation, animal husbandry, poultry farming and fish culture.

For the goal to encourage the nitrogen cycle in the soil and to enrich the soil fertility, many legume plants with the ability of nitrogen fixation are planted (Table 8).

Table 8 Amount of nitrogen fixing in legume plants

Tree species	Annual amount, kg/ha
Acacia auriculaeformis	13.6
Acacia mangium	93.2–298.1

The experimental plot is designed according to the following proportion: forest 70%, farmland 20% and pond 10%. There are recently forest 100ha, 75%; orchard 18.7 ha, 14%; nursery 3.4 ha, 2.5%; pasture 1.4 ha, 1%, pond and reservoir 8 ha, 6% in the total area of 143 ha.

Subject

Studies on plant introduction and design of community. The aim is to enrich the plant resources and biomass in the region. The following contents would be surveyed.

The growth, development and adaptation of plants; the rate of photosynthesis and productivity of plants; the transevaporation and water balance of plants; nitrogen fixation and soil improvement of plants.

Studies on rational model of structure in eco-economy. The aim is to solve the problems

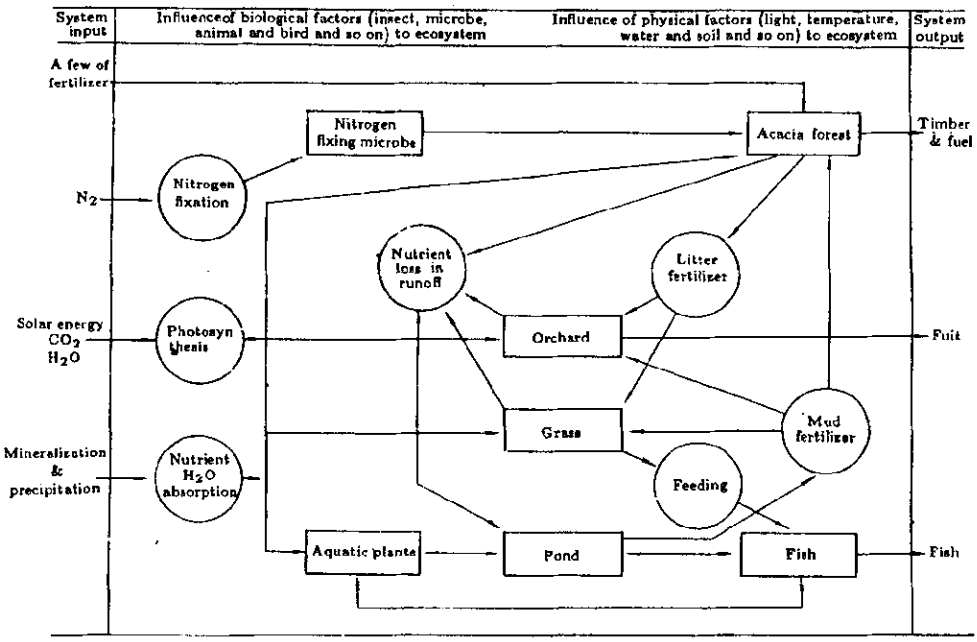

Fig. 5 Diagram on energy flow and substance flow in forest, orchard and fish pond complex ecosystem in lower subtropical downland in Heshan County

of water and fertilizer in the agriculture of lowland. The man-made ecosystem of close nutrient cycle is designed on the small watershed in lowland (Fig. 5). Mixed forest of *Acacia mangium* and *Acacia auriculaeformis* is planted at the top of hill. *Citrus spp.*, *Litchi chinensis* and other fruit trees are grown on the middle slope. Fishes are fed in pond and reservoir. *Pennisetum purpureum* (Elephant Grass) is cultivated on the bank as fish food. The mud from the bottom of the drained pond could be the manure for fruit trees, Elaphant Grass and seedlings in the nursery. The water in the pond and reservoir may be irrigated for the fruit trees seedlings and grasses. The continual development of ecology and economy would be achieved (Ma, 1987).

Studies on rational structure and species diversity and stability in man-made forest ecosystem. The afforestation and increase of forest coverage are the basis of eco-agriculture in lowland areas in Guangdong Province. Severe damage could be caused by the destruction of forest. For example, in northeastern region in Guangdong, erosion occurred after the forest was heavily destroyed. In June 1986, the region was attacked by a strong typhoon and it rained for

30hours, 6000000ha of cultivated field was flooded, and eight hundred million kg of grains were lost and 125000 houses were destroyed. On the other hand in a county in eastern Guangdong, afforestation over a wide area has been achieved in recent years, the forest coverage being more than 63.8% in the county. Therefore, the drought has almost disappeared and the agricultural production has been increased.

In the experimental plot, the following forests have been planted respectively in five small watersheds for the studies on man-made forest ecosystem: legume mixed forest, non-legume mixed forest, eucalypti mixed forest, pine mixed forest and grassland for the contrast. The following contents would be surveyed: the changes of plants, animals and soil microbes and their interrelations; the productivity of man-made forest ecosystem; the comparison of forest microclimate in different elevations and directions; the relation between atmospheric acid deposition, forest and chemical composition of soil; the nutrient cycle in forest ecosystem; water cycle and water balance in forest ecosystem.

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