Improving Degraded Lands: Promising Experiences from South China

改良退化的土地

——华南経验成功在望

Bishop Museum Bulletin in Botany 3

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PREFACE

Deforestation of tropical, hot, wet lands worldwide continues to expand with accompanying adverse impacts on the productivity of the renewable resource base. One mechanism to slow this trend, or perhaps reverse the process, is to learn how to improve the productivity of those degraded lands that resulted from tropical forest clearing and associated damaging land-use practices. Researchers of the People's Republic of China are carrying out a variety of combined biological and engineering field experiments on various sites throughout South China that show promise for improving productivity of tropical degraded lands. Inherent land productivity describes the ability of land resources to sustain long-term production of vegetation and a broad range of other benefits to society such as water quality, biological diversity, and wildlife habitat. Land is broadly defined to include soil, water, and all physical, chemical, and biological components of a productive ecosystem.

This report summarizes a sampling of Chinese tropical research aimed at making degraded lands useful once again. The report synthesizes information presented at a five-day workshop held on September 9 - 13, 1991 at the University of Hong Kong's Kadoorie Agricultural Research Centre. Some 40 participants attended, mainly from Chinese research institutions plus a few Chinese government representatives; a lesser number of others attended from Hong Kong and the United States. Those from Hong Kong represented academic institutions, government, and the private sector. The United States' participants comprised the workshop organizers.

Literature describing the methods and techniques developed, tested and used in many tropical countries to address degraded land problems has grown rapidly in recent years. Although some literature describing Chinese approaches and their experiences has been available in English, much of the work published in Chinese is not well known outside of China. Some valuable information exists in ancient Chinese documents and some Chinese researchers today are re-examining this literature to find clues to how problems of degraded lands were dealt with long ago and whether some of this information could be incorporated productively in today's technologies. In addition, many unpublished reports related to on-going and recently completed research exist in Chinese institutions. One goal of this workshop was to assess the Chinese experience and increase the exposure of their past and present technical methods and research for dealing with improving the productivity of degraded lands, determine what approaches worked and what failed, and identify gaps in the knowledge base.

Another workshop objective was to assess the applicability of techniques developed in South China to similar environmental settings elsewhere in the tropical world. Combining new and old technologies into mutually supportive, integrated land-use systems needs thoughtful attention. Technologies should be adaptable to different cultures, affordable, fast working, and safe to humans and the natural environment. Further, the technological packages should lead to improved land and water quality, expanded economic land-use options, and improved quality of life.

Workshop discussions also identified possible mechanisms and localities for follow-on, cooperative research related to improving the productivity of China's tropical degraded lands. Individuals or groups of participants presented fifteen general plans for possible follow-on activities. Such cooperative pilot activities would be to test innovative technological packages that might involve, for example, the Bishop Museum, and other interested Chinese, Hong Kong, and U.S. institutions. Proposed field sites included many parts of tropical China with some possible collaborative work in Hong Kong and other degraded tropical areas. Such work could involve biological and physical analysis of various approaches to improving degraded lands as well as important economic and sociocultural investigations.

A one-day field trip focused on two Hong-Kong sites. One site at Tai Tong showed the results of ongoing Hong Kong Government efforts to improve the usefulness of some highly degraded hilly lands. The Kadoorie Farm and Botanic Garden, situated on one side of Hong Kong's highest mountain, Tai Mo Shan, demonstrated the beneficial results of long-term efforts supported by a single private donor. These efforts, begun in 1954, were to develop an agricultural training site and provide education and technical assistance to local farmers. Today, this operation remains active in agricultural research and training and also has become a well-known botanic garden.

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A number of individuals gave significant time to support workshop planning, operations, and field trips. Dong Jianlong, 2nd Secretary for Science and Technology of the Chinese Permanent Mission to the United Nations, assisted the Workshop Director make contacts with Chinese research institutions in a pre-workshop visit to China, and with arrangements to bring the Chinese participants to Hong Kong. The State Science and Technology Commission of the People's Republic of China facilitated the procedural requirements for the Chinese participants' travel to the workshop in Hong Kong. Several Ph.D. candidates of the University of Hong Kong provided their assistance throughout the workshop to ensure smooth running of the activities, including Chen Rongjun, Department of Botany and Department of Geography and Geology; Zhuang Xueying, Department of Botany; and Guan Dongsheng, Department of Geography and Geology.

The workshop field trip activities would not have been possible without the invaluable assistance of: Dr. Raynor Shaw, Quaternary Geologist of the Hong Kong Geological Survey; Dr. K.C. Lam, Senior Lecturer of the Department of Geography, the Chinese University of Hong Kong; Mr. F.Y. Wong, Senior Development Officer of Hong Kong's Agriculture and Fisheries Department; Dr. Richard Webb, Landscape Architect of the Hong Kong Territorial Development Department; and Chung Yim-Hing, Manager of the Kadoorie Farm and Botanic Gardens of the Kadoorie Agricultural Aid Association. In addition, Dr. Chi-Yung Jim, Lecturer in Soil Science and Biogeography of the Department of Geography and Geology, University of Hong Kong provided a pre-field trip briefing for the workshop participants.

Dr. R.D. Hill, Reader in Department of Geography and Geology of the University of Hong Kong, arranged and led an evening panel discussion of relevant research underway at the University of Hong Kong (see Hill, R., this report). In addition to Dr. Hill, the panel included Dr. Richard Corlett, Lecturer in the Department of Botany; Dr. A.W. Jayawardena, Senior Lecturer in the Department of Civil and Structural Engineering; Ph.D. candidates Lawrence Chau of the Department of Botany, and Chen Rongjun, Zhuang Xueying, Guan Dongsheng mentioned above. Mr. Chris Lonsdale, Managing Director of Permaculture Asia Ltd., Hong Kong, presented an additional evening briefing on his organization's goals and regional field activities.

The workshop team received valuable advice and support from Professor D.K.O. Chan, Director of the University of Hong Kong's Kadoorie Agricultural Research Centre (KARC) and Mr. Lin Yang Ching, Assistant Director of KARC. Numerous others took time to provide the workshop team with advice during the early stages of planning. Special thanks to the many Chinese individuals and organizations that assisted in institutional visits and field sites in August 1990 and to the support staff of KARC and Robert Black College of the University of Hong Kong providing assistance during the workshop activity.

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IMPROVING DEGRADED LANDS: PROMISING EXPERIENCES FROM SOUTH CHINA

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Degraded Tropical Lands Of China: Problems And Opportunities

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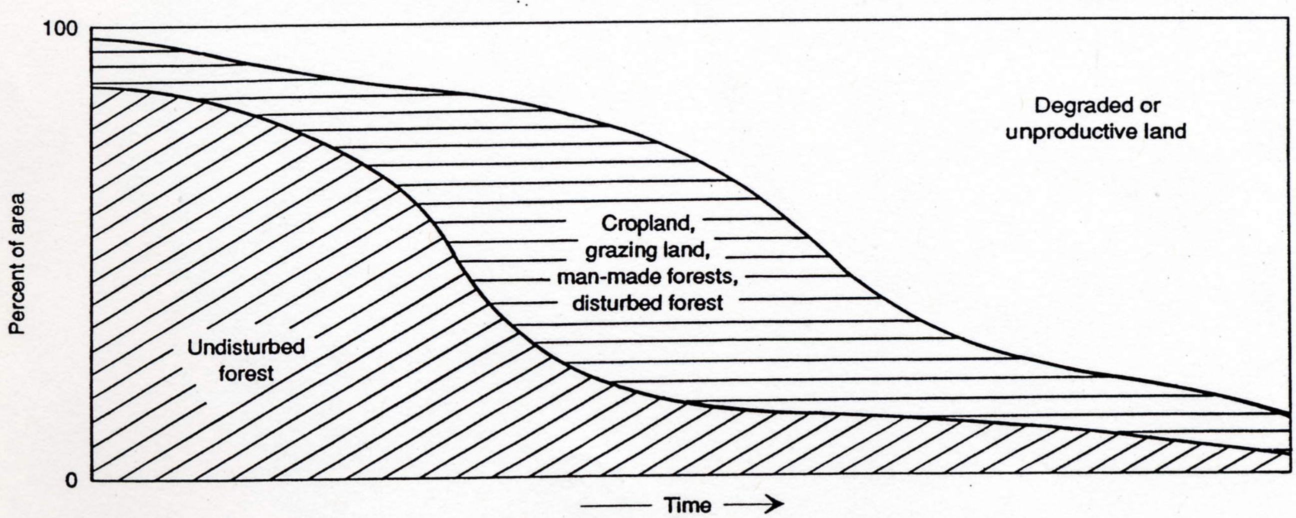
INTRODUCTION[1]

The adverse effects of forest loss and allied land degradation in the hot, wet, tropics are common knowledge today. A pattern of increasing, widespread natural resource destruction stands out, whether we look at extensive deforestation that began perhaps 1,000 years ago in tropical China (Anderson, 1988), or focus on current forest losses in the Amazon. Negative environmental impacts resulting from population growth, urbanization, growth of rural industries and transportation systems, and use of poor agricultural practices are growing concerns. These negative impacts in tropical China are pervasive—excessive soil erosion leading to landslides, burial of agricultural lands and wetlands, and sedimentation of stream, river, and nearshore marine ecosystems; ponding of toxic leachates draining from eroded sediments; water-logging of agricultural lands; continuous removal of forest litter for fuel; habitat elimination and extinction of plant and animal species; and sandstorms—all giving rise to displacement of human populations as the resource base is degraded. As the extent of degraded land expands, productive lands come under increasing pressure (figure 1).

Land degradation stemming from vegetation loss is common to tropical areas, however, in South China the prevalence of granitic bedrock accentuates many of the problems. Fresh granite in its unweathered state is a poor source of plant nutrients, but when deeply weathered the nutrient suite becomes even more restricted consisting largely of aluminum, silicon, iron, and water (table 1). Particularly difficult tropical degraded lands composed of

Figure 1—Conceptual Diagram Indicating Land-use Changes Typical of Tropical Asia



SOURCE: Office of Technology Assessment, 1984. *Technologies to Sustain Tropical Forest Resources*, 344 p.

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1 This material was derived largely from workshop discussions and presentations; the additional information cited in the text is included as references for this chapter.

broad expanses of deeply weathered granitic rocks extend across about 30 to 40 percent of Fujian and Guangdong Provinces, 10 to 20 percent of Hunan, Guangxi, and Jiangxi Provinces (Gong, 1986) and many nearshore islands as well. Rock weathering depths here commonly reach 30m to 60m (IDRC Final Report, 1990).

Land clearing has set in motion some physical, chemical, and biological processes that adversely affect the land's renewable resources. Controlling the processes that degrade tropical land, though difficult, has been accomplished by Chinese researchers and farmers on small areas. The techniques show promise for larger areas of China and perhaps for other countries as well. Opportunities may exist to expand use of land restoration technologies within China and other areas suffering similar land degradation problems through existing academic institutions. For example, China's Correspondent University of Rural Area Agrotechnology for Prosperity, uses correspondence techniques in its training for rural technicians. Some 200,000 rural students were trained between 1985 and 1987. This education mechanism could be suitable for promoting beneficial land-use practices throughout tropical China (Shen and Zhang, 1991) and perhaps internationally.

Land Clearing and Associated Impacts

Slash-and-burn agriculture has removed most of the primary evergreen broad-leaved forest in South China (Luo and He, 1986). The successive clearings and scarcity of seed-dispersing wildlife makes natural revegetation difficult. Removal of vegetation promotes a variety of ecological changes that lead to degraded landscapes. Primary changes that occur include increased soil temperatures, reduced soil organic matter, soil compaction, and soil erosion. These initial changes can be interrelated. For example, increased soil temperatures can promote decomposition of existing soil organic matter, and lack of surface vegetation means that soil organic matter will not be replaced. Further, the complex of these features can lead to adverse impacts on downstream ecological components. Soil erosion may lead to sedimentation of aquatic systems and burial of agricultural lands.

Table 1—Chemical Composition of the Common Fine-grained Minerals in Highly Weathered Rocks and Soils of the Hot, Wet Tropics

Mineral name	Molecular proportion Al_2O_3	SiO_2	H_2O	Fe_2O_3
Kaolinite	1	2	2	-
Halloysite	1	2	2-4	-
Allophane	∽1	∽1-2	Variable	-
Imogolite	∽1	∽1	∽3.5-4.0	-
Gibbsite	1	-	3	-
Boehmite	1	-	1	-
Quartz	-	1	-	-
Geothite	-	-	1	1
Hematite	-	-	-	1

Soil-surface temperatures increase significantly following the loss of vegetative cover. For example, maximum soil-surface temperatures in tropical South China are reported to range from 50° to 80°C under direct sunlight. Soil surface temperatures under fires from slash-and-burn agriculture range from 200° to 300°C (Phillips, 1965; Batchelder, 1967). Although such temperatures decrease rapidly with depth, the 50° to 80°C surface temperatures are high enough to damage or kill seed sprouts. This is especially true for seeds that are accustomed to the cool, moist conditions that existed prior to forest clearing.

Soil organic matter decreases quickly as soil temperature and biotic decomposition rates increase. Further, removal of vegetation and litter for fuel largely inhibits buildup of new soil organic matter. Soil organic matter plays a large role in holding nutrients in a form available to plants. Even small decreases in soil organic matter can have adverse impacts on the soil's ability to hold plant nutrients in a usable form (Montagnini and Sancho, 1990). For example, a decrease in soil organic matter from two percent to one percent is equivalent to a 1,125 kg loss of fixed nitrogen/ha (White and Collins, 1976).

The kinds of clay minerals present in soils also affect the fate of important plant nutrients. Where annual rainfall reaches at least 125 cm, the abundant clay mineral that forms during rock weathering processes in Hong Kong and elsewhere is the hydrated form of halloysite (Parham, 1969a and 1969b). Halloysite also is present in rock weathering products of South China (Chang, 1963; Gong, 1986; Li, Wang, Han, and Zhang, 1983; and Xu, Jiang, Yu, and Yang, 1986).

Hydrated halloysite (halloysite $4H_2O$) can hold nutrients in an easily exchangeable form, however, exposure to direct sunlight or the thermal effects of slash-and-burn agriculture, over time can dehydrate it irreversibly to halloysite $2H_2O$. In this form, the mineral's ability to hold plant nutrients in an exchangeable form decreases significantly from 40-50 meq/100 gm to 5-10 meq/100 gm (Grim, 1968). The ion exchange reduction caused by the combined decrease in soil organic matter and the dehydration of halloysite further reduces the soil's productivity. Such soil degradation conditions are widespread across many parts of South China.

Loss of soil clay minerals and organic matter also results in significant decreases of soil microelements (up to 27 percent). These include copper, zinc, manganese, cobalt, molybdenum, and boron, many of which are vital to the formation of vitamins, enzymes, and hormones that may be required by certain animals or plants. The quality and yield of crops, and animal reproduction can decrease from microelement losses (Openlender, 1979).

With the loss of vegetative cover and soil organic matter, intense tropical rains compact the surface soil. Clay-size particles plug small soil pores, inhibit water infiltration, and increase runoff and erosion. Water infiltration in such sealed or crusted soil in general is 6 to 8 times less than under forest cover (Lal, 1986). Under these conditions, water runs off the land quickly causing pronounced soil drying on uplands. Sparse vegetation characteristic of drier environments commonly replaces original vegetation and can lead to a mistaken impression that a regional climate change has occurred (West, 1986).

The area of severe erosion in the nine provinces of South China increased from 60,000 km^2 in the 1950s to 170,000 km^2 in the 1980s largely as a result of damage to or destruction of the land's vegetative cover. Some 50 percent (about 100,000 km^2) of China bounded by the Tropic of Cancer and the South China Sea is in a degraded condition. The land either is barren or supports a cover mostly of scrub or savanna vegetation (Vegetation Map of China, 1979). Hainan Island's forests, for example, covered 39.8 percent of the land in the early 1950s, 25.7 percent in 1956, and only 8.9 percent in the 1980s. However, damage has not been limited to terrestrial vegetation. For example, Hainan Island's mangrove forest area has been reduced in size from 10,000 ha to 1,300 - 2,000 ha just over the past several decades.

Soil erosion rates from devegetated surfaces can be high. For example, a barren, hilly, deeply weathered granitic area of Deqing County, Guandong Province now is seven to 13 m lower than it was 1,000 years ago from sheet and rill erosion alone (Luk and Yao, 1990). Similarly, Hong Kong's topography is estimated to be about 27 meters lower than it was 1,000 years ago (Lam, 1977).

Incision of gullies to depths of 10-80 m can occur in the weathered granite during exceptional rainfall that carries away large volumes of sediment. Silts and sands on barren Hong Kong hills, for example, are eroded rapidly during torrential tropical rains. Boulders of unweathered granite (core stones) as large as automobiles sometimes slide and tumble down barren hillsides when the sediments become saturated. In addition, eroded sediments damage aquatic productivity and bury what were once freshwater and marine nearshore aquatic breeding grounds.

Because runoff occurs so quickly where vegetation is absent, the water-carried sediments derived from weathered rocks accumulate in the lowlands clogging streams and rivers causing flooding. Sediments fill valley bottoms and marine and brackish water inlets as well (Grant, 1960). Where sediments have blanketed valley floors and runoff is slow, drainage waters sometimes carry enough iron in solution to make the waters toxic to plants and animals (IDRC Final Report, 1990).

Waterlogging affects many parts of South China and has damaged 130,000 ha of lowlands in Guangdong Province alone. The silting rate of the riverbeds of Guangdong Province generally is about 10 cm/yr (IDRC Final Report, 1990). Consequently, the watertable rises and flooding and waterlogging of adjacent agricultural fields results. To offset the waterlogging, farmers have developed dike-pond systems. They construct ponds to raise fish, and grow a variety of vegetable, tree, and fiber crops on the surrounding dikes. The dike-pond system has existed for about 600 years in the Zhujiang delta and today covers 59,000 ha.

When granite weathers chemically, the quartz component remains largely unchanged and accumulates on the land surface. Coarse quartz sands are swept from the weathered hills to lower elevations during heavy rains, filling valleys and covering agricultural fields. Fine-grained quartz sands on the other hand, are carried downstream and deposited near river mouths along the coast. Strong sea winds and typhoons at times move the sand inland burying fields and human settlements. For example, wind-blown sands became a severe problem on Pingtan Island, a granite island lying off the southeast coast of Fujian Province (Zhou, 1990). The island had a covering of primary tropical rainforest about 1,000 years ago (Sung Dynasty). Widespread forest and vegetation clearing led to soil erosion and the accumulation of quartz sands. During the fall of each year, strong winds caused sand storms so severe that sand covered roads and disrupted communications. In some cases, the people abandoned their villages. Similar conditions exist along much of the South China's mainland coast and on some nearshore islands.

To reduce potential for sand movement inland, windbreaks have been established now along much of the sand-covered coastal belt. At first, salt-tolerant *Casuarina* trees were commonly used for coastal windbreaks and for a fuelwood source for the local farmers; today, the use of mixed-species windbreaks is increasing. Tree cutting normally is not allowed but the local people are permitted to rake up litter beneath the trees for fuel. By doing so, few nutrients are returned to the soil, and when replanting is necessary, the newly planted trees have difficulty surviving.

The consequences of forest clearing on these hilly lands of tropical China obviously lead to a whole host of interrelated problems (e.g. soil erosion, waterlogged fields, and coastal sandstorms). Clearly, these problems are expressions of a land-use system gone wrong. Setting priorities to improve these degraded lands is easier where each problem is viewed as part of a system rather than being viewed separately (figure 2).

Sharing research information from all parts of the degraded system can reinforce a successful systems approach. For example, reforesting eroded hills will lead to reduced sediment loads in associated drainage ways. Reduced sediment loads in runoff will foster downcutting of silted riverbeds which in turn will reduce the amount of waterlogged fields and perhaps lower the water level in nearby fishponds. As the rivers continue scouring their channels, the wind-blown sand problem should diminish along the coast. However, with reduced amounts of sand being deposited at the river mouths and along the shoreline, unwanted coastal erosion ultimately may arise.

ADDRESSING THE PROBLEM

Human efforts still focus largely on maintaining or improving the quality of today's productive lands and on conserving remaining natural areas.[2] An additional challenge exists, however. That challenge is to blend old and new science and technology into new systems for land improvement and to apply the systems to solve the degraded/abandoned land problem. "Rehabilitation of degraded places may become the dominant activity of conservationists in the twenty-first century (Soule, 1989)." With per capita arable land as low as 0.03 ha in some parts of South China, loss of productive land is a serious problem today.

The climate, parent rock, and topography of South China predispose it to soil erosion problems. Human-induced factors such as rural industrialization, urbanization, expanded transportation systems, over-exploitation of forest resources, accessing of new agricultural lands, and poor cultivation practices compound the situation (Zhou G., 1991). To some degree this is a result of early Chinese policy that identified tropical South China as the nation's "breadbasket" and a corresponding goal of having each province become self-sufficient in food production. Poor populations typical of the region have little access to alternative livelihoods. Thus, many rely on subsistence agriculture and must operate using low capital input farming practices.

Chinese scientists have developed a variety of approaches to restore degraded lands, including: 1) solving soil erosion and associated nutrient loss problems, 2) developing "stereoagriculture," and 3) developing agricultural production schemes that provide risk reduction through diversity and incorporation of high-value commodities.

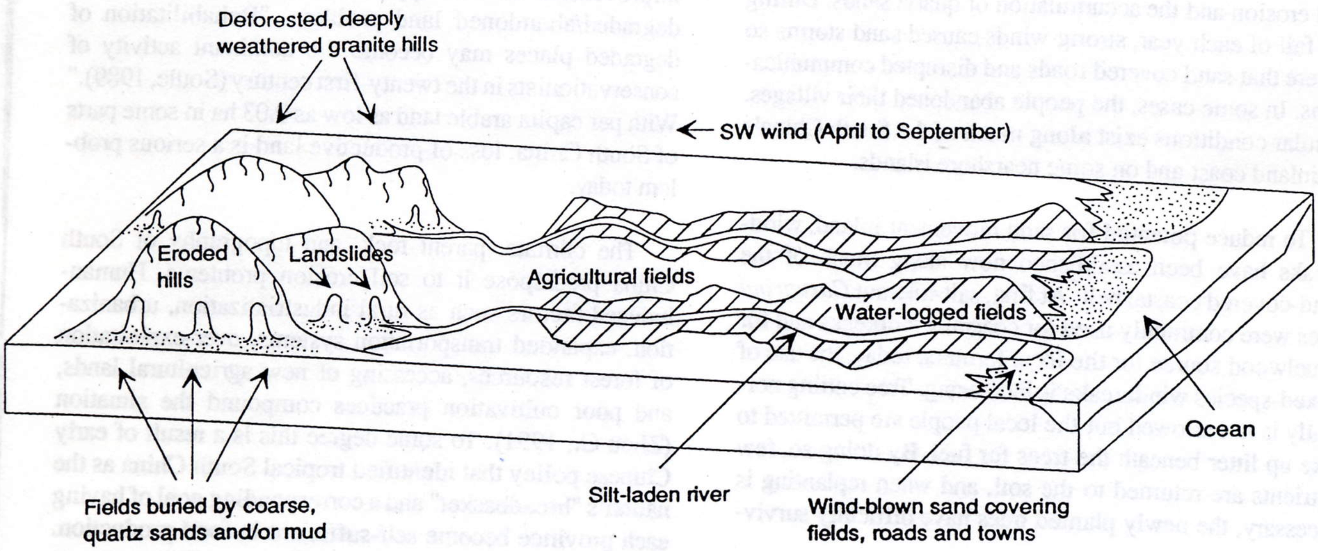
Approaches to Reduce Soil Erosion

Soil erosion and associated nutrient loss problems are the primary obstacles to restoration of degraded land. Approaches to halt soil erosion focus generally on combinations of engineering and biological measures. Policy actions have been taken to promote and protect erosion control activities. Although sheet and gully erosion are noted in current research activities, greater attention is placed on gully erosion ("benggang").

While efforts focus on hilly areas, some work has been accomplished in lowland areas subject to waterlogging (e.g., deltas, floodplains, coastal regions). These lowland techniques also employ engineering and biological measures primarily in the form of extensive networks of chan-

2 Inherent land productivity here means the ability of the land resources to sustain long-term production of vegetation and provide broad range of other benefits to society such as good water quality, biological diversity, and wildlife habitat. Land is broadly defined to include soil, water and all physical, hemical, and biological components of a productive ecosystem.

Figure 2—Sequence of Events Leading to Common Problems of Weathered Granitic Regions of South China



Notes:
- deforestation of weathered granite hills
- soil erosion, landslides, increased runoff, fine sands and silts removed by rains
- hills covered by a residual layer of coarse quartz sands
- heavy rains wash coarse quartz sands and other sediment onto fields at food of hills burying soils and crops
- fine sands and silts carried downstream by running water
- stream sediments build up stream bed
- fields inundated during flooding
- groundwater table rises waterlogging fields
- fine sands dropped along coast and moved by long-shore currents forming sandy beaches
- April-September southwest monsoon winds blow beach sand over agricultural fields, roads, and towns.

nels and vegetative cover on the channel interstices. The results are the dike-pond and field-pond production systems.

Natural vegetation patterns are mimicked in reforestation plans. Although little undisturbed original forest remains in South China, literature suggests that these areas were likely covered with moist forests, wet forests, and rain forests at one time. Successful reforestation efforts have been based on similar combinations providing dense, multi-storied canopies and effective protection of soils from heavy rains. Ground cover, planted initially, is phased out after canopy establishment.

Engineering measures to reduce soil erosion in hilly regions focus on check dams, hillside catchments, hillside diversion channels (cascadeways), and terraces. Check dams placed at the gully opening slow floodwater and trap sediments, ultimately raising the mouth of the gully. Check dams are constructed of local materials such as loose rock or sand. In cases of severe gully erosion, terraces may also be built on gully sides to promote vegetation establishment.

Biological measures to reduce soil erosion and nutrient loss tend to be implemented in conjunction with engineering measures. However, in cases of mild sheet erosion, biological methods alone may be used. Hilltop reclamation concentrates on planting fast growing trees and leguminous ground covers. Leguminous ground covers provide additional soil coverage and contribute to improving soil fertility.

In addition to physical methods employed to solve soil erosion problems, certain policy actions have been taken. Measures include restricting access to erosion prone areas, banning logging, and reforesting of specific areas. However, impoverished nature of the region, impedes implementing, enforcing, and monitoring of these policies.

Development of Stereoagriculture

China's scientists and technical experts began developing ecological agriculture in the late 1970s to address the environmental, agricultural, and economic difficulties of South China. Efforts today are supported by the central and local government (Chen Y., 1992; Liu Q., 1991; and

Wu J., 1992). Ecological agriculture blends the principles of mixed communities and nutrient and energy cycling with China's traditional organic farming and emphasizes the fullest use of solar energy and biological resources. It is a production system intended to maintain long-term land productivity, to fit into the social fabric, and to increase economic opportunities for farmers.

Stereoagriculture is an important form of ecological agriculture that is practiced in hilly areas of South China. This form of agriculture is designed to generate a variety of products (e.g., foods from plants and animals, firewood, and medicines) from a topographically varied site. Additional benefits include improvements in environmental quality and reduced economic risks for producers. Each piece of the overall system is developed to fulfill ecological functions for the specific sub-system and contribute to maintaining the function of linked sub-systems (box 1). For example, forest development on hilltops reduces soil erosion, runoff volume, and increases soil moisture storage capacity. These benefits accrue directly to land topographically lower by increasing water availability for crops throughout the year and reducing erosion that leads to sedimentation of water systems or flooding of agricultural fields. Thus, stereoagriculture provides a blend of conservation and production systems based on matching species and environmental characteristics.

The multi-tiered, multi-purpose plant communities of stereoagriculture systems are designed to take full advantage of each ecological setting. Nutrient cycling is a critical aspect of ecosystem productivity. Dependent on the soil ecology (i.e., interactions of soil microbes, fungi, and organic matter within the framework provided by the inorganic soil constituents), nutrients are continuously moved through the soil-plant-animal continuum. In a properly functioning ecosystem, nutrient partitioning is such that adequate amounts exist in the various parts of cycle. Movement of nutrients through the ecosystem provides the food necessary to support the diversity of biological inhabitants necessary to maintain the system.

In agricultural systems where large amounts of plant products are removed, nutrient replenishment from external sources may be necessary. However, in some cases, well-planned nutrient cycling within an agricultural system can reduce the need for external fertilizers and provide associated economic benefits as well. Chinese stereoagriculture systems optimize nutrient cycling within the production system in a variety of ways. Green manures

Box 1—Components of A Stereoagriculture System

Stereoagriculture is an application of ecological agriculture principles across a variety of hilly ecosystems under a unified management regime. The basic approach blends nutrient and energy cycling with mixed plant and animal communities appropriate to the ecological setting. Sub-systems are designed to function individually and to provide benefits to linked sub-systems.

Hilltop management typically is designed as conservation forest in existing stereoagriculture systems. Efforts might include reforestation with fast growing tree and ground-cover species and restricting access. Activities have focused on identifying optimum community combinations to promote rapid growth and maximize canopy development. Multistoried, multi-species communities have proven the most effective.

Hillside management tends to become a blend of conservation and economic forest. This type of forest may be developed to satisfy local fuel and timber needs or even be enhanced further to provide raw materials for local industries and thereby contribute additional economic benefits.

Foothill management takes on a more traditional agricultural approach with a focus on mixed systems of orchards, livestock, and crops. Maximizing use of soil and water resources is accomplished through intercropping and agroforestry methods. Leguminous crops are interplanted with orchards to provide nitrogen for the trees and forage for livestock.

Lowland or river bank management largely is devoted to grain production, aquaculture, and livestock. These systems tend to be highly complex and maximize nutrient cycling within the production system. The dike-pond system, with a history of over 500 years, exemplifies lowland management.

The diversity of sub-systems and their constituent parts generates a wide variety of products and benefits for local communities. In addition to improving environmental quality, well-designed systems can provide for local fuel, lumber, food, and fiber needs and contribute to export earnings.

and livestock manures are recycled in most of the production systems. Care is taken to develop appropriate soil microbial communities to promote mineralization of organic matter for crop uptake.

Energy, in the forms of solar radiation, atmospheric gases, and rain can be used effectively in a "manipulated" ecosystem to reduce the level of external nutrient and energy input. For example, solar radiation naturally is converted to biomass through photosynthetic processes, providing the feedstock for biomass conversion systems. Thus, livestock and crop wastes may be used to generate methane energy for home consumption through a biogas digestor and thus reduce overall waste. This type of cycling can increase energy availability and reduce fossil fuel consumption and fuelwood collection.

Associations between agroecosystem components can offer a variety of benefits to the production system, including growth promotion and productivity increases. In some cases, the exact mechanism through which beneficial associations operate is unknown, yet results clearly indicate that benefits are accruing. Typically, growth promotion arises from beneficial effects on the microclimate due to the establishment of hardy vegetation. For example, windbreak establishment may allow growth of species less tolerant to temperature extremes, salt spray, or periodic drought.

Three-dimensional aspects of the chosen plant community are important in evaluating potential complementary associations among the different components of a production system. Foremost among these are aboveground plant morphology and rooting geometry. Production systems may focus on either attribute or both and may be developed for perennial or annual crops or a mixture of the two. This approach has been used successfully in agricultural production systems as well as strict conservation activities.

The results of interdisciplinary teams of Chinese researchers striving to improve the land's productivity on a wide variety of difficult and damaged sites in tropical South China show promise. Most workshop authors (this report) describe such interdisciplinary experiments and pilot projects from various parts of South China. Assessing these experiences and synthesizing their combined knowledge provides new ideas and direction to researchers from China and other tropical regions where similar degraded lands exist. Box 2 lists common elements of successful Chinese systems.

PLANNING AHEAD

A broad ecological approach in project planning and design may reduce potential for unanticipated adverse impacts resulting from project implementation. While potential beneficial impacts of improving land productivity are identified during project planning and in fact may represent the project goal, identifying potential near- and long-term adverse impacts linked to goal achievement is more difficult. Further, these adverse effects may promote the spread of disease, reduce the quality of certain renewable resources, reduce biodiversity, damage cultural cohesivity, and change economies of scale. Using ecological principles in project planning and design may help to anticipate potential adverse impacts. This approach is likely to require additional basic and applied research, continuous monitoring and evaluation of activities, and adaptive project implementation schemes to allow new information to be integrated into ongoing projects.

Goals

In its simplest form, the problem addressed by South China researchers is depicted in figure 2: natural forest is converted into lands more productive of goods and services for human communities, which subsequently degrade into lands largely incapable of providing for human needs and wants. The obvious question is how to return the system to its previous productivity—how to make productive land out of degraded land? Other important questions are: Who should benefit from the improved land productivity? What do they need? What should the landscape provide after improvement? and What might happen if the goals are achieved?

Experience shows that whatever land restoration actions are taken, they should be: 1) safe to humans and the natural environment, 2) affordable, 3) fast working, and 4) adaptable to different cultures. These attributes should lead to efforts that: 1) improve land quality, 2) expand economic land-use options, and 3) improve quality of life for local populations. Solutions, therefore, require interdisciplinary approaches and strong local community participation.

A number of specific techniques have been used by Chinese researchers to reduce processes of degradation, and increase land productivity, each contributing to certain objectives of land restoration (see box 3). Different combinations of techniques will be necessary to increase productivity, and local community prosperity, of different

Box 2—Common Elements of Successful Ecological Agriculture Systems in South China

Numerous examples of successful eco-agricultural systems exist in tropical South China. Although the specifics of the activities vary from project to project they share some common principles including:

- Establishing clear goals for a land-improvement plan and methods to minimize risks to farmers.
- Combining landscape management with agronomic systems to achieve conservation and economic goals.
- Blending new techniques into traditional agricultural practices to ease their adoption by farmers.
- Developing systems appropriate for available local labor, investment, and infrastructure. Incorporating local support through, for example, a grassroots organization.
- Providing alternative fuel sources (e.g., biogas, coal, kerosene, firewood crops, fuelwood plantations), and fuel-saving devices (e.g., improved cookstoves) to reduce pressure on woodlands and grasslands.
- Increasing economic opportunities for farmers by designing systems that provide multiple products from plants and animals (e.g., food, chemicals, medicines, firewood), some of which can be harvested in the first year and others in each succeeding year.
- Combining engineering and biological measures to slow water runoff and soil erosion quickly and efficiently including identifying low-impact uses for erosion-prone areas.
- Designing tree cover to minimize adverse impacts of strong winds (e.g., shelterbelts, windbreaks, oriented tree planting).
- Improving grassland forage species with judicious use of organic and commercial fertilizers.
- Improving habitats for animals that can help control agricultural pests and disperse seeds.
- Planting multi-storied, multi-species systems that provide desired canopy densities and products and that improve the microclimate; maximize interception of solar and water resources; and maintain long-term soil productivity.
- Recycling by-products or wastes from each subsystem (e.g., fish ponds, home gardens, animal wastes) to other subsystems to minimize the need for costly external inputs.

SOURCE: China Tropical Lands Workshop, 1991.

sites. And systems must be designed to comply with circumstances and needs at different levels: homestead (e.g., minimized risk, product diversity, subsistence provisions, and cash income), community (e.g., cultural stability, hazard protection, time and labor availability, educational and vocational opportunities), and landscape (e.g., disaster mitigation, regulation of nutrient and energy flows, maintenance of essential environmental services).

With such a broad array of needs, problems, and sparse resources, establishing clear and achievable goals becomes essential. Goal setting is a thoughtful process, one that requires including elements of quantification and time considerations to allow for measurement of progress toward the goal. Without providing such measurements, the goal is open ended. For example, a person's stated goal might be to reduce erosion in a certain degraded area. Stated is this way, neither the rate of progress nor the level of success can be measured against the goal. Is the desired erosion reduction 1 percent, 10 percent or perhaps 80 percent? Over what period of time is this reduction to be achieved: 6 months, 2 years, or 20 years? With a stated goal, for example, of reducing erosion by 30 percent in 6 months, measurement of progess is possible and beneficial to associated design, research, implementation, monitoring, evaluation and planning processes.

Anticipating Potential Adverse Impacts

Activities to improve productivity of degraded lands, by nature, involve changing the ecological balance. The integrated nature of an ecosystem means that a change in one part may trigger changes in other parts. The damage from potential adverse impacts that might arise from such changes may be increased if they are not anticipated in project planning and design stages, and if monitoring, evaluation, and adaptation activities are not established for a project.

The existing physical, biological, and chemical renewable resources of a site are affected directly by efforts to improve land productivity. Further, social, cultural, and economic changes that may be generated by activities to enhance the productivity of degraded lands are additional complicating factors in foretelling the outcome of a project plan and design. These links, although not commonly assessed, are equally important in an ecological approach to project planning and design.

Physical changes of an ecosystem may include modifications of the land surface, hydrologic features and vegetative cover (e.g., surface and groundwater). These types of changes may result from engineering activities designed to reduce soil erosion through water flow diversion or

Box 3—Selected Means to Improve Productivity of Degraded Lands

Primary objective	Possible actions
Minimize soil erosion	build check dams, cascadeways, runoff baffles, terrace hillsides, hillside grading to reduce slope, protect existing vegetation, and revegetate with fast-growing species.
Revegetate hillsides	restrict access, plant fast-growing cover species (grasses, ferns, vines), trees, or mixtures of both, reduce erosive action of water on hilltops with ridge-top water collection, and protect and promote populations of seed dispersing animals.
Reduce flooding	raise river banks, channel river flow, and provide water catchments.
Increase soil fertility	prohibit hillside burning and slash-and-burn cultivation, prohibit litter removal from forest areas, incorporate nitrogen fixing species in planting activities, recycle nutrients, apply commercial fertilizers as needed, and provide year-round vegetation coverage.
Improve soil moisture retention	increase soil organic matter, revegetate barren areas, and develop ridge-top water catchments to supply drip irrigation systems.
Reduce waterlogging	develop drainage systems, incorporate high water-use plants, develop dike-pond systems, and protect wetlands as needed.
Reduce burial of agricultural lands	revegetate uplands, stabilize dunes, and build shelterbelts for agricultural fields and coastal areas.
Reduce overcutting of trees and grasses	restrict access, provide alternative energy sources, provide more efficient stoves, provide alternative construction materials, and develop fuelwood forests/grasslands.
Diversify production systems	combine plant and animal production, design altitude/climate/slope zones of economic vegetation use, improve market access, and develop new markets.
Provide alternative income-producing activities	develop local industries based on local, resources (e.g., tourism, crafts, mining of mineral resources, etc.), and develop value added/processing industries to increase economic benefits from resource extraction.

biological activities to increase water uptake and use. Stemming erosion is a key activity in improving the productivity of degraded lands and generally results in improved conditions in the project area. However, unanticipated indirect impacts arising from such activities may occur. For example, reduction in sediment movement downstream may contribute to shoreline erosion in distant areas dependent on sediment for beach replenishment.

Water diversion projects to irrigate land for food production may reduce the flow of the donor water body, producing breeding grounds for certain disease vectors such as mosquitos. As people move in to cultivate the newly established productive land, disease vectors and potential hosts/targets are brought together. Nearly 1,000,000 new cases of malaria are reported each year and of these the majority are related to development activities (Otterstetter, personal communication, 1992).

Biological changes of an ecosystem may include modifications in the variety, composition, and range of plants, animals, and microbes present. Project activities may increase the abundance of certain plants or animals (e.g., for food or tourism). These introductions will have significance for the level of resource extraction needed to support the increased population. In turn, some species may be outcompeted and eliminated from the ecosystem. If the species outcompeted are pests to humans, the result may be deemed beneficial. However, if other beneficial species are dependent on the lost biological feature (e.g., for food or lifecycle completion) they too may be eliminated or significantly reduced. This can affect the maintenance of biological diversity. Thus, alteration of the ecosystem may have effects further down the line and not directly linked with the initial change fostered by the intervention. It is these types of changes that are difficult to identify early on and calibrate in ecosystem manipulations.

Changes in the chemical balance of the soils and waters associated with the reclaimed area can also lead to unforeseen problems. Introduction of external inputs such as agricultural chemicals may lead to adverse effects on surface and groundwater. For example, heavy fertilizer use to promote plant growth may result in high levels of nitrate moving into surface and groundwater resources. High nitrate levels, whether from natural (e.g., manures) or commercial (e.g., fertilizers) sources, can have significant adverse human health effects.

The workshop presentations and discussions clearly established that effective activities are underway to improve the productivity of some degraded areas in South China. However, information on the potential long-term adverse impacts is lacking in most cases, largely due to the short history of these projects. In some cases, current projects have been developed from a history of failed activities and thereby have incorporated lessons learned (i.e., effectively used data to modify project design and implementation). However, collection of baseline data on potential areas of impact and examination of possible new links present in the altered ecosystem may offer opportunities to identify potential adverse impacts at the project planning stages generally. Monitoring and evaluation of environmental, social, and economic features of the project will provide additional data for use in current and future projects. Further, establishment of adaptive project implementation schemes may facilitate development of revised protocols for activities to improve the productivity of degraded lands (figure 3).

CONCLUSION

It seems clear from the scale of the tropical degraded lands problem in China that cooperation and innovation among researchers throughout the world will be necessary (Zhou G., 1991). Learning from the Chinese experience is part of the solution. Figure 4 is a map of the provinces of South China, and Hong Kong. Listed below the map is a directory for the reader to help identify the general geographic sites related to papers in this volume.

Figure 3—Basic Components of Improving Land Productivity in Degraded Lands [Cascadeway of Progress]

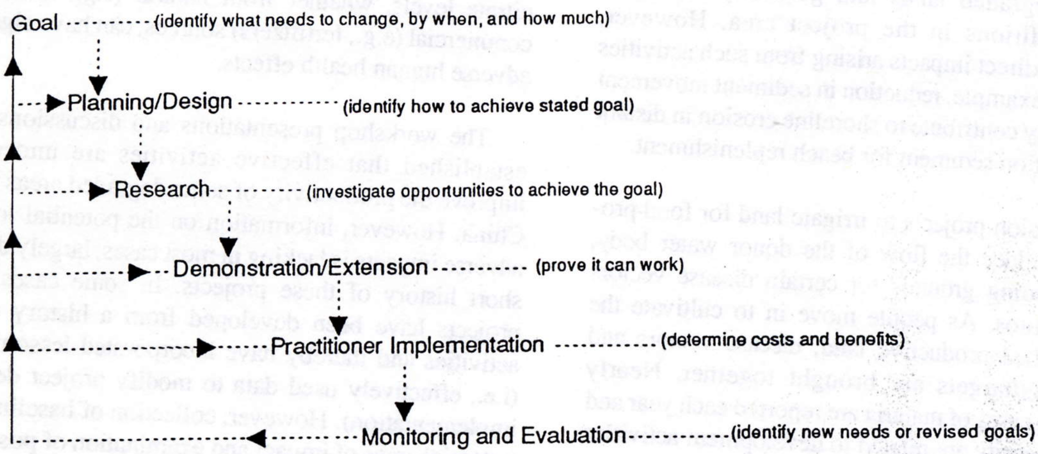
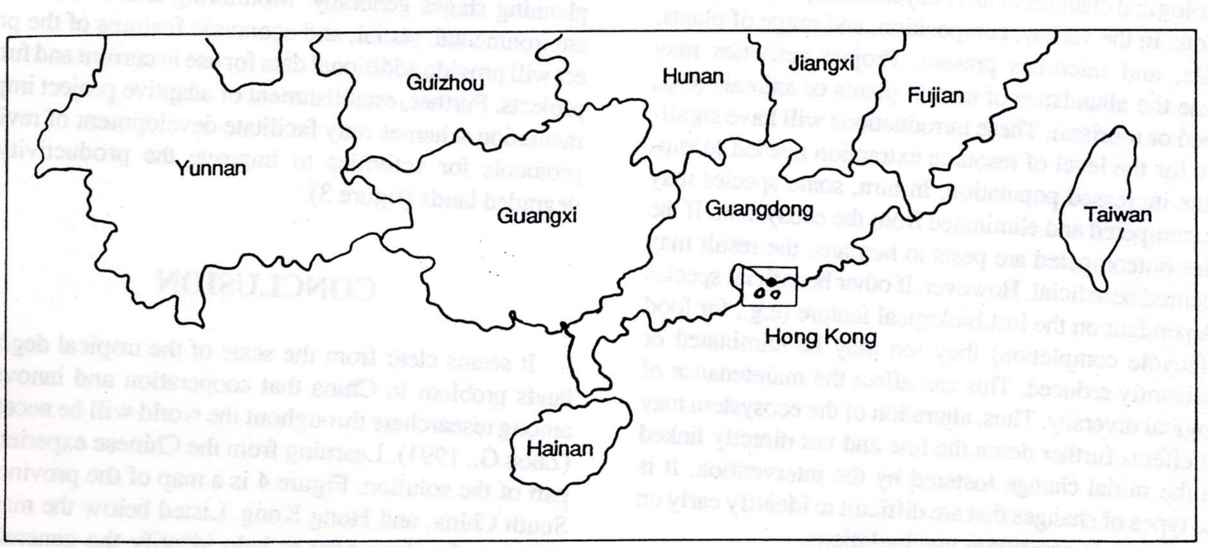


Figure 4—Study Localities of Workshop Papers



Yunnan Province	Guangxi Province	Hainan Province	Guangdong Province	Hong Kong	Fujian Province	Regional China
Li T. Song Q. Xu Z.	Li J.	Feng Y. Jiang Y. LInag J. Luo L. Ong S. Xu D. Xue D.	Chen C. Chen R. Han Z. Huang P. Huang Y. Li H. Lin X. Liu H. Luo S. Xie M. Xu G. Zhang H. Deng H. Liang G.	Chung Guan D. Hill, R. Jim C. Shaw, R. Webb, R. Zhuang X.	Zheng D.	Deng N. Luo S. Ni S. Zhao Q. Liu H-S

Note: Only first author listed above for papers in this volume.

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