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Degraded Lands: South China's Untapped Resource

By Walter Parham

"In a real sense the land does not lie; it bears a record of what men write on it. In a larger sense a nation writes its record on the land, and a civilization writes its record on the land – a record that is easy to read by those who understand the simple language of the land."

Dr. W.C. Lowdermilk, 1953, former Assistant Chief
United States Soil Conservation Service

Damaging agricultural and forestry practices over the past millennium have degraded half of the land in China bounded by the Tropic of Cancer and the South China Sea, drastically reducing its biological productivity and environmental services. The damage to South China's hilly tropical/subtropical forests probably began in the Sung Dynasty as population expanded to the south. The settlers most likely used slash and burn techniques to clear land for farming. Forest cover provided building materials and firewood to the settlers, but also served as a habitat for tigers, leopards, wild pigs, and deer. Population growth put unremitting pressure on the land. Eventually, erosion washed away much of the topsoil and much of the degraded land was abandoned. Today, only about one square kilometer of the original tropical monsoon evergreen broad-leaved forest remains.

China recognizes the enormous economic price it is paying for damaging a critical natural resource. It has lost land that could be used to produce food and income for rural populations. The loss of vegetation means that rain falls directly on the soil, causing fine particles to seal the surface. Instead of the soil absorbing rainfall, much of the sediment-loaded runoff flows directly into streams and rivers, often leading to disastrous floods like the ones that ravaged the valleys of the Yangtze and Yellow Rivers in 1998. The highlands suffer landslides, river valleys suffer as silt-choked rivers waterlog farmlands, and coastal agricultural fields suffer damage from the buildup of wind-blown sands. And of course, China and the world are also paying an enormous environmental price as entire ecosystems are threatened and as the loss of habitats leads to extinctions.

Fig. 1 *Degraded landscape in Wuhua County, Guangdong Province, 24 deg. N. Lat., Rainfall 1600 mm (64 inches). (Photograph by Professor Liang Gaozhou, 1987).*

Little doubt exists that policies to prevent further degradation of forest ecosystems are essential. But since such large areas of the globe have already been severely degraded by human activity, it is crucial to identify practical strategies for large-scale restoration. South China may provide a unique test of what can be achieved technically and politically. Experimental programs indicate that much of South China could be restored to farm production in as little as 2 years after restoration begins. This would mean that an investment in restoration could simultaneously increase local incomes, stop land degradation, and greatly mitigate flooding.

In addition, the process of re-vegetating the land has the effect of greatly increasing the amount of organic matter in the soil as well as in the roots, the above-ground parts of trees, and other vegetation. The organic matter stores huge amounts of carbon. While data remains uncertain, it seems possible that restoring half of the degraded land in China's five southern provinces could capture carbon dioxide equivalent to the amount generated by all US cars and trucks for a period of at least a decade.

Even though China has had programs to reforest degraded lands for a number of years, the devastating 1998 floods greatly accelerated China's concern. Restoring degraded land in South China is surely an area where Chinese interests and global environmental interests intersect – especially in the area of slowing greenhouse gas production. The

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Chinese scientific and technical capabilities in this area are impressive and a partnership with the United States could be enormously profitable. China has been reluctant to commit itself to specific actions in climate change, and the Bush administration has been adamant that it will not move unless developing countries take concrete action. Surely this is one place where this impasse might be broken.

In This Issue ...

Characterizing the Problem

During the last 1,000 years, slash-and-burn agriculture has removed much of the primary monsoon evergreen broad-leaved forest in South China. The destruction continues in the remaining original forests under the relentless pressure of a growing population and poverty in rural areas. In spite of vigorous efforts in birth control, China's population continues to increase by about 11 million people a year. Many eroded hills were abandoned years ago by farmers, but because the most productive, flat agricultural lands are now being filled with growing urban populations and industry, poor farmers are being forced back into previously damaged hilly lands. Their use of firewood, coupled with hillside cultivation, often results in disastrous erosion which leaves little more than weathered granite for soil.

The extent of the damage is enormous. 21.5 percent of South China's land is degraded and eroded[1]; 45 million hectares in the five southernmost provinces.[2] In the Pearl River watershed, 4.34 million hectares of hilly cultivated land face erosion problems.[3] Deeply weathered areas extend over 30 to 40 percent of Guangdong and Fujian Provinces, 10 to 20 percent of Hunan, Guangxi, and Jiangxi Provinces and many near-shore islands as well.

The process of degradation follows a predictable path. When vegetation is removed in these regions, the exposed soil bakes in the sun; it reaches temperatures so high that that seeds and sprouts are killed or stunted. Since new vegetation cannot be established easily, soil organic matter is reduced, and the soil becomes desiccated. Soil organic matter decreases quickly as soil temperature and biotic decomposition rates increase. Further, removal of vegetation and litter by farmers for fuel inhibits buildup of new organic matter. Soil organic matter plays a

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large role in retaining nutrients in a form available to plants. Even small decreases in soil organic matter have a pronounced negative effect on the soil's fertility. Granite underlies most of South China and when the original topsoil is removed by erosion, the surface becomes a mixture of aluminum-rich clays and quartz sand that contain very few minerals useful to plant life.

The loss of vegetative cover and soil organic matter leaves the soil subject to damage from intense tropical rainfall. With little organic matter in the soil, clay particles are moved by raindrops and plug soil pores, thus inhibiting water infiltration and increasing runoff and erosion. Residual boulders of fresh granite (core stones) as large as automobiles sometime slide and tumble down hillsides when the surrounding soft weathered material is eroded during heavy rains. The finer-grained eroded sediments damage aquatic productivity and bury what were once freshwater and near-shore marine aquatic breeding grounds. The remaining coarser, sandy material of the weathered granite yields soils of low fertility. Stripped of vegetation that would otherwise have absorbed or slowed the flow of water, the water pours rapidly into streams and rivers, cutting deep ravines in the soft, deeply weathered granite.

Fig. 2 *Residual granite boulders covering weathered granite on Tai A Chau, Soko Islands, Hong Kong. Native vegetation has been degraded to a cover of grasses and shrubs. (Published with the permission of the Head of the Geotechnical Engineering).*

Impacts

The most direct impact of this disastrous loss of productive soil is reduced agricultural production. Farmers trying to produce crops under these conditions face great difficulties even when using commercial fertilizers. The soil of the weathered granite is poor at holding the plant nutrients contained in commercial fertilizers. The problem is exacerbated by the fact that fertilizer runs off the land quickly during heavy rains.

China cannot afford to abandon potentially productive land, let alone lose more to erosion. It is already losing enormous amounts of land to new towns and other nonagricultural uses. Per capita arable land in China now is about 0.1 hectare, only 47 percent of the world average. But China estimates that it lost about 50,000 square kilometers of its arable land from 1986 to 1995, the equivalent of the total agricultural land area of Japan. Food production is not the only problem. The loss of much of China's forest cover today has made wood products China's leading import costing the country \$2 to \$5 billion annually.

Economic losses also result from waterlogged fields and coastal sand storms that result directly from the soil erosion. Some 710 million tonnes of sediment were carried through the Three Gorges part of the Yangtze in 1998 – a 33% increase over the loads measured before 1990. In parts of Guangdong Province, sediment-choked streams and rivers have caused the water table to rise and have waterlogged adjacent farm fields. Since the waterlogged land is useless for conventional farming, the Chinese introduced the "dike-pond system." Ponds are dug and used for raising fish and vegetables are grown on the tops of the dikes surrounding the ponds. Ironically, this system may have to be discontinued if erosion is controlled. Once controlled, the streams and rivers will cut deeper channels, thus lowering the water level in the fishponds.

In the few areas where reforestation of eroded hills has reduced erosion and sediments in the rivers, the river has begun to cut through years of deposited sediment to return to its original bed. This lower water table reduces water logging of adjacent land – and the fishponds begin to dry up. In some places, pumps had to be installed to draw water from the streams and rivers to keep the water level in the fishponds stable.

Sandstorms are another effect of the heavy sediment load created when granite weathers in the wet tropics. Coarse quartz sands move from the weathered hills to lower elevations during heavy rains, filling valleys and covering agricultural fields. Fine-grained quartz sands, however, are carried further downstream and deposited near river mouths. Strong sea winds and typhoons periodically blow the sand inland, burying agricultural fields and human settlements. To reduce the movement of sand by wind action, the Chinese built windbreaks along much of the sand-covered coastal belt. Salt-tolerant trees, satisfactory for such coastal windbreaks, were planted near the shore. Because these trees are vulnerable to local people looking for firewood, the government normally prohibits tree cutting, but allows them to rake up litter beneath the trees for cooking-fuel.

Loss of covering vegetation and soil means that heavy tropical rains flow rapidly into streams and rivers triggering disastrous flooding. The damaging floods and landslides in lands adjacent to the Yangtze and Yellow Rivers in 1998 were a direct consequence of the loss of forests and other vegetation in the rivers' headwaters and over-farming. These floods killed many and destroyed homes, roads, bridges and other infrastructure. In Jiangxi province alone, the government had to resettle 600 thousand people from along the flooded Yangtze River.

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Some Solutions

Basic Strategies

Scientists in research institutions throughout South China have worked for decades to develop and test methods for restoring degraded lands to productive lands using a combination of agriculture and forestry methods called *agroforestry*. Since funds are scarce and the problem large, any viable solution must be able to begin creating an income for the region's farmers within a few years. This has led to some ingenious and promising strategies for restoring some of the most severely weathered regions. Techniques, of course, must be adapted to fit each cultural and environmental region. Many of the most effective approaches rely on knowledge gathered from traditional systems practiced by ethnic minority groups in the affected regions.

The process starts with a fast growing ground cover that can shade the soil and make it possible for other seeds to germinate. Care must be taken to ensure that this new cover survives the dry season when grass fires present serious hazards. Fire prevention can be extremely difficult in areas where open flames are used for cooking and for religious practices. These early plantings are typically made at the beginning of the rainy season when the ground is comparatively cool. The wet season gives the plants an opportunity to establish themselves and provide leaf cover for shade. It is essential to pick pioneer species that can provide some income for farmers in the first year – income that will sustain the farmers until other crops establish themselves later.

Once soil temperatures have been lowered, a variety of fruit trees, firewood trees, food crops, medicinal plants, and other food crops can be planted. Careful animal husbandry can contribute to a stable and sustainable system.

Part of the art is finding a combination of crops that can occupy the same site. Above ground, this means matching demands for sunlight and shade. Rubber trees, for example, require bright sunlight, but valuable herbs can be grown in their shade. Below ground, it is essential to arrange root systems of intercropped plants so they do not compete excessively for water and soil nutrients.

Fig. 3 *Rubber/tea agroforestry system at Xishuangbanna, Yunnan Province. (Photo by W. Parham, 1991).*

Once established, these systems contribute organic material to the soil, slow rainfall runoff, help replenish ground-water reservoirs, and reduce water and wind erosion. Deep tree roots help to anchor the soil and prevent landslides, and the shade from the leaves lowers the local surface air temperatures, facilitating crop growth. In many cases, birds and other wildlife return to reestablished habitats in the area.

One of the greatest challenges is finding ways to make productive use of the varied topography of Southern China – including the steep hillsides. Farming hilly areas is essential, because urban development is forcing farmers off many lowland areas. A technique called *stereoagriculture* has been developed in which forests are restored to the hilltops while a mixture of intercropped orchards and food crops, fishponds, and small animal grazing are introduced in the flatter lands below.

The forests provide both a conservation reserve that provides habitat for many native species, protects against erosion, and can also be used to produce revenues. The management practices permit some animal grazing and limited harvesting for fuel and timber markets.

Most of these processes are labor intensive, but do not require large amounts of commercial fertilizers or pesticides. While they are strange to industrial nations, they are well suited to the resources of Southern China.

Zeolites

A soil amendment that may make a major difference in Southern China is zeolites. Zeolites are a group of naturally occurring fine-grained minerals with pronounced ion exchange properties. Some deposits exist in South China. Research at the South China Agricultural University shows that additions of small amounts of zeolites to highly weathered, low-fertility soils significantly slows the leaching of nitrogen and potassium fertilizer and helps release tightly bound soil phosphorus to the plants. Recent tests in China show that small amounts of zeolites added to the soil increased the biomass production of corn by as much as a 29.5 percent. The Chinese work shows that zeolites can also help prevent agricultural pollutants from entering the ground-water and surface waters, help make clean-water resources last longer where fish and turtles are raised in ponds, reduce chicken feed requirements, and increase the survival rate for turtles while decreasing disease.

Fig. 4 *Stereoagriculture in Wuhua County, Guangdong Province. (Photo from Luo Shiming, South China Agricultural University, Guangzhou, 1991).*

Demonstrated Successes

Several demonstrations conducted in Yunan Province over the past decade show the power of their land restoration methods.[4] Beginning with heavily weathered granite soils, scientists introduced a variety of fast-growing food and medicinal plants to provide early income for the farmers and planted them among rows of young tea plants and rubber trees. The rubber/tea system involves planting alternating rows of rubber trees and tea bushes in a way that ensures the 30 percent shade needed to produce high quality tea.

As the rubber trees and tea bushes grow larger, the tea bushes help to moderate the microclimate near the base of the rubber trees, thus protecting the near-ground parts of the rubber trees and their roots from periodic damaging cold waves. The low-lying, flexible tea bushes will survive typhoons that damage the rubber trees, assuring the farmer of income even in bad times.

The carefully managed system allows the rubber trees to be tapped for their latex one year earlier than normal as well as produce greater quantities of latex during their lifetime. Tea production is also higher than average. The income realized from these sites has been significantly higher per unit area than any achievable from a monoculture approach. And of course, the carefully designed restoration leads to greatly improved environmental conditions: restoring organic material to the soil, reducing soil erosion, and minimizing runoff and flooding.

Carbon sequestration

Restoring degraded land to productive uses also provides a cost-effective tool for removing carbon dioxide from the atmosphere, thereby reducing the risk of climate change. Little carbon exists in the soils of highly eroded land, but new plant growth stores carbon in roots, stems, and leaves. Complex soil ecologies involving bacteria and other organisms in the soil also accumulate carbon. The rate of carbon sequestration starts out slowly when the plants are young, accelerates as they grow larger, and then slows after the ecosystem matures. During land restoration, the rate could be extremely high, because current carbon levels in the soils are low and because a long growing season means that large volumes of biomass are produced annually.

Table 1
Net Above-Ground Sequestration of Carbon in Biomass ($gC/m^2/yr$)

Forest[5]	
Lower subtropical evergreen broad-leaved forest at Heishiding	2200;3700
Lower subtropical evergreen broad-leaved forest at Dinghushan	2600
Broad-leaved and coniferous forest at Dinghushan	2100
Native Chinese pine *(Pinus massoniana)* forest at Dinghushan	840
Grassland[6]	
Grasses alone at Lam Tsuen Country Park, Hong Kong	480
Grasses including herbs, ferns, and shrubs at Lam Tsuen Country Park, Hong Kong	532
Grassland at Guangzhou (Shipai)	500
Man-made polyculture locality[7]	
A three-story, artificial system of a windbreak, rubber-tree stand, and legume cover crop at Danxian County, Hainan	1853

Data on the amount of carbon fixed by different agroforestry systems is sparse. Some related data from South China is summarized in Table 1. These figures do not include the carbon sequestered in roots and organic matter below ground. For example, maximum root depth for tropical evergreen forests is 7.3 m^3 [8] and the root biomass is estimated to be 5 kg/m^3. [9]

Given the large areas in South China that might be restored to a dense vegetative cover, Chinese land restoration could have a major impact on world carbon flows. Restoring the 45 million hectares in the five southernmost Chinese provinces at the rate of 1000 gC/ha/year would result in a sequestration rate of 450 million metric tonnes of carbon (MMTC) per year. For comparison, the United States produces about 1500 MMTC per year in carbon dioxide.

Recent Chinese Land Restoration Programs

The Chinese government has become increasingly active in land restoration during the past few years. This is because of the devastating effects of agricultural land loss with the possible loss of its ability to feed its own people, as well as the disastrous effects of floods and landslides. Last year, the national government established strict land-use controls in an effort to slow the loss of arable land to non-agricultural uses. The government also established 10 ecological protection zones along a number of damaged rivers, including South China's Pearl River. Activity in these zones is strictly regulated, and all actions destructive to the environment are prohibited. Population limits have been established for each area and the government simply resettles residents where allowed limits are exceeded.

The government has also provided a series of incentives to replant eroded regions. The government provides 150 kg of free grain and about

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US$9.00 to farmers for each 1/15 hectare planted with trees and grasses. Farmers are given free coal to discourage them from burning shrubs and trees for fuel. Originally planned as a three-year project, in 2000 the program was extended to eight years (five years if farmers grow fruit trees).

A massive new program plans to pay farmers in the headwaters of the Yangtze and Yellow rivers to plant trees and grasses instead of farming. Some 343 thousand hectares of damaged farmland has been selected for reforestation with advanced planning underway for an additional 490 thousand hectares.

While these programs are a step in the right direction, they face the same problems encountered by restoration programs in most parts of the world where farmers live close to subsistence. Farmers desperate for income and fuel continue to farm and cut firewood from forests in spite of legal prohibitions established by distant bureaucrats. The effect of the Chinese prohibition on forest cutting has led to massive forest cutting in Burma along its border with China to provide wood for China. The cutting has resulted in enormous damage to Burma's tropical forests. This is clearly a multinational problem.

Where Do We Go From Here?

Restoring degraded lands in South China would have significant global as well as regional and local benefits. It may be possible to construct programs that pay for themselves in immediate economic returns while protecting precious ecosystems and habitats and tying up large amounts of carbon. But this opportunity will only be captured very slowly without a significant increase in research, development, and assessment. It will also require training large numbers of professionals skilled in adapting the research products to local conditions. Comparatively, modest investments by the United States or multinational organizations could have an enormous constructive effect. It should also be an area where political agreement is easy, because the projects would aim to achieve economic development and reduce immediate flood risks as well as providing broad environmental benefits.

An expanded international research and demonstration program could be put in place quickly because South China has many excellent government and university research programs in land restoration anxious to cooperate with their counterparts in the United States and other countries. Small but highly effective research and demonstration activities in land restoration are located in many parts of South China. Unfortunately, few are adequately funded, and thus they often are not effective in communicating their results. Even in China, many universities and government decision makers are unaware of the value of these programs.

A major international program to seize the opportunity presented by degraded land in China could begin quickly with two programs:

(1) helping China develop a detailed research roadmap for land restoration and economic development in South China, and
(2) establishing an international research and demonstration site where techniques to improve South China's degraded lands can be tested, measured, improved, and demonstrated for farmers, Chinese and foreign researchers and leaders.

A well-designed research program is needed to support the massive land restoration program that must be undertaken. The research must identify restoration techniques that deliver both environmental and economic benefits – and be adaptable to the diverse environmental and cultural landscape where such restoration efforts must operate. The program should also support continuous and careful assessments and a way to ensure that the results of these assessments are made available to research teams. Assessments would include those of the potential physical, biological, social, economic, and political effects of applications of the research.

Fortunately, there are many strong research institutions in China eager to work in these areas. The South China Agricultural University (SCAU) in Guangzhou, a strong institution in agroecology and agroforestry, could act as a focal point for managing an effort to produce an effective research design for South China if funding were available. The first step would be to develop a partnership with the region's other centers of excellence in related fields and with related research organizations in the United States and elsewhere. SCAU has a successful track record in research and is supported by many foreign foundations. A logical first step would be to organize a conference to design a practical plan of action for applying agroecological and agroforestry techniques broadly. The plan could provide valuable guidance for all levels of government.

Demonstrations

Carefully documented demonstrations of land restoration methods can provide critical information about how to proceed and attract attention to the ideas developed. Research could begin immediately using two small, degraded, near-shore islands that belong to Zhuhai, the Special Economic Zone surrounding Macau. Zhuhai has an outstanding record in environmental concern and has agreed along with the islands' government to make these islands available for such research. One island is uninhabited and the other has one small fishing village on it. The research and demonstration sites provide easy access to interested researchers and their students, government decision makers who live in the nearby large population centers such as Hong Kong, Macau, and Guangzhou, and leaders of the surrounding area's farm population. Strong support for this proposed activity exists within the local governments, government research institutions, and the islanders themselves. The Zhuhai Science and Technology Commission coordinates the involvement of Chinese institutions interested in participating.

Agroecological demonstrations could focus on such topics as identifying those biological systems that quickly improve soil quality, improve the microclimate, trap plant nutrients effectively, reduce erosion significantly, withstand damaging effects of strong winds, and improve habitats for native fauna. Research and demonstrations of various combinations of plants that produce food, firewood, chemicals, and medicines will exist side by side. Emphasis on reintroduction and use of native species of plants and animals to benefit the new agroecosystems is a key goal. Merely planting large expanses of degraded lands with exotic tree species may slow erosion but may not solve other important associated problems.

While new funding sources must be found, science-based ecotourism programs, a rapidly growing industry in some parts of the world, could provide additional support. Science-based ecotourists interested in participating actively in scientific projects in various parts of the world pay their own way from their home to the research site and pay to participate in assisting project scientists. Science-based ecotourists are well-educated people willing to work under the direction of local scientists on worthwhile projects. They generally help to collect field data, prepare research sites, and provide general assistance to the scientists while learning something of a foreign culture and the workings of scientists.

Conclusion

Without question, the cheapest and more effective way to ensure that the world's soil remains productive and natural environments preserved is to protect them from being damaged in the first place. Programs encouraging sustainable farming and forestry practice and efforts to slow or stop development in virgin areas are essential. But nearly 2 billion hectares of the earth's soils are already considered degraded[10] — an area roughly equal to 70% of all the land in cultivation today.[11] 1.2 billion hectares of land are considered to be in an "extreme" or "moderate" stage of degradation. Techniques for restoring these lands must become a high priority. China provides an excellent opportunity to learn what can be done. With per capita arable land as low as 0.03 ha in some parts of South China, and continued risks of disastrous flooding, the need for immediate action is obvious – and there is a good research base to build on. In spite of their diversity and limited funding, research institutions in South China have developed a set of techniques that offer real promise. These techniques draw on many disciplines because any realistic program must make technical and economic sense as well as being acceptable to local cultures. While the details of the methods will clearly differ around the world, these core principles must apply. Solutions must be affordable, fast working, increase incomes and improve the quality of life for local populations, and result in clear, and sustainable land management practices.

Fig. 5 *A degraded, deeply weathered and eroded granite region near Castle Peak, Hong Kong, covered predominantly with grasses and shrubs. Published with the permission of the Head of the Geotechnical Engineering*

Language and other problems mean that the Chinese work is not well recognized outside of China. But both the Chinese and US research would clearly benefit from stronger collaboration. It is not an opportunity we should miss.

[We should insert one or two sentences about Wally here.]

Notes:

[1] Shi, 2000

[2] Peng, 2000

[3] Yang, 2000

[4] *Improving Degraded Lands: Promising Experiences from South China* in 1993.

[5] Chen Z., Wang B., and Chang H., 1996, Productivity of the lower subtropical evergreen broad-leaved forest in China, Higher Education Press, Guangdong, p. 125

[6] Guan D., 1993, Production of dry matter and nutrients for a grassland in Lam Tsuen Country Park, Hong Kong; (in) Improving degraded lands: promising experiences from South China, eds. W.E. Parham, P.J. Durana, and A.L. Hess, Bishop Mus. Bull. In Botany 3, Bishop Museum Press, Honolulu, p. 207-215.

[7] Hao Y., 1986, Rubber cultivation in China's tropical regions; Intecol Bulletin, v. 13, p. 89-91.

[8] Canadell, J., Jackson, R.B., Ehleringer, J.R., Mooney, H.A., Sala, O.E., Schulze, E.D., 1996, (abst.) Maximum rooting depth of vegetation types at the global scale; *Oecologia*, v. 108, p. 583-595.

[9] Jackson, R.B., Canadell, J., Ehleringer, J.R., Mooney, H.A., Sala, O.E., and Schulze, E.D., 1996, (abst.) A global analysis of root distributions for terrestrial biomes; *Oecologia*, v. 108, p. 389-411.

[10] Lal, Rattan, "Soil management and restoration for C sequestration to mitigate the accelerated greenhouse effect", Progress in Environmental Science (1,4) 1999.

[11] 1.45 billion hectares are in cropland (World Resources Institute, www.wri.org/wri/wr-96-97/wr96dtlc.pdf)