SOIL EROSION AND MANAGEMENT IN SUBTROPICAL GRANITE AREAS – HETIAN TOWNSHIP OF CHANGTING COUNTY, FUJIAN PROVINCE

Yang Xuezhen[A] *and Huang Yanhe*[B]
[A] Fujian Soil Conservation Committee Office, Fuzhou Fujian 350001, PRC
[B] Resource and Environment College, Fujian Agriculture and Forestry University, Fuzhou, Fujian 350002, PRC

Abstract
Situated in south-east part of Changting County, Fujian Province, at 116º18'-116º31' E and 25º33'-35º48' N, Hetian Township enjoys a subtropical monsoon climate, with the annual mean temperature ranging between 17ºC and 19.5ºC, maximum air temperature 39.8ºC, minimum air temperature -4.6ºC, and maximum air temperature of slope land surface 68.2ºC. The rainfall varies within one year, with the annual average rainfall of 1,700mm, of which the rainfall from April to June accounts about 50% of the total annual rainfall, with many rainstorms, which accounts for 67.4% of the whole year. As the largest basin valley of Changting County, Hetian Township is surrounded by the low hills with open land in the center area. The zonal vegetation was subtropical broad leaf evergreen forest. However, due to the long time man-made destruction, there is no longer existing the original vegetation, but being replaced by the secondary conifer forest. Black granite is the main soil forming rocks while the granite red soil is the main soil type of the township. Soil erosion and management of the township enjoys the trueness to type in the subtropical granite areas.

Additional Keywords: monsoon, vegetation, conifer forest, Fujian Province

Soil Erosion in Hetian Township

In accordance with the in satellite RS investigation result of the year 2000, water erosion is the main type soil erosion of Hetian Township, with the total erosion area of 15633 ha, occupying 53.7 % of the total land area. It is obvious that the soil in Hetian Township has been seriously eroded, of which, the areas for different degrees ranging from slight erosion, medium erosion, intensive erosion, extreme intensive erosion to severe erosion are 8737, 2188, 3514, 505 and 688 ha, respectively. The percentage of erosion areas are as follows: 55.89, 14.00, 22.40, 3.23 and 4.40 %, respectively.

Soil Erosion and Degradation in Hetian Township

Damage to the soil profile

It is no doubt that soil erosion has caused the damage to the soil profile. In July 2002, 13 soil profiles have been tested (Table 1) except the profiles at Wu Tongling and Shuidongfang. The former one enjoys the complete A-B-C layers because of being covered by the thick vegetation for a long time, without any soil erosion. And the later one appears the gradually differentiated A-B-C layers because of the good water and manure conditions and the well developed vegetation under the forest at the original Heijin District. Although different erosion intensity, the topsoil of the rest 11 soil profiles all have been denuded. The granite red soil that should have thick B layer, while after years of denudation, B layer of most soil profiles only left scores of centimeters except the site of Saifang. Long time soil erosion caused the deficiency of soil profile configuration, especially the lack of first layer and shallowness of B layer impressed the difficulty to the effective management, reducing the recovery capacity of natural ecology.

Impact of erosion to aggregation of the soil

Table 2 shows the analytical result of topsoil collected from various sampling points in July 1988. It shows that the intensive or extreme intensive eroded soil contains low aggregation soil, only various ranging from 16.44 to 22.60 %. While the slightly eroded soil contains the aggregation soil up to 37.80 %. From the percentage of micro-aggregation soil, it appears that the content in slight erosion is more even than that of in intensive erosion. From 0.25 cm to <0.001 mm, the contents in various levels of micro aggregation soil are 23.87, 18.69, 5.98, 12.15, 10.30, 10.30%, 43.87, 0.34, 0.29 and 1.06 %, respectively. The less content of aggregation and disproportionality will affect the permeable and moisture capacities of soil and soil osmosis.

Erosion and soil chemical degradation

In accordance with the research of Huang Yanhe, erosion will cause the worsening of soil chemical characters, but not all the chemical characters are related to soil erosion. Chemical characters sensitive to erosion mainly include organic matter and nitrogen. Table 3 shows that no matter which erosion degree, organic matter content in eroded

Table 1. Surface layer and thickness of soil profile

Site	Erosion Intensity in 1983	Erosion Intensity in 2002	Soil Layer and Thickness (cm)
Unmanaged Area of Shuidongfang	intensive	intensive	C (0-100)
Original Wattle Area of Shuidongfang	intensive	no obvious	A(0-10)
Site behind Management House of Shuidongfang	intensive	slight	B (0-70)
Site beside the Runoff Pool of Shuidongfang	intensive	medium	B (0-70)
Bashili River	intensive	not obvious	B (0-64)
Chestnut Orchard of Luodihe	intensive	not obvious	B (0-20)
No. 1 Pasture of Luoshan	intensive	intensive	B (0-19)
No. 2 Pasture of Luoshan	intensive	slight	B (0-55)
No. 2 Pasture of Luoshan	intensive	slight	B (0-19)
Small Saifang	intensive	medium	B (0-49)
Site at Saifang	Extreme intensive	Extreme intensive	B (0-100)
Site of Youfang	severe	severe	BC(0-38)
Wu Tongling	not obvious	not obvious	A(0-23)

Table 2. Soil aggregation structure

Sample Site	degree	Micro-aggregation (%) (Surface Layer)					Aggregation(%) (Surface Layer)					
		0.25-0.05 mm	0.05-0.01 mm	0.01-0.005 mm	0.005-0.001 mm	<0.001 mm	>5mm	5-2 mm	2-1 mm	1-0. 5 mm	0.5-0.25 mm	Total
No. 1 Luodi – Unmanaged	intensive	36.4	33.7	0.1	0.1	0.2	5.7	1.2	2.5	6.8	5.8	22.6
Shuidongfang – Unmanaged	Extreme intensive	17.6	48.9	0.4	0.6	1.5	1.6	2.6	4.1	5.5	6.5	20.3
Hexi – Unmanaged	Extreme intensive	26.3	37.9	0.2	0.2	0.1	1.1	1.8	2.08	7.20	5.23	17.4
Qiankeng of Sanzhouan	intensive	20.4	54.9	0.6	0.2	2.5	0.9	1.9	1.6	4.1	8.0	16.4
Average		25.2	43.9	0.3	0.3	1.1	2.3	1.9	2.59	5.9	6.4	19.1
Wai Zengkeng	slight	23.9	18.7	6.0	12.2	10.3	3.7	6.5	11.0	10.0	6.6	37.8

soil is very low, some even down to 0.6 g kg^{-1}, same as nitrogen. Even the slope after conservation, the soil fertility still stays at low side (the sampling sites for data collection in July 2002 are all the eroded slope land conserved by measurement in 1983). Concerning the active nutrient, besides the active potassium, the active nitrogen and active phosphorus also are low. This explains that nutrients in eroded soil of Hetian Township is limited not only in supply quantity but also in intensity.

Table 3. Changes of topsoil fertility

Site	Time	Erosion Degree	Organic Matter (g/kg^{-1})	N (g/kg^{-1})	Active N (mg/kg^{-1})	Active Phosphor (mg/kg^{-1})	Active K (mg/kg^{-1})
No. 1 Luodi Mountain – Unmanaged	July 1998	intensive	0.6	0.12	5.0	3.0	43.0
Shuidingfang – Unmanaged	July 1998	Extreme intensive	6.6	0.2	17.0	2.0	32.0
Hexi – Unmanaged	July 1998	Extreme intensive	0.9	0.05	8.0	1.0	59.0
Qiankeng of Sanzhou'an – Unmanaged	July 1998	intensive	1.12	0.08	6.0	5.0	60.0
Site Near Runoff Pool of Shuidongfang	July 2002	medium	3.78	0.19			
Chestnut Orchard of Luodihe	July 2002	no obvious	4.77	0.05			
No. 2 of Luodi Pasture	July 2002	slight	1.96	0.28			
No. 3 of Luodi Pasture	July 2002	slight	13.02	0.33			

Soil Erosion Management in Hetian Township

Hetian Township was once the Willow Village with luxuriantly green forest, deep and clear river. However, within nearly a century, excessive deforestation has seriously destroyed the ground vegetation, and caused the gradually aggravated soil erosion. In the 1940s, soil erosion in Hetian Township was very serious. Recorded by Zhang Mutao (former staff of Soil Manure Conservation Zone of Fujian Provincial Research Institute) in 1940s, almost 60 % of hills were destroyed, trees were rare, and also densely covered gully. The serious soil erosion has attracted the

attention by Kuomintang government at that time. In 1940, the Soil Manure Conservation Experimental Zone in Hetian Township was established by Fujian Provincial Research Institute. It started the systematic research on soil conservation in intensive erosion zone of Hetian Township. It tried to adopt the measures such as construction of check dam, preparation of land for water conservation, recovery of vegetation and increasing input of organic manure to conduct soil husbandry.

Until the 1950s, it developed the soil conservation measures taking conservancy area and pine plantation as the main measures, initially reached the hill afforestation. However, the achievement at that period was totally destroyed at steel making drive period and 3 years natural disaster period. From 1960s to 1970s, although the approach of combination of engineering and biological measures was adopted for soil conservation, the conservation effect percentage was still at low side. From 1980s to 1990s, especially in April 1983, led by former secretary of Fujian provincial Party Committee, Xiang Nan, the concerned leaders, specialists and technicians inspected the soil conservation activities of Hetian Township. Mr. Xian Nan took in charge by himself the draft Soil Conservation - Three Character Primer, clearly identified the guidelines, policies and measures of soil conservation and gave great support on the aspects of technology and funds. Since 2000, Fujian Provincial Party Committee and Fujian Provincial Government have given high priority to the comprehensive soil conservation in Changting County. The management of intensive erosion area in Hetian Township also attracted the attention. By summarizing the years' conservation experiences of Hetian Township, the typical conservation types are as follows: arbor and shrub mixed forest, wattle forest plantation, facilitation of recovery of ground cover, plantation of grass for forest growing, recovery of biodiversity of pine community, closing the hillsides to facilitate afforestation, and the comprehensive management of small watersheds.

Arbor and shrub mixed forest

The typical sample site for management is the Bashihe. The land was prepared in the winter of 1981 and afforestation started from spring 1982. The land preparation adopted the contour trench type of 2-3 m long, 0.6 m wide, 0.4 m deep and 0.4 m wide at the bottom, 1.5 m distance between two trenches. There is an earth ridge on the trench. When preparation, it will be reserved the original arbors such as masine pine, guger trees, mixed with the cordate telosma, shrub Lespedeza, false indigo, etc. At the same time, 0.1 kg cottonseed cake, 0.2 kg Ca, Mg and phosphorus, 1 kg swine waste of basal fertilizer was applied in every one meter long ditch. Twice application of complementary fertilizer were applied at the year of planting, of which, 25 g urea was applied to each arbor in May and 25 g cottonseed cake and 25 g Ca, Mg and phosphorus was applied to the arbor in August. In May of second year, 50 g cottonseed cake was applied to each arbor, no fertilizer was needed for shrub and masine pine. Because of planting the fast growing leguminous plants, the coverage at the same year reached more than 40 %, quickly achieved the effect of ground cover. The biodiversity of flora also increased. In accordance with the investigation in 1992 (Table 4), the diversity of arbor layers, vegetation under forest and community flora all increased. The increase of biodiversity in eroded land profited from the land preparation and fertilization, artificial mix of cordate telosma, shrub lespedeza and false indigo trees, that helped the improvement of ecological environment in the eroded land and favorable for the growing of vegetation under the forest. Such measures enjoy the obvious effect on the soil erosion control. Based on the measurement, adopted the model of contour trench for mix of arbor and shrub, the soil erosion modulus was only 449 t $km^{-2}yr^{-1}$ in the preceding 6 years, which was already down to the allowable erosion amount level of Fujian Province (the allowable erosion amount of Fujian Province is 500 t km^{-2} yr^{-1}). While the soil erosion of the unmanaged slope was still as high as 8580-10000 t km^{-2} yr^{-1}. The soil conservation effect was achieved because of the land preparation and continuously recovery of ground cover.

Table 4. Investigation on flora diversity (400 m^2)

Measures	**Arbor**			**Arbor Layer D_{sh}**	**Vegetation under Forest D_{sh}**	**Community D_{sh}**
	Species	**Name**	**Num.**			
Comparison	1	Massons Pine	102	0	0.70	0.83
Arbor and Shrug Mix	3	Massons Pine	100	0.86	1.13	1.24
		Firs	78			
		Guger Tree	10			

Mix of arbor and shrub has obvious cultivation effect to the soil fertility. Table 5 shows that after the management, the content of organic matter and N in soil is 4.3 times and 2.6 times of that in the comparison area. The active nutrients were also improved, the total amount of microbe in soil was 29.7 times of that of unmanaged area, especially that the bacteria amount has been increased greatly (Table 5).

Table 5. Topsoil fertility (0-10 cm) and microbes (1992)

Measures	Organic Matters (g/kg^{-1})	N (g/kg^{-1})	Active N (mg/kg^{-1})	Active Phosphor (mg/kg^{-1})	Active K ($mg\ kg^{-1}$)	Bacteria ($10^3/g^{-1}$)	Epiphyte ($10^3/g^{-1}$)	Rayungus ($10^3/g^{-1}$)	Total Microbe ($10^3/g^{-1}$)
Comparison	2.7	0.15	20.2	0.9	30.7	4.75	0.41	0.15	5.31
Closing	11.5	0.39	50.6	2.1	50.8	138.06	17.38	2.11	157.55

Plantation of wattle forest to facilitate the recovery of ground cover

On the extreme intensively eroded slope, it adopted the contour ditch for land preparation. The ditches were constructed along the contour with 100 cm wide, 50 cm deep and 60 cm bottom width, 2.5 m distance between two ditches. 1000 kg raw garbage, 25 kg fused calcium magnesium phosphate, 375 kg swine waste and 1kg borax were applied in every mu (667 m^2) land. The afforestation was started from March 1984, supplementary fertilizers were applied at the end of April and the early June, 1.5 kg urea $mu^{-1}time^{-1}$. In 1985, it applied once supplementary fertilizer of 5 kg mu^{-1} urea. In 1986, it applied once supplementary fertilizer of 10 kg mu^{-1} Ca and 10 kg mu^{-1} ammoniam sulphate. According to the measurement from April 1 to August 31 1988, soil erosion in unmanaged area reached 3358.45 t km^{-2}, soil erosion of wattle forest plantation area was 284.44 t km^{-2}, which is only 8.5 % of unmanaged area. After the analysis to the soil samples collected in 2002 from the wattle forest experimental area and unmanaged area, the result is shown in Table 6. The organic matter and N content in the management area are 13.0 times and 9.4 times that of unmanaged area. A layer also appeared in the soil profile; that means the soil ahs developed in a good circle.

Table 6. Changes in topsoil fertility

	Organic Matter ($g\ kg^{-1}$)	N ($g\ kg^{-1}$)	Profile Configuration
Unmanaged	1.26	0.05	B(0~60)-C(>60)
Managed	16.37	0.47	A(0~10)-B(10~62)-C(>62)

One issue is that the wattle trees have been frozen to death by the frost in 1991 and 1994; there are still some problems in the cultivation. It is needed to discuss whether the wattle trees are suitable to be extended in Changting County. But after planting wattle forest, it is the fact that the positive succession of vegetation on extreme intensive eroded slope. In accordance with the biodiversity sample sites (20 x 20 m^2) investigation in September 2002, in the original wattle forest, there are arbors of 27 Masson pines, 6 Japanese jacquer trees, 1 paulownia, 1 camphor and 2 wattle trees, 11 shrubs of wild Japanese jacquer trees, and 18 herbs of *Dicranopteris dichotoma, Miscanthus floridulus*, etc. While in the unmanaged area, there were only some old Masson pines and sparse *Dicranopteris dichotoma* and wild wilted hay.

Planting grass to recover the flora diversity of Masine pine community

On the intensive eroded slope, it adopted the whole cultivation or strip trench for land preparation (reserve the original Masson Pine old trees), applied with the waste fertilizer, 112.5 kg urea were fertilized every ha with three times additional fertilizer. About 20 species of grasses were planted. After 17 years' conservation, the investigation shows that by the measures of land preparation, grass planting and fertilizing, it has improved the

micro-environment for flora, which not only reduces soil erosion, but also increase the flora species. The flora increased from eight genera of seven families before conservation to 23 genera of 15 families.

Closing of hillsides to facilitate afforestation

Based on the climate condition advantages of Hetian Township, the plants grow fast with the strong natural recovery capacity of vegetation. Therefore, since 1983, it has started the closing of 27200 mu area of hillsides to facilitate afforestation. In July 1988, random sample investigation was conducted on effect of closing measures, the results are shown in Table 7.

Table 7. Statistic statement of various erosion areas

	Intensive and More	Medium	Slight	No Erosion
Area in 1983 (ha)	5540.13	1890.40	1733.47	0
Area in 1988 (ha)	4087.13	2016.07	1750.33	1310.47

Five years after closing, the intensive erosion area reduced to 1453 ha, medium erosion area increased 125.67 ha, slight erosion area increased 16.87 ha and non-eroded area increased to 1310.47 ha. The erosion degree lightened and the erosion area reduced. One problem must be solved during the closing is the wood logging by farmers. Based on the initial investigation, about 20 million kg wood are fired by the farmers of Township each year. Hetian Township is not the coal mining area; farmers can only use wood for fire, which of course resulted in the problem of deforestation. In the Soil Conservation Program of Hetian Township Phase I Project, Fujian Provincial Government has given the Hetian Township special subsidy and coal supply target. Only after the farmers solved the problems of fire, the closing of hillside to facilitate afforestation can be smoothly implemented. Through the management, masine pine trees grow very well with the coverage of 80 %. Diversity of vegetation under forest and community flora also increased. Table 8 shows the investigation result in 1992 to the mountain land closed from 1980. The diversity of vegetation under forest and community flora within the closing area is 2.1 times and 1.84 times, respectively, of that without closing area. This explains that abundant water and heat resources of subtropical zone are favorable for the self recovery of ecosystem.

Closing of hillsides to facilitate afforestation has obvious effect on the breeding of soil fertility. Table 9 shows that, through such measures, the organic matter and nitrogen content of soil is 9.0 times and 6.5 times that of unmanaged area. The active nitrogen, active phosphorus and active potassium in soil are also increased. The total amount of microorganisms in soil is 840 times of that of in unmanaged area.

Husbandry and innovation of Old Masson pine forest

To those medium eroded land with poor conditions of site and to the intensive eroded land with good conditions of site, the husbandry, complementary fertilizer and innovation to the Masson pine forest of more than 1800 middle aged and young trees are as follow: dig hole 40 x 30 x 30 cm (surface width x depth x bottom width) at upgrade of tree crown projection site in each March. 1500 holes per ha, 250 g complex or organic manure will be fertilized to each tree hole compressed by soil. To those areas with the Masson pine less than 100 trees mu^{-1}, it may be fertilized to the firs, or other weed trees evenly distributed. To those lands with the sparse vegetation, coverage less than 30 %, mixed and sowed the 1.5 kg ha^{-1} broadleaf paspalum seed, 45 kg ha^{-1} urea and 30 kg ha^{-1} soil in the holes. Through 3 years' fertilizer dressing, it facilitated the growing of old pine trees and recovery of vegetation.

Table 8. Investigation on flora diversity (400 m^2)

Measures	Arbor			Arbor Layer D_{sh}	Vegetation under Forest D_{sh}	Community D_{sh}
	Species	Name	Num.			
Comparison	1	Masson pine	102	0	0.70	0.83
Closing	1	Masson pine	108	0	1.50	1.53

Table 9. Topsoil fertility (0-10 cm) and microorganisms (1992)

Measures	Organic Matters (g/kg)	N (g/kg)	Active N (mg/kg)	Active Phosphor (mg/kg)	Active K (mg/kg)	Bacteria (10^3/g)	Epiphyte (10^3/g)	Rayungus (10^3/g)	Total Microbe (10^3/g)
Compariso	2.7	0.15	20.2	0.9	30.7	4.75	0.41	0.15	5.31
Closing	24.2	0.98	88.6	3.4	100.4	3842.00	243.00	376.00	4461.00

Small watershed comprehensive management

Comprehensive management of Zhuxihe Small Watershed in Hetian Township is a successful example. Such watershed is located in the middle part of Hetian Township, with the area of 43.67 km^2, which is the most serious soil erosion area of Changting County. Since 1940, it started the soil conservation. After 60 years' hard work, it passed the check and acceptance for national demonstration small watershed in 2000. Especially since the comprehensive development and management of Zhuxihe Small Watershed from 1995, the accumulated managed soil erosion area reached 1939.9 ha, 82.5 % of total area. The conserved area of forest and pasture accounts for 83.7% of feasible land for forest and pasture. The soil erosion volume reduced from 310600 tons down to 79400 tons, with the soil conserved percentage of 74.4 %. Average income per capita of farmers reached 2327 yuan. It has achieved the good benefit on soil conservation and ecological environment improvement.

The successful experiences of comprehensive management to Zhuxihe Small Watershed include: (1) scientific plan and management. Taking the small watershed as the unit, prepared with the agriculture, vegetative and engineering measures, the comprehensive management to the hill, water, farmland, forest, access road and pasture, not only conserved 1939.9 ha eroded land, but also governed 79 gullies for construction for check dams, constructed 15.35 km long access road. In addition, 2371 farmer households use coal instead of wood for cooking, 130 biogas digesters have been developed. (2) strictly followed the measures for closing of hillsides to facilitate afforestation, such as used coal to substitute wood, and subsidized the farmers, regulated the laws and regulations for law enforcement.

Problems and Issues

Fragile ecosystem

Through scores of years' management, it has achieved effect to the soil erosion in Hetian Township. The vegetation types increased, the flora component developed to the trend of sophistication, and the vegetation variety index increased. But, there is still great difference compared with the vegetation variety of local forest, the vegetation of ecosystem is at lower stage at the way to positive going succession. Due to poor self restorability, the system is weak in anti-interference to outside world, easily be degradation again affected by the impact of environment. Some slope land of Luodi pasture is the sample, that the system degraded after the management due to the lack of administration and pine tree branches cutting.

Low soil fertility – the remaining problem in the soil conservation of Hetian township

There is almost no fertile topsoil in the serious granite erosion area of Hetian Township. The soil fertility is very low. In the past management, the measures used were focus on the blood transfusion to the system without the corresponding effective measures to develop its own functions. Therefore, once the management measures stopped, the system evolution would be suspended or slowed which could not meet the goal of fundamental soil conservation. In the future management, the application of measures shall enjoy the functions of conservation and husbandary, that cannot only conserve the soil but also develop the better soil functions.

Weak pertinence of measures affect the soil conservation effect

Since the unique characteristics of soil erosion, the conservation measures of Hetian Township shall also enjoy the features. However, due the backward of scientific research, there are few measures with the pertinence, which could not achieve the ideal soil conservation effect.

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