CHAPTER 3

LIVING IN ECOSYSTEMS

This chapter traces the histories of several ecosystems and the people whose lives depend on them, whose actions have degraded them, and who hold the power to restore them. Included are the grasslands and traditions of pastoralism of Mongolia; a community-managed forest in India; mountain watersheds and downstream urban areas in South Africa; the agricultural plains of Machakos, Kenya; and the wetlands and croplands of southern Florida in the United States. These are places where the inhabitants are striving to safeguard their future, which depends so clearly on the health of their ecosystems.

Five brief stories from Cuba, the Caribbean, the Philippines, New York City, and the watershed of Asia's Mekong River complement the detailed case histories. Many of the cases and stories encompass multiple ecosystems, but for simplicity they are grouped in this chapter by the ecosystem most critical to the featured management challenge.

Together, the cases and stories capture diverse experiences from around the world–varying spatial scales, population sizes and densities, and ethnic groups. They illuminate the driving forces and impacts of degradation and the analyses of ecosystem condition presented in the earlier chapters. They also reflect the variety of trade-offs that we face as inhabitants and managers of ecosystems. For example, South Africans planted income-generating but invasive nonnative trees, then paid a high price in terms of diminished water supply to cities and towns. Drainage and conversion of parts of the Everglades to agriculture fueled the growth of the Florida sugar industry but reduced the ecosystem's water retention and filtration capacity and threatened biodiversity. The state government was able to intensify commercial cutting of timber in Dhani, India, from the 1950s through the 1970s but at the long-term expense of local livelihoods.

Individually, some of the cases and stories address many management issues, others just a few. None offers any ready-made "fixes" for ecosystems that have been degraded, but all can encourage an exploration of questions crucial to the future productivity of ecosystems:

- What causes an ecosystem to decline? Who gains the benefits of ecosystem use and who pays the costs of decline?
- What conditions increase recognition that ecosystem misuse or overuse must be supplanted by efforts to alleviate pressures and ensure long-term productivity? What circumstances move people to concern and action?
- How do we create the public and political will to take action to restore an ecosystem?
- What mechanisms and policies can help prevent ecosystem decline or ensure long-term sustainability?
- To what extent, and over what time frame, are an ecosystem and its services amenable to restoration?

The search for answers to these questions underscores the complexities of ecosystem change–the often-surprising natural dynamics of ecosystems as well as the human management challenges. Through case studies, we can examine ecosystems and the people who live in them as constituents in larger geographical regions and social contexts. No ecosystem, even an isolated Mongolian grassland or a forest in a small community like Dhani, is managed by a single person or institution that can act unilaterally. Ecosystem management is the sum of many individuals and institutions–public and private, formal and informal–and political and economic factors. A widening network of connections further complicates management. Many ecosystem problems have local roots and local or regional consequences. But the causes of problems such as acid rain, ozone depletion, invasive species, and global warming can originate in a neighboring country–or even half a world away–and affect us all.

A G R O E C O S Y S T E M S

Regaining the High Ground: Reviving the Hillsides of Machakos

In Machakos, necessity is the mother of conservation. Because water is scarce and rainfall unpredictable in this mostly semiarid district southeast of Nairobi, farmers have learned to husband water. They collect water from their roofs, they channel road runoff onto their terraces, they scoop water out of seasonal streams or perennial rivers, and they dig ponds to collect rain. To minimize soil erosion, farmers have adopted a system of conduits, tree planting, and terraces found nowhere else in Kenya. "These [measures] are the lifeline of the people here in Machakos," said Paul Kimeu, soil and water conservation officer for the Machakos District.

Conservation efforts, plus persistence and hard work, have enabled the people of Machakos, the Akamba, to survive in the face of drought, poverty, and land degradation. In the 1930s, severe soil erosion plagued 75 percent of the inhabited area and the Akamba were described as "rapidly drifting to a state of hopeless and miserable poverty and their land to a parching desert of rocks, stones, and sand" (Tiffen et al. 1994:3, 101). Today, once-eroding hillsides are productive, intensively farmed terraces. The area cultivated increased from 15 percent of the district in the 1930s to between 50 and 80 percent in 1978, and the land supports a population that has grown almost fivefold, from about 240,000 in the 1930s to about 1.4 million in 1989 (Tiffen et al. 1994:5; Mortimore and Tiffen 1994:11). This environmental transformation has been called "the Machakos Miracle" (Mortimore and Tiffen 1994:14, citing Huxley 1960).

But the benefits of the "miracle" have not reached everyone. Those with the least fertile land often lack the financial

(continues on p. 152)

Box 3.1 Overview: Machakos

Through innovation, cultural tradition, access to new markets, and hard work, farmers in Kenya's Machakos District have turned once-eroding hillsides into productive, intensively farmed terraces. However, economic stagnation, population growth, increasing land scarcity, and a widening income gap raise the question: Is Machakos' agricultural transformation sustainable?

Ecosystem Issues

Agriculture

Since the 1930s, the Akamba people of Machakos have terraced perhaps 60–70 percent of arable fields to protect them from erosion. Land conditions and agricultural output have also benefited from penned livestock, tree planting, composting, and other measures. Yet with decreasing arable land per capita and sluggish economic development, poverty remains a problem for some, particularly during droughts. Poverty, in turn, decreases farmers' ability to invest in sustainable technologies and management.

Freshwater

Most streams in Machakos are seasonal, rainfall is variable, and groundwater limited. Water projects and conservation activities have expanded irrigation, reduced the risk of crop failure, cultivated higher-value crops, and freed labor from fetching water. But about half the population still lacks potable water and water availability constrains industrial and urban growth.

Forests

Contrary to expectations, aerial photos suggest that the District has become more, not less, wooded since the 1930s. Small-scale tree planting efforts have been beneficial; farmers plant trees to stabilize soils and supply fruits and timber. Akamba also minimize deforestation by using dead wood, farm trash, and hedge clippings for firewood.

Management Challenges

Equity and Tenurial Rights

Some of the most severe agroecosystem degradation in Machakos emerged in the decades when the colonial government divested the Akamba of their land rights and restricted market access. By contrast, greater Akamba control over farm techniques, lands, and livelihoods have coincided with self-led, often independently funded innovations in conservation.

Economics

Improved access to markets, the growth of urban areas like Nairobi and Mombasa, and the right to grow lucrative cash crops provided incentive for farmers to implement new technologies and maximize productivity. But market access remains difficult and economic growth sluggish; decreasing farm size and labor shortfalls are additional roadblocks to further agricultural intensification.

Stakeholders

For decades, government officials and farmers disagreed about farming objectives and methods. In an atmosphere of inequality and mistrust, officials promoted or regulated technologies that the Akamba did not accept or perceive as viable. Greater environmental progress has occurred since Akamba farmers have gained a more equal voice in the decisions about agricultural management and methods.

Information and Monitoring

NGOs, government extension workers, researchers, and self-help groups have vastly improved the information and resource base available to farmers, but improvements in the information base must be ongoing. For example, researchers have emphasized the weakness of data with which to analyze change in extent and condition of Machakos ecosystems, including data on soil health, changes in land use and vegetation, and production.

Timeline

1600s–1700s Akamba first occupy the Machakos uplands.

1889 Europeans arrive.

1895 British Protectorate of East Africa is established.

1897–99 Consecutive drought seasons result in devastating famine; 50–75 percent of Akamba die.

1906 British colonial government designates the most fertile Machakos lands as "White Highlands" for European settlers; Akamba are restricted to "Native Reserves." Only Europeans are allowed to grow high-value export crops like coffee and tea.

1928–29 Drought and famine strike.

1930s Growth of human and livestock populations without room for expansion cause farmlands on Native Reserves to deteriorate. Akamba migrate out of Reserve settlements in search of work or to occupy other lands illegally.

1933–36 Successive droughts occur. Officials acknowledge the "Machakos problem" when 75 percent of inhabited area is plagued by soil erosion.

1937–38 Colonial government creates the Soil Conservation Service and attempts to impose conservation measures on Akamba, including compulsory reductions of cattle. Akamba protest.

1940–45 Conservation funding and number of available male farm laborers are limited during WWII; famine relief is required.

1946 Government makes significant investments in land development and conservation in Africa—in Machakos in particular. Emphasis is on compulsory communal work, including government-selected systems of terracing.

1949–50 Consecutive drought seasons ensue.

1950s Growth of urban areas increases demand for agricultural products, making terracing and water conservation profitable and attractive.

1952 News spreads among Akamba that cultivators who use bench terraces, rather than government-mandated narrow terraces, are making big profits, sparking voluntary construction of bench terraces.

1954 Swynnerton Plan to revolutionize agriculture emphasizes production of crops for export. For the first time, Akamba are granted the right to grow coffee, another incentive to terrace land and a source of cash with which to purchase farm inputs.

1959–63 Akamba turn to political activity in build-up to Kenyan Independence (1963). Conservation efforts slow, as they are perceived as tainted by colonial authority.

1962 Akamba surge onto former Crown Lands. Population growth rates in some areas reach 10–30 percent per year, as people seek to escape land shortages in other areas.

c. 1965–70s Recognizing the potential for higher yields, farmers renew soil and water conservation efforts largely without government aid. New roads improve access to Nairobi, and growth of canning plants encourages fruit and vegetable production and, in turn, terracing.

1974–75 Drought returns.

1975–77 High prices for coffee inspire tripling of production and heavy investment in land conservation.

1978–80s Numerous church-led projects and national and international NGOs provide support for community development, including famine relief, food production, and water supply and irrigation.

1983–84 Drought strikes—called "dying with cash in hand" because of severe food shortages. After the drought, more terraces are rapidly constructed.

1996–98 Droughts followed by El Niño rains ruin subsistence crops and force farmers to sell livestock for food.

2000 Perhaps as much as 65 percent of farms are terraced, many farmers use additional conservation measures.

resources to tap the water below it. Higher living standards seem most achievable by those households with access to nonfarm income, but population growth and economic stagnation contribute to a shortage of jobs in towns and cities. For those farmers without access to nonfarm income, lack of capital or credit limits their ability to implement innovative agricultural practices.

On the one hand, then, Machakos offers a dramatic example of how knowledge, innovation, and respect for the vital services that soil and water provide have enabled people to restore and even increase the productivity of severely degraded lands. On the other hand, Machakos illustrates the continued vulnerability of both ecosystems and people in the face of cultural, economic, and environmental change.

A Land of Hills and Dry Plains

Machakos lies on a plateau that gradually slopes southeast from 1,700 to 700 m elevation, broken by groups of high hills. Rain has always been precious in Machakos; annual rainfall ranges from 1,200 mm in the highlands to less than 600 mm in the lowlands of the southeast and the dry plains of the extreme northwest (Mortimore and Tiffen 1994:12; Tiffen et al. 1994:18). Less than half the district has more than a 60 percent chance of getting enough rain to grow maize, the Akamba's preferred staple (Mortimore and Tiffen 1994:12, citing Jaetzold and Schmidt 1983). In most years the highlands are the only region that can support reliable agricultural harvests without irrigation.

The Akamba are believed to have settled the uplands of Machakos in the 17th and 18th centuries, when most of the area was an uninhabited thorny woodland. Evergreen forests crowned the wetter highlands and grasslands carpeted the drier plains. The Akamba raised cattle, goats, and sheep and cultivated grains, pulses, and sweet potatoes on wet hills. Close to water they irrigated small plots of vegetables, bananas, and sugarcane. They became skillful traders, providing ivory, honey, beer, ornaments, and weapons to the Kikuyu and Masai in exchange for food. Their lives changed dramatically in the late 1890s, however, after smallpox, cholera, and rinderpest decimated both human and animal populations and drought devastated the land. By 1900, 50–75 percent of the Akamba had perished in some areas; perhaps only 100,000 people were left in the district (Tiffen et al. 1994:44, citing Lindblom 1920; Tiffen 1995:4).

At about the same time, the new British colonial government gained sufficient power to impose boundaries on the Akamba and other native people in Kenya. They created several "Native Reserves" and claimed some of the best farmland for themselves in "Scheduled Areas" or "White Highlands." Though the Akamba retained most of their traditional lands, the government's policy blocked any expansion, with European ranches and farms on two sides and government-controlled "Crown Lands" on the other two.

Traditionally the Akamba had responded to drought, decreasing soil fertility, and population growth by moving to new fields or ranges. Without this mobility, shifting cultivation gave way to continuous cultivation. Although the population of both people and cattle in the Akamba reserve grew, the colonial government strictly enforced the reserve boundaries to maintain political control. By 1932, some 240,000 Akamba lived in Machakos, more than double the population at the turn of the century (Mortimore and Tiffen 1994:11). Within the reserves, soils became exhausted and crop yields fell.

For the already stressed ecosystem and its people, the return of severe drought in 1929 was catastrophic. The Akamba called the drought "*Yua ya nzalukangye*" or "looking everywhere to find food" (Tiffen et al. 1994:5). Then, from 1933 to 1936, droughts occurred during six of the eight semiannual growing seasons–the long rains from March to May, and the short rains from October to December. Locusts invaded the withering maize crops, and voracious quella birds ate the remains. Cattle denuded the parched brown hillsides, then began to starve, soon followed by the Akamba themselves. When the rains did come, the region's highly erodible red soil bled from the steep hillsides in torrents. Historical photographs reveal a landscape of treeless hillsides, deep gullies, denuded slopes, and fields stripped of topsoil.

Changing Attitudes: From Compulsory Conservation to Akamba Innovation

In reports written from 1929 to 1939, colonial agricultural officers argued that rapid population growth, surplus livestock, deforestation, and unscientific farming methods were leading to massive degradation of the region's natural resources. The Akamba recognized the worsening environmental crisis, too. "[T]his place was becoming a desert," reflected Joel Thiaka, a farmer from Muisuni, in 1938 (Tiffen et al. 1994:44).

Several factors prompted the colonial government to invest in land development: a global antierosion movement, catalyzed in part by the Dust Bowl in the United States; the increasing African populations; and the expense of providing emergency food aid to ward off massive starvation during times of drought (Tiffen et al. 1994:179). In 1937 the colonial government created a Soil Conservation Service led by Colin Maher. The Service's first efforts included the confiscation and slaughter of "excess" Akamba cattle. After Akamba protestors rallied in Nairobi, those initiatives were abandoned (Tiffen et al. 1994:181–182).

Maher next launched "compulsory conservation projects." These required Akamba to plant grass and build terraces–

structures used for centuries in Asia and Africa to cultivate steep hillsides. When these activities progressed too slowly, Maher mandated the building of conservation structures with government tractors and paid-labor gangs. The Akamba again protested, fearful of another government land grab; according to Akamba tradition, anyone clearing or cultivating land had permanent use-rights to the property. Some Akamba even threw themselves in front of the tractors. The Akamba finally agreed to send one family member two mornings a week to work on forced-labor gangs building terraces and water conservation projects and planting fodder crops.

The terraces that Maher required Africans to construct during this period were narrow-based terraces, also known as contour ditches. Building these small structures required workers to dig a shallow trench and throw the soil downhill to create a small berm to capture runoff. Though easy and relatively fast to construct, narrow terraces were also quick to wash away and required significant maintenance. They soon lost favor with Akamba farmers, but not with Maher.

Although soil conservation efforts languished during World War II (1940–45), they were renewed with vigor by an expanded Department of Agriculture after the war, as wide-scale erosion and famine returned to Machakos. There was much African opposition to many of these "betterment" projects. Yet several Akamba innovations emerged in the ensuing decades from these controversial programs, innovations which laid the foundation for the "Machakos miracle," though few recognized them at the time. One was workers' experimentation with the construction of a bench terrace called a *fanya juu.*

Fanya juu terraces are constructed by digging a trench along the contour of a slope and throwing the excavated soil uphill to form a gently sloping field with an earth embankment that collects rainfall and slows runoff. Though they require considerable labor to construct, such bench terraces soon become stable and require only periodic maintenance of the berm. Maher, however, thought they were too labor-intensive for the Akamba, and thus had mandated narrow terraces.

Maize, beans, and mango and banana trees are part of this well-designed hillside terrace.

Box 3.2 Machakos Agriculture

Results from a 1998–99 survey involving several hundred farmers and 484 plots of land suggest that the efforts put into conserving soil and water in Machakos have been well rewarded. The survey shows that terracing is by far the most popular conservation measure. Farmers who use terracing often use multiple conservation measures—adopting them as a package (Zaal 1999). Other research suggests that there was a substantial increase in productivity per hectare in the Machakos District between the 1930s and 1990s (Tiffen et al. 1994:95–96).

Land and Water Conservation Measures in Machakos

About half the terraced plots also incorporated another conservation measure.

Percent of Fields Given Over to...

Terracing	65.7
Grass strips	14.0
Grass terrace border	10.7
Trash lines	8.5
Agroforestry	2.3
Cover crops	1.0
Open ridges	0.6
Stone terrace	0.4
Cut-off drain	0.2

Source: Zaal 1999.

Benefits of Terracing

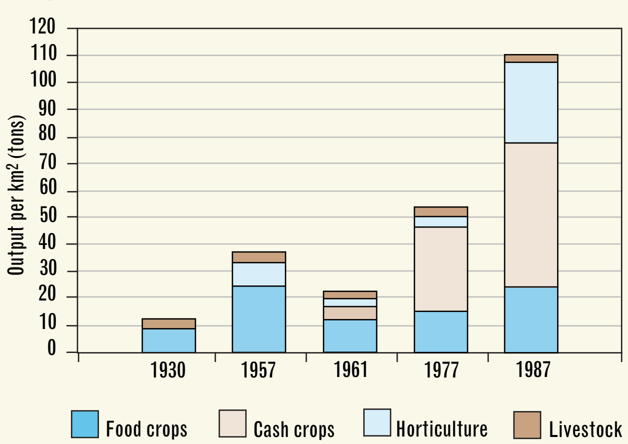
The survey showed that farmers who use terraces reap numerous benefits.

Percent of Farmers Experiencing...

Higher land value	97
Higher yield levels	94
Greater stability of yield	94
Less erosion	76
Less use of fertilizer	75
Less labor to plant	53
Less labor to weed	43

Source: Zaal 1999.

Crop and Livestock Production in Machakos



Source: Tiffen et al. 1994:95.

But the Akamba have a saying: "Use your eye, the ear is deceptive" (Tiffen et al. 1994:152). Many of the Akamba men fought as part of British forces overseas, where they saw other agricultural practices at work. In 1949, one veteran built a bench terrace patterned after one he had seen in India. He harvested a good crop of onions that he sold for a profit. Other farmers in the area soon followed his lead. After Maher's retirement in 1951, farmers were allowed to choose whether to have contour ditches or *fanya juu* in the compulsory betterment programs; more and more chose *fanya juu*.

During the 1950s, more than 40,000 ha was terraced in Machakos (Mortimore and Tiffen 1994:14, citing Peberdy 1958). One incentive for this large-scale shift to terraces was the government's decision in 1954 to allow Akamba farmers to grow coffee for the first time–a decision based on the Swynnerton Plan's emphasis on producing lucrative cash crops for export. The Akamba were eager to reap the economic benefits of growing coffee, but coffee can only be planted on steep slopes if they are terraced, to ensure that the nutrients and moisture essential to coffee's growth are retained. Other farmers used terraces to grow tomatoes and other vegetables for the expanding town of Nairobi.

Another breakthrough that would promote self-led Akamba innovation and conservation occurred in 1956. The new and mainly African-staffed community development service under a government-appointed chief replaced the hated compulsory work gang with the *mwethya*, or traditional work party, whose members chose each other and their own leaders. Normally Akamba families called a *mwethya* for a special project, such as building a hut; neighbors would help in exchange for food. With technical support from the government, *fanya juu mwethyas* were soon busy all over the district building terraces and undertaking other projects.

Since many Akamba men worked outside the district, most of the laborers who worked on the conservation projects and in the first *mwethya* were women. This was the first time in Akamba history that women were elected to leadership positions, providing them with increased status and political power and reinforcing the value of education for daughters. The traditional work group evolved, too, into self-help groups that today pool money as well as labor and are connected with organizations that provide community development, agricultural extension, and literacy services.

Kenya's independence from colonial rule in 1963 spurred a surge of Akamba families onto former Crown Lands. The new government ended all funding for soil conservation, and for a few years terracing fell out of favor with the Akamba, who saw conservation efforts as tainted by the colonial regime. But soon farmers who had seen the benefits of the *fanyu juu*–for yields of staple crops like grains and beans, cash-crop production, and survival during drought–began to build them again, on their own, either through *mwethyas* or hired labor. In fact, more terraces were built from 1961 to 1978 than were built during the 1950s, and without any government aid (Tiffen and Mortimore 1992:363). The period from 1960 to 1980 was also characterized by a phase of steep growth in land productivity in Machakos (Tiffen and Mortimore 1992:365). Another 8,500 km of terraces were built annually between 1981 and 1985, half of them by farmers with no outside assistance. By the mid-1980s, aerial surveys showed that 54 percent of Machakos' arable land was protected from erosion, with more than 80 percent protected in hilly areas (Tiffen et al. 1994:198). A 1998–99 survey of 484 fields in Machakos suggests that about 60 percent are terraced; many farmers also use additional conservation measures (Zaal 1999:5).

Overall, some 76 production technologies were introduced or expanded in the district between 1930 and 1990, including introduction of 35 crops varieties, 5 tillage practices, and 6 methods for managing soil fertility (Mortimore and Tiffen 1994:16). Many of these conservation and land development mechanisms were Akamba innovations.

The expansion of market opportunities clearly affected the popularity of conservation measures. The coffee boom in the 1970s, for example, increased demand for labor on the farms and in coffee processing factories and transport to markets. Coffee prices fell in the late 1980s, but large international horticultural firms in Nairobi began to encourage Machakos farmers to produce crops like French beans as export crops. Citrus, pawpaws, and mangoes have proved similarly successful with the rise of Kenya's canning industry and the growth of towns and tourist trade. According to a 1981–82 survey, 41 percent of rural income came from nonfarm businesses and wages (Mortimore and Tiffen 1994:16). For decades such income, usually earned by Akamba men with jobs outside the district, has been invested in farm improvements such as building terraces or water storage tanks and planting trees and hedges.

Farmers also began to invest in planting and protecting trees. Photographs comparing landscapes in 1937 and 1990 show a substantial increase in the density and average size of farm trees (Tiffen et al. 1994:218). Because farmers, particularly women, spent increasing time foraging for firewood after hillslopes were cleared, they developed the practice of planting woodlots to facilitate gathering. Often farmers planted trees at the bottom of their plot so as to minimize water uptake from their own crops and maximize that from their neighbors'; that location offered the added advantage of helping to keep hillside soil in place. Women farmers have favored fruit tree plantings because they offer household food supplies and an independent source of cash (Tiffen et al. 1994:221).

Adaptive changes in livestock management and the adoption of ox-drawn plows for weeding and cultivation have contributed to Akamba farmers' success. Since no communal grazing lands remain, animals are now fed on the farm. More than 60 percent of the district's livestock are stall-fed or tethered for all or part of the year, requiring fodder feeding, but also supplying manure for fields (Mortimore and Tiffen 1994:19, citing African Development and Economic Consultants 1986). Added advantages of "zero-grazing" systems are increased milk yield, reduced destruction of vegetation through overgrazing, decreased disease incidence, and labor savings. A transition to foddering cattle also brought the care of cattle into the female domain, further empowering women. Many women now derive useful income for themselves and the farm through milking, for example. Cutting of fodder by women, usually from napier grass on terrace edges, encourages their involvement in terracing.

Machakos' agricultural success didn't come without environmental costs. As the cultivated land in the district grew from 15 to nearly 80 percent, native plant and animal populations decreased dramatically, including some of Kenya's rarest species, such as the rhinoceros. Poaching and encroachment in Tsavo National Park and other protected areas remains a problem (Kenya Web 1999).

Small-scale, traditional irrigation in Machakos is based on seasonal streams.

Box 3.3 Ranking the Challenges in Machakos

At a 1999 conservation workshop sponsored by the World Resources Institute in Machakos, farmers unanimously agreed that lack of water was their most pressing concern, followed by farm size and land scarcity. As the population has increased, farms have been divided among heirs until the average farm size is little more than 1 ha. The high-potential lands have all been taken, so people are farming more marginal lands, either in the plains or on steep mountainsides where the government prohibits agricultural activities.

Lack of capital to invest in farm improvements and technologies and the lack of a ready labor pool were also at the top of this group's list of constraints to conservation. Because more children are in school and older children are migrating to cities to find work, women now provide most of the farm labor in Machakos—while still carrying out traditional responsibilities like raising children, keeping house, and fetching fuel and water.

Soil erosion didn't make their list of challenges. In fact, the largest contributor to soil erosion in the district today isn't farms but rather poorly constructed or unrepaired roads and sand mining from river beds by the concrete industry, which has flourished in conjunction with a building boom in Nairobi. Many roads are etched with deep gullies along steep roadsides, made worse by the El Niño rains, but repair requires public or community resources on a scale that the citizens of Machakos simply don't have. Poor roads also increase the cost of imported foods and the cost of transportation to get Machakos-produced goods to retail markets in places like Nairobi and Mombasa. Road conditions during the rainy season make it difficult for farmers to get their produce to markets before it spoils. Because the district is not completely supplied with electricity, food processing or refrigeration is not always feasible.

A road that connects Machakos Town to district hillsides. On the left is a roadside drain. Maize and bean crops and mango, banana, and eucalyptus trees are visible in the background.

An example of poorly maintained terraces near Machakos. Theses show only minimal management to reduce erosion of the unprotected terrace berms. Further up the slope this farmer has planted maize, beans, cassava, mango, and banana trees.

Machakos Today

"In Machakos today people are building soil conservation structures without being forced," says George Mbate, an economist with USAID (interview 19 February 1999). "They've come to relate production of crops with proper soil management."

The effect of drought is not as damaging today, thanks to investments in terraces; retention ditches, which encourage water seepage to the cropped area; and cut-off drains, which collect water and discharge it safely without causing erosion on the farm. The manure that farmers apply to fruit trees not only fertilizes the soil but improves water infiltration, lessening water runoff. Short-season maize varieties and early planting to allow enough time to prepare the land for the "long-rains" crops are also beneficial. These techniques, along with diversification of income from urban jobs, have made it possible to reduce food imports and famine relief, even during droughts (Tiffen and Mortimore 1992:373).

But even terraced crops are vulnerable, and the problems of Machakos are far from solved. Droughts in 1996 and 1997, followed by El Ninõ rains in 1998, ruined subsistence crops and forced some farmers to sell livestock to buy food. In the semiarid areas good harvests were achieved, but the heavy rains hit the hilly areas of Mwala division particularly hard, rotting crops, leeching nutrients from the soil, and destroying terraces, houses, and latrines.

"Most times, it's a food-deficient area," admits A.M. Ndambuki, agricultural officer for the district (interview 1 March 1999). "In a good year, there's enough food for that season. This year [1998] with the drought, we didn't harvest anything. Now almost all the food we're eating comes from outside the district." Importing food rather than producing it wouldn't be a problem if there were sufficient opportunity to earn money, but in Machakos, there is not. Many of the poorest farmers must search for alternative, often low-wage rural jobs in order to feed their families.

The farmers who fare the best are those like Samuel Milo, who grows tomatoes, maize, beans, and sugarcane on the sloping land of his 16-ha farm. He maximizes his terraces by planting napier grass for fodder on the terrace embankments, and a row of banana trees in the gullies to protect against erosion and to supply fruits. He plants trees as windbreaks between crops, too, and has a woodlot from which he sells timber and gets his firewood. His 4,200 coffee plants produce high-quality beans that he sorts, processes, and sells. By keeping his five cows penned and fed on napier grass harvested from the terrace, instead of allowing them to graze, he saves land space and has fertilizer for the soil.

But Mr. Milo is not just enterprising and conservation-minded, he is also fortunate. His farm is unusually large and a stream runs through his property. He has built an irrigation channel above the stream. Thanks to income-generating crops, he has been able to run a pipe from another stream into a large underground storage tank built on his property, ensuring a steady water supply.

Other farmers are not so lucky. For many, adaptations and conservation techniques like Mr. Milo's are too expensive or labor intensive. For the farmer with limited resources to hire help, for example, terracing can take years. In one Machakos village, researchers found that only 57 percent of farmers could afford the capital needed to produce cash crops for the market or to purchase farm inputs like fertilizer. Those were usually farmers with family members who earned money from off-farm jobs in urban areas (Murton 1999:40).

Another economic change that may undermine poor farmers' ability to apply best farm practices is a polarization of wealth and land. In 1965, the poorest 20 percent of the households in Mbooni owned 8 percent of the land; in 1996, they owned 3 percent. By contrast, the richest 20 percent owned 40 percent of the land in 1965 and 55 percent in 1996 (Murton 1999:41). This creates a group of viably large farms, but leaves very small farms struggling in poverty. Land concentration occurred as wealthier farmers, often those with a nonfarm income source, bought out farmers who sold their medium-sized or small farms. Some of the farmers who sold their farms migrated onto the former Crown Lands—the more fragile lands and drier frontier areas. There more acreage was available, but more inputs were needed to produce the same income.

Why do people bear the hardship of pioneering a new farm in difficult conditions or hang on to a tiny plot in the uplands? Because for the Akamba, owning land "is part of your identity, your value, your culture," according to Dr. Samuel Mutiso (interviewed 25 February 1999), a Kamba who heads the geography department at the University of Nairobi and is Kenya's representative to the UN Convention on Desertification. "We are torn between two worlds," he said.

Can the "Miracle" Continue?

"The changes in Machakos didn't come overnight," says Mutiso. Spurred by necessity and eventually freed from the constraints of dictatorial government land policies, the Akamba successfully intensified land use by selecting and adapting new technologies from a variety of places. They switched to more profitable crops, better staples, manure fertilizers, and systems of multiple cropping, reduced grazing, and tree cultivation. Community-level planning and leadership, such as the *mwethya* groups, and community preferences in technology and crops far more effectively increased fertility and decreased erosion than imposed conservation programs. When farmers have economic incentives to conserve soil—higher yields, the opportunity to grow more profitable crops, and access to markets—they are willing to invest more capital and labor in bench terraces. In a sample of five areas, the proportion of total area treated with soil conservation measures rose from about 52 percent in 1948 to 96 percent in the older settled areas in 1978. The areas also reflected substantial gains from soil erosion reduction and from rainfall infiltration and soil moisture retention (Tiffen and Mortimore 1992:368).

Migration to urban areas provided a flow of remittances that augmented capital for agricultural development. Income and experience from nonfarm jobs were combined with government extension efforts to dramatically facilitate the transfer of knowledge, technology, and capital to the farms.

Another important change was a shift from central government decision making about ecosystem issues to greater district-level participation, including direct engagement of local leaders in seminars. This approach afforded an opportunity to work with, rather than against, the Akamba's intimate knowledge of the land's problems and their culturally preferred agricultural methods. It also capitalized on their abiding attachment to the land. "It is not just economic," says Maria Mullei (interview 17 March 1999), an agricultural officer with USAID who also farms in Makueni, "you love the land so you protect it." In fact, much of the incentive and capital for the retreat from expected ecological disaster came from the people of Machakos themselves.

Decreasing farm size, growing land scarcity in the face of population growth, and loss of communal grazing lands also have pressured the Akamba to use their land and water as efficiently as possible. Yet no one has suggested that population growth might encourage further conservation, land intensification, and productivity. Today, population growth rates in Machakos are about 3 percent per year (Mortimore and Tiffen 1994:13). With increasing population density and high costs of raising children, however, birth rates are starting to fall.

Less encouraging are signs that without capital some erosion protection and water conservation technologies cannot be adopted even if they would improve the land. For example, more farmers would like to put in water storage tanks but face the problem of limited financial resources. On some upland farms there are too few bulls to haul plows, and terraces are too small to allow plows to turn easily.

Cyclical poverty may emerge, as Murton (1999) found in Mbooni, which was part of Machakos district prior to 1992. Those with an off-farm job, more fertile soils, or a water source fare better. Those that fare better and increase productivity are most able to switch to higher value crops, like citrus fruits and French beans, and tap commercial markets. But others abandon farming or migrate to marginal lands. Although all children complete primary school, the poorest families may not be able to afford to send their children to secondary school, which may deny them the opportunity to secure the off-farm jobs that lead to personal income.

The future of agricultural innovation and land productivity in Machakos also depends in no small part on the larger economy in which the district operates. The technologies to protect the land are in place, but the present greenness of the fields does not guarantee anyone a living. Economic and environmental sustainability also are determined by food prices, the availability of urban jobs, and external resources for improvement of roads or electrification to help farmers tap commercial markets.

Tempered by such challenges, Machakos remains an encouraging story, a place where the expected progression toward further environmental degradation has not occurred, a place where farms flourish in place of deserts. Whether such rewards and growth are sustainable will be determined in the decades to come.

Cuba's Agricultural Revolution: A Return to Oxen and Organics

The fall of the Berlin Wall in 1989 and the subsequent demise of communism in the Soviet Union occurred half a world away from Cuba. But the repercussions of that revolution directly affected Cuban soils: it transformed Cuba's agricultural lands by forcing a radical shift to organic inputs and farming methods on a scale unprecedented worldwide.

Cuban Agroecosystem Management from 1959 to 1989

From 1959 through the 1980s, being part of the socialist trade bloc significantly influenced Cuba's economic development and ecosystem management. Though a highly industrialized country that produced pharmaceuticals and computers as well as crops, sugar was the staple of the Cuban economy. By 1989 state-owned sugar plantations covered three times more farmland than did food crops (Rosset 1996:64). Sugar and its derivatives constituted 75 percent of the total value of Cuba's exports, purchased almost entirely by the Soviet Union, Central and Eastern Europe, and China (Rosset and Benjamin 1993:12). High crop yields were attained through agricultural methods that were more mechanized than in any other Latin American nation, in addition to extensive use of pesticides, fertilizers, and large-scale irrigation.

In return for its exports of sugar, tobacco, citrus, minerals, and other items, Cuba imported about 60 percent of its food as well as crude oil and other refined products, all from the socialist bloc at favorable terms of trade. Forty-eight percent of the fertilizer, 82 percent of the pesticides, and much of the fuel used to produce the sugar crops were imported as well, along with 36 percent of the animal feed for Cuban livestock (Rosset and Benjamin 1993:10, 15).

This trade regimen—though highly import-dependent—enabled Cuba's 11 million people to achieve economic equity, rapid industrialization, and advancements in quality of life. In the 1980s, Cuba exceeded most Latin American countries in nutrition, life expectancy, education, and GNP per capita. Sixty-nine percent of the population was urban, with virtually no unemployment (Rosset and Benjamin 1993:12). Ninety-five percent of Cubans had access to safe water and 96 percent of adults were literate (FAO 1999:20).

The Advent of Alternative Agriculture

The crumbling of the socialist trade bloc in 1989–91 brought upheaval to the Cuban economy and its conventional model of agricultural production. Cuba lost 85 percent of its trade (Murphy 1999). The United States tightened its already stringent economic blockade against Cuba, compounding the country's difficulties.

Cuba's access to basic food supplies was severely threatened. As food imports were halved, caloric intake dropped 22 percent, protein 36 percent, and dietary fats 65 percent (Bourque 1999). According to the FAO, Cuba endured the largest increase in undernourished people in Latin America in the 1990s—a jump from less than 5 percent to almost 20 percent (FAO 1999:8). Imports of pesticides, fertilizers, and feeds were reduced by 80 percent and petroleum supplies for agriculture were halved (Rosset 1996:64).

To avert widespread famine, Cuba had to find a way to produce twice the amount of food with just half of its previous agricultural inputs. The result is that Cuba is now in the midst of the largest conversion from conventional high-input chemical agriculture to organic or semiorganic farming in human history (Rosset 1996:64). Cuban farmers are attempting to produce most of their food supply without agrochemicals.

Cuba's prior investments in science, education, and agricultural research and development proved a great asset during these dire economic straits. In the 1980s, concerned by Cuba's vulnerability as the sugar plantation of the eastern bloc, government leaders had invested $12 billion in training scientists in biotechnology, health and computer sciences, and robotics

Cuba's Dependence on Imported Food, pre-1990

Imported foods accounted for 57 percent of Cubans' total caloric intake.

Food	Percentage of Food Imported
Beans	99
Oil and lard	94
Cereals	79
Rice	50
Milk and dairy	38
Animal feed	36
Meat	21
Fruit and vegetables	1–2
Roots and tubers	0
Sugar	0

Source: Rosset and Benjamin 1993:10.

(Rosset 1996:65). Although Cuba comprises only 2 percent of Latin America's population, it is home to 11 percent of the region's scientists (Rosset and Benjamin 1993:4).

Agricultural scientists influenced by the international environmental movement of the 1970s had begun to criticize Cuba's dependence on foreign inputs and the toll that conventional cultivation techniques were taking on the island's agroecosystems. As they noticed increasing pest resistance and soil erosion, many shifted their research in the 1980s to alternative methods of crop production, particularly the biological control of insect pests (Rosset and Benjamin 1993:21).

Most important, Fidel Castro gave his full support to the "alternative model" during this "Special Period." The government emphasized the importance of using Cuba's own scientific expertise instead of imported technology. "Cuban scientists will create resources that will one day be more valuable than sugarcane" Castro said in 1991. "Our problems must be resolved without feedstocks, fertilizers, or fuel" (Rosset and Benjamin 1993:24).

That was easier said than done. Cuban scientists had developed several alternative agricultural techniques during the 1980s but they were largely untried. Plus, the transition from chemical to organic agriculture takes time–roughly 3–5 years to regain soil fertility and re-establish natural controls of insect pests and diseases (Rosset and Benjamin 1993:25). Cuba did not have the luxury of 3–5 years.

Cuba's Access to Selected Imports in 1989 and 1992

Item	1989	1992	Percentage Decrease
Animal feeds	1,600,000 MT	475,000 MT	70
Fertilizer	1,300,000 MT	300,000 MT	77
Petroleum	13,000,000 MT	6,100,000 MT	53
Pesticides	US$80,000,000	>US$30,000,000	63

Source: Rosset and Benjamin 1993:17.

The first challenge was soil fertility. Fertilizer availability dropped 80 percent after 1989. To fill the void, Cuban farmers have employed a variety of "biofertilizers" and soil amendments, including composted animal wastes, cover crops, peat, quarried minerals, earthworm humus, and nitrogen-fixing bacteria. Though the *Rhizobium* bacterium has long been known to help legume crops obtain nitrogen from the atmosphere, Cuban scientists also have used *Azotobacter*, a free-living nitrogen-fixing bacterium, to supply nitrogen to many nonlegume crops. *Azotobacter* offers added advantages of shorter crop production cycles and reduces blossom drop, helping Cubans achieve a reported 30–40 percent increase in yields for maize, cassava, rice, and other vegetables (Rosset and Benjamin 1993:43). Similarly, the substitution of worm humus for chemical fertilizers increased yields of various crops by 12–46 percent (Monzote n.d.:9).

Intercropping, once rare in commercial scale farming, is being revived to diversify crop production and boost soil fertility. Another key component of Cuba's soil management efforts is reforestation; many forests were razed after the 1959 revolution to plant sugarcane and provide fuel for sugar manufacturing. In 1989–90, more than 200,000 ha were reforested (Rosset and Benjamin 1993:50).

The country is recycling its waste products on a massive scale, including household garbage and composted livestock and human waste. Wastewater is used to irrigate cane fields. Filter press cake, a by-product high in phosphorous, potassium, and calcium, serves as fertilizer. Bagasse, or dry pulp, is fed to livestock and burned to generate electricity for machinery in many sugar mills.

Cuba has a history of using biological controls for insect pests that dates back to 1928, when growers began releasing mass-reared parasitic flies (*Lixophaga diatraeae*) into sugarcane fields to control cane borers. Since the food crises, however, use of biological controls has intensified. Growers have been releasing predatory ants (*Pheidole megacephala*) to control the sweet potato weevil (*Cylas formicarious*), a method that has proven 99 percent effective (Rosset 1996:66).

Cuban researchers have focused also on the use of entomopathogens–bacteria, fungi, and viruses that infect insect pests but are nontoxic to humans. *Bacillus thuringiensis*, Cuba's first commercially produced biopesticide, is a soil bacterium widely used to control lepidopteran pests in pasture, cabbage, tobacco, corn, cassava, squash, and tomatoes, as well as mosquito larvae that transmit human diseases. The fungus *Beauveria bassiana* has also been used successfully against sweet potato and plantain weevils (Rosset 1996:67). In contrast, prior to 1989 the most common pesticide used in Cuba was methyl parathion, one of the most acutely toxic pesticides in the world (Gellerman 1996). By the end of 1991, an estimated 56 percent of Cuban cropland was treated with such biological controls, representing savings of US$15.6 million per year (Rosset and Benjamin 1993:27).

Overall, nonchemical weed control has been less successful than pest controls in Cuba, as elsewhere. Nevertheless, researchers continue to develop methods that hold promise—crop rotations based on mathematical modeling, methods involving weed densities, and traditional methods used by peasants before the advent of herbicides.

Perhaps the most striking change in the agricultural landscape was the return to the use of oxen in the fields while Russian tractors, lacking parts and fuel, were idle. Though more labor-intensive, ox traction actually provides advantages to Cuban farmers. Oxen are cheaper to operate, do not compact the soils, can be used in the wet season long before tractors, and their fodder provides much-needed organic fertilizer. New ox-powered plows, planters, and cultivators were developed, and the government encouraged oxen breeding programs to expand the herd.

Promotion of Small Farms and Urban Gardens

Alternative farming methods alone couldn't bring Cuba out of its agricultural slump. Huge Soviet-style state farms controlled 80 percent of the nation's agricultural land. The vast monocultures of sugarcane, pineapples, citrus and other crops they once produced with chemical fertilizers and pesticides were incapable of developing the natural pest controls or soil fertility produced by smaller, more dynamic organic systems. As a result, the state farms became extremely vulnerable to pests and disease (Rosset 1996:65, 69).

By contrast, *campesinos* were quick to adapt the new technologies, and their productivity soared. Many were descendents of generations of small farmers with long family and community traditions of low-input farming, and they remembered techniques that their parents and grandparents used

In the 1980s, Cuba used highly mechanized agricultural methods. After the economic crisis, oxen teams were substituted for tractors on both small and large farms. The number of oxen teams has tripled in the last decade. There is also a growing network of small workshops producing implements for farming with oxen teams.

such as intercropping and manuring. Even before the country-wide emphasis on organic agriculture in the 1990s, the small farmers had proven their efficiency: they worked only about 20 percent of the land but produced more than 40 percent of the domestic food supply (Rosset 1996:65, 68–69).

In 1993 the Cuban government broke up the unproductive state farms into Basic Units of Cooperative Production–worker-owned cooperatives that controlled about 80 ha each. Although the government still owns the land and sets production quotas for key crops, coop members own everything they produce above the quotas and can sell it in new farmer's markets. Sales at markets flourished and severe food shortages disappeared by mid-1995 (Rosset 1996:69–70).

Intensive, raised-bed agriculture is the model for urban agriculture in Cuba. These farms, called *organoponicos,* are approximately 1 ha and produce, on average, 20 kg of vegetables per square meter (Bourque 1999). Farmers rely on large applications of organic fertilizers from local sources and only use biologically based pest controls when absolutely necessary.

Another factor that helped stave off hunger was the promotion of urban agriculture by the Cuban government on private and state land, which gardeners can use at no cost. Today, Havana alone has more than 26,000 self-provision gardens (Moskow 1999:127) that produced an estimated 541,000 tons of fresh organic fruits and vegetables for local consumption in 1998. Some neighborhoods were producing 30 percent of their food. Price deregulation provided another incentive, enabling urban farmers to earn two to three times as much as urban professionals (Murphy 1999).

Will the Organic Revolution Be Overthrown?

In the 1996–97 growing season, Cuba recorded its highest-ever production levels for 10 of the 13 basic food items in the Cuban diet, largely because of small farms and backyard production (Rosset 1998). But FAO data suggest that total Cuban crop production in 1996–98 was still 40 percent lower than in 1989–91 (World Bank 2000:122), perhaps in part because sugar crop yields have not yet recovered. Furthermore, pest and disease outbreaks continue. Many of the biopesticides require critical timing of applications to work, and the quantity and quality of materials produced by the cooperatives vary widely. At one point a shortage of glass jars needed to grow fungal spores held up production (Rosset 1996:72).

Such stumbling blocks have led outside observers to speculate that the organic revolution in Cuba may dissolve after the economy improves and trade barriers come down. The topic is a subject of debate among Cuban agricultural scientists and farm managers, many of whom remain dedicated to high-input chemical agriculture common in the West (Mueller 1999).

Whatever the outcome, Cuba's ongoing experiment with alternative agriculture has left a powerful mark. Even though Havana now enjoys increased food availability, urban agriculture is stronger than ever (Murphy 1999). In a recent survey, 93 percent of gardeners interviewed affirmed their commitment to producing food in urban areas and once vacant lots even after the "Special Period" ends (Moskow 1999:133). Cuban scientists are already exporting their expertise, working with Mexico, Bolivia, Brazil, Laos, and other countries to develop and export biological controls for the coffee weevil and other pests (Bourque 1999). Moreover, Cuba has succeeded in feeding its people without the high inputs of conventional agriculture, providing a model that other countries can follow.

COASTAL ECOSYSTEMS

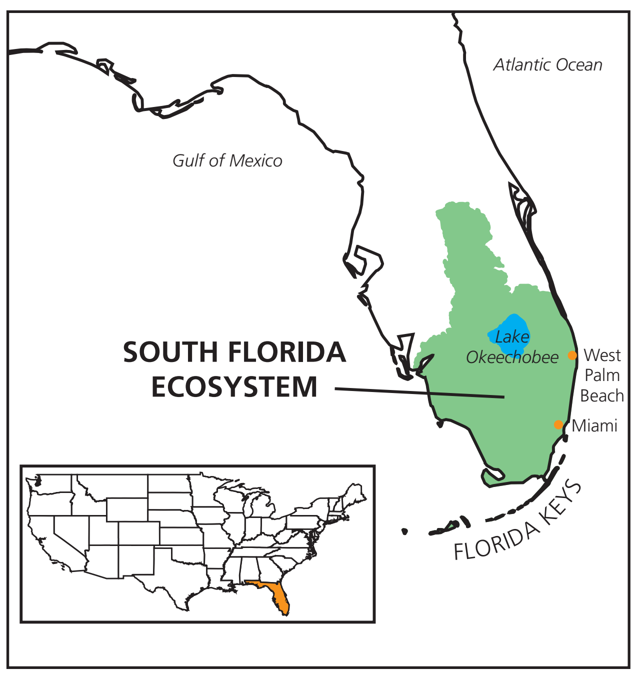
Replumbing the Everglades: Large-Scale Wetlands Restoration in South Florida

Look down on South Florida from a high enough altitude and the problem is obvious. Lake Okeechobee, the liquid heart of the giant watershed that covers the lower third of Florida, stands penned behind floodproof dikes. Massive changes in the landscape have clearly altered the flow of water through the area. Below Lake Okeechobee, the original shape of the Everglades is barely recognizable arcing south for 160 km from the Lake to the mangrove shallows of Florida Bay.

Water dominates the South Florida ecosystem like few other places in North America. This was once an unbroken marshland of sawgrass and small tree islands, fed by a shallow sheet of water flowing south from Lake Okeechobee. Now the marsh is a series of disconnected tracts separated by dikes, drained by a web of major and minor canals. Croplands–mostly sugarcane–have displaced the entire northern third of the Everglades; only the southern end remains in a relatively natural state as Everglades National Park and Big Cypress National Preserve.

The benefits of these changes–and the beneficiaries–are as clear as the changes themselves. To the east of the Everglades, safe behind a levee, lies the greater Miami area–a sea of tract houses and high-rise buildings, home to 6 million people and a burgeoning center of tourism, trade, international investment, and retirement living. The levees and canals protect the populated eastern corridor from floods and effectively turn most of the remaining tracts of Everglades into reservoirs for water supply. Agriculture, which represents the other major land use in the area, depends even more on the

(continues on p. 166)



Box 3.4 Overview: Florida Everglades

In what may be the world's most ambitious effort to restore an ecosystem, U.S. government agencies, business interests, and environmentalists are combining forces—and US$7.8 billion—to reverse a century of draining and diking in the Florida Everglades. This vast inland marsh houses a rich assemblage of plants and wildlife and is the water source for the Miami area's 6 million residents and South Florida's lucrative farming sector.

Ecosystem Issues

Freshwater

The 23,000 km^2 Kissimmee-Okeechobee-Everglades watershed was once a single hydrologic system of rivers, lakes, and wetlands. Flood control and water supply structures have drastically reconfigured this once free-flowing water, reducing the water volume and disrupting the natural flooding and drying cycle. Nearly half of the wetlands have been lost; saltwater intrusion and pollution from intensive agriculture are additional problems.

Coastal

Changes in the natural water flow in the Everglades have greatly reduced the quantity of freshwater reaching the coast at Florida Bay, disrupting estuary salinity levels, and causing seagrass die-offs and turbidity in the bay. Traditional bird colonies have abandoned nearby mangrove forests and brackish marshes.

Agriculture

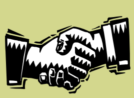
Croplands have displaced about one-third of the Everglades, but have made South Florida counties important producers of sugarcane, subtropical fruits, and winter vegetables. That output, however, now is threatened: agricultural acreage in Southern Florida is giving way to urban sprawl and soil subsidence.

Management Challenges

Economics

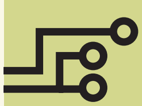
Although the restoration bill is daunting, the cost of allowing the Everglades' decline to continue could be far greater, particularly for local residents and businesses. For example, further declines in the health of Florida Bay could bring losses of more than $250 million/year in lost tourist dollars and reduced commercial fish catches. The area's $2 billion agriculture sector depends even more on the flood control and reliable water supply that the network of water control structures brings. No one has yet put an economic value on the many species whose lives hang in the balance of restoration.

Stakeholders



Sustaining the restoration effort will demand ongoing negotiations and commitment among an array of stakeholders—federal, state, and county governments; agribusinesses; environmental, sport, and recreation groups; and Native American tribes. Because restoration is intimately connected with regional patterns of land and resource use and economic expansion in Southern Florida, all of the area's 6 million residents are also ultimately affected.

Information and Monitoring



No restoration project of this magnitude has ever been undertaken; its effects on the social and biological aspects of the system are not entirely known. The many unknowns make ongoing monitoring of the ecosystem's health and productivity particularly essential: to ensure the maximum effectiveness of the $7.8 billion investment, to provide feedback to stakeholders, to guide changes in the restoration plan, and to inform similar efforts elsewhere.

Timeline

c. 0 AD Native Indian tribes—the Tequesta and the Calusa—migrate into South Florida.

1513 Spanish explorer Ponce de Leon claims Florida for Spain.

1820s Settlers from the United States begin to migrate south into Florida.

1821 U.S. purchases Florida territory from Spain.

1835–42 and 1855–58 The "Seminole Wars": Seminoles escape into the Everglades interior to avoid U.S. government troops.

1845 Florida territory is granted statehood in the United States of America.

1848 U.S. government first recommends draining Everglades for agriculture.

1855 Alligators begin to be hunted for their hides; at least 10 million killed from 1870 to 1965.

1881 Hamilton Disston finances first large-scale experiment in draining and farming in the Everglades.

1907 The Everglades Drainage District founded to fund major drainage canals.

1917 Four major canals completed from Lake Okeechobee to the Atlantic Ocean.

1926 and 1928 Hurricanes kill 2,500 people and cause more than $75 million in damages.

1928 Tamiami Trail (first road across the Everglades) is completed.

1947 Record rains flood 90 percent of southeastern Florida for 6 months. Everglades National Park is established.

1948 Central and South Florida (C&SF) Project is authorized.

1954–59 Everglades Agricultural Area created by diking and draining the northern Everglades.

1963–65 C&SF water managers stop water from flowing into Everglades National Park in order to fill new water conservation areas.

1970 Severe drought occurs.

1973 Construction complete on major elements of the C&SF Project.

1980–81 Severe drought occurs.

1983 Governor Robert Graham initiates Save Our Everglades program.

1986 Major algal bloom on Lake Okeechobee prompts state action to lower phosphorus pollution entering the lake.

1988 Seagrass die-offs and large algal blooms begin in Florida Bay. Federal government files suit against the South Florida Water Management District for releasing water polluted with agricultural runoff into the Everglades.

1991 Florida passes the Everglades Protection Act, mandating control of nutrient pollution of the Everglades.

1992 U.S. Army Corps of Engineers begins review of C&SF Project to determine how to reduce ecosystem damage.

1993 Federal government establishes the South Florida Ecosystem Restoration Task Force.

1994 Florida enacts the Everglades Forever Act to establish a comprehensive program to restore significant portions of the Everglades. Governor's Commission for a Sustainable South Florida is established.

1997 Restoration of the channelized Kissimmee River begins. Construction begins on the first of six filtering wetlands to remove phosphorus from agricultural runoff leaving the Everglades Agricultural Area.

1998 U.S. Army Corps of Engineers releases $7.8 billion plan to reconfigure the C&SF Project to restore a more natural water cycle.

flood control and reliable water supply that the network of water-control structures brings.

But the benefits that have come from bending the natural water cycle to human need have brought less welcome changes to the ecosystem. The Everglades and the whole of the South Florida ecosystem are uniquely dependent on the area's distinctive water flow pattern. When people began to disrupt this pattern, the health of the ecosystem began to deteriorate–at first slowly, but more rapidly in the last 2 decades. Wading bird populations have plunged, seagrass beds in Florida Bay have died back, sport and commercial fishing has suffered, and nonnative plants and fish have invaded, among other effects. Even the assurance of a plentiful water supply has evaporated as the urban population grew and the capacity of the Everglades to store water shrank.

Can the South Florida ecosystem be restored to health? Local powerbrokers and the public think so, and have already committed more than $2 billion to the effort over the last decade. Recently they have embraced a new $7.8 billion Everglades restoration plan proposed by the U.S. Army Corps of Engineers–the most ambitious and extensive ecosystem restoration effort in the world. With the goal of duplicating, as much as possible, the region's original water patterns, engineers are poised to rip out certain levees, refill some canals, and re-allocate water throughout the region. There are no guarantees of success, and even if some recovery occurs, scientists are not sure how much the total health of the ecosystem will improve over the long term, given that the Miami region is still developing rapidly. Yet the restoration effort has clearly generated local enthusiasm, as well as high-level support from the state and federal governments. How a contentious band of government agencies, business interests, and environmental and sporting groups came to agree on such an expensive and difficult program is a story of how convincing–and threatening–an ecosystem in distress can be.

Draining the Marsh, Stopping the Flood

Water had long been a barrier to human settlement of the Everglades region. Prior to the 19th century, a few Native Indian villages dotted the coast, but the marshy interior of the Florida Territory remained largely unpeopled until bands of Seminole and Miccosukee Indians fled to the Everglades to escape U.S. government troops in the 1830s.

Early white settlers regarded the Everglades and other seasonally flooded tracts as wasted land, inhospitable to commerce, food production, transportation, and personal safety, and fit only to be drained and "improved." At first, agriculture was the focus of these schemes. With a tiny population and no major cities or industrial base, Florida looked to its fertile muck soils for its future.

THE BEGINNING OF FLORIDA'S AGRICULTURE

In 1881, Philadelphia millionaire Hamilton Disston financed the first real attempts to drain and farm marshlands in South Florida on a 20,000 ha tract in the upper Kissimmee Basin. His success with rice and sugarcane crops on reclaimed land bore out the land's potential productivity. His canals–the area's first–opened a water route from Lake Okeechobee to the Gulf Coast. By the late 1920s, agriculture was well established around Lake Okeechobee and elsewhere in the basin and the rudiments of a drainage system–five major canals from Lake Okeechobee to the Atlantic–had been dug (Light and Dineen 1994:53–55; Light et al. 1995:120–122).

But these early canals and levees were not sufficient to protect the region from the disastrous floods that periodic hurricanes brought. Hurricanes in 1926 and 1928 claimed more than 2,500 lives and left an estimated $75 million in damages when flood waters breached the low levee protecting the farming areas south of Lake Okeechobee. These disasters intensified efforts to keep the lake safely within its bounds. The levee was raised and two flood bypass routes, to the east and the west, were created to help vent flood waters directly to the Gulf and Atlantic coasts rather than allowing the waters to flow south along their natural course (Light and Dineen 1994:55).

Unfortunately, when major hurricanes again hit the Everglades in 1947 and 1948, inundating 90 percent of southeastern Florida for 6 months, it was clear that flood protection was only partial at best. State and local representatives, backed by their powerful agricultural and urban constituents, pushed for the federal government to step in and fund a lasting solution to the area's flood problems (Light and Dineen 1994:58; USACE 1998:I–22).

THE CENTRAL AND SOUTH FLORIDA (C&SF) PROJECT

Federal officials responded with a major public works program–the Central and South Florida (C&SF) Project. It began in 1950 and took more than 20 years to complete. The C&SF Project is a large interlocked system of drainage canals, levees, pumps, water control gates, and water storage areas. The levees separated the Everglades from the urban eastern corridor to provide flood protection from Lake Okeechobee waters. As a by-product, the drainage canals and pumps allowed water tables in the area east of the levee to fall as much as 1.5 m, permitting suburban development to flourish (Light and Dineen 1994:58–76).

The intent of the C&SF Project was not just to tackle the flood threat, but also to secure an adequate water supply for both agricultural and urban users. Indeed, too little water was frequently as great a problem as too much. Drought years were not uncommon, bringing saltwater intrusion into local well fields and wildfires to the dry peat soils (USACE 1998:I–7).

To assure an ample water supply, C&SF Project engineers divided the central Everglades into three enormous tracts confined within perimeter dikes. These are the Water Conservation Areas. The Water Conservation Areas act as giant reservoirs to store water from the Kissimmee basin and Lake Okeechobee and serve as the principal recharge areas for the aquifer that supplies water to the urbanized eastern coastal strip.

A third major element of the C&SF Project was the creation of a special agricultural zone in the rich soils just south of Lake Okeechobee. The Everglades Agricultural Area, as it is called, converted about 20 percent of the original Everglades to intensive agriculture. Much of the 300,000 ha within the area is planted in sugarcane, making the sugar industry a significant economic force in the area (Light and Dineen 1994:60–66).

Providing Everglades National Park with sufficient water to keep it healthy was also on the list of project goals. In reality, this took a much lower priority than keeping human communities safe from floods and provided with water and became a sore point soon after the massive water project came on line. From the start, Everglades National Park supporters and conservationists were leery of the degree to which the C&SF plan would alter the natural water flow, but the fervor for flood control swept away their objections (Light et al. 1995:126–131).

Trade-Offs: An Ecosystem in Transition

Overall, the C&SF Project has brought huge social and economic benefits to the region. Since the Project began in 1950, urban expansion in the Miami–Palm Beach corridor has brought new neighborhoods and livelihoods along with an additional 4.5 million people (USACE 1998:V–12). In the process, it has fueled the robust expansion of the service industries and international trade sector that currently account for more than half of the South Florida economy (GCSSF 1995: Regional Overview p.2).

Agriculture, which is largely the product of wetlands drainage and flood control works, contributes at least $2 billion annually to local coffers–a small but politically significant part of the local culture and economy (SFERTF 1998a:9). South Florida counties lead the nation in production of sugarcane, oranges, grapefruit, and snap beans and produce a variety of other important winter vegetables and tropical fruits that cannot be grown elsewhere in the United States. Even the lodging and resort industry, which is vital to the area's $14 billion tourist economy (1995), relies on the water supply that the C&SF Project assures (SFERTF 1998a:9–10).

But changes in the water cycle and land-use patterns in South Florida have impaired the natural functioning of the ecosystem in a number of important ways, degrading the services that it has traditionally supplied and threatening to undermine the region's economy.

LOST WATER CAPACITY

The most fundamental physical change in the ecosystem is that it no longer has the capacity to store and release enough water to meet all the demands of the region's wildlife and human communities, particularly in dry years. Conversion of large tracts of Everglades and other marshes to farmlands and suburbs has reduced the sponge-like capacity of the watershed to retain water in the wet season and release it during the dry season. By some estimates, nearly half of South Florida's original complement of wetlands has been lost, with a concomitant loss of storage capacity (SFERTF 1998a:3).

LOST SOIL CAPACITY

Draining and lowering the water tables over much of the watershed has caused widespread land subsidence and serious soil loss in many areas, threatening the future of the region's agriculture. In some parts of the Everglades Agricultural Area, topsoil loss from drying and oxidation of the peat soils exceeds 2 m–a loss of nearly half the original depth (Davis 1998). Topsoil loss has already brought a few fields perilously close to retirement and has convinced some observers that the area's future for agriculture is limited to only a few more decades (Snyder and Davidson 1994:107–108; Davis 1998).

LOST WATER QUALITY

Runoff from farm fields and urban areas has contaminated the water cycle with pollutants, lowering water quality throughout the region. Phosphorus contamination is the

(continues on p. 170)

Box 3.5 The South Florida Ecosystem

The South Florida ecosystem occupies a single large watershed—the Kissimmee-Okeechobee-Everglades watershed—that covers roughly the lower third of the state and its coastal waters, an area approximately 23,000 km^2 (McPherson and Halley 1996:16). Within this enormous region are several distinct environments, including freshwater marshes, wet prairies, cypress swamps, and pine forests in the interior; coastal prairies, beaches, and mangrove forests fringing the coasts; and coral reefs and seagrass beds in the warm waters of Florida and Biscayne Bays and the Straits of Florida.

Water flow across the region and into the coastal waters is the dynamic thread that weaves these communities into a single larger system—an interconnected tapestry of wetlands, uplands, and coastal and marine areas (USACE 1998:II–2).

At the center of the ecosystem are the Everglades, which originally stretched in a 11,650 km^2 swath from Lake Okeechobee to Florida Bay (McPherson and Halley 1996:16). Today, the Everglades have been nearly halved in extent, with Everglades National Park in the south preserving only a fifth of the native marshlands (USACE 1998:5–4).

The dynamics of the South Florida ecosystem were—and still are—driven by a seasonal cycle of flooding and drying. Most of the region's 100–165 cm of annual rainfall occurs from May through October and, under the natural regime, much of the land was flooded during this rainy season and gradually dried out during the late fall and winter (McPherson and Halley 1996:8). Natural water flow through the system is generally from north to south, but is very slow because of the flatness of the terrain. Water originating in the Kissimmee Basin in the north, where elevations are slightly higher, gradually flowed south through wetlands bordering the Kissimmee River and into Lake Okeechobee, which acted as a giant reservoir. Under high-water conditions during the wet season, the lake overflowed its southern banks, spilling water into the Everglades in a broad sheet just inches deep over much of the marsh. This sheet flow makes of the central Everglades a shallow, vegetation-covered river—a "river of grass," as the Everglades is frequently called. Because the slope is so gentle, with elevations falling just 6 m between Lake Okeechobee and Florida Bay, it takes the water flowing through the Everglades an average of 12 months to reach the coast (Jones 1999; USACE 1998:II–3).

Sources: Birbeck 1990; Davis and Ogden 1994; ESRI 1993; Florida Department of Environmental Protection 1996a, 1996b.


LandSat Image of South Florida Ecosystem, 1994
Urban area
Sugarcane
Cypress swamp
Pine forest
Mangrove forest
Historic Everglades extent

most serious problem. The level of phosphorus in Lake Okeechobee and portions of the Everglades is now well above the natural tolerance of the ecosystem, throwing the biological community out of balance. For example, phosphorus levels have doubled in Lake Okeechobee in the last 20 years resulting from manure runoff from dairies and cattle ranches, causing repeated algal blooms and at least one significant fish kill in the 1980s (USACE 1998:III–21).

Phosphorus contamination of the Water Conservation Areas and Everglades National Park is just as worrisome as the situation in Lake Okeechobee, though the contamination comes from a slightly different source. Exposure of the peat soils in the Everglades Agricultural Area to air during cultivation naturally releases phosphorus as the soils oxidize. Phosphorus-enriched irrigation water pumped out of the Everglades Agricultural Area has already allowed cattails–which thrive under high-phosphorus conditions–to begin to displace the usually dominant sawgrass vegetation in some portions of the Water Conservation Areas. Scientists worry that too much phosphorus may next change the balance of plant and animal life in Everglades National Park (Armentano 1998; SFWMD 1998b:3–6).

LOST BIOLOGICAL DIVERSITY

Populations of many species of wildlife and fishes have dramatically declined as their food sources and nesting or spawning sites have degraded or disappeared. Disrupting the water cycle has also altered the seasonal pattern of flooding and drying on which the life cycles of many Everglades species depend. Sixty-eight species in the South Florida ecosystem are now listed by the U.S. Fish and Wildlife Service as endangered or threatened with extinction (SFERTF 1998a:3).

Populations of wading birds, including herons, egrets, storks, and spoonbills, have been particularly hard hit. Scientists estimate that in 1870, some 2 million wading birds crowded the marshes and estuaries of South Florida. By the 1970s that number had dropped to a few hundred thousand–about 10 percent of their historical level. The decline continues today (De Golia 1997:45).

The loss of biological diversity in the area is disturbing both from a conservation and an economic standpoint. Conservationists worldwide have recognized South Florida, and specifically Everglades National Park, for its biological richness. The Park is one of only three sites in the world to be designated a World Heritage Site, an International Biosphere Reserve, and a Ramsar Wetland of International Importance. The Park is also an important tourist destination, attracting 1 million visitors annually. If current patterns of damage continue in the Park, area officials have warned that the economic impact could be substantial. A government study calculated that if the recent declines in the health of Florida Bay at the southern end of the Park continue, economic losses could mount to more than $250 million/year in lost tourist dollars and reduced commercial catches of shrimp, lobster, snapper, and grouper (GCSSF 1995:Introduction p.2).

LOST NATIVE SPECIES

Exotic plant and animal species have invaded more than 3.7 Mha in South Florida and threaten to displace many of the native species, especially in Everglades National Park (SFERTF 1998a:3). Changes in the natural water cycle have fostered the spread of invasives such as *Melaleuca*, Brazilian pepper, and old world climbing fern, all of which thrive in dryer conditions (SFWMD 1998b:7). The system of canals,

Box 3.6 Indicators of Everglades Decline

Loss of Tree Islands in Water Conservation Area 3

The health of tree islands is one of the best indicators of the overall hydrologic condition of the Everglades. These havens of biodiversity support more species than any other habitat in the central Everglades and are the first to suffer during drought and the least tolerant of abnormal flooding.

Year	Number of Tree Islands	Total Area (ha)	Area Loss, 1945–95 (%)
1940	1,041	8,907	—
1995	577	3,433	62

Source: **SFWMD. 2000a:2-32–2-34.**

Loss of Nesting Populations of Everglades Wading Birds

Since their numbers first began to be tracked and efforts to restore them began, the great egret is the only one of the Everglades wading birds to meet, and indeed, exceed its restoration target. The numbers for the other birds, however, continue to decrease.

Species	1931–46	1974–81	1982–89	1997–99	Restoration Target
Great egret	5,000–8,000	6,500	4,200	5,084	4,000
Snowy egret and Tricolored heron	20,000–30,000	16,000	5,000	1,862	10,000–20,000
White ibis	175,000–225,000	29,000	12,500	5,100	10,000–20,000
Wood stork	5,000–8,000	2,650	750	279	1,500–2,500
Total	205,000–271,000	54,150	22,450	12,325	25,500–36,500

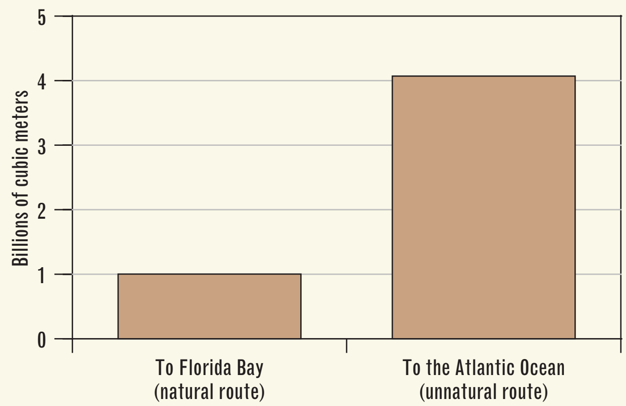
Sources: Ogden 1994:542; Ogden 1999:16.

Box 3.7 Restoration Means More Water and Clean Water

Currently, the C&SF project diverts much of the Everglades natural water flow for flood control. To prevent flooding, 3–4 times more water is released directly to the Atlantic Ocean than makes its way through the Everglades to Florida Bay. Water released to the Atlantic is lost for use by humans and wildlife. Restoration plans involve capturing some of this lost flow.

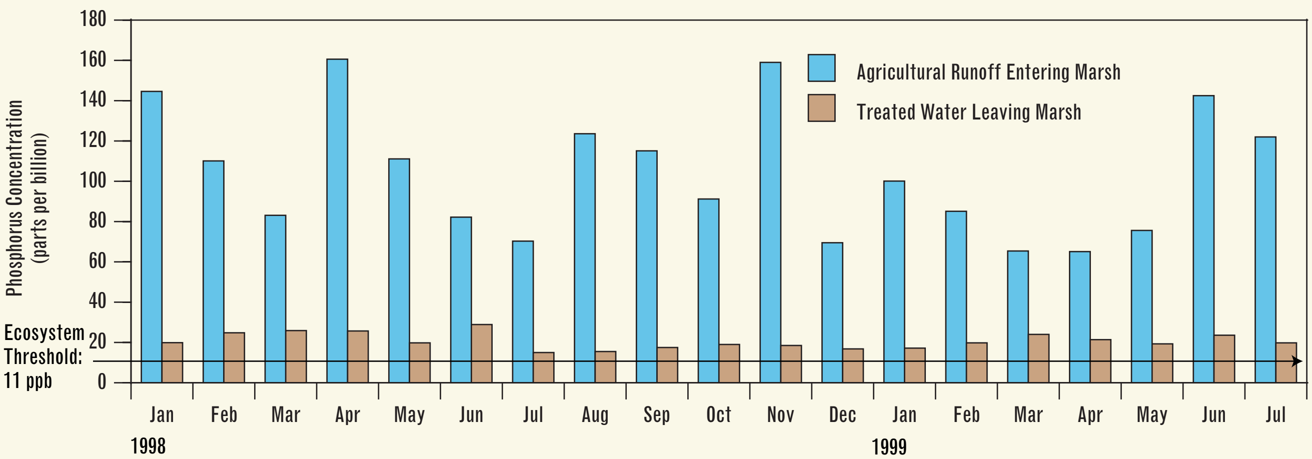
Restoration will also involve a major effort to remove phosphorus pollution from agricultural runoff by filtering it through 16,000 ha of artificial wetlands before releasing it into the Everglades. Filtering marshes reliably reduce phosphorus to 20 parts per billion (ppb) or less. Unfortunately, scientists believe that the ecosystem threshold where phosphorus begins to affect Everglades marshes is about 11 ppb, meaning an additional filtering step will be needed.

Discharge of Rainfall in the Everglades Region, 1980–89



Source: Light and Dineen 1994:82.

Everglades Nutrient Removal Project



Source: SFWMD 2000b.

which provides unnatural routes into natural areas, has also been an important pathway for the spread of invasives such as the water hyacinth and the Asian swamp eel–a relatively new introduction whose voracious appetite may threaten native fishes (Armentano 1998; SFWMD 1998a:24).

A Change in Attitudes

The decline of key features of the ecosystem took time to be noticed, and even when environmental damage was obvious, a consensus on how to tackle the problem took years to evolve. But several key events and crises moved the process forward. As always, water–or lack of it–took center stage in convincing people that the alterations they had made in the natural system were anything but perfect.

From 1963 to 1965, C&SF water managers prevented water from flowing south into Everglades National Park in order to fill the newly constructed Water Conservation Areas. Drought conditions during those years meant the Park was water starved. Breeding colonies of ibis and egrets failed to form in their traditional spots for three consecutive years. Television cameras brought the Park's plight to a national audience and drove home the point that water conflicts were likely to become more common as water demand in the rapidly urbanizing area grew. The U.S. Congress subsequently ordered water managers to deliver adequate water to the Park, but the fight over how much was "adequate" would consume many more years and eventually direct the design of the restoration plan (Light et al. 1995:127, 129).

In 1970 drought struck again. The water shortages that plagued South Florida were so intense that state politicians took action, passing landmark legislation that mandated a regionwide approach to water management (Light et al. 1995:133). Governor Robert Graham launched the Save Our Everglades program in 1983–the first attempt to address the problems of the ecosystem at a regional scale, and the first public initiative to set out the goal of restoring the components of the ecosystem to something approaching their natural state (Light et al. 1995:142).

Rather than start to improve, conditions throughout the ecosystem continued to decline. In 1988, an ecological clarion call heralded the ecosystem's precarious health. Florida Bay is a shallow, tropical estuary at the southern tip of the Florida peninsula; a rapid die-off of seagrasses and a striking decline in water clarity occurred and continued for several years. Large, sustained algal blooms began to plague the waterway and commercial and sport fishing catches suffered (Armentano 1998; USACE 1998:III–23).

At about the same time, Dexter Lehtinen, a brash U.S. government attorney, filed suit against the regional water authority, the South Florida Water Management District, for releasing water polluted with agricultural runoff into the Everglades. The U.S. government suit–based on the water district's own studies–claimed that excess phosphorus from the Everglades Agricultural Area was threatening Everglades National Park and nearby Loxahatchie National Wildlife Refuge. The immediate intent of the suit was to force the District to require farmers to clean up their effluent before releasing it. But the larger effect of the suit was to highlight the inherent contradictions in the District's traditional service to the local agricultural community–to provide irrigation water and take away runoff–and its responsibility to provide clean water to Everglades National Park (Aumen 1998; Light et al. 1995:144–146).

At first the District fought the lawsuit; but in 1991, newly elected Governor Lawton Chiles directed the agency to admit that there was, indeed, a problem and begin to collaborate with federal authorities rather than continue to waste resources fighting the lawsuit. This began a process of redefining the Water District's mission to include stewardship of the South Florida ecosystem. The District eventually became a key promoter of the idea of ecosystem restoration (Aumen 1998).

In 1993, the federal government formed the South Florida Ecosystem Restoration Task Force, which has become a central player in developing a coherent restoration plan for the entire ecosystem. The Task Force has acted as the convening body to bring together all the parties with a legal interest in the restoration–a list that includes 10 federal and state agencies, several local county governments, the Miccosukee and Seminole Indian Tribes, and the South Florida Water Management District. Agribusiness interests, environmental groups, and sport and recreation groups also participate in the public hearings where decisions on restoration matters are made (SFERTF 1998a:7).

Just as significant, the state in 1994 created the Governor's Commission for a Sustainable South Florida, which has bluntly asserted that the problems with the South Florida ecosystem are intimately connected with the larger regional patterns of land and resource use and economic expansion. Without tackling these patterns, the Commission warns, restoration activities will not be effective in the long run (GCSSF 1995:Executive Summary p.1).

Restoring the Flow, Revitalizing the Ecosystem

What does restoring the South Florida ecosystem really mean? A decade of scientific study, debate, and negotiation has led to a broad consensus on what needs to be fixed and where to begin. Current plans already include 200 projects that restore habitat, manage urban growth, realign farming practices, and reconfigure the C&SF Project's water-control structures.

Three broad goals are behind these projects (SFERTF 1998a:1, 8–10):

- Restore the area's natural hydrological patterns as much as possible; the shorthand term for this is "getting the water right."

- Increase the health and extent of wildlife habitat so that depleted species can recover.

- Relieve pressure on the ecosystem by taming suburban growth and encouraging an economy that balances the needs of humans and the biological limits of the natural system.

GETTING THE WATER RIGHT

The first goal–restoring a more natural hydrological pattern–is the foundation on which all other aspects of ecosystem recovery are built. It forms the focus of the US$7.8 billion plan put forward in 1998 by the U.S. Army Corps of Engineers to revamp the C&SF Project. The basic strategy of this ambitious plan is to increase the capacity for storing water within the watershed. This will allow water managers to quit venting so much water directly to coastal estuaries from Lake Okeechobee during high water times and make it possible to direct water flows into the Everglades at the most appropriate times and in more sufficient quantities. It will also increase the water available for urban water supply and agriculture (SFERTF 1998a:8; USACE 1998:I–ix).

Computer models of the region's water flow predict that as population and industry continue to grow over the next 30 years, water shortages could occur, on average, every other year in most of the region's urban areas if the system is not reconfigured to store more water (USACE 1998:iv). This would strike hard at the area's economic stability and quality of life, and pit urban water users against farmers and both of these against the environment. Currently more than three times as much water is discharged directly to the coast than is allowed to continue its natural flow pattern through Everglades National Park and into Florida Bay (McPherson and Halley 1996:39). This water is essentially wasted for environmental and human purposes.

To create more storage in the system, the restoration plan calls for a combination of (a) new surface reservoirs, some created from existing rock quarries; (b) marshes; and (c) the use of an innovative technique of pumping water down wells into a shallow aquifer in the wet season for temporary storage and recovery during the dry season. These three elements will be combined into an interconnected system along the eastern flank of the Everglades that will also serve as a buffer against the encroachment of suburbs (USACE 1998:v–vi). In the Everglades Agricultural Area, converted cropland will also act as surface reservoirs. To implement this strategy, federal and state officials in 1999 bought a 259-km^2 tract of sugarcane fields that will be retired from production and eventually receive overflow flood waters (McClure 1999b). Elsewhere, advanced wastewater treatment plants will allow water managers to reuse wastewater to recharge coastal aquifers.

Restoration plans will also require that farmers discharge cleaner water into the Everglades. The legal settlement of the 1988 federal lawsuit against the water district directs farmers to use cultivation practices that reduce the phosphorus they release into their drainage water. At the same time, farmers in the Everglades Agricultural Area must pay one-third of the cost of constructing some 16,000 ha of special phosphorus-scrubbing marshes–the largest constructed wetlands in the world–through which they will send their drainage water before it goes into the Everglades. Ultimately, farmers will have to extract even more of the remaining phosphorus from their effluent in order to meet new water quality restrictions due to take effect in 2003. Researchers still haven't decided how this can be done at a reasonable cost (Aumen 1998).

Removing barriers to the sheetflow of water through the Water Conservation Areas and into Everglades National Park is also an essential part of restoring a more traditional hydrological pattern in the region. Current plans call for removing approximately 800 km of canals and levees within the Water Conservation Areas and revamping a portion of a major road that cuts through the Everglades; gates and culverts are to be installed along the road to restore the sheetflow interrupted by the road since its completion in 1928 (USACE 1998:vi).

RECOVERY OF WILDLIFE

Reconfiguring the C&SF Project to restore a more natural hydrological cycle should help with the second major restoration goal–improving habitat quality and recovering wildlife populations. The original system was huge and hydrologically interconnected. Animals could typically find appropriate food supply and breeding grounds somewhere within the system under a range of natural conditions. Draining and diking the watershed broke up the system's connectivity and disrupted the ability of many animals to find suitable habitats timed to their life cycle (USACE 1998:vii–viii).

By removing internal levees and allowing the delivery of more water, more appropriately timed and directed, water managers hope to recreate many conditions that favored wildlife. They anticipate that species at every level of the food chain–from small minnows and crayfish to alligators, herons, and otters–will start to recover their original population density and distribution. Water district biologists have particular hopes that wading bird populations will rebound; these birds are perhaps most sensitive to the habitat conditions over the entire watershed (USACE 1998:vi–ix).

But just how much and how fast the living elements of the ecosystem will recover is still very much in question. Scientists have drawn up biological criteria to judge whether the system is truly recovering; but there is still controversy and concern over what to expect, especially given its high price tag. Some critics feel that the recovery plan will not recreate the original hydrological pattern sufficiently to allow large-scale recovery and will yield far smaller benefits to wildlife than advertised (McClure 1999a; Santaniello 1998; Santaniello 1999; Stevens 1999). Even government biologists are cautious. They have labored hard to draw up an integrated strategy to ensure that the restoration plan benefits as many of the area's endangered species as possible, but do not expect all of the beleaguered species to survive.

CURBING DEVELOPMENT

Modifying development and economic activities in the Miami urban corridor so that they are less environmentally destructive is probably the most challenging of all restoration goals. Biologists and water planners know that without progress on this front, their efforts to restore the South Florida ecosystem will eventually be drowned in the flood of new development still surging into the Miami urban corridor. Each year, some 29,000 people relocate to the area to take advantage of the climate, natural beauty, and expanding economy (SFERTF 1998b:iii). By 2010, officials expect the region's population to expand to 8 million; by 2050, some forecasters think the population could nearly triple to more than 15 million (GCSSF 1995:Regional Overview p.1).

Plans to manage this expected influx include a number of steps to curb the proliferation of urban sprawl. A regional program called "Eastward Ho!" is encouraging local governments to establish urban development boundaries and to redirect new growth back into already developed areas by building on unused urban parcels, redeveloping run-down sites, and cleaning up brownfields. Modifying building regulations to require higher housing density in new suburban developments is a second essential step that restoration advocates are pressing on area governments. Upgrading the area's transportation system so that it encourages denser, less automobile-dependent development is also considered an important part of the overall effort to reduce the impact of future growth.

None of these steps will be easy; they involve land-use decisions by a large number of local governments whose land-use plans currently lack much regional coordination and are subject to intense local political pressure (GCSSF 1995:Executive Summary pp.1–7).

Beyond the Everglades

It is impossible to know yet whether the effort to rejuvenate the South Florida ecosystem will ultimately succeed. On one level, the Everglades restoration effort has made an impressive start and boasts a list of accomplishments and advantages that paint a hopeful picture: it enjoys widespread popular and political support that comes from a basic understanding of the current state of the system, its vulnerability to further decline, and an acceptance of the tenet that some minimum of ecosystem health is required to support the local economy and the quality of life that people enjoy. That alone is a tremendous step forward. But the difficulty of actually bringing back healthy populations of wading birds, returning full productivity to Florida Bay, or recovering even one of the 68 endangered species whose survival hangs in the balance cannot be underestimated.

Yet regardless of the outcome, the Everglades effort has already offered many lessons. First, it shows how vulnerable ecosystems are to single-purpose management, especially when managers are ignorant of the basic workings of the ecosystem. Without knowledge of how changes in area hydrology were likely to affect the South Florida ecosystem, it was impossible for the Army Corps of Engineers to foresee the trade-offs they were making when they built the C&SF Project. And even if they had had such knowledge, it was probably outside their mandate to act on it, given their primary goals of flood control and improved water supply.

The Everglades experience also provides a thoroughly convincing economic argument for taking care to not degrade a critical ecosystem in the first place. The $7.8 billion price tag for what is just the first stage of the overall restoration effort leaves no doubt that large-scale ecosystem restoration requires a huge investment–often many times the expense of altering the system in the first place. Still, this may be inexpensive compared to the benefits that will be lost if the ecosystem continues to degrade or fails completely. The tourist trade alone is worth $14 billion annually to the South Florida economy and the ecosystem's health is directly tied to that industry's overall success.

Perhaps the most important lesson is that the idea of ecosystem restoration is extremely compelling. The public's and politicians' acceptance of a restoration program of such magnitude and expense shows that a well-articulated vision of a restored ecosystem can be a potent force for consensus and change. At the same time, the Everglades experience leaves no doubt that following through on this vision requires patience and commitment. It takes time to learn how and why an ecosystem is failing and how to put it right again; time to negotiate the inevitable controversies about how best to spend the precious dollars available to attain maximum recovery. Efforts to restore the Everglades have taken nearly 3 decades to mature to their present state, and it will undoubtedly require much longer than 3 more decades for the Everglades to heal.

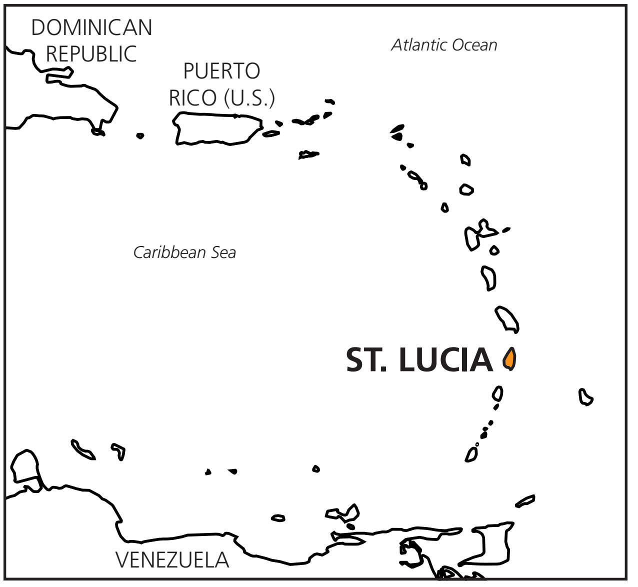
Ultimately, even attaining some level of ecosystem recovery will not be enough. Keeping the restored ecosystem from failing again will be the ultimate test and will require making good on the much more ambitious vision of a regional economy that does not, through its impacts, smother the renewed life so carefully nurtured.

Managing Mankòtè Mangrove

Some people call mangroves "the roots of the sea." Mangroves are gnarled, salt-tolerant trees that grow in intertidal zones and estuaries where the ocean, land, and freshwater meet; they cling to the loose soils, sands, and muds with a maze of roots that can withstand waves and erosion. These unique, adaptable plants, of which there are about 60 species, are found along the majority of the world's subtropical and tropical coastlines.

Some coastal residents might also call mangroves "the roots of their community." The forests, swamps, and wetlands where mangroves thrive are ecosystems of great biodiversity and productivity. Coastal residents use mangroves for fuel, construction materials, food, medicines, and tannins. For fishers the mangroves' networks of roots provide breeding grounds for many kinds of sea life. The leaves, small branches, propagules, and fruit that fall from the trees contribute to production of detritus that supply the fish and other wildlife with an abundant food supply. Mangroves are also prime nesting and migratory sites for hundreds of bird species. By serving as a buffer along the coastline, mangrove forests protect coastal areas, crops, and towns from flooding during storms, shelter fishers' boats, and protect coral reefs from suspended solids. Plus, mangroves control sedimentation and coastal erosion.

But a mangrove's natural resilience and value affords it little protection against a growing number of anthropogenic threats, as communities and institutions on St. Lucia's southeast coast came to understand in the 1980s. That realization inspired an innovative program to enable local residents to reap the benefits of Mankòtè, St. Lucia's largest mangrove forest, without degrading its ecosystem services and long-term viability.



Changing Community Practices

Mankòtè was part of a U.S. military base during World War II. When the base closed and the area became public land in 1960, the 63-ha mangrove–20 percent of the total mangrove area of the country–was still covered with well-developed trees (Geoghegan and Smith 1998:1). As an open-access resource, it was soon subjected to varied and often destructive uses ranging from seasonal fishing, bird hunting, and crab catching to waste dumping and spraying of pesticides for mosquito eradication (Smith and Berkes 1993:123–124).

The greatest stress on the mangrove, however, was the extensive tree cutting by local citizens for commercial charcoal production. By the early 1980s, charcoal production had become a major source of subsistence income and an important cottage industry. The use of mangrove wood for charcoal is popular because it is cheap relative to petroleum-based fuels, can be easily transported, and is slow burning. Mankòtè became the main supply of charcoal for about 15,000 residents of Vieux Fort, a nearby community, and others in the southeast portion of the island. Although no data are available, older residents of the area observed that during those years, smaller trees in the mangrove were being harvested and large trees were becoming scarce (Smith 2000).

At about the same time, a regional NGO, the Caribbean Natural Resources Institute (CANARI), identified the Mankòtè mangrove as a priority area for conservation. CANARI soon realized that the charcoal producers themselves were key to Mankòtè's protection. Although charcoal producers' harvests were putting pressure on Mankòtè, they practiced a number of sound management measures. For example, they cut on a rotational basis, allowing time for the trees to regenerate before recutting, and left uncut the species of mangroves that make poor charcoal but provide cover to impede the evaporation of the swamp.

CANARI proposed a management strategy that was innovative and controversial for its time. They advocated that the mangrove be managed in collaboration with the harvesters–a landless, poor group with no legal right to the resource, but also the people most dependent on the mangrove and most damaging to it. With the government's tacit approval, CANARI launched what has become an ongoing effort to test ways to save the mangrove and maintain the charcoal producers' incomes (Geoghegan and Smith 1998:4, 7).

Among CANARI's key steps was to organize the harvesters into an informal cooperative of about 15 people; the cooperative is called the Aupicon Charcoal and Agricultural Produc-

The woodlot, as originally conceived, was to be managed by and benefit the group as a whole. Members would be organized for harvests and other activities. Similarly, pole production in the mangrove was meant to be a group activity. However, it has proven easier for people to continue using the mangrove and the woodlot without strict coordination of activities. Extractions are made by individuals or small teams and recorded each month.

ers Group (ACAPG). CANARI works with the group to monitor and track trends in charcoal production and the status of the mangroves. ACAPG committed to a set of sustainable harvesting practices, including a ban on cutting trees that line waterways, preservation of large trees, and cutting on a slant to preserve the tree's stump.

To reduce pressures on the mangrove, government agencies, local NGOs, and the harvesters sought to create a new wood supply for charcoal production. Between 1983 and 1985, the Department of Forest and Lands planted a 62-ha woodlot close to Mankòtè with fast-growing hardwoods, mainly *Leucaena*, and with a palm species that ACAPG members can harvest to make brooms. The government also loaned the producers a large plot of land and encouraged the producers to plant it with marketable products.

There have been significant communal harvests of plantation wood recently, although initial efforts in plantation and agricultural endeavors were plagued with problems, from fires to the charcoal producers' inexperience with agriculture, marketing, and working together. The woodlot is still far from a replacement for mangroves, but management strategies and income-diversifying opportunities continue to evolve. For example, in 1993 the harvesters began leading tourists and school groups on tours of the mangrove as an income-generating opportunity. Local NGOs have provided guide training; technical assistance grants to build interpretive signs, a boardwalk, and a viewing tower; and assisted with tour promotion and organization (Smith 2000; Brown 1996).

To limit outside threats to the mangrove, local institutions successfully protested the Department of Health's mosquito eradication program that was damaging the mangrove's fauna and hydrological functions, and secured the designation of Mankòtè as a marine reserve in 1986. That designation affords the mangrove complete protection from any extractive use without written permission of the Chief Fisheries Officer, ending years of illegal waste dumping. The charcoal producers have sole rights of use of timber resources (Smith 1999).

Like most participatory approaches to ecosystem management, the Mankòtè strategy has taken more than a decade to achieve many of its objectives. By the 1980s, the overall trend of degradation of the tree cover had been reversed. Monitoring four species of trees in each of four transects between 1986 and 1992 showed a significant increase in the number of mangrove stems larger than 25 mm/m^2–from 0.10 to almost 2 (Smith and Berkes 1993:126–127). The basal area, or total area of stems, increased fourfold. Because 1991 was a year of particularly high charcoal production, the increased regeneration of mangroves noted in the 1992 survey is especially noteworthy. Field observations and interviews indicate that preservation methods are still used rather than clear-cutting (Smith and Berkes 1993:126–127). Although the data are still limited, research in the last several years suggests that density and size of trees have continued to increase, while charcoal production has averaged 2 tons/month in early 2000, slightly less than the average in the past 15 years (Smith 2000).

Mankòtè's future is still uncertain. An economic downturn in St. Lucia could bring new pressures to the mangrove. The government continuously receives proposals for the development of the mangrove and surrounding land; fortunately, key agencies are concerned about identifying what kind of development would be possible without encroaching on the mangrove and its functions. Research is under way to ascertain other potentially significant pressures on the mangrove, including the impacts of crab hunting and fishing, and to test the effectiveness of some silviculture practices in the mangrove, with the hope of improving yields from regeneration. Nevertheless, there is agreement among all parties that the informal, collaborative arrangement at Mankòtè currently provides greater protection to the mangrove than any government agency or other institution can do on its own. The arrangement has also allowed rural families to continue to reap economic benefits.

BOLINAO RALLIES AROUND ITS REEF

With its cascading waterfalls, rolling hills, white beaches, and spectacular sunsets, Bolinao has been called nature's masterpiece. But the most valuable asset in this northern Philippines municipality may be its 200 km^2 of coral reefs. About one-third of Bolinao's 30 villages and 50,000 people depend on fishing to make a living (McManus et al. 1992:43), and the Bolinao-Anda coral reef complex serves as the spawning ground for 90 percent of Bolinao's fish catch. More than 350 species of vertebrates, invertebrates, and plants are harvested from the reef and appear in Bolinao's markets each year (Maragos et al. 1996:89).

Imagine, then, the dismay among local residents, marine researchers, and NGOs who learned in 1993 that an international consortium intended to build what was claimed to be the world's largest cement factory right on Bolinao's coral reef-covered shoreline. The cement industry ranks among the three biggest polluters in the Philippines (Surbano 1998), and the plans for the Bolinao complex included a quarry, power plant, and wharf. It can take 3,500 pounds of raw materials to produce 1 ton of finished cement; pollutants commonly emitted from this energy-intensive industry include carbon dioxide, sulphur dioxide, nitrous oxide, and dust–about 360 pounds of particulates per ton of cement produced. Another by-product is highly alkaline water that is toxic to fish and other aquatic life (Environmental Building News 1993).

The ensuing debate over the plant's construction brought a new urgency and focus to local efforts to ensure the long-term viability of Bolinao's coastal resources. Pitted against a politically and economically powerful business consortium, residents successfully challenged the idea that a cement plant's short-term economic benefits would offset the risk of long-term ecosystem ruin. That outcome is an unusual and significant achievement, particularly in developing countries, where citizen advocacy and broad-based participation in natural resource management is likely to face daunting obstacles, including limited access to both environmental information and the political process.

Bolinao's Threatened Marine Ecosystem

Bolinao's environmental fragility had been recognized, in some quarters, long before a Taiwanese business group called Tuntex announced its plans to build a mammoth cement complex. A 1986 study by the Marine Science Institute at the University of the Philippines, for example, documented significant damage to Bolinao's coral reef system. Researchers found that about 60 percent of the region's corals had been killed, mostly through destructive fishing practices that relied on dynamite and cyanide to enhance catches (McManus et al. 1992:44). In 1992, Bolinao's once-booming sea urchin industry was shut down indefinitely after the urchins had been exploited nearly to extinction to satisfy export demand for roe (Talaue-McManus and Kesner 1995:229). Fishers, fish vendors, and shell craftspeople had noted diminished catches, changes in dominant species, and decreases in the size of mature fish.

But it took the possibility that a cement factory would cause further deterioration of the area's marine resources to galvanize widespread action on behalf of the ecosystem. "We launched a vigorous education campaign focused on the cement plant's potential environmental impacts," explains Liana Talaue-McManus, a researcher from the Marine Science Institute (Talaue-McManus 1999). For many, this was the first time that they fully understood the extent and richness of their community's natural resources, as well as its vulnerability.

The plant complex would be located in the middle of the reef system, within 3 km of the municipal center. This was an ideal spot from investors' perspectives, given its abundance of limestone, the deep channel for marine transport, and Bolinao's proximity to Taiwan. Investors argued that the cement production complex would not cause any pollution, but local residents soon began to suspect otherwise.

With support from the University of Philippine's researchers, a local NGO–the Movement of Bolinao Concerned Citizens–challenged the Tuntex consortium. They played a critical role in the 2-year struggle against the cement

plant, rallying opposition and raising awareness of the complex's potential impacts. Those impacts, as their research revealed, could include air pollution, erosion from the quarrying of limestone, damage to the reefs from the widening of the shipping channel, oil pollution from shipping, and the threat to their limited freshwater supply.

Their efforts were rewarded. In August 1996, the Philippines Department of Environment and Natural Resources (DENR) denied "with finality" the application for an environmental permit, citing the unacceptable environmental risks the cement plant would pose to aquatic life and coral reefs, and the conflicts that would arise with existing land and marine uses (Ramos 1996).

Crafting a Long-Term Management Plan

The hard work of ecosystem protection didn't end with the cement plant fight. In fact, for Bolinao residents and NGOs, the toughest part of ecosystem management was ahead. Local NGOs are still working toward a larger goal: developing a coastal resource management plan that empowers fishers and other community members to participate in long-term decisions about the management and health of their resources.

Consensus on how to conserve and protect the marine areas has long been elusive. Since the early 1990s, a coastal planning team composed of representatives from the Haribon Foundation and from the Marine Science Institute and College of Social Work and Development (both at the University of the Philippines) sought to mobilize Bolinao's villages on behalf of marine protection. But many issues polarized the community:

- Most of Bolinao's fish harvesters are poor, with the reefs serving as their sole source of food and income. As farmlands deteriorated, many farmers migrated to reef areas, exacerbating competition for marine resources. Increased population in the coastal areas increased the amount of organic pollution; the pollution, in turn, reduced the resilience of Bolinao's coral reef ecosystems. Because of poverty, resource depletion, tradition, and lax enforcement of bans, fishing methods known to be destructive were sometimes still used.

- The town leadership lacked adequate information about the marine ecosystem and needed technical assistance to make sound resource decisions.

- Access to milkfish fry and siganid fishing in Bolinao was governed by an inequitable but ingrained system. Those who won concessions from the local government–through a sometimes corrupt bidding process–garnered exclusive privileges to fish in an area. Subsistence fishers were banned from the area or forced to sell their catch to the concession holders at below-market prices. The result was illegal fishing and minimal incentive to regulate the harvest, but significant income for the local government.

- One survey found that the number of aquaculture pens in the Caquiputan Channel between the Bolinao mainland and the islands of Santiago and Anda had increased from 330 in December 1996 to 3,100 in July 1997 (Talaue-McManus et al. 1999). Although they produced revenues for the town's political and economic elite, they reduced fishing grounds and navigation areas, causing water quality declines and fish kills.

- Resort owners wanted the shorefront left open and free of activity, while subsistence and deep sea fishers needed navigation and docking areas.

The challenge of finding a balance between these actors and between the different uses of the coastal resources made it all the more impressive when, in 1997, NGOs successfully crafted "a collective vision for the long-term viability of Bolinao's coastal living resources" (Talaue-McManus et al. 1999). This coastal development plan drew on more than 2 decades of scientific research by investigators from the Marine Science Institute and was drafted by 21 representatives of the municipal government, the religious sector, members of the fishing industry, ferryboat operators, and environmental advocates through community workshops and meetings.

The plan divides the municipal waters of Bolinao into four zones with different use designations–"reef fishing," "ecotourism," "multiple use" (which includes milkfish pens and fish cages), and "trade and navigation." One zone includes a marine protected area. The next steps were to determine exactly what activities were to be allowed or prohibited in each zone, to ensure that the marine protected area remains truly protected, and, of course, to implement the plan. Implementation is still under way.

Most of those involved agree that local input has been a hallmark of Bolinao's ecosystem management process. They credit the participatory process with winning much greater public acceptance for Bolinao's coastal development plan than a traditional plan could have secured; most often, plans are drawn up quickly by outside consultants with little or no local input. Plus, by including direct resource users–subsistence fishers and fish vendors as well as the local government–in the zoning process, there is a greater chance of achieving conservation goals. Local stakeholders are, after all, the people who will ultimately either respect the new rules and regulations or ignore and evade them. An ongoing research program, such as that conducted by the Marine Science Institute, is an important complement to the planning effort. It serves as a source of knowledge and data that public representatives can draw on to make informed decisions.

Perhaps the best news is that Bolinao is part of a growing number of communities, organizations, and sectors of government in the Philippines that are using a "bottom up" rather than "top down" approach to natural resource management, building on a long tradition of strong citizen advocacy. And although Bolinao's coastal development plan is still very much a work in progress, one thing appears certain: more and more people will get involved as the plan is implemented. As word has spread in the Philippines about the Bolinao experience, other municipalities have turned to the University of the Philippines-Haribon team. They seek help in formulating their own coastal development plans, offering the promise of more research and monitoring on the status of coral reef ecosystems, and generating new strategies and models for reef protection and new management abilities within local communities.

FOREST ECOSYSTEMS

Up from the Roots: Regenerating Dhani Forest through Community Action

Dhani Forest has reincarnated itself from the roots up. The stubbled, degraded slopes of a decade ago have regenerated more rapidly than many thought possible. Protected from uncontrolled grazing and harvest, root stumps have sprouted new branches, grasses have flourished, streams have recharged, and wildlife have returned. So, too, have the livelihoods of local villagers who traditionally made their living harvesting forest products, such as fuelwood and siali leaves used in making leaf plates. Under the supervision of a committee of local villagers, limited harvesting of forest products has resumed, steadily increasing the flow of benefits from Dhani to the five communities that flank the forest.

The rebirth of this mixed deciduous forest in the state of Orissa in India marks a new approach to managing the State's depleted forests–one that returns limited control to local communities. In fact, the State has had little to do directly with the forest's regeneration. The five villages surrounding the forest initiated the restoration effort. They crafted a detailed plan to regulate forest use, to carefully husband what remained of the forest and enhance it where they could, to distribute the forest benefits fairly, to educate their children in forest conservation, and to resolve disputes arising from their plan. They nursed the forest back to health because it had stopped giving them what they needed. In doing so, they became leaders in a trend toward community forest management that has spread across Orissa State and all of India.

(continues on p. 184)

Box 3.8 Overview: Dhani Forest

Twenty years ago, Dhani Forest in Orissa State was badly degraded. Commercial harvesters had removed much of the forest canopy; local residents had cleared slopes for crops, gathered fuelwood relentlessly, and allowed cattle to graze the forest floor heavily. Today, this mixed deciduous forest is reborn, thanks to a five-village effort to ensure its survival. These villages have become leaders in a trend toward community forest management that is spreading across India.

Ecosystem Issues

Forests

The 2,200 ha Dhani Forest is a primary source of food, fuel, building materials, fibers, and medicines for local people. Their dependence makes Dhani both extremely vulnerable to overuse and critical to protect.

Agriculture

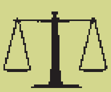
At various times, villagers have cleared lower slopes of the forest to expand agricultural areas and feed their families. Clearing forest, however, decreased their supplies of leaves that serve as farm fertilizer and food and other resources that cushion the effects of drought and crop failure.

Freshwater

Local stream flows and water tables are vulnerable to changes in Dhani's forest cover and soils. Diminished water flows, in turn, affect the health of soils and crops in adjacent agroecosystems.

Management Challenges

Equity and Tenurial Rights

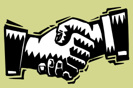


Today, villagers' rights to manage and use part of Dhani Forest's output is legally recognized—a far cry from the 1950s when the Orissa Forest Department ignored villagers' use rights and granted permits to contractors to harvest timber there. Yet some people argue that the State still does not treat the villages' forest protection committee as an equal, and some believe that the State should completely surrender title to Dhani Forest.

Economics

Dhani Forest's renewed health is essential to both local subsistence and local market economies. The State also reaps economic benefits; local management has lowered its forest protection expenses and is creating an asset from land that might otherwise be unproductive.

Stakeholders



Dhani's restoration and protection require collective decision making among the five villages who crafted the forest's protection plan, plus the cooperation of other neighboring villages who might infringe on this open-access forest. Restoration also depends on the State's willingness to respect community management and the value of nontimber ecosystem goods and services.

Information and Monitoring

Dhani Forest's successful restoration has largely depended on folk knowledge, wisdom, and commitment; the same is true of many similar projects in India. Orissa State has contributed some technical expertise, but more scientific analysis to complement local management is needed—guidance and research that are beyond the resources of the Dhani community.

Timeline

Pre-1799 Most forests in India are managed sustainably at the community level.

1799 British rule of India introduces commercial timber production and soon exhausts many forests.

1865 The British colonial government asserts state monopoly over forests with the Indian Forest Act.

1878 Purview of the Indian Forest Act is expanded and local control is further diminished. Dhani Forest remains under the control of Orissa's Raja until 1947 and is generally well managed.

1914–18 World War I massively increases demand for Indian timber.

1920s Railway lines reach Orissa, providing easier commercial access to Orissa's forests.

1940–45 India serves as the sole supplier of timber to Allied forces in the Middle East and Persian Gulf during World War II; forests are also under siege for fuelwood to offset the loss of coal to the war effort.

1947 Indian independence and state socialism put an emphasis on industrialization and use of forests for timber production and commerce rather than local use.

1940–50s Population in villages near Dhani begins to increase notably, intensifying pressure on the forest.

1950s Land Reform Bill declares forests on the boundary of a village to be village forests. Villages begin protecting and regenerating these tracts. National Forest Policy reinforces the state's exclusive control over forest protection, production, and management.

Late 1950s Tribal groups mount a sustained challenge to the continual denial of their rights to use forests.

1960 Orissa's Forest Department takes control of Dhani Forest and begins to permit commercial timber harvests; traditional conservation and community management systems decline.

1971 Beginnings of Joint Forest Management in Arabari in West Bengal and other districts.

1979 State permits a second major timber harvest in Dhani Forest.

1987 The villages closest to Dhani form a forest protection and management system to protect about one-third of the forest.

1988 Orissa becomes the first state to formally recognize local forest protection committees like Dhani's.

1991 Several other villages begin protecting another section of Dhani Forest.

1993 Orissa enters into a Joint Forest Management agreement with the villages surrounding Dhani Forest.

1997 Orissa awards the Dhani villages the *Prakriti Mitra* (Nature's Friend) award.

1998 Dhani Forest's canopy has filled out and the forest supplies increased goods and services.

1999 A cyclone severely damages Dhani Forest and the livelihoods of forest-dependent groups.

2000 A total of 400,000 ha is now under the protection and management of some 10,000 local villages throughout Orissa. The Dhani villages are active in the local federation of forest-protecting villages.

From Restricted Use to Overuse

Traditionally, local village folk did not own or manage the 2,200 ha of Dhani Forest. Nonetheless, they accrued many of the forest's benefits to augment their subsistence through a well-regulated system of forest harvesting.

Until Indian independence in 1947, the Dhani Forest lay within the domain of the Raja of Ranpur, one of 30 feudal states in Orissa that maintained a semi-independent status during the British colonial period. In Ranpur, as in other nearby feudal states, the Raja, or king, regulated access to forests and all forest products. During British rule, the Raja acted like a landlord, paying taxes on the forest estate to the colonial government. Some forests were essentially off-limits to local use. In others, villagers were permitted to meet their needs for timber and other forest products in exchange for modest royalty payments to the Raja or in exchange for free labor. Sometimes special considerations were given to the poor and to local tribal peoples with particularly high dependence on the forest.

After obtaining the required permit, villagers could gather a variety of products for personal use, from bamboo and wood for housing and agricultural tools, to fruits, fibers, leaves, and flowers. The forest rules banned cutting of selected "reserved" trees, and it was forbidden to sell or export trees without a permit from the ruler. The royal family also retained the privilege of hunting all wildlife within the forest.

The Raja maintained a separate administration of rangers, foresters, and guards to manage the "reserve forests," as forests like Dhani were known. The rangers strictly enforced the forest rules, both to prevent overuse by locals and to capture any commercial revenues from timber sales. Even without free access, villagers faced no shortage of forest products. During the Raja's tenure, the picture was one of a generally healthy forest with an abundance of resources.

In the early 1950s this picture began to change. Population was increasing rapidly, and agricultural land to meet local food requirements came into greater demand. Villagers cleared some of the forests on the lower slopes for planting using traditional swidden cultivation methods. More important, the era of the Raja's strict control had ended and the states of the newly independent India struggled to forge a "modern" forest policy–one that favored commercial uses of timber over meeting local needs. In 1960, the State Forest Department, which now controlled Dhani Forest, began permitting commercial contractors to harvest timber and remove much of the canopy in Dhani's low-lying areas. Villagers pressed some of the cut areas into crop production, and the State tried to establish teak plantations in other sections.

Over the next 2 decades, commercial cutting continued and local use intensified. Village cattle grazed the forest floor intensively and villagers gathered fuelwood relentlessly. Some came from more distant villages where forests were already exhausted. Sometimes even rootstocks were extracted for sale. Illegal timber cutters also took from the forest, smuggling out timber to meet growing urban lumber demands.

In 1979, the State allowed a second major timber harvest that left the forest devoid of large trees. Alarmed by the access given to outsiders, local villagers accelerated their own timber cutting in a rush to claim some of the forest goods and associated income for themselves. By the mid-1980s, the whole of Dhani Forest was degraded, much of it badly.

A Time for Action

The degradation of Dhani Forest had far-reaching impacts on the lives of local people. Materials from the forest on which they had always depended fell into short supply. People had to traverse long distances to collect fuelwood and to obtain small amounts of timber for house construction and farm tools. Firewood for traditional cremations dwindled. Fruits, tubers, herbs, and leafy vegetables that had long augmented food supplies during lean times gradually disappeared. The lack of forest productivity removed the cushion that the forest had always provided during dry periods and crop failures.

With the forest canopy removed, the forest soils dried out, reducing stream flows and decreasing local water tables. Because agriculture is the main occupation in the surrounding villages, soil moisture and water availability were prime concerns. Soil erosion also became a problem, affecting fertility in some neighboring fields. Loss of forest canopy also meant loss of the leaves and other sources of "green manure" that farmers had depended on for fertilizer.

Dhani Forest's worsening condition struck directly at the local economy, too. Without sales of products collected from the forest, many villagers had no source of cash. Selling fuelwood was the primary commercial activity, but the sale of leaves from kendu trees and siali vines was also important, particularly for women and poorer families. Approximately 50 Harijan families (the lowest castes and those with little land and high daily use of forest products) depend on the income from siali leaf collection in Dhani Forest. During peak season after the rains, one person working all day can collect as many as 3,000 leaves, which can then be stitched together into leaf plates or sold in bulk in Chandpur, the nearest town. Mats woven from date palm leaves were also sold locally; tubers like tunga, karba, and pichuli, as well as medicinal plants and vines, brought substantial local income. As these products dwindled, the pressure to migrate out of the nearby villages to urban areas for wage labor increased.

By the mid-1980s, villagers were convinced that Dhani Forest's poor condition was a serious community matter. They had begun to realize that it was they who were losing the most–not the private logging contractors or the State Forest

Department. It also disturbed them that future generations would inherit a depleted ecosystem. In early 1987, a respected village elder, Kanduri Pradhan, organized a meeting among the five villages that lay closest to Dhani Forest–Barapalli, Arjunpur, Panaspur, Balarampur, and Kiyapella. In ensuing meetings, a group of residents from all five villages discussed their options for collectively protecting Dhani Forest. A few villages in the Ranpur area had already begun to protect their forests, and this encouraged the group to commit to a joint program of action to guard and manage more than one-third, or 840 ha of Dhani Forest.

The decision to jointly manage Dhani Forest was a significant social and political event for the villages. Close cultural ties already linked the villages–they shared the observance of some local festivals, for instance, and a common school. Prior to their decision to protect the forest, they had formed an inter-village committee to coordinate collective activities. Yet they were also socially diverse, comprised of an assortment of tribal peoples and Hindu castes, including Brahmins (the most influential caste), Khandayats (farmers), and Harijans (the least powerful castes). Each of these groups lived in its own enclaves. Indigenous tribal people, the Saora and the Kandha tribes, populated Kiyapella and Panaspur villages. Balarampur village had a mixed tribal and Harijan community. In Barapalli and Arjunpur villages, Khandayats and Brahmins dominated. Dependence on the forest, however, linked them all, and village representatives realized that any hope of real forest protection lay in joint action.

A Plan for Life

By September 1987, the five villages had formalized their commitment to protect Dhani Forest. They formed a forest protection committee called the Dhani Panch Mauza Jungle Surakhya Committee. Out of lengthy discussions on the causes of the forest's poor condition and the possible ways to relieve pressures on the forest came a plan to restrict human uses of the forest.

From the beginning, the effort to protect and rejuvenate Dhani Forest was a true community affair. The elders of all households in each of the villages sat on the general body of the forest protection committee, which made all policy and budgetary decisions. A smaller executive committee included two members from each village to help implement the general committee's decisions. Community members were also required to take turns serving on the 25-person patrol squad that kept a daily vigil at the forest, restricting public access and preventing further degradation.

At first, the protection plan was simple: keep people and cattle out except for very restricted uses. Gradually, as the community's experience with protection evolved, so did the protection plan. The forest protection committee drew up an elaborate set of regulations and a schedule of fines. Cutting a valuable timber species like teak, for example, drew a fine of 1,001 rupees–a stiff penalty in the context of local incomes. In essence, the committee forbade any unsupervised cutting or collection of forest materials and set strict limits on those goods that could be harvested. The committee banned anyone entering the forest from carrying an ax or other sharp implement that could be used to cut woody material. It also banned grazing during the rainy season (July–September) to encourage regrowth of ground vegetation and restricted human access during the summer months to prevent fires. To help restore the lower slopes of the forest, the committee negotiated with local farmers to end the practice of periodically cultivating these areas.

It did not take long for Dhani Forest to rebound. Although they had lost much of their foliage, many of the trees and shrubs still had intact root systems and a number of these species were naturally fast growing; simple protection from defoliation allowed them to spring back. Still, Dhani is not the forest it once was. Some valuable species that were once abundant, like Sissoo, mango, Kendu, and Harida, are now scarce. The original forest species composition has been altered further with the planting of nonnative species like eucalyptus.

But even casual observers can see the improvements in the forest's condition. By mid-1999, the forest canopy had filled out and Dhani Forest boasted more than 250 plant species and 40 bird species. Other wildlife had begun to return as well. Soil erosion had diminished and stream volumes had increased, benefiting the agricultural fields that border the forest.

However, nature dealt the Dhani restoration a setback in October 1999 when a powerful cyclone battered Orissa, uprooting some 90 million trees in its path (Watts 1999). Although Dhani Forest is about 60 km inland, its forest canopy sustained considerable damage, losing many large teak, eucalyptus, and other valuable trees. Fierce winds uprooted bamboo bushes as well and destroyed many siali vines, ruining the siali leaf crop for the year (Singh 2000). In spite of the damage, Dhani Forest remains a functioning forest–testimony to the careful management that in just a little more than a decade transformed a degraded forest patch into a living community resource.

Sharing the Benefits

Conflicts with villagers who were harvesting against the rules were fairly frequent in the initial days of forest protection. But as the protection scheme gained acceptance within and beyond the local villages, cooperation increased. Soon the patrolling squad dropped to 10 people–two from each village–and in 1992 a professional watchman was appointed. At first the community paid the watchman with households' contributions of rice or cash donations. Gradually, revenues from sales of bamboo from the forest increased enough to fund the watchman's salary.

Locals' acceptance of the protection plan has been reinforced by a steady increase in the benefits they reap from the fast-regenerating forest. The forest protection committee has capitalized on the fact that short-term benefits demonstrate progress and breed long-term community support. As the forest has grown healthier, the committee has gradually raised the allowable harvest of different forest products, while taking care to make sure these uses are sustainable and do not impede long-term forest recovery.

Today, local villagers enjoy a much-increased supply of traditional forest products. Firewood from an annual cleaning and thinning operation is shared equally among the five villages, and locals can enter the forest any time to collect fallen branches, leaves, fruits, berries, and tubers at no cost. They also can collect green wood for cremations. With a permit, villagers can obtain poles and timber for a nominal fee, but they must appear before a committee and justify their need and the exact amount they require. Likewise, they can purchase up to 100 bamboo stalks for a fee. All materials are for personal use only and cannot be bartered or sold.

The forest protection committee has also taken care to extend the benefits of their management beyond the five villages. With permission and payment of a higher fee, neighboring villages can obtain many of the same forest goods as local villagers. Special concessions are made for community festivals if a village does not have access to any other forest. Victims of house fires can get timber for repairs at no cost.

Beyond Timber and Fuel: Pursuing Social Goals

The community effort to restore Dhani Forest has always been motivated as much by social as by biological goals. The community's forest management plan has grown to include much more than simple protective measures and rules for distributing benefits.

The Committee's local economic development efforts are perhaps its most ambitious work. The Committee has focused on improving the incomes of local people–mostly tribal peoples and Harijans–who are most dependent on the forest for a living and who effectively lost their livelihoods when the forest was closed to unrestricted use in the early days of Dhani's protection. At the Committee's urging, the State Forest Department has donated two leaf-plate stitching machines and trained local women's groups in siali leaf processing. The Committee was also instrumental in bringing a State-supported dairy program to the area; 40 forest-dependent families each have received one cow to provide a small income from milk.

The community also has decided to augment the natural growth in the forest by interplanting fruit trees, like cashews, that produce a crop that can be consumed locally or sold for cash. Other trees that produce collectible products are planted to help diversify the products that local people can harvest and to increase their production and dependability.

To fund the forest augmentation work and other community development activities, the forest protection committee aims to market any excess bamboo that remains after villagers' needs are met. A state survey of bamboo stocks (pre-cyclone) in the forest suggests that this can be a significant and sustainable source of revenue.

A related activity is the forest protection committee's efforts to pass on the traditional values of this forest-based community to the next generation of forest managers. Once every few months, the village children accompany the forest guard in his rounds. The guard familiarizes them with the plants, and teaches the children their common uses and local religious significance. The children also take part in raising seedlings and planting them to augment the forest stand. Children from Dhani visit various schools in the region to share their understanding of the forest and its importance with children whose villages are not yet involved in forest protection.

Equity and Other Challenges

Community forest management efforts like those in Dhani Forest have become quite common in Orissa and elsewhere throughout India. More than 6,000 rural communities in Orissa alone have made some attempt to protect local forest parcels for common use (Nayak and Singh 1999:8); 120 of these are in the Ranpur area (Panagrahi and Rao 1996:2). Like the Dhani villages, many of these communities have shown remarkable ingenuity, sophisticated planning, and success. But as with any group endeavor, forest protection by rural communities faces many obstacles. In some cases, the protection effort breaks down after a few years because of conflict within or between villages over how to manage the site. The problem becomes more acute once the forest regenerates and trees become larger and more valuable, increasing the temptation to harvest.

One source of internal conflict stems from the social structure of the community itself. Local forest protection programs have evolved in the same social context that has traditionally given rise to caste, class, and gender inequalities. An elite group often dominates the village decision-making process, which may marginalize women and lower-status sections of the community.

Also, the very act of protecting forests by limiting access to them tends to adversely affect the poorer and more forest-dependent members of the village, who have few other options for fuel and livelihood.

There are approximately 2,000,000 villagers living in some 10,000 villages across Orissa. More than 400,000 ha of forest is under JFM by village communities, but what they want is sole rights over the forests they protect and manage. They have formed a state-level forum to fight for ownership.

Dhani reflects both of these problems. The impetus for forest protection–and control of the forest protection process–has always been strongest in the villages populated with higher castes that owned land and had less absolute dependence on the forest. Conversely, the villages populated by tribal people and Harijans have shown greater reluctance to participate and have complained of less power over the forest's management. The forest protection committee's attempt to provide more income sources for the poorest members of the community has evolved as a response to this tension.

Likewise, the Dhani villages have wrestled with gender issues. Until 1995, the general committee (the main body of the forest protection committee) consisted of family elders, usually men. Since then it has included two members–one man and one woman–from each family in the five villages. The executive committee, a group of 21 villagers who implement the decisions of the larger general committee, has also included women since 1995, but only three and they are not routinely consulted when important decisions are made. Including women in the forest management makes sense because women are the predominant forest users, collecting most of the firewood, leaves, and other plants that enter local commerce.

Conflict with outside villages is another typical complication in forest protection efforts. Villages that have traditionally made use of a forest, yet have not been part of the effort to protect it, sometimes resist when a community group tries to limit free access to the forest. The conflict may remain latent as long as the forest is degraded, but once the forest regrows, neighboring villages may want a share. This was the case in Dhani. Kadamjhola, another village bordering Dhani Forest, declined to participate in the original forest protection plan but now wants to share in the project. The five original Dhani villages have agreed to involve Kadamjhola in the protection and management scheme.

Other neighboring villages have also sought a share of the replenished flow of forest products. In earlier years, these villages regularly infringed on the protected forest patch, causing many disputes. But in 1991, with the encouragement and advice of the forest protection committee, several of these villages joined together to protect their own piece of Dhani Forest–a section adjacent to the parcel that the five Dhani villages have under management. The efforts of the two groups will reinforce each other and reduce pressure on both parcels.

The Dhani Forest protection committee also has helped other community forest management groups resolve conflicts through their role in the recently formed regional federation of forest-protecting villages that has sprung up in the Ranpur area.

(continues on p. 190)

Box 3.9 History of Indian Forest Management

Although overuse of Dhani Forest did not begin until the 1950s, Indian forests have been systematically exploited for centuries. Many of the policies and inequities in wealth and political power that permitted historical forest destruction still influence the use and restoration of forests like Dhani.

British rule in India (1799–1947) left an indelible imprint on Indian forests, both through the outright destruction of forests for commercial timber and by dismantling centuries of local traditional forest governance systems. Certainly Indian forests had been altered prior to the arrival of the Europeans—for settled agriculture, for example—but in 1799 most were relatively unpressured. Pepper, cardamom and ivory were the only forest products for which there was significant commercial demand, and land for subsistence hunting and gathering was ample. Many forests in India were managed locally, with village systems and cultural traditions that carefully regulated members' harvesting practices.

But in the 19th century, the British turned to Indian timber for the royal navy's ships, for gun carriages, and to construct and fuel an expanding railway network. Large landowners, called *zamindars,* also promoted the conversion of forests to agriculture to make money and meet the tax demands of the colonial administrators.

By the mid-1800s, the British were concerned about rapidly dwindling supplies of teak, sal, and deodar—the best timbers for railway construction—and the government sought to expand its legal purview over Indian forests. They criticized villagers' customary use of forests as random and unscientific; colonials complained that rural Indians had become accustomed to grazing cattle and cutting wood wherever they wished. Although some colonials recognized that there were, in fact, complex systems of local forest governance that warranted praise and strengthening, their voices were overwhelmed by the assertion of the proprietary rights of the colonial government to India's forests.

The 1878 Forest Act dismantled the last vestiges of rural community control and instituted new classifications for forests: the compact and most valuable areas were labeled "reserved" or exclusively claimed for the state, others were classified as "protected"–places where the local people were given certain privileges but no formal rights. Eventually the colonial government converted many protected areas into reserve forests. Large areas of forest under the control of India's princes were also drawn into the colonial Act. Leases with local landlords and rajas divested surrounding populations of their forest rights. By World War II, the Forest Department's instructions were to produce the maximum output possible.

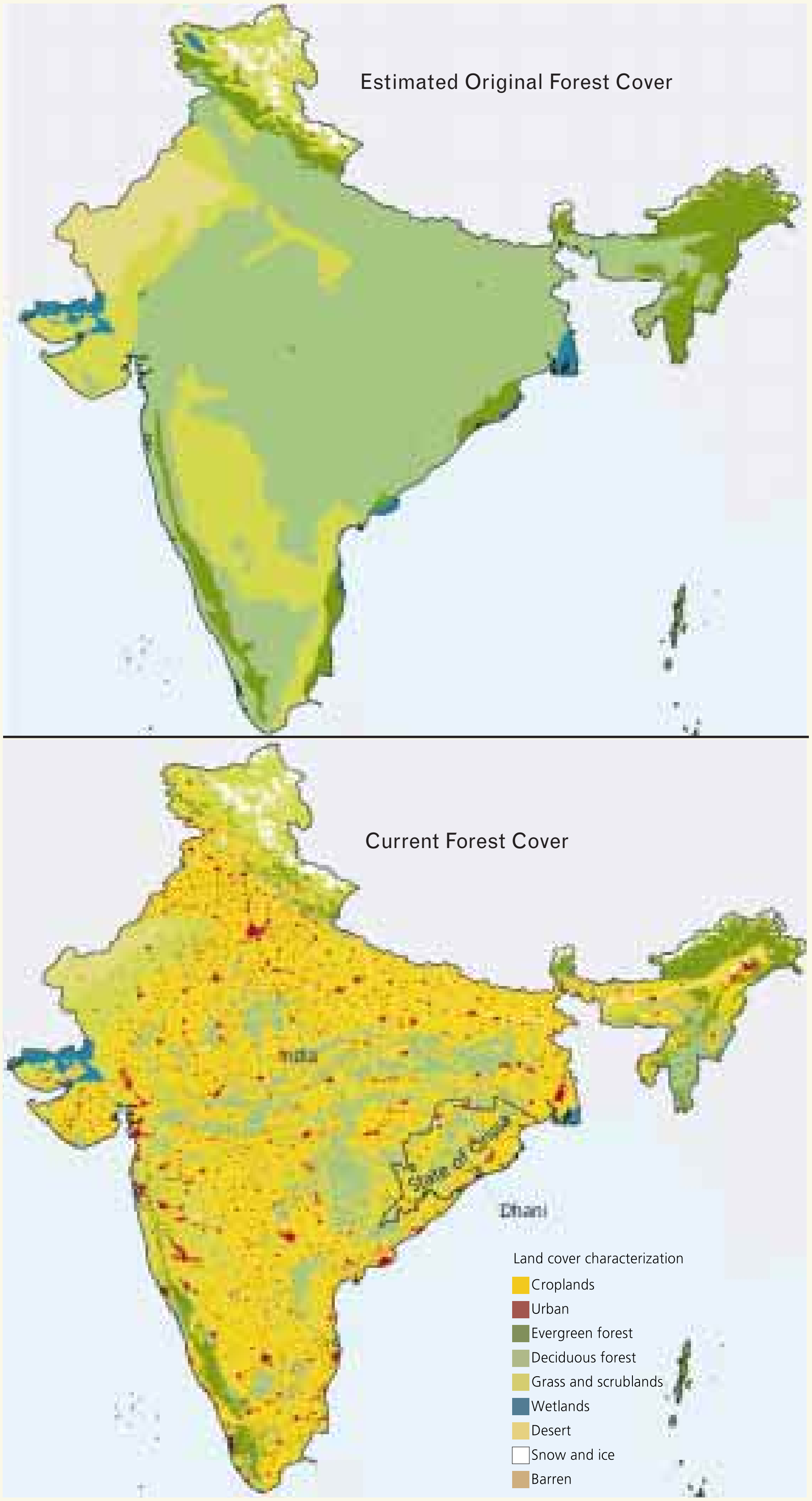
Traditional conservation and community management systems went into decline. In some areas, sale or bartering of forest produce was prohibited. New laws restricted small-scale hunting by tribes and British foresters. Indian princes sought to ban the traditional use of *jhum*—the shifting clearing and cultivation of forest in rotation—with the hope of enhancing the commercial value of their forests. Even in the few places, such as Madras, where the classification of *panchayat*, or village forests, lingered, bureaucratic government rules impaired their functioning. Loss of control induced a sense of helplessness among villagers, and protected areas became vulnerable to exploitation by both residents and outsiders.

With Indian independence in 1947, the domain of the Forest Department grew and the scope for local community management shrank still more. The Indian government took over extensive forests owned by landlords. But before surrendering their lands, many landlords cut as many trees as possible.

Clarifying the Forest Classifications

The terms used to describe forest-use rights and access privileges have specific connotations in the context of Indian forestry laws.

- **Reserve Forests** are those for which all rights are recorded and settled by the state. They represent the highest degree of state control—the state grants privileges but not rights to people.
- **Protected Forests** represent a lesser degree of state control, whereby rights are recorded but not yet settled.
- **Village Forests** constitute a fuzzier category. These are forests under management of representative village bodies, but the nature of these bodies and the kind of control they have varies. In the 1930s, for example, the state granted to village bodies some isolated, unprofitable (for the state) forest patches in western India in a bid to renew and bolster traditional management practices; these, for example, are referred to as village forests.
- **Common Property Lands** are lands with no individual ownership where resources are shared according to some established social norms. Grazing lands traditionally used by village communities are an example. Village forests can also be thought of as common property lands.



Sources: MacKinnon (1997) and Global Land Cover Characteristics Database Version 1.2 (Loveland et al. 2000).

Industrialization was an important objective of the newly independent Indian government and state timber plantations and production of paper and other wood-based industries were subsidized.

By the 1970s, when government forests were largely exhausted, some of the best tree stocks in India were what remained of locally managed village forests—like Dhani. The forest industry turned to some of these village forests and attempted to extract timber without the consent of local leaders.

At the same time, a growing population put those remaining forests under extreme pressure to be converted to other uses or to produce more wood, fuel, timber, and nonwood products. One survey found that between 1950 and 1980, the number of people supported by a single hectare of common property went from 4.9 to 13.7, with poor families deriving 77 percent of their fuel and fodder from such lands (Pachauri and Sridharan 1998:126, citing Jodha 1990).

In the early 1970s, however, experiments in Joint Forest Management were initiated, and would lead to a new era of forest co-management.

The pressures of population growth and forest conversion continue, yet Dhani and other forests are beginning to regenerate. Villagers are testing their rights to manage, reap, and perhaps even gain title to the lands they have restored. And governments at all levels are starting to realize the economic benefits of managing a forest for its nontimber goods and services—from leaves to healthy soils—as well as for its commercial timber potential.

State vs. Local Control: Who Should Reap the Benefits of Regeneration?

Title to Dhani Forest–both the land and the trees themselves–rests with the State of Orissa, yet it is only through the efforts of the Dhani villagers that a functional forest exists on the formerly degraded site. A similar situation exists on most of the forests in Orissa that have been regenerated through local community forest management–a total of approximately 400,000 ha, or about 7 percent of the State's forest lands (Mahapatra 1999:34). This tension between legal state control and de facto local control has been a source of local dissatisfaction and political friction for years.

In 1988, responding to pressure from a rapidly growing number of forest-protecting communities, Orissa became the first state to formally recognize the legitimacy of local forest protection committees. Soon after, it established a joint forest management (JFM) program through which it allows villages to co-manage local forests while sharing forest products with the state. Under the JFM formula, local communities are entitled to 100 percent of minor or intermediate harvests of commodities like fuelwood and nontimber products like leaves, grass, and fruits, and 50 percent of major harvests of timber.

Although the state maintains this is an equitable division, many local villagers throughout Orissa disagree. The State, they argue, has shown little interest in local forest management until now, when forests have begun to regrow and their value has risen. They complain that the State treats them like junior partners in the management effort, even though they have done the bulk of the restoration work. Many of these villages believe the State should surrender title to forests entirely to the local communities that protect them. Local activism over the subject of forest ownership has increased steadily in recent years, and the question of the State's role and right to harvest weighs heavily in the future of local forests like Dhani (Mahapatra 1999:32–42).

Dhani's own experience with the State has been more positive than most. Orissa State showed little interest, interference, or involvement in the beginning of the protection effort. In 1993, however, the State entered into a JFM agreement with the Dhani villages and has since been forthcoming with support. Lately, the State has cleared up one of the gray areas in the JFM rules: how to share the bamboo harvest. The state has also actively supported economic development initiatives of the Dhani community and offered technical help in improving the forest stand.

Even while it has maintained good relations with the State, the Dhani community has been active in the regional federation of forest-protecting villages. It has also taken a more visible role beyond the borders of Orissa, becoming a major learning center for those who want to study community forest management. In recognition of the Dhani villages' success in protecting and restoring the forest, Orissa State awarded them the *Prakriti Mitra* (Nature's Friend) award in 1997.

Forest Regrowth, Community Renewal

For the past 15 years, Dhani Forest has served as an 840-ha classroom. It has offered the community–and the world–some basic lessons in the value, degradation, and restoration of forest ecosystems.

The forest has always been a central feature–both spiritual and economic–in the lives of the communities around Dhani. It has been a source of livelihoods, a place for ritual, and the tangible abode of nature. As the forest condition degraded and these forest benefits dwindled, the fabric of the community began to fray. Both local subsistence and the cash economy suffered. Food supplies became less stable. Periodic migration out of the community for wage labor increased.

But the years of forest scarcity had a positive effect as well. Desperate to regain the benefits of the forest, the Dhani villagers came to a collective decision to act on their own–a grassroots campaign that provided a common rallying point among villagers and helped renew their traditional link to nature in the form of "Mother Forest."

Their efforts have brought tangible and significant financial reward to the communities. They have added money to the common village fund. They have also brought economic opportunities to the poorest and most forest-dependent villagers, the residents hardest hit by the original decision to limit access to the forest and an essential element in the long-term success of the restoration effort.

On another level, the Dhani experience emphasizes the importance of granting local residents a voice in how the ecosystems they live in are managed. Annexation of Orissa's forest lands by the State left locals with little control and stripped them of most of the forest's benefits. This set up the conditions for Dhani's demise. In contrast, when locals reasserted their control, they quickly established a workable management plan that garnered the community's and eventually the State's support. In this instance, and in many villages throughout India, community forest management has been far more effective than state management. Although Orissa State has acknowledged this truth in the form of its JFM program, there are indications that it still is unprepared to relinquish the level of control that local communities feel they deserve.

The Dhani example nonetheless demonstrates that the state can play a useful role in supporting community forest management. By lending financial and technical support to the community's forestry and community development goals, Orissa State improved the Dhani's prospects for success over the long term (Singh 2000). Experience here and in many other villages shows that community institutions such as the Dhani Forest protection committee tend to get stronger and more effective once they achieve financial and institutional independence. To the extent that the state has helped hasten that independence, it has nourished the roots of Dhani's restoration.

Box 3.10 The People of Dhani's Villages

Harijan women stitching siali leaf plates.

The five villages that manage Dhani Forest are home to 1,244 people in 212 households. Twenty-four percent of the households are families of the lower castes of Indian society, 29 percent are tribal, and 46 percent are upper caste families. Since 1935, the number of households has increased from 28 to 224—an increase of 700 percent. The economies of these villages are heavily forest dependent—75 percent of their income comes from a combination of forest resources and agriculture. Populations increased most in villages where families in the upper castes predominate, but lower caste and tribal families are the most dependent on forest products.

Caste Composition

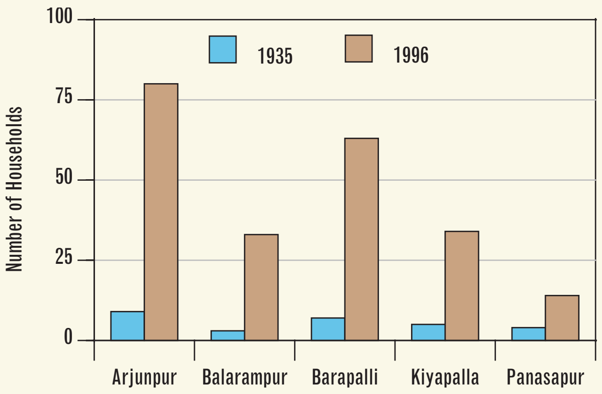
Caste refers to the hereditary social classes of Hinduism; it governs the occupations members can aspire to and their associations with members of other castes. The division is based on wealth, inherited rank or privilege, or profession.

	Number of Households			
Villages	Upper Castes	Lower Castes	Tribals	Total
Arjunpur	52	21	—	73
Balarampur	4	11	18	33
Barapalli	43	19	—	62
Kiyapalla	—	—	30	30
Panaspur	—	—	14	14
Total	99	51	62	212

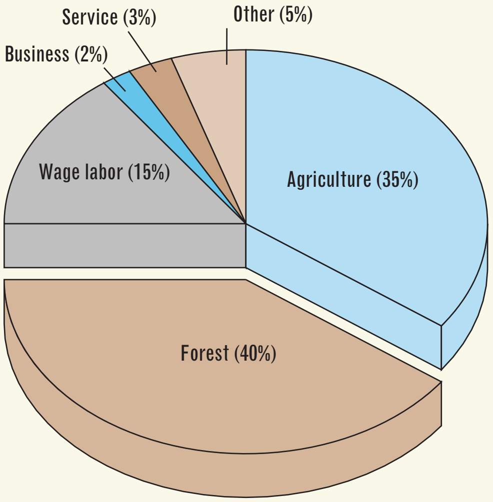
—, Data not available.

Source: Nayak and Singh 1999.

Population Trends in the Five Villages that Manage Dhani Forest, 1935–96



Sources of Primary Income in the Dhani Villages



Box 3.11 Joint Forest Management in India

India's Joint Forest Management (JFM) initiatives are based on the concept of collaboration between local people and state authorities. Local people participate in forestry activities on land that remains, essentially, under state control; the Forest Department provides financial assistance and technical advice.

Joint Forest Management grew out of the tension in the 1970s and 1980s between Forest Department staff and local communities. This was an era of political upheaval in many states. Villages had increasing need for forest resources but decreasing access to them, as the government aggressively promoted state plantations in barren and degraded forest lands that had always been used by local people. In fact, by 1980 nearly 23 percent of India's land area had been placed under state management; the majority of the affected rural population were denied access to their traditional resource bases. Nonetheless, Indian forests were losing ground, converted to other uses. For example, during 1959–76, Indian forests lost 2.5 Mha to agriculture, mostly to encroachment by the people living on forest peripheries.

A woman carries a "head load" of wood from rejuvenated Dhani Forest.

During this period, Dr. Ajit Banerjee, a young Forest Service officer posted at a small research station in West Bengal, was exploring alternative methods of forest management. In 1971 Banerjee initiated an experiment in Arabari in which local villagers would work with Forest Department staff to jointly manage forest patches adjacent to their settlement. The idea was to provide residents with a supply of biomass and sources of income through the sale of nontimber forest products—fruit, leaves, mushrooms, twigs, and fodder grass—and in exchange the communities would help restore and protect the forests. Soon, 618 families from 11 villages were working with the West Bengal Forest Department to restore more than 1,200 ha of forest, salvaging sal trees where good rootstocks remained and planting barren patches with fast-growing species like cashews. Some of the deforested areas were cultivated with rice, jute, and maize. The produce was sold to member families at a nominal price. The members could get firewood and fodder free for their own use.

By the early 1980s, jointly managed forests in Arabari were flourishing. Today, West Bengal, Orissa, and other states have formally endorsed the "Arabari experiment" as a general model for jointly managing forests. Widespread replication of the JFM model—with corresponding regeneration of forests—offers strong evidence that the recognition of traditional rights of local people to use forest resources could be the most important condition for managing a forest sustainably.

There remain several challenges to the further success of JFM. Marketing of nontimber forest products is still under the control of an organized lobby of large merchants. The state-run corporation responsible for marketing timber remains vulnerable to a group of contractors who keep prices low at auctions. Moreover, the efficient functioning of forest protection committees still depends on, in many cases, the personal efficiency and willingness of concerned Forest Department officials.

Community Managed Forests in 15 of 30 Orissa Districts

District	Villages (no.)	Land Under Protection (ha)	District	Villages (no.)	Land Under Protection (ha)
Angul	630	6,000	Mayurbhanj	750	35,000
Balesore	450	7,000	Nabrangpur	150	1,000
Baudh	25	2,500	Nayagarh	650	110,000
Bolangir	600	24,000	Puri	250	6,000
Debgarh	110	4,500	Raigada	75	8,000
Dhenkanal	732	8,000	Sambalpur	650	80,000
Ganjam	80	2,500	Sundargarh	125	5,000
Koraput	125	12,250			

Source: Mahapatra 1999.

FRESHWATER SYSTEMS

Working for Water, Working for Human Welfare in South Africa

South Africa is waging a new sort of turf battle. Beginning at dawn each day, thousands of citizens wield scythes, axes, and pesticides against a rapidly advancing and thirsty enemy: the alien trees, shrubs, and aquatic plants that thrive in South Africa's mountain watersheds, drainage basins, and riparian zones. These invading nonnative plants are literally drinking the water that people desperately need in this semiarid country.

Imported for aesthetic and economic reasons and unchecked by natural enemies, alien plants have infested 10 Mha, or 8 percent of the country (Versveld et al. 1998:32). Their noxious spread creates a chain reaction of ecological and economic disasters. In addition to depriving South Africans of needed water, these plants obstruct rivers, exacerbate the risk and damage of wildfires and floods, and reduce biodiversity by crowding out native vegetation.

Destroying trees and aquatic plants may seem counterintuitive to basic concepts of watershed protection and ecosystem management. Watershed conservation is most often associated with the prevention of deforestation. But South Africa is a country naturally dominated by grasslands and fire-prone fynbos shrub vegetation that, because of its low biomass, requires little water–unlike an infestation of large alien trees and woody weed species.

Common invader species such as wattle (*Acacia*), silky hakea (*Hakea sericea*), and pine (*Pinus*) increase the aboveground biomass of fynbos ecosystems by 50–1,000 percent. The invaders dramatically decrease runoff from watersheds

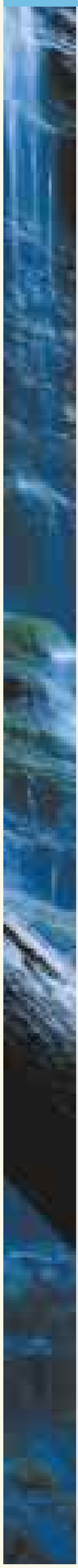
(continues on p. 196)

Box 3.12 Overview: South Africa's Invasives

Nonnative plants have invaded 10 Mha of South Africa. Though they provide valuable timber and other benefits, invasive plants deprive the country of precious water, reduce biodiversity, obstruct rivers, and increase risk and damage of wildfires and floods. South Africa's response, a multiagency effort called the Working for Water Programme, has hired thousands of poor, disadvantaged citizens to remove invasive species while acquiring a living wage and new skills.

Ecosystem Issues	
Freshwater 	Since the invasion of South Africa by nonnative plants, the water quantity provided by the country's freshwater ecosystems to downstream areas has dramatically decreased—by as much as 82 percent in some watersheds.
Forests 	Converting grasslands and native forests to nonnative plantations made it possible for South Africa to increase fiber production. Today, timber contributes R1.8 billion to the national economy and forest-based industries another R10 billion. The trade-off: the nonnative trees drink almost 7 percent of water that would otherwise flow into rivers—far more than native species.
Grasslands 	Already one-third of South Africa's Cape Floral Kingdom, a grassland and fynbos shrubland ecosystem, has been lost to urbanization, agriculture, and forestry. Invasives now threaten biodiversity in the remaining 90,000 km^2 of fynbos, home to 45 percent of the subcontinent's plant species. Invasives also increase soil erosion after wildfires and floods.
Agriculture 	Conversion of lands to agriculture and habitat disturbance from road building and other developments promotes the spread of nonnative plants.
Management Challenges	
Equity and Tenurial Rights 	The end of apartheid began to return a voice to black citizens, whose control over land and water had previously been drastically limited. This era also brought a new commitment to supplying sufficient water to all. If that commitment is sustained, it provides impetus for the Working for Water Programme and other restoration efforts that promise to provide more water at minimal cost.
Economics 	Once almost free, the government now charges citizens for water to discourage overuse and waste. Charges for other major water consumers like the forestry and agriculture sectors are critically needed, too, but hotly contested.
Stakeholders 	The Working for Water Programme has found some common ground with stakeholders, but more difficult policy negotiations are ahead. For private landowners and commercial foresters, many invasives are valuable crops or decorative elements of yards; controlling them brings higher costs than benefits.
Information and Monitoring 	Research on the impacts of invasives on water supply helped generate interest in today's integrated invasive plant control effort. More economic studies that illustrate the impacts of invaders and the financial benefits of control are essential to help justify the increasingly large-scale funding that the Working for Water Programme requires.

Timeline



c. 1000 Traders and nomads introduce plant and animal species to Southern Africa, but none significantly impact native vegetation.

1652 The Dutch colonize South Africa's Cape. They soon import more than 50 crop plants from Europe, Asia, and South America; some are present-day invaders.

1820–1870 A large influx of settlers from around the world introduces 11 of the 12 invasive species that now cause the greatest problems in fynbos.

1880s–1890s Botanists begin to note the spread of nonnative plants over mountain slopes and losses of endemic species in Cape fynbos vegetation. At the same time, foresters promote mountain plantations of nonnative trees.

1920s Controversy about effects of forest plantations on water supplies begins, even as demand for commercial timber and related products drives high rates of afforestation with nonnative hardwoods that continue for the next 60 years.

1930s Rapid spread of prickly pear (*Opuntia aurantiaca*) in the succulant Karoo sparks awareness of the threat invasives pose in arid areas as well as fynbos. Threats to biodiversity in grasslands and savanna are not fully understood for another 50 years.

1934 The South African parliament appoints an interdepartmental committee to assess water preservation options.

1937 The Weeds Act is passed, one of the first major legislative attempts to deal with invasives, but a lack of field staff and resources makes it difficult to enforce.

1940s–1970s Hydrological studies show that plantations have a negative effect on streamflow. Efforts to control invasives are launched, but they are uncoordinated, erratic, and hampered by limited follow-up after clearing.

1948 Apartheid designates 83 percent of South African land "whites only." Rural land and water laws in ensuing decades mainly serve white interests. Blacks are denied access to the political process.

1970 The Mountain Catchment Act gives the Department of Forestry management responsibility for high-lying areas; invasives there are tackled in earnest, with plants cleared from tens of thousands of hectares. The Plant Research Institute conducts vital research on biological controls for invasive plants.

1983 Conservation of Agricultural Resources Act grants government wider power to control invasive species and introduces the idea that landowners are obliged to manage their land sustainably.

1986 International program on biological invasions focuses attention and research on plant invasions in South Africa. A review of catchment experiments provides unequivocal evidence of the detrimental effect of nonnative plants on stream flow.

Late 1980s Responsibility for management of mountain catchments is passed from the Department of Forestry to the provinces; lack of funding ends momentum for integrated invasive plant control programs. Plants re-invade cleared areas.

1989 International SCOPE program on biological invasions focuses attention and research on South African plant invasions. A review of catchment experiments provides unequivocal evidence of the effect of nonnative plants on streamflow.

1993 Further government-sponsored research determines that clearing invasive vegetation can improve runoff from catchments.

1994 Apartheid ends. South Africa becomes a constitutional democracy.

1995 The Working for Water Programme is founded by South Africa's Minister of Water Affairs and Forestry, hires 7,000 people, and clears 33,000 ha in its first 8 months.

1998 The National Water Act recognizes water as a common resource; commits to protecting its quantity, quality, and reliability; and grants each South African a right of access to 25 l of water per day. Meeting that commitment to 14 million people without access to sufficient water is a daunting challenge.

2000 The Working for Water Programme employs tens of thousands of people and has successfully cleared more than 450,000 ha of land of invasive species, yet millions of hectares still require attention.

through greater water uptake from soil and subsequent transpiration (van Wilgen et al. 1996:186, citing Versfeld and van Wilgen 1986). Currently, invasive species in South Africa consume about 3.3 billion m^3 of water each year, almost 7 percent of the water that would otherwise flow into rivers (Versveld et al. 1998:iv). That's nearly as much water as is used by people and industries in South Africa's major urban and industrial centers (Basson 1997:10).

South Africa's response to the invasion may be the largest and most expensive program of alien-plant control ever undertaken. It is also an effort to address the impoverishment of black South Africans–poverty being one of the legacies of apartheid, the system of white rule that ended in 1994. Through a multiagency effort called the Working for Water Programme, the government has hired thousands of citizens to hack away the thirsty invasive plants and to turn the byproducts of their labors into saleable goods such as fuelwood, furniture, and toys. Since its inception in 1995, the Programme has offered men and women opportunities to acquire a living wage and new skills. In some project areas, the Programme provides childcare, community centers, and health and national water conservation education.

By uniting social goals with ecosystem restoration, and by capitalizing on public pressure to provide more water to millions of people, Working for Water has mustered political will, public support, and funding at a time of fierce competition among the many social welfare projects visualized by South Africa's new democratic government. Still, success is far from assured and the stakes are high. If the Programme fails, many pervasive invaders could double in extent over the next 10–20 years (Versveld et al. 1998:vi), jeopardizing the water supply to cities, industries, and agriculture. The Programme's high cost, conflicts of interest with landowners, and management and safety problems cannot be ignored. But the multiple dividends that Working for Water pays are substantial: a healthier ecosystem, more water at less cost, and employment for thousands in a country where opportunities to escape poverty are rare.

The Plant Invaders

Today, invasive plants and animals are considered one of the gravest threats to the biodiversity of natural ecosystems worldwide. That awareness, however, has come relatively recently. For centuries alien plants were seen as desirable; their cultivation offered immediate economic returns and social benefits, although their costs were usually slower to manifest. Alien plants can spend decades living innocuously in nonnative settings before some subtle adaptation or shift in ecological dynamics triggers an invasion. Even after years of study, it is not always clear which organisms will aggressively invade new ranges, where invasions will occur, when, or why.

A ribbon of invasive alien pines *(Pinus pinaster)* on the horizon; these pines spread from a plantation just over the mountain. They radically alter the structure of the fynbos and reduce streamflow from rivers.

IMPORTING THE INVADERS

Nonnative plants certainly seemed harmless to the Dutch, who introduced more than 50 plants within the first few years of their settlement at South Africa's Cape in 1652 (Wells et al. 1986:29). For the next 150 years, colonists from all over the world continued to import species that would provide firewood, timber, food, and shade, and would stabilize sand drifts, enhance gardens, and remind them of home.

In total, about 8,750 plant species have been introduced into South Africa. Fortunately, only 2 percent have become seriously invasive, mainly trees and shrubs that mature quickly, multiply prolifically, spread easily, and fare well in disturbed conditions (van Wilgen and van Wyk 1999:566). Species imported from southern continents and other fire-prone ecosystems, like Australia, took hold particularly readily in the fynbos, where fires trigger seed release and create conditions conducive to germination.

Some of the most problematic species took root in the late 19th century when forest authorities began to promote afforestation of the mountains around Cape Town. Imported pines, eucalyptus, and wattles were promoted to supply tannin and timber, since the extent of South Africa's natural forests is limited by climate and the fire regime. Officials believed also that alien plants would increase the water supply and provide aesthetic relief; they called the naturally bare and stony slopes of the Cape's mountains "a reproach and an eyesore." Government foresters provided private growers with free seeds and transplants of the alien species and awarded prizes for the best plantations (Shaughnessy 1986:41).

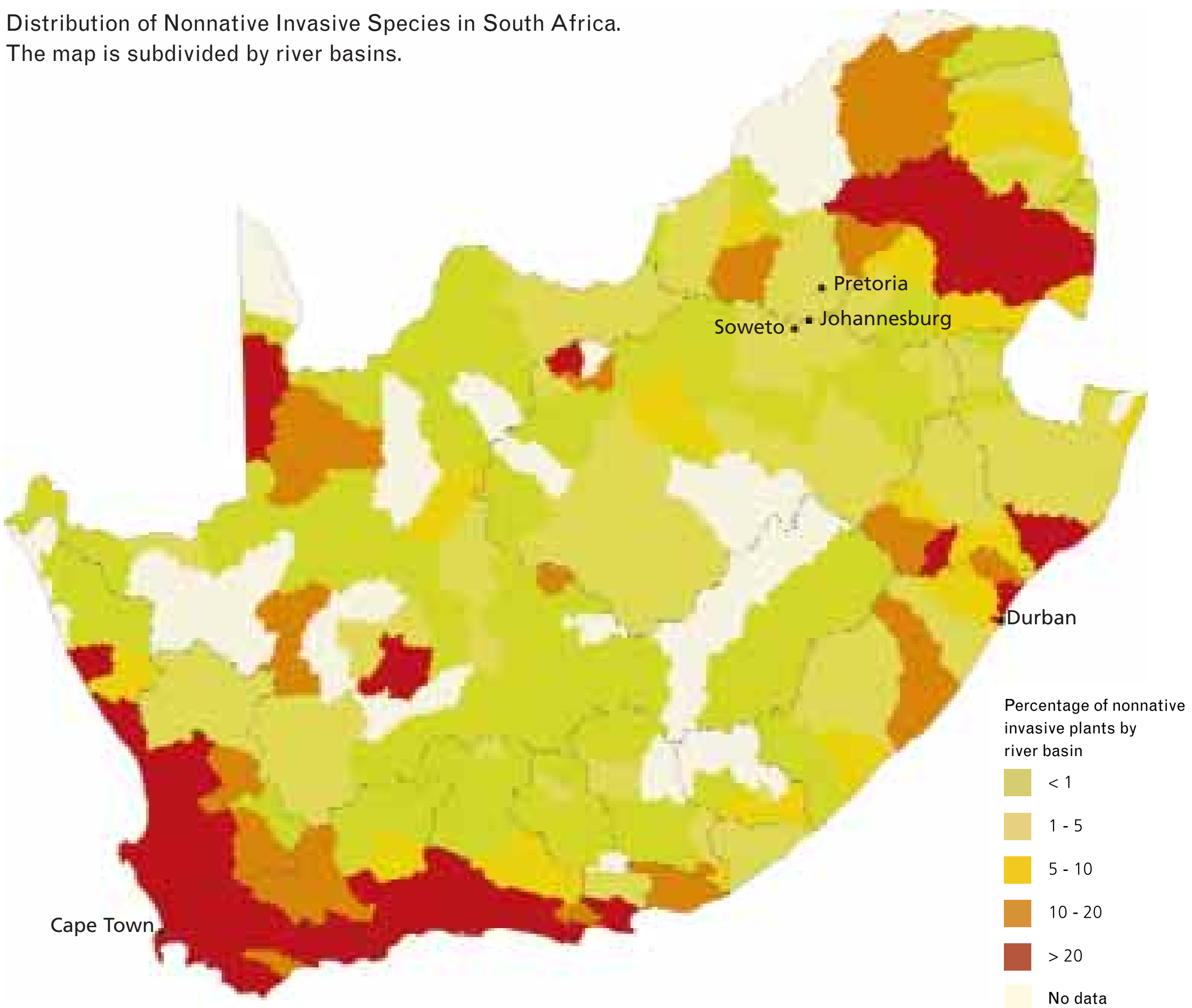
The nonnative trees proved fast growing and able to take root on all kinds of marginal lands. South Africa soon trans-

Box 3.13 Most Widespread Plant Invaders in South Africa

Species	Origin	Reason for Introduction	Approx. Area and System Invaded	Water Use (millions of cubic meters)
Syringa *(Melia azedarach)*	Asia	Ornamental, shade	3 Mha; savanna, along riverbanks, disturbed areas, roadsides, urban open spaces	165
Pines *(Pinus species)*	North America and Europe	Timber, poles, firewood, shade, ornamental	3 Mha; widespread in mountain catchments, forest fringes, grasslands, fynbos	232
Black wattle *(Acacia mearnsii)*	Australia	Shelter, tanbark, shade, firewood	2.5 Mha; widespread, except in arid areas	577
Lantana *(Lantana camara)*	Central and South America	Ornamental, hedging	2.2 Mha; forest and plantation margins, water courses, savanna	97

Sources: Versveld et al. 1998:75; Working for Water Programme n.d.:4.

Distribution of Nonnative Invasive Species in South Africa. The map is subdivided by river basins.



Sources: Versfeld et al. 1998; USGS 1997.

formed grasslands and scrub-brushland habitats–largely unsuitable for agriculture and grazing though very rich in native biodiversity–into state-owned and private plantations to feed the burgeoning timber industry and pulp and paper mills. Today, plantations of alien trees cover 1.52 Mha. Natural forests cover less than 7,177 km^2–about 0.25 percent of South Africa (Le Maitre et al. Forthcoming).

Unfortunately, in riparian zones fast-growing aliens drink almost twice the amount of water that the same trees consume in areas away from rivers (van Wilgen and van Wyk 1999:567). And, plantations can only grow in the higher rainfall areas, like South Africa's mountain catchments. There they garner "first take" on some of the key water supplies for South Africa's lowlands. Although mountain catchments encompass just 8 percent of the land surface, they provide 49 percent of the total annual freshwater runoff for the country (van der Zel 1981:76).

LOSING WATER, GAINING AWARENESS

As early as the 1800s, South African botanists expressed concern that introduced plants might suppress and replace natural vegetation, eventually turning the species-rich fynbos into a biological desert. But among land managers and policy makers, there was little interest in alien plant control for almost another 100 years.

The threat of water shortages–more than the potential loss of biodiversity–is what eventually motivated a reevaluation of South Africa's land management practices. Suspicions that the proliferation of alien plants might be linked to water supply problems arose in the 1920s when farmers' associations petitioned the government to investigate why South Africa's rivers were drying up. The government initiated a series of experiments to assess the impact of commercial forestry on water resources in mountain areas. In study catchments, fynbos shrublands and grasslands were heavily planted with alien pines and eucalyptus, and the impact on stream flow was monitored and compared to untreated control catchments. In the following decades, researchers found stream flow sensitive even to small changes in catchment vegetation cover. In KwaZulu-Natal Drakensberg, for example, there was an 82 percent reduction in stream flow in grassland catchments 20 years after planting with pines, a 55 percent reduction in fynbos catchments in the Western Cape 23 years after planting with pines, and a total drying up of streams in Mpumalanga Province 6–12 years after completely replacing grassland catchments with pines and eucalyptus (van Wilgen and van Wyk 1999:x). Despite these findings, until the 1990s, efforts to protect watersheds and combat the spread of invasive plants were small and sporadic, petering out when funding waned.

Finally ecologists were able to galvanize support for change with a critical body of evidence that water losses to unchecked invasives could be economically disastrous. Advances in technology enabled the development of computer models that simulated the growth, spread, and water use of alien plants in a fire-prone landscape. The results were eye-opening. Even sparsely infested areas are likely to become dense with invasives over the next half century, resulting in reductions in streamflow of 30–60 percent (van Wilgen et al. 1997:406). During the dry months when water needs are greatest, runoff in some invaded catchments could be reduced to zero, converting perennial streams to seasonal ones.

Unchecked alien plants would have dire implications for the Cape region's native wildflower, foliage, and dried flower harvests and for the 1.3 Mha of irrigated croplands that produce 25 percent of the country's agricultural output (IWMI 1999:4). The Western Cape's harvests of apples, peaches, and pears, for example, depend entirely on water derived from adjoining mountain catchments; and the deciduous fruit industry generated gross export earnings of more than US$560 million and employment for 250,000 people in 1993 (van Wilgen et al. 1996:185).

The impetus for invasives control gained further momentum from a political transformation–the end of apartheid in 1994. A democratically elected government brought a new national focus to equitable water access, a radical departure from a history in which water was seen as the property of the person whose land it ran through, usually white farmers. Now, under South Africa's 1998 Water Law, all water is a common resource. Each South African has a right of access to sufficient water for basic needs, an amount provisionally set at 25 l/person/day.

Since 14 million South Africans have inadequate or no water supplies (Koch 1996:12), translating this new "right" into practice will make prior water shortages seem trivial. South Africa is already water stressed, and rapid population expansion in metropolitan areas like Cape Town threaten to create regional water crises. Studies have predicted that in parts of the Cape, water demand in the year 2010 could be 70–106 percent higher than in 1990 (Marais 1998:2, citing Spies and Barriage 1991).

A New Kind of Turf Battle

Watershed protection and poverty alleviation are dual goals paired effectively in South Africa's Working for Water Programme. In 1995 Kader Asmal, Minister of Water Affairs and Forestry, was convinced by the arguments of scientists and conservationists that clearing invading plants could supply water and other ecological benefits. He proposed that the government use Poverty Relief funds to hire disadvantaged citizens to remove invasive trees, shrubs, and aquatic plants.

The first year of the plant-clearing effort had a budget of R25 million and employed more than 6,100 people (van Wilgen 1999). Now in its fifth year, Working for Water's 1999–2000 budget is eight times larger–R202 million (van Wilgen 1999)

A Working for Water team clears a dense stand of *Pinus pinaster* in the mountains above the coastal town of Kleinmond, about 120 km east of Cape Town.

and funding 240 projects in eight heavily infested provinces. At times, employment has risen to 42,000 people, many of whom have never been employed before or only labored as migrant workers (Working for Water 1998, 1999). Priority is given to clearing invasives from riparian zones and areas with the greatest number of disadvantaged citizens.

PROTECTING THE WATERSHEDS

The Programme has cleared in excess of 450,000 ha of infested land. In some places streams have flowed again for the first time in decades (van Wilgen 1999). The clearing of a dense stand of pines and wattles from 500 m of river bank in Mpumalanga Province, for example, soon resulted in a 120-percent increase in stream flow. Removing pines for 30 m on either side of a stream (just 10 percent of the catchment) in the Western Cape resulted in a 44-percent increase in stream flow a year later–more than 11,000 m^3 of water gained per cleared hectare (Scott 1999:1151–1155; Dye and Poulter 1995:27–30).

Twelve to 18 months after clearing an area, workers must eliminate alien seedlings with herbicide treatments or burning and replant the land with indigenous species. Follow-up also may require the use of biological controls such as species-specific insects and diseases from the alien plant's home country. Examples include the tiny gall wasp that prevents the long-leafed wattle from flowering and producing seeds, or leaf-feeding insect species that damage the leaves and stems of lantana, another aggressive invader. In most cases, biological methods cannot control alien plant species on their own–they cannot remove existing established stands of trees, for example–but they can provide a cost-effective means of minimizing the invaders' future spread and an alternative to herbicide applications near water.

ALLEVIATING POVERTY

Working for Water's momentum comes as much from the jobs it creates as the water that flows anew from project areas. Employment is a powerful lever for change in a country with 37 percent unemployment (in 1997) (UNEP 1999, citing South African Institute for Race Relations 1998); 50 percent of all households are classified as "poor," earning less than R353/ adult/month (May 1998). In many project areas, citizens lack reliable sources of clean water, electricity, and permanent homes. Few have the education or skills to take on available jobs, especially those in an increasingly technological labor market.

Programme workers are paid a daily wage of R22–R55–on par with local wages for similar jobs (Marais 1999). Most workers spend the day removing invasives with scythes and chain saws. Some employees trained in mountaineering start the week with a helicopter flight to parts of Mpumalanga and Western Cape provinces that are inaccessible by foot. There they clear alien vegetation from peaks and gorges, camping until a return flight home on Friday.

The Programme's social welfare benefits are expanding along with the water supply. By supporting child daycare centers, Working for Water has built a workforce that is more than 50 percent female, including many single mothers. The Programme also strives to create jobs for youths, rural residents, and the disabled. Worker training and education, provided in collaboration with government agencies, schools, and nonprofit organizations, complements hiring programs. Topics include environmental awareness and health education–from first aid, to family planning, to HIV/AIDS prevention.

TEMPERING THE TAP

While striving to restore the mountain watersheds to a state of uninvaded abundance, the Working for Water Programme serves to awaken citizens to a new appreciation of the limits of South Africa's precious water resources. A combination of incentives is spurring the adoption of conservation measures and providing Programme income.

A major impetus comes from South Africa's new Water Law, which explicitly recognizes the need to protect "the quantity, quality, and reliability of water required to maintain the ecological functions on which humans depend" (see next page). Some municipalities where Working for Water operates

(continues on p. 202)

Box 3.14 South Africa's New Water Law: Managing Water for Equity, Economic Growth, and Ecosystem Resilience

Reforming the way water is managed is central to South Africa's economic and political reconstruction. Since the democratic elections of 1994, the nation has crafted a suite of water policies, including the Water Services Act of 1997 and the National Water Act of 1998 (NWA), to redress past inefficiencies, inequities, and environmental degradation. These new policies are considered among the most progressive in the world.

Like other countries, South Africa's has crafted water-sector reforms that emphasize a decentralized approach to water management, encourage local participation in decision making, and use innovative water pricing practices (Saleth and Dinar 1999:iii). What sets South Africa's approach apart are its far-sighted and ecologically grounded commitments to manage water efficiently, while ensuring equity of access and the sustainability of the resource. These goals have required radical departures from the nation's old practices.

Protecting Ecosystem Integrity

South Africa's new water policy is based on the principle that the nation must maintain the natural ecosystems that underpin its water resources if it expects to meet its ambitious water provision goals. To this end, the NWA requires that the country maintain an environmental "reserve"—the amount of water that its freshwater ecosystems require to remain robust (NWA No. 36, Chap. 3, Parts 2 and 3). The law also encourages an integrated, watershed-based approach to water management; actions that could fall under the law's purview include modifications of land-use practices along stream corridors, the clearing of nonnative vegetation, and measures to reduce the production of pollutants.

Water Allocations to Satisfy Basic Needs

The NWA establishes a "basic needs reserve" for humans, too—an allocation of water for drinking, food preparation, and personal hygiene. This reserve, provisionally targeted at 25 l/person/day, is guaranteed as each citizen's right (DWAF 1994:15; Water Services Act No. 108). To ensure that everyone has access to the reserve, the law directs the Department of Water Affairs and Forestry (DWAF) to oversee the provision of water and sanitation across the provinces.

After a supply of water to meet basic human needs and the environmental reserve is assured, South African law requires that remaining water be allocated so that: (a) all people have equitable access to the resource for productive purposes, especially within the agricultural sector; and (b) all people have equitable access to the benefits that flow from water use, such as jobs. For example, under law, the country would seek to remedy such inequities as the distribution of irrigation water; currently, irrigation accounts for more than half the water used in South Africa, but black farmers have access to less than 10 percent. The NWA also specifies that the government can implement water charges (described below) for certain regions or groups to further the goal of equitable access.

Water as Public Property

The 1998 law makes all water public property, repealing the previous statute that assigned water rights based on property ownership (NWA No. 36, Ch.4). For example, a landowner now needs permission to make large-scale water withdrawals from water that crosses his or her property. Other regulated water uses include storing water, impeding or diverting the flow of water in a watercourse, engaging in activities that can reduce stream flows such as plantation forestry, irrigating land with waste water, or altering the banks of a watercourse.

Individuals who want to use water beyond reasonable amounts for domestic use, livestock, emergencies, and recreation must apply for temporary licenses (NWA No. 36, Chap. 4, Part 1 and Schedule 1). Water authorities grant licenses for specific uses, like irrigation, and for specific periods of time. The maximum grant of water rights is 40 years, but all licenses of any length are subject to review at least every 5 years to ensure equitable distribution in a watershed. Reviews are conducted to maintain water quality, to redress situations where water has been over-allocated, or to address situations in which socioeconomic demands have changed. Licenses can be traded or auctioned.

New Governance Structures

The scope for local participation in water management in South Africa has been vastly broadened while the capacity to coherently plan and integrate water management at national and watershed levels has been retained.

At the national level, DWAF is charged with establishing the details of the national water strategy, making decisions about water transfers among watersheds, meeting the terms of international agreements in shared river basins, and determining water quality standards. But the responsibility for actually allocating water to users within an individual watershed rests with local "Catchment Management Agencies" (CMAs) (NWA No. 36, Chap. 7, Part 1). The CMAs and other institutions are expected to operate with broad participation from all interested parties—for example, they must make all applications for water licenses public and judge all water users' responses.

It is also worth noting that South Africa's water laws are among the first in the world to grant water rights to a person who farms a given piece of land, whether the person is the formal owner or merely the user of the plot. This arrangement is substantial help to holders of communal land (International Water Management Institute 1999:8).

Water Fees for Equity and Efficiency

The NWA relies on water fees as the main tool for financing the provision of water and encouraging efficient use (NWA No. 98, Chap. 5, Part 1). The law requires the DWAF to develop water pricing strategies and gives the agency considerable discretion in varying water prices by location, depending on circumstances. For example, the agency can apply a given water charge on a national or regional basis, or simply within a specific water management area. The DWAF can use three types of water fees:

- A charge to cover the full financial costs of providing access to water, including the costs of developing, operating, and maintaining the water infrastructure.

- A watershed management charge, which can apply to the use of rivers and other water bodies for waste disposal as well as to water consumption. Funds generated can be used to support water management, conservation, and research.

- A resource conservation charge that can be applied where a particular water use significantly affects others in the watershed. These charges are intended to reflect the scarcity value of water in a water-stressed area.

Implementation Challenges

South Africa's water reforms are lauded internationally, and people across South Africa recognize the merits of the changes outlined in the new water policies. Nevertheless, implementing the new policies is challenging. Weak management and inadequate training have plagued many water delivery projects in the past 5 years, and some communities have resisted paying the new water charges. These early experiences demonstrate that, no matter how lofty the goals, instituting profound changes in the management of a resource as basic as water takes time, both to build support among the wide array of water users and to build the capacity and professionalism of local water institutions.

An equally great challenge posed by the new water policies is the need for the South African government to take a multidisciplinary approach to water management issues. Hydrological and engineering considerations—for decades, the water department's focus—now are merely pieces of a larger management framework that gives equal consideration to economic, social, and ecosystem issues.

use water conservation campaigns to help implement that law. Prepaid meters encourage citizens to pace their water use and "save" water. Citizens use "grey water" (wastewater) in the garden, water-efficient toilets, and low-flow showerheads. They refrain from irrigation between 11 a.m. and 2 p.m., when 60 percent of the water applied evaporates.

Another conservation incentive is an increase in what had been some of the cheapest water prices in the world. Sliding scales for household water use make the first 5 m^3 of water just R0.007 each, but each additional cubic meter has a higher price–as much as R0.14/kl for use of more than 60 kl/household/month (van Wilgen 2000).

The results are striking. In Hermanus, for example, water use decreased by 25 percent, while revenue from the sale of water increased by 20 percent, helping to fund a local Working for Water project. Conservation measures have allowed Hermanus can delay building expensive additional water supply capacity–like a new dam (Working for Water 1998:17).

CALCULATING THE BOTTOM LINE

Currently, Working for Water is spending R200–R250 million/year, mainly on worker wages. Financial support comes principally from the government's Reconstruction and Development Programme and Poverty Relief funds, and about 40 percent from water tariffs (van Wilgen 1999). Substantial training, materials, and staff for the social welfare programs are provided by many partner agencies. In Walker Bay near Hermanus, landowners are paying half the clearing costs and the full maintenance costs. In Cwili-Kei Mouth/Komga on the Eastern Cape, farmers are paying 60 percent of the cost to clear their land (Marais 2000; Working for Water 1998:17). Programme leaders hope to replicate these models.

Yet at current rates of work and efficiency, the plants are still spreading faster than the Programme is removing them. Assuming an alien expansion rate of 5 percent/year, watershed restoration and plant control will require about 20 years of work–an annual investment of about R600 million. That's a total cost of about R5.4 billion, plus long-term maintenance of about R30 million/year (Versveld et al. 1998:iv–vi).

Still, put in the context of other water supply options, plant-clearing programs and watershed protection may be the best buy. One study suggests that the additional water generated by clearing aliens from catchments in the Western Cape would cost just over R0.06/m^3. By comparison, it would cost, per cubic meter, R5.70 to secure water from the best dam option in the Western Cape, R1.50 for treating sewage water, and R4.80 cents for desalination (van Wilgen et al. 1997:409; van Wilgen 2000). The studies also showed that early investment in clearing is financially prudent. The spatial cover of invasives in fynbos regions appears to spread and intensify from light to dense within four to six fire cycles (50–80 years). To clear lightly infested areas costs about R825/ha compared to R5,875/ha to clear a densely invaded area (Versveld et al. 1998:vi).

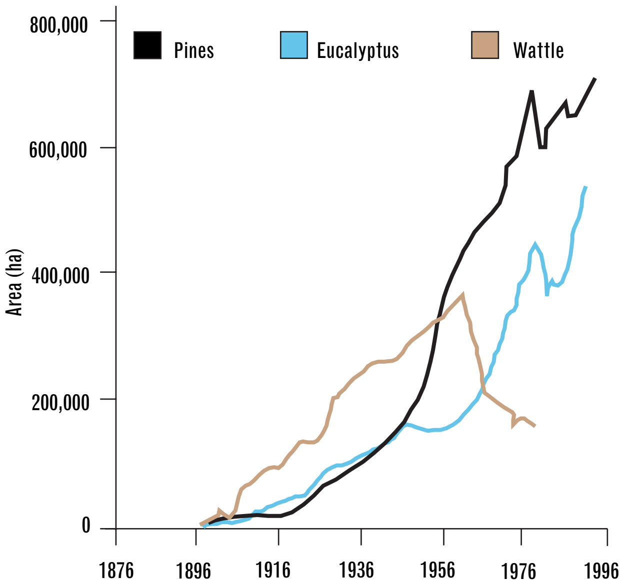
WINNERS AND LOSERS

Not only does the government face steep plant-clearing and weed-control costs, so do private companies and landowners. Many of the species targeted as "pests" sustain one of the country's fastest growing economic sectors: plantation forestry contributes 2 percent to South Africa's GDP, about R1.8 billion/year; and products from pines, eucalyptus, and wattles contribute another R10 billion/year. Yet forestry is a major source of invaders. Thirty-eight percent of South Africa's invaded areas are occupied by nonnative species used in commercial forestry, and nearly 80 percent of invasive pines occur within 30 km of plantation forestry (Nel et al. 1999:i,1,19). Many rural landowners are reluctant to finance the restoration of invaded areas for which they are responsible–areas where species like wattle and eucalyptus have escaped from intended use on farms as windbreaks, shade trees, and wood lots. Plant nurseries, too, have been targeted for tighter regulations on sales of invasive plants.

Private landowners and Working for Water have found some common ground. Working for Water proponents do not propose banning the use of invasives on plantations, and many landowners are eager to control weeds like lantana, bugweed, and chromolaena, which obstruct plantation operations and increase the fire hazard. The forest industry has committed to a code of conduct that requires riparian zones and nonafforested areas in their estates to be kept clear of alien plants. Some forestry companies have helped plant-control efforts by clearing weeds and commercial species from riverine areas or assisting with planning, mapping, vehicle donations, and worker training.

But broader consensus on the financial responsibility of the forest companies and the thousands of small independent farmers for clearing and controlling invasives is elusive. Not all agree

The Expansion of Forestry over the Past Century



Source: Nel et al. 1999: 20.

Box 3.15 Valuing a Fynbos Ecosystem

The ability to estimate the value of South Africa's ecosystems with and without invasives has proved key to securing support for clearing programs. For example, a 1997 analysis valued a hypothetical 4-km^2 fynbos mountain ecosystem at R19 million with no management of alien plants and at R300 million with effective management of alien plants. The analysis was based on the value of just six major goods and services provided by the ecosystem: water production, wildflower harvest, hiker and ecotourist visitation, endemic species, and genetic storage (Higgins et al. 1997:165). The authors also determined that the cost of clearing alien plants was just 0.6–5 percent of the value of mountain fynbos ecosystems. That may be a very conservative estimate, given the extraordinary species richness and endemism in South Africa's eight biomes and the fact that invading plants threaten to eliminate about 1,900 species (van Wilgen and van Wyk 1999, citing Hilton-Taylor 1996).

In fact, South Africa's biodiversity is perhaps the strongest long-term justification for limiting the extent of invasives, but the most difficult ecosystem service to value. It is possible, for example, to estimate a "market worth" for fynbos plants when developed as food and medicines or horticultural crops. However, it is more difficult to put a value on a species like the Cape Sugarbird, whose habitat is endangered by invasions in the Western Cape, or the oribi antelope, threatened by invaders that disrupt grasslands habitats.

Benefits and Costs Associated with the Black Wattle *(Acacia mearnsii)* in South Africa

The black wattle, an aggressive invader, provides significant commercial benefits and is an important resource for rural communities. But one recent analysis suggests that its costs may be more than twice as high as its benefits.

Wattle Benefits	Net 1998 Value (R6 = US$1)	Wattle Costs and Negative Impacts	Net 1998 Value (R6 = US$1)
Timber and other commercial wood by-products, including tannins, pulp, woodchips	$363 million	Reduction of surface streamflow estimated at 577 million cm^3 of water annually	$1,425 million
Firewood	$143 million	Loss of biodiversity	Unknown, but believed to be significant
Building materials	$22 million	Increases in the fire hazard	$1 million
Carbon sequestration	$24 million	Increase in erosion	Unknown
Nitrogen fixation	Unknown	Destabilization of river banks	Unknown
Medicinal products	Unknown	Loss of recreation opportunities and aesthetic costs	Unknown
Combating erosion	Unknown		
Total	>$552 million		>$1,426 million

Source: de Wit et al. Forthcoming.

with proponents of Working for Water who advocate more clearing near and downstream from plantations and fines for illegal plantings within 20–30 m of riparian zones. Plus, the Programme advocates a polluter-pays approach to seed pollution, which would hold those who use invasives responsible for the costs if the plants spread. Private landowners question the practicality of trying to measure seed pollution. They fear being blamed for impacts caused by others, including the backlog of removal to be done in riverine areas–at least some of which were likely infested by the government before plantation forestry was privatized. Unless these disputes are overcome and the stakeholders work cooperatively, Working for Water's efforts will be crippled.

Foresters also oppose Working for Water's advocacy of water tariffs on "stream flow reduction activities"–effectively, a tax on the water consumed by their trees to help fund the clearing of alien-infested catchments. These tariffs will force the forest industry to come to grips with a system in which water is no longer a free service; the industry fears that such water controls will inhibit its global competitiveness. Singling out the forest industry for user fees complicates the dispute. Sectors like agriculture and mining pump more water from rivers than forestry but are not likely to be charged for several years. Detailed knowledge of their impact on water use lags far behind that of forestry, making it difficult to issue permits and bills.

Working for Water also poses problems for the many rural communities that depend on invasive plants for firewood, shelter, and food such as honey, prickly pears, and guava. So far, the Programme has avoided clearing where invasive plants are a major fuel source for impoverished communities, or has sold or donated felled species as firewood, charcoal, or barbecue wood. Eventually, though, it may be necessary to develop locally managed woodlots of species with minimum invasive potential or of fast-growing indigenous species.

The Programme's Future

Securing the buy-in and support of landowners is only one of a gamut of daunting obstacles faced by Working for Water. Living up to its promise of creating empowerment and alleviating poverty for local communities may prove harder than plant removal. The scope for employment in catchment clearing is massive if Programme funding is sustained, but it is less clear whether the Programme can provide meaningful and sustainable livelihoods for a significant number of people.

Success may depend on the Programme's ambitious aim of shifting many of the 92 percent of its participants who currently remove plants into higher-paying, permanent jobs in fire management, ecotourism, and "secondary" industries (Fynbos Working for Water Allied Industries 1998:4). Secondary industries are businesses that turn cleared invasives into profitable products like firewood, treated processed timbers, and crafts. Through a partnership between the Green Charcoal Company and Working for Water, for example, a factory is manufacturing charcoal processed from harvests of invasive alien trees. This partnership lowers the Programme's clearing costs and simplifies follow-up treatment of the cleared areas by removing the felled wood. In Mpumalanga Province, the Programme is producing wood chips that can be mixed with cement to create panels for inexpensive, insulated home construction. A possible partner is the Homeless People's Federation, a network of savings and credit collectives that help disadvantaged citizens secure loans to build homes or start businesses. Perhaps the most poignant example of the secondary industry concept is the mills that Working for Water is building to produce, from invasive biomass, low-cost coffins. There is no shortage of buyers. The devastating spread of HIV/AIDS in South Africa has forced thousands of impoverished families to spend precious funds to bury relatives in expensive coffins.

But running a successful secondary industry requires management and business acumen and a labor force with solid technical skills. That is one reason why Working for Water seeks to sign contracts with established businesses–to gain managerial, marketing, and product development experience for workers and establish outlets for the felled wood or finished products. Programme workers also gain critically needed training. An assessment of Working for Water found that about 70 percent of laborers lack the skills for furniture building, saw-milling, industrial woodworking, or ecotourism (Fynbos Working for Water Allied Industries 1998:8). That relegates the bulk of untrained laborers to lower-paying firewood, bark, and chip industries.

The management deficit identified in the secondary industries also hinders Working for Water as a whole. The idea and vision for the Programme were implemented quickly by Programme founders eager to begin "doing" rather than "planning." The rapid Programme expansion appears to have short-changed worker training. Thirty-six percent of the Western Cape projects reported problems, such as removal of the wrong species, use of the wrong extraction methods, or failure to carry out the required follow-up prescriptions (Raddock 1999). Some projects are led by managers who lack experience, training, mentoring, and supervisory skills. Worker productivity flags under the daily-pay system, and poor management exacerbates the problem.

To improve quality control and productivity, Working for Water is shifting from the daily wage to a contract system. The best workers are promoted to "contractors" who identify people with initiative and form a labor team. After training, the contractors can bid on plant removal and restoration jobs that fall under the auspices of the Programme and can contract with private industries to clear invasives from railway and utility easements or other large land holdings. In test contract system areas, productivity is up 30–50 percent, and in some places more than 65 percent of the clearing is achieved by self-employed teams (Marais 1999; Botha 1999).

Fynbos vegetation is a shrubland characterized by a mixture of three main growth forms: proteoids, ericoids, and restioids.

The environmental goals of the Programme present challenges as well. Some allege that Working for Water is too politically driven, leading to an emphasis on labor initiatives rather than research, monitoring, and conservation practices such as careful rehabilitation of cleared areas. The return of a full complement of ecosystem services in cleared areas mandates that topsoil be replaced followed by mulching and plantings of indigenous vegetation to prevent soil erosion; that nutrient cycling be initiated; and that the provision of a clean water supply be promoted. If felled trees are not removed, wildfires can burn very hot (invaded grassland and shrubland sites have 10 times more fuel than non-invaded ecosystems), killing indigenous seed banks and causing soil to become water repellent. In subsequent rainfalls, sheet and gully erosion may result. Prevention of further invasions through careful management of primary infestation routes and sources–roads, railways, rivers, and actions of private landowners–requires more attention, too.

Programme success also depends on overcoming financial problems. Until the government's recent commitment to provide funding in 3-year cycles, varying levels of income meant labor contracts could be as short as 1 month. Also, the timing of cash flows does not always correspond with optimal seasonal work plans. For example, the ideal time to cut wattles is in the winter when cold temperatures would help kill trees, but funding has sometimes only been available in the summer when regrowth is strongest. Another problem is that sudden infusions of cash from the Poverty Relief Fund might necessitate surges in hiring and clearing efforts without adequate management.

A Complex Fabric of Solutions

Without its tangible social welfare benefits, few democratic governments would embrace an investment of public resources on the scale of the Working for Water Programme. In a country with poverty as widespread as in South Africa, it would be hard to convince public leaders that limiting the spread of alien plants–even with compelling evidence that biodiversity or water is at risk–outweighs the need to provide a living wage.

But Working for Water relates ecosystem protection to local residents' lives, viewing social context not as a static background but as a promising avenue for ecosystem restoration. Rather than cordoning off one problem from another, the Programme weaves a solution around all of them. A surplus of unemployed citizens is tailored into a resource, not a drawback. Felled wood is an input, an opportunity for entrepreneurs, and a source of Programme funding, not waste. Clearing trees in a community offers a chance to provide education programs.

Many hands weave Working for Water's complex fabric of solutions. The Programme benefits immeasurably from a savvy public relations campaign and the support of myriad government agencies. Programme promoters have garnered international recognition and R23 million in foreign aid (Gelderblom 2000). Programme managers capitalize on marketing opportunities, such as outfitting workers in bright-colored T-shirts printed with the Programme logo and the names of financial sponsors. Partnerships with government agencies, nonprofit organizations, and the private sector yield management advice, research, ideas, and staff and materials. Perhaps most important, the tacit buy-in of those many partners has transformed Working for Water from an idea to a multimillion-dollar project in just 5 years. The high levels of recognition that the Programme has gained among national and international publics and policy makers also offers insurance against cutbacks in tough budgetary times.

Whether Working for Water can grapple comprehensively and cogently with invasive plants, water conservation, poverty, and even worker health remains to be seen. There is the strong possibility that the Programme will fall short of its goals. Controlling invasives completely may not be possible, but partial success will still warrant acclaim. Even if invasives' spread continues to outpace Working for Water's efforts, the Programme's expenditures have already translated into more water. The Programme's social welfare strategies have brought about greater public understanding of the value of ecosystem services, better health education, and worker skills training. These investments cannot be lost.

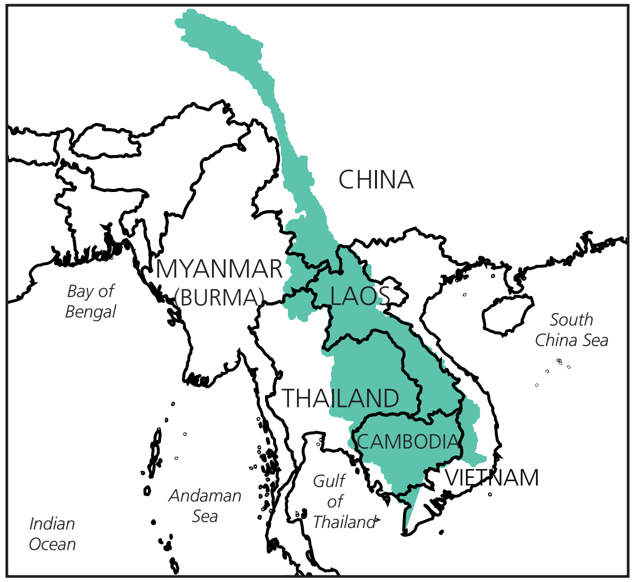
Persistence is critical to what must be an ongoing process of watershed restoration and biodiversity protection in South Africa. Sustaining the necessary public and political interest, sufficient to ensure millions in annual funding, is no small task. But the need for water–mandated for all by law and essential for economic growth–plus the need for jobs may be the ultimate insurance that the Working for Water Programme will succeed.

Managing the Mekong River: Will a Regional Approach Work?

The Mekong River represents a last chance of sorts—the last chance to tap a large, relatively pristine river basin's potential to supply energy and water without destroying its environmental integrity. The Mekong is the world's 12th longest river, stretching 4,880 km from its source on the Tibetan plateau to its outlet on the coast of Vietnam. It is the 8th largest river in terms of annual runoff and perhaps the world's least exploited major waterway in terms of dams and water diversions. But the Mekong's 795,000 km^2 watershed includes six of Southeast Asia's richest and poorest nations—Cambodia, China, Lao PDR, Myanmar, Thailand, and Vietnam. All these governments are eager to promote economic development using the Mekong's water resources (MRC 1997:14–15).

The drive to dam and divert the Mekong threatens the traditional uses of the river—as a source of fish and a barrier to salt water penetration into the rich Mekong delta soils. Ideally, a new model of coordinated regional water management will preserve those benefits while sharing new ones. The Mekong River Commission (MRC), originally known as the Mekong Committee, was established among the basin countries in 1957 to address potential conflict over hydropower development. The MRC provides a vehicle for joint management of the river and for the coordination of development strategies for the lower Mekong basin. In 1995, after almost 4 decades of political turmoil had hampered the Commission's effectiveness, the basin countries reaffirmed their interest in working together. Cambodia, Lao PDR, Thailand, and Vietnam signed the Agreement on Cooperation for the Sustainable Development of the Mekong River basin, which acknowledges the need for regional action. China and Myanmar have observer status.

Yet the MRC lacks any real power to develop or enforce a unified vision of sustainable water use in the basin, and each of the riparian countries is pursuing its ambitious development plans largely independently at this time. Can a truly regional approach to Mekong management evolve in time to influence the basin's environmental future?



Damming the Mekong

The Mekong River and its tributaries have a potential hydroelectricity generating capacity of 30,000–58,000 MW (MRC 1997:5–19). Although plans to construct major hydroelectric dams have been afoot for years, as of 1997 less than 5 percent of this potential had been exploited.

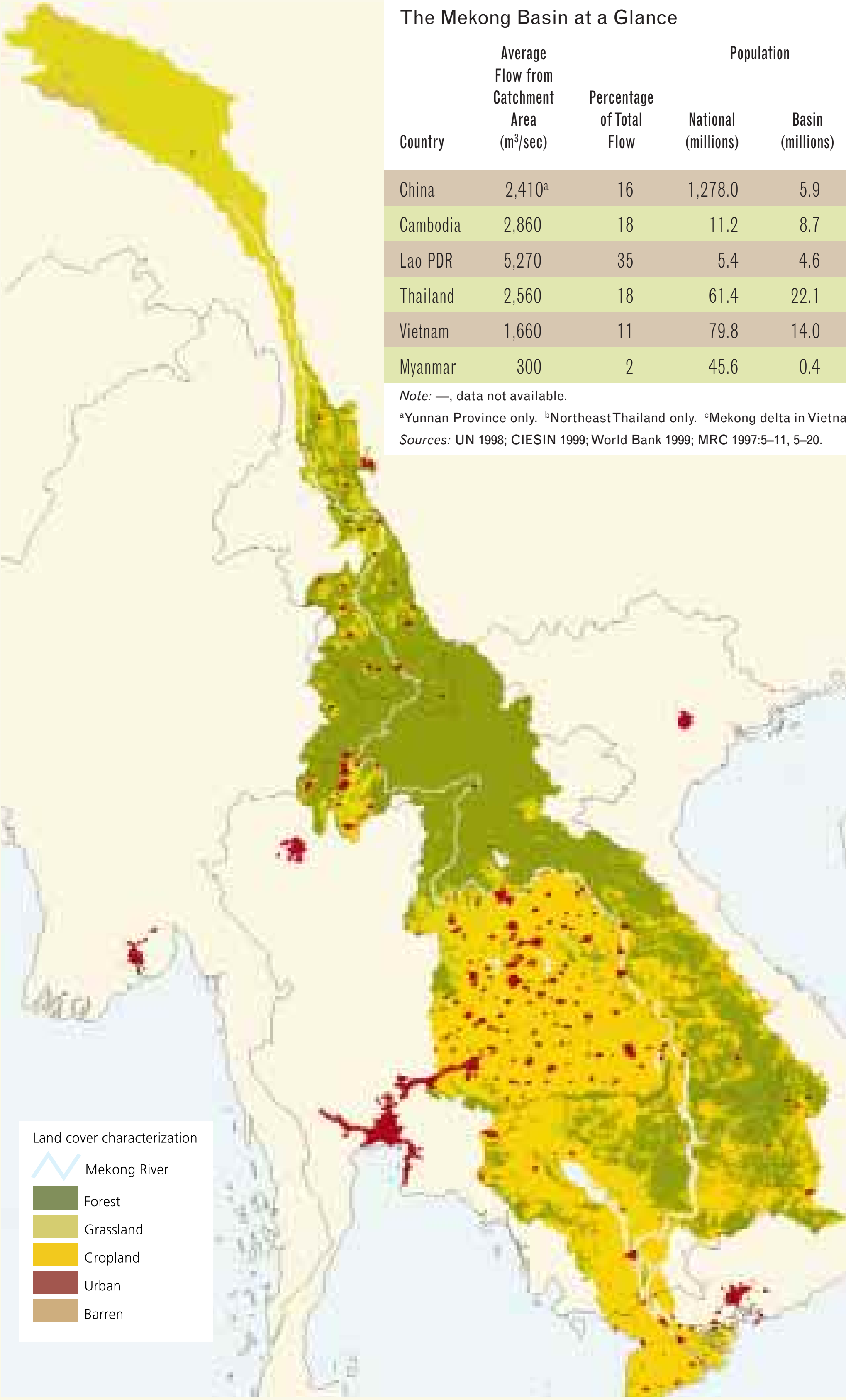
Now, however, scores of large dams are under serious consideration in response to both the growing regional demand for electricity and the desire of the nations in the basin to earn foreign exchange from international sales of hydropower. The financial crisis that erupted in Asia in 1997 shook Thailand's economy particularly hard, slowing electricity consumption and delaying power purchase agreements and dam start-ups, but energy demand is expected to pick up again quickly as the recession recedes (EIA 1999). By 2020, electricity demand in the Mekong region could be six times greater than in 1993 (MRC 1997:5–9).

Hydropower potential varies greatly among the riparian nations. Highland countries like China and Lao PDR possess the greatest share, while countries like Vietnam and Cambodia—along the slower-moving, lower reaches of the Mekong—possess relatively little. Currently, major pressures on the Mekong include:

- China's Yunnan province at the top of the watershed is planning a cascade of up to 14 dams on the upper Mekong—known locally as the Lancang River. These dams would have a total installed capacity of 7,700 MW, equivalent to 20 percent of China's current energy consumption. Because of Yunnan's remoteness from China's more developed areas and the chance to earn export dollars, Yunnan authorities are likely to export electricity to Thailand. China has also proposed plans to divert water from the Mekong into the Yellow River to meet Northeast China's growing demand for water.

- Many of the tributaries feeding the Mekong in Thailand have already been dammed to provide power and irrigation water to its arid eastern provinces. However, Thailand has

Box 3.16 How the Mekong's Hydropower Resources Are Divided



The Mekong Basin at a Glance

Country	Average Flow from Catchment Area (m^3/sec)	Percentage of Total Flow	Population: National (millions)	Population: Basin (millions)	GDP ($ billions)	Consumption: Electricity (KWh/ person/yr)	Consumption: Fish (kg/ person/yr)
China	2,410[a]	16	1,278.0	5.9	902.0	260[a]	—
Cambodia	2,860	18	11.2	8.7	3.0	55	13
Lao PDR	5,270	35	5.4	4.6	1.8	55	7
Thailand	2,560	18	61.4	22.1	153.9	900	15–27[b]
Vietnam	1,660	11	79.8	14.0	24.8	140	21–30[c]
Myanmar	300	2	45.6	0.4	—	60	—

Note: —, data not available.

[a]Yunnan Province only. [b]Northeast Thailand only. [c]Mekong delta in Vietnam only.

Sources: UN 1998; CIESIN 1999; World Bank 1999; MRC 1997:5–11, 5–20.

long-standing plans to divert water from the Mekong into the water-scarce Chao Phyra River, the main source of water for Thailand's economic heartland.

- One-third of the total flow of the Mekong originates in Lao PDR. Given its abundant rainfall and rugged topography, estimates of the country's hydropower potential reach 7,000 MW, of which only a fraction is currently exploited. Laos has prepared plans to construct as many as 17 new dams during the next decade to reduce the country's poverty. Most of the hydroelectricity will be sold to Thailand and Vietnam. Thailand already buys electricity from Lao PDR's Nam Ngum dam and is negotiating to buy power from the planned Nam Theun II dam.

Not all the proposed projects will be developed, however. Only a handful are both technically feasible and economically viable, and public and NGO outcry against some–like Nam Theun II–may stall construction. For those hydropower plans that do hold economic promise, the private sector stands ready to invest. Often the funding comes through "build-own-operate-transfer" (BOOT) projects, in which foreign investors finance, construct, and operate a dam, recouping their investment and sharing risk during a concession period, then transfer ownership of the project to the government.

Vulnerability Downstream

Although dams and diversion projects dominate the official development discourse, the Mekong has long provided many other environmental benefits to the basin's 55 million inhabitants. Approximately 30 percent of households in the Mekong delta are below the poverty line and most of the rural population depends on the river and its tributaries for their survival (MRC 1997:4–6).

For example, the fish caught in the Mekong are the source of 40–60 percent of the animal protein consumed by the population of the lower basin, and fish sustain an even higher percentage of people in much of Cambodia (Institute for Development Anthropology 1998:87–88). The 900,000 tons of fish harvested annually (Friederich 2000) and the Mekong's extraordinary fish species richness are threatened by dams, which interfere with spawning cycles by preventing fish migrations.

Dams also reduce the seasonal floods that sustain fish spawning and nursery grounds in the wetlands upstream and the delta region. The flood cycle, keyed to the monsoon rains, is a critical factor in the life cycle of many of the area's aquatic species. Even slight changes in peak flood flow could threaten the region's fish production and food security (MRC 1997:3–8). Impacts observed at dams already constructed on Mekong tributaries illustrate the area's vulnerability. At Nam Pong reservoir in Northeast Thailand, the number of fish species found in the river dropped from 75 to 55 after impoundment. Fishermen upstream of Thai dams at Tuk Thla and Kompol Tuol saw their catches decline from 5–10 kg/day to 1–2 kg/day after the dams were built (MRC 1997:5–14).

Altering the annual flood cycle, reducing the silt load of the water, or diverting the Mekong's flow could also have serious impacts on agriculture in the Mekong delta. Flood waters deposit 1–3 cm of fertile silt each year on the lowland floodplains in Vietnam and Cambodia, sustaining these intensively farmed areas (MRC 1997:2–17). In addition, river flows during the dry season are important for controlling salinity penetration into interior areas from the coast. According to the Vietnam Water Resources Sector Review, seawater penetrates up to 70 km inland during the dry season. If current trends in water abstraction in the delta continue, the area affected by salinity could increase from 1.7 to 2.2 Mha (Xie 1995:10). Increased salinity was cited as the primary cause of rice yield declines of 50–90 percent in Tra Vinh province over the last 30 years (Nguyen 1998:4).

The dangers that dams could pose to the biodiversity of the Mekong must also be considered in the context of the environmental degradation that the region has already suffered. A combination of deforestation, increasing conversion to intensive, chemical-dependent agriculture, continued population growth, and mangrove clearance for shrimp aquaculture in the delta region has compromised the basin's environmental health. Vietnam, for example, has already lost approximately 85–90 percent of its forest cover, largely because of decades of war and reconstruction. In Thailand, perhaps 55–65 percent of forests has been cleared for agriculture and tree plantations (WCMC 1994:106–107). Some of the highest rates of deforestation in the world continue to plague the riparian countries (FAO 1999:132). Many remaining forests are of poor quality, affecting water retention in the basin and promoting land degradation and soil loss in the uplands (MRC 1997:3–5). Disrupting flood cycles or decreasing base flows during dry times through water diversions could add significantly to these existing stresses.

Furthermore, where will countries resettle the thousands of people who will be displaced by dams? Just the nine proposed mainstream dam projects could displace 60,000 people (MRC 1997: 5–24).

Conflict Brewing?

With all its mighty waters, the Mekong ecosystem is finite and fragile. The array of current demands and future plans for the river has already led to increasing competition among the basin countries. The MRC was established to minimize the conflicts inherent in managing a river that crosses many international borders, but its efforts at regional coordination have been largely unsuccessful (China Environment Series 1998). Although it collects hydrological data from the basin, the MRC has done little to analyze the data, promote debate among the partners on the cumulative effects of their water developments, or craft a common vision of how water should be shared. As a result, the governments of Cambodia, Vietnam, Lao PDR, and Thailand are competing for international funding for their dam-building projects and have "... adopted a rhetoric of cooperation and sustainable development to mask underlying conflicts and competition" (China Environment Series 1998).

Complicating the equation is the fact that China is not a member of the MRC, although it controls the upper reaches of the river and has an ambitious dam-building program in place. China is reluctant to join the MRC until water-use rules are clarified and it is assured that restrictions on dam building and water diversions will not interfere with its upper Mekong development plans. The agreement specifies that the watershed nations have neither the right to veto the use nor the unilateral right to use the water of the Mekong. This implies that dam construction on the river's mainstream would only proceed by consensus, a system unacceptable to China.

In reality, compromise will be difficult for all the basin countries, whose negotiating powers vary greatly as a function of their location within the river basin and their wealth. Based on the size of its economy, China has by far the greatest capacity to mobilize funding and technology to exploit its "share" of the Mekong. Because its portion of the river runs through sparsely populated territory, China also has a relatively small population that depends on the river for irrigation and fish production. China, therefore, has much to gain and little to lose from dam construction. Cambodia and Vietnam, on the other hand, are extremely vulnerable because of their downstream location, relative poverty, and the large number of people that depend directly on the Mekong for their livelihoods. Lao PDR, one of the poorest nations in the world, is desperate to develop its hydropower resources to spur economic growth. Thailand is in an intermediate position. It has the largest within-basin population among the riparian countries, but has the economic and human resources to withstand potentially negative changes in the river upstream.

A Regional Vision

Despite the current imbalance of power among the riparian countries and the potential for conflict, the benefits of a regional approach are compelling. Development of a regional electricity transmission grid, for example, would benefit from a coordinated plan to develop the basin's hydropower potential. A regional grid would facilitate China's ability to market hydropower to other energy users in the region, offering advantages all around. In addition, a regional growth plan that helps expand the economies of the lower Mekong basin countries and promotes open markets in the region provides a longer-term inducement for Thailand and China to cooperate.

A basin-wide approach to water management would also offer clear environmental advantages. It would, by definition, force the riparian countries to examine how dams on the upper reaches of the river would affect flow conditions downstream. Currently, upstream countries can pursue water withdrawals and hydropower production while ignoring repercussons such as salt water intrusion, decreased catches for subsistence fishing, and soil depletion.

Since the governments in the region unanimously favor developing the region's hydropower potential, a regional approach to water management would not necessarily mean less power generation, but it would offer a chance to distinguish between environmentally "good" dams and "bad" dams. The challenge is to select dams that meet strict environmental and economic standards. Some have argued, for instance, that dams on the Lancang and in the uplands of Lao PDR are "good" because they generate a lot of power without displacing many people and flooding large areas. Thus, the social and environmental costs are relatively small. It is also possible that dams could actually benefit the local environment in some ways. Planners of Lao PDR's Nam Theun II dam have proposed earmarking a portion of the hydropower revenue for forest conservation in the surrounding watershed. Protecting forests around dams is desirable because it reduces sedimentation, lowers maintenance costs, and prolongs dam life.

But capitalizing on the benefits of a regional approach to water development and use in the Mekong region will take quick action, given the rapid changes under way. Water experts warn that now is the time to rethink basin-wide water management, not after the dams and diversion schemes have been built and the environmental and geopolitical repercussions are felt.

The MRC has a critical role to play in promoting regional cooperation. It has been criticized for failing to seriously address the potential negative environmental impacts of proposed dams and diversion schemes, and it has failed to build the predictive modeling capacity that is needed to assess the trade-offs between river basin development options. But the MRC reaffirmed its commitment to environmental analysis and assessment in 1995 and to serving as a regional information center on environment and development in the Mekong River basin. These developments could help basin nations to better visualize the benefits of a regional approach to managing the Mekong watershed and to quantify the damage–environmental and social–that may occur if they pursue an uncoordinated approach.

New York City's Watershed Protection Plan

To safeguard the city's drinking water, in 1997 New York City chose to launch an ambitious environmental protection plan, rather than build an expensive water filtration plant. By protecting its watershed the city would employ nature's ability to purify water while preserving open space and saving money. But as this widely heralded example of watershed protection is implemented, many question whether it will, in fact, deliver all that it promises.

For more than a century, New York City residents have enjoyed drinking water of such purity that it has been dubbed "the champagne of tap water." That water–about 1.3 billion gallons per day–flows from an upstate watershed that encompasses 1,970 mi² and three reservoir systems: the Croton, Catskill, and Delaware (NRC 1999:3, 17). Until relatively recently, undisturbed soil, trees, and wetlands provided natural filtration as the water traveled through the Catskill Mountains and the Hudson River Valley before reaching 9 million residents of the city and its suburbs. The only regular treatment needed was standard chlorination to control waterborne diseases such as cholera and typhoid.

But in the last several decades, development has brought increasing numbers of people and pollutants to the watershed, straining the land's buffering and filtering capacities. More than 30,000 on-site sewage treatment and disposal systems and 41 centralized wastewater treatment plants discharge wastewater into the upstate watersheds (NRC 1999:358). Runoff from roads, dairy farms, lawns, and golf courses contains fertilizers, herbicides, pesticides, motor oils, and road salts.

The need to attend to the development-pressured upstate watershed became clear in 1990. The U.S. Environmental Protection Agency (EPA) put New York City on notice: protect the source for the Catskill and Delaware reservoirs–the watershed, nature's own treatment plant–or construct and operate a water filtration system. Filtration would cost \$3–\$8 billion, according to various estimates, potentially doubling the average family residential water bill (Ryan 1998). By comparison, the City determined that the price tag for watershed protection would be just \$1.5 billion, increasing the average water bill of a New York City resident by about 1–2 percent, or \$7 per year (Revkin 1995, State of New York 1998).

The EPA's warning was compelled by the 1989 Surface Water Treatment Rule, which requires that surface water supplies for public water systems be filtered unless stringent public health criteria are met and extensive watershed protection strategies minimize risks to the water supply. The rising levels of bacteria and nutrients in the watershed, plus the risks posed by antiquated sewage treatment plants and failing septic systems, put New York City's Catskill and Delaware supplies in danger of violating the Rule. The Croton supplies

east of the Hudson River were in bigger trouble already: because of that area's greater pollution pressures, filtration was mandated. Even though the Croton system supplies just 10 percent of the City's water, compared to the 90 percent that flows from the Delaware and Catskill systems, the cost to build and maintain that plant is still expected to be at least \$700 million (Gratz 1999).

The cost savings from protecting the Delaware and Catskill supplies were clear, but crafting and implementing a major ecosystem protection plan is no small undertaking. Nationwide, less than 2 percent of municipalities whose drinking water systems are supplied by surface water have demonstrated to the EPA that they can avoid filtration by instituting aggressive watershed protection programs (Gratz 1999). The vast majority are far smaller than New York, less populated, and own substantially more of the critical watershed lands. When the protection agreement was crafted, New York City owned just 85,000 acres of the watershed, less than 7 percent of the total critical area, including the land beneath the reservoirs (Ryan 1998); another 20 percent was owned by the state (NRC 1999).

With so little watershed land under its direct control, but millions of water users dependent on it, New York City needed to obtain the support of upstate landowners for open-space conservation and stronger land-use protection. But from the perspective of upstate communities, watershed restrictions such as land acquisitions, limits on where roads and parking lots can be constructed, and strict standards for sewage treatment systems amounted to outsiders threatening local taxpayers' economic viability. Still, after years of contentious negotiations, city, state, and federal officials, some environmentalists, and a coalition of upstate towns, villages, and counties forged a 1997 watershed management agreement that convinced the EPA to extend its filtration waiver until 2002.

Perhaps the most crucial element of the program is the state's approval of New York City's plan to spend $250 million to acquire and preserve land in the watershed, with priority given to water-quality sensitive areas (NRC 1999:213). A local consultation process helps protect the interests of watershed communities. Other plan elements include new watershed regulations, direct city investments in upgrades to wastewater treatment plants to minimize contamination, city funding of voluntary farmer efforts to reduce runoff, and payments to upstate communities to subsidize sound environmental development (State of New York 1998).

In addition to economic savings, the ecosystem protection program offers some additional advantages that filtration cannot. It lowers health risks that are present even with filtration–for example, the risk that a sewage plant will malfunction or an incidence of the disinfectant-resistant pathogen *Cryptosporidium* will occur. Land acquisition and development controls also mean more land for parks, recreation, and wildlife habitat.

Ownership of Critical Watersheds

Only a handful of major U.S. cities have unfiltered water supply systems—mostly those that can ensure long-term water protection because significant portions of the critical watershed lands are owned by the water utility or are designated as protected open space under state or federal ownership and management. New York City is an exception—and accordingly, it must rely heavily on the cooperation of private upstate landowners to help protect its drinking water.

City	Ownership (percent) Public	Ownership (percent) Private	Watershed Area (acres)	Population Served (millions)
Seattle, WA	100	0	103,885	1.2
Portland, OR	100	0	65,280	0.8
New York, NY	26	74	1,279,995	9.0
Boston, MA	52	48	228,100	2.4
San Francisco, CA	100	0	475,000[a]	2.3

[a]Supplies 85 percent of the city's water; 15 percent is filtered and comes from other publicly owned watersheds.
Sources: NRC 1999; personal communications.

But whether this dramatic effort will prove to be a bargain remains to be seen. Among the unknowns are the effectiveness of voluntary pollution protection commitments by farmers, and still-evolving knowledge of best management practices to control roadway, lawn, farm, and other runoff. Environmental organizations are concerned that the negotiated settlement contains serious loopholes in the watershed rules and land-buying requirements. For example, the agreement provides no limits on the number of new sewage treatment plants that can be built in the City's cleanest reservoir basins.

Nor does the agreement specify an absolute acreage requirement that the city must purchase in the watershed, only that the city must *solicit* the purchase of 350,000 acres. The City projects that this approach could lead to its acquisition of about 120,000 acres, allowing it to increase its holdings to 17 percent of the critical land area in the next 10 years (Gratz 1999). However, the City's solicitation efforts might yield far less land, since the plan relies on the cooperation of upstate residents–and even 17 percent ownership gives the City limited watershed control. Another problem is that the plan sets criteria for types of land to be acquired but no assurance that the "best" lands from the perspective of water quality will be purchased, since land is obtained on a willing buyer/seller basis. From the perspective of the Natural Resources Defense Council, the plan may allow too much development to take place on sensitive watershed lands and the scientific aspects of water management were given insufficient attention by negotiators under pressure to craft a politically acceptable plan (Izeman 1999, Revkin 1997). Other concerns include inadequate requirements for buffers–zones of vegetation where discharge of pollutants, and development, cannot take place (NRC 1999:14)–and the agreement's failure to emphasize pollution prevention as much as pollution control.

Only years of extensive water quality monitoring will prove whether the watershed protection program is sufficient to protect public health. At the moment, the water is still deemed safe to drink, but some still think filtration ultimately will be required.

Shortcomings aside, the agreement is laudable. It formally acknowledges the interests of watershed residents and stresses the need to implement watershed protection plans fairly and equitably. Elements of the New York City watershed agreement may serve as a model for other communities. There is a growing recognition that filtration, by itself, is no panacea. It can reduce the threat of waterborne pathogens, but it cannot completely eliminate the threat, especially if the source water is poor. Watershed protection offers a cost-effective approach to clean drinking water, and benefits the environment as a whole. The challenge in the case of New York City is the need to compel many people and communities to work together, putting aside self-interest, toward the twin goals of saving the watershed and saving money.

GRASSLAND ECOSYSTEMS

Sustaining the Steppe: The Future of Mongolia's Grasslands

For thousands of years, most of central Asia's high steppe has been the realm of nomadic herders and their horses, camels, goats, sheep, and cattle. Today, this expanse of grasslands–the largest remaining natural grasslands in the world (WCMC 1992:287)–is divided, politically, between Russia, China, and the Republic of Mongolia. This entire region is sometimes called "Inner Asia."

For Mongolia, with a human population of just 2.4 million in a land area the size of Western Europe, there would seem to be an abundance of pasture for its 30 million head of livestock. But natural conditions make the grasslands of Inner Asia highly vulnerable to damage from human activities and slow to recover. The growing season is just 4 months long. Annual precipitation ranges from just 100 mm in the most arid regions to 500 mm in limited northern areas, and in much of the region is less than 350 mm. The steppe is subject to intense winds, snow can cover the ground 8 months of the year, and in the dry season grass and forest fires are common. These ecological and climatic factors inhibit the growth of vegetation and increase the severity of erosion in areas with unprotected soils (Palmer 1991:55).

In an environment of extremes, herders have recognized the merits of moving their herds seasonally or more frequently. Herd mobility seems to sustain the fertility of rangelands, and thus benefits livestock health and food security. In the feudal period, herders would rotate animals over pastures where they had access to abundant seasonal grasses or shelter from harsh weather–usually pastures to which use rights were coordinated by local authorities, such as lords or monasteries and their officials. Occasionally herders would use a technique called *otor*–movement of livestock to even more distant and lesser-used pastures. *Otor* helped to intensively feed the animals and prepare them for severe, grass-scarce winter and

spring seasons and could be used to relieve pastures when a shortage of forage or degradation became evident.

Important aspects of these coordinated, large-scale, highly mobile systems endured in Mongolia even through the socialist government campaigns that organized livestock herders into collectives in the 1950s. Since 1990, however, Mongolia has reoriented its economy from central planning toward privatized land and free markets. This has brought new opportunities to some, but it has also created social and economic conditions that are undermining the long-standing mobile herding culture and perhaps threatening its continued existence. Systems of wide pastoral movement, in many cases, broke down when the collectives ended and have been replaced with lower-mobility, small-scale pastoralism. This trend may pose a significant threat to the sustainability of Mongolia's grassland ecosystems.

A similar shift from mobile herding to more sedentary livestock rearing mixed with farming systems had already occurred in the Chinese and Russian regions of Inner Asia, and the environmental effects are discouraging. Like Mongolia, these countries experimented first with organizing herders into collectives–Russia in the 1930s and China in the late 1950s. Then, decades later, they privatized livestock operations in a bid to modernize and increase production. Meat and wool production increased but with costs to the ecosystems, including pasture degradation. Estimates vary widely, but local studies in Buryatia and Chita in Russia and in Inner Mongolia in China suggest that as much as 75 percent of grasslands has suffered some degree of degradation (Humphrey and Sneath 1999:52; Gomboev 1996:21). According to Chinese government figures, just 44 percent of Inner Mongolia's grasslands are considered usable and in good condition (Neupert 1999:426).

By comparison, Mongolia's grasslands are in relatively good condition. Officials have calculated that moderate or severe degradation affects 4–20 percent of pasture lands (Government of Mongolia 1995:28).

The ecosystem problems in parts of China and Russia underscore for Mongolia the merits of preserving elements of the mobile herding practices. Incorporating mobile herding into the modern Mongolian economy may be essential to local livelihoods and national prosperity. Grasslands cover about 80 percent of Mongolia's 1.567 million km^2 land area and agriculture–mainly livestock herding–supplied 33 percent of Mongolia's GDP in 1998. Approximately half the national workforce works in the agricultural sector, mostly as pastoralists (herders) (National Statistical Office of Mongolia 1999:45, 54, 95; Statistical Office of Mongolia 1993:6). Mongolian exports of livestock products have collapsed since the end of the socialist trade bloc in 1989–91, but in better economic times, pastoralism supplied substantial raw materials such as wool and hides for Mongolia's export trade and fledgling industrial sector. And Mongolia's future economic growth depends at least in part on livestock production. Economic growth is a priority for Mongolia, whose per capita GNP of US$380 (1998) makes it one of the poorest countries in Asia (World Bank 2000:11).

At individual and local levels, the meat, milk, and transport that livestock provide are vital to the many herders and their families living in remote, inaccessible places. Price inflation and fuel and commodity shortages during the current transition to a market economy make livestock even more essential to households' food security.

"Following the Water and Grass"

Large-scale, highly mobile herding operations have ancient roots. From the 17th until the 20th century, Mongolia was divided into administrative districts called *hoshuu* or "banners" ruled by a hereditary lord or a Buddhist monastery. The commoners were bound to particular geographic areas and required to work for local authorities. Buddhist monasteries, nobility, and the imperial administration owned millions of animals that were herded by subjects and servants who generally received a share of the animal produce in return.

The pastoral movement systems could be sophisticated. The herder groups were flexibly organized, consisting of one or more families. Herders and their families might move large groups of horses, sheep, goats, and other domesticated or semidomesticated animals to selected seasonal pastures in an annual cycle (Simukov 1936:49–55). Because different animals have different grazing habits, animals were segregated by species for efficient pasture use. Sheep, for example, crop so close that horses and cattle cannot get at what is left, forcing horses to dig up grass roots to eat. Some members of the herder group might specialize in working with a particular species. Others might cut wool, milk animals, make felt for tents, or help the group move to a new camp.

There was enormous variation in frequency and distance of moves. In better-watered northern regions, herders might move livestock twice a year. In other areas, herders might make three to four long-distance moves; in some places, more. The ancient Chinese description for these pastoral activities was "following the water and grass" (Hasbagan and Shan 1996:26).

With local lords and monasteries to coordinate general access to pastures and to support pastoral movement, herding families usually could share seasonal pastures efficiently and avoid pasture overuse. These flexible herding systems and collective-use arrangements also ensured that water sources or the best pastures were not controlled by a few herders to the detriment of the whole herding system (Mearns 1991:31).

Such herding principles and techniques have been passed down through the ages with remarkable continuity. Some pas-

(continues on p. 216)

Box 3.17 Overview: Mongolia's Grasslands

Nomadic herders have grazed livestock on Mongolia's vast but fragile grasslands for thousands of years. By rotating animals over shared pastures in collaborative seasonal and species-segregated patterns, herders have anchored their country's economy without degrading its ecosystems. Recent political and economic changes, however, may be eroding these sustainable practices. Analyses of neighboring grassland regions in China and Russia warn of the degradation possible when large-scale mobile herding practices decline and small-scale static systems expand.

Ecosystem Issues

Grasslands	Estimates of grassland degradation are much debated and range from 4 to 33 percent, but the clear potential for further degradation is cause for alarm. Grasslands are the basis of livestock production and approximately half of Mongolia's workforce depends on pastoralism or agriculture for their livelihoods and food security. Overgrazing, mining, vehicular traffic on the steppe, and other pressures threaten grassland biodiversity. Among the mammals at risk are Mongolia's gazelles, wild camels and horses, and the Asiatic wild ass.
Agriculture	Much of Inner Asia is not well suited for growing crops; half of all cultivated land in Mongolia is considered degraded. Sedentary livestock will require conversion of more land to agriculture to supply food and fodder for animals and people.
Freshwater	Mongolian herding practices are dictated in part by the uneven and irregular distribution of water in Mongolia. Growing concentrations of herders and settlements near water sources intensify pressure on natural resources in those areas. Those same water sources supply irrigation water for agriculture; agricultural water use in 2000 is projected to triple its 1970 amount.
Forests	Forests, found primarily in Mongolia's wetter, mountainous areas, are critical to the protection of soil, grasslands, water resources, and wildlife diversity. However, reduction of forests by logging, use for fuelwood, and forest fires is accelerating.

Management Challenges

Equity and Tenurial Rights	For centuries a variety of collective tenure arrangements have helped sustain grasslands and produce healthy livestock in Mongolia. The recent transition to private land and herd ownership, however, has decreased flexible systems such as rotational grazing and access to shared grazing lands. In some areas land tenure is ambiguous; in others wealthier pastoralists have fenced large areas of high-quality grasslands.
Economics	Reorientation from a centrally planned to a market economy may spark environmental problems and widen income inequality; poorer pastoralists may not be able to capitalize on economies of scale and access large areas of high-quality pastures. The government has cut supportive services to herders since the breakup of collectives, and few pastoralists can afford the fuel or other inputs necessary to sustain mobile herding operations.
Stakeholders	Privatization is bringing divisive elements to herding communities. The influx of new herders with limited experience in animal husbandry, the widening gap between rich and poor herders, and absentee herd ownership all weaken the system of shared beliefs and preferences for mobile herding that once helped protect grassland condition. Sustainable management suggests the need for government policies that facilitate and encourage mobility rather than sedentary production.
Information and Monitoring	Pastoralists' ecological knowledge, understanding of local geography, and animal husbandry skills need to be incorporated into management policies. There also is room for scientific analysis and research to help guide a transition to privatization without losing the best aspects of mobile herding. Assessments of pasture condition, arable land, and livestock use, and identification of pastures that are of strategic importance to mobile herders would greatly aid the transition.

Timeline

1691–1911 Mongolia becomes a frontier province of China. Herders move livestock for Buddhist monasteries, high lamas, and aristocratic lords in rotations over common lands; pasture rights are regulated by the local institutions and among clans and families according to customary law.

1911 Expulsion of Manchus in northern Mongolia brings a decade of Mongol autonomy.

1921 Bolshevik uprising in Russia inspires revolution in Mongolia.

1924 Mongolian People's Republic is founded in northern Mongolia, creating the world's second communist state after the Soviet Union (USSR). The southern part of Mongolia remains under Chinese control and becomes the Inner Mongolian Autonomous Region in 1947, though it lacks real political autonomy.

1929–32 The Mongolian government attempts to forcibly collectivize herding households. Thousands of Buddhist lamas are killed and private property is confiscated. Herders slaughter 6–7 million head of livestock in protest.

1932 The Mongolian government shifts to a more gradual organization of collectives; cooperation among herding households is encouraged. Russia has already collectivized most rural residents at this time.

1949 The communist People's Republic of China is founded. Rangelands in Xinjiang, Inner Mongolia, and other areas are nationalized, removing them from the control of landlords, Mongol princes, lamaseries, and clans.

1950s–60s Chinese and Russian governments emphasize agricultural expansion and highly mechanized farming methods.

1950s Socialist government campaigns in Mongolia increase momentum for the organization of pastoralists into collectives. Expansion of area under cereal and fodder crop production begins.

1950s Russia and China encourage use of foreign breeds of sheep and other livestock to increase productivity; these "improved" breeds eventually prove weaker and decrease herd mobility.

1955 A ceiling is placed on private livestock holdings in Mongolia to encourage the emergent collectives.

1957 China begins to establish large collectives (People's Communes) in rural districts and eradicates customary use-rights for pastures. Grasslands become pressured as livestock herds and cultivated area expand.

1960s Virtually all of Mongolia's herding households are members of collectives and all land is owned by the state. Households look after a share of the collectives' herd, although they are also permitted to own some private stock. Mongolia begins expanding its cultivated area.

1980s China begins shift from a centrally planned to free-market economy. Agricultural communes are dissolved and livestock distributed to pastoral households. Farmers and pastoralists have leases for lands, but uncertainty over pasture rights and location discourages mobility. Fenced areas emerge in the once-unbounded steppe. The communist era ends in Russia. Influenced by political change in the USSR and Eastern Europe, Mongolia begins a transition to a democratic government and market economy.

Early 1990s Farms in Russia retain communal structure despite the new central government policies; many farm leaders are reluctant to hand over land and livestock to individual private farmers.

1991 Prices are freed from state control. Constitution of Mongolia acknowledges the principle of private land ownership, but pastureland is specifically excluded from private ownership and lease systems are developed. Mongolia begins to dissolve collectives; herd numbers soon increase more than 20 percent.

1994 More than 90 percent of Mongolia's animals have been transferred to private ownership. Many are owned by "new" herders who were allocated animals in the dissolution of the collectives; some opt for more sedentary herd management. Land degradation is perceived around herders' settlements.

2000 Severe economic crisis that began with the breakup of the USSR continues to limit economic growth and reconstruction in Mongolia. Government resources to support mobile herding are scarce and the gap between wealthy and poor herders grows.

toralists still shift their herds 150–200 km between summer and winter pastures. Others shift their herds 25–50 km, and some less than 10 km depending on social and economic conditions (Humphrey and Sneath 1999:221–222). But many pastoral systems are, fundamentally, still mobile, and pastoralists continue to stress the benefits of mobility and cooperative grazing for pasture and livestock health.

Science tends to support what herders have observed for generations. Ecological studies show that continuous grazing of livestock in the same pastures can be much more damaging than systems of pasture rotation (Tserendash and Erdenebaatar 1993:9–15). Dense populations of sedentary livestock can impair grass regrowth. Some plant species may gradually disappear and be replaced by poorly palatable weeds or poisonous plants that can sicken or kill livestock. Once a pasture's soil is severely damaged, wind can cause desertification.

A New Era in Mongolia: 1921–90

The pastoral culture experienced major new influences in the 20th century. After only a decade of Mongol autonomy, following the collapse of the Chinese Qing Dynasty, struggles for power led to the 1921 Bolshevik-inspired revolution. Socialist central planning emerged under the leadership of the Mongolian People's Revolutionary Party in 1924. This era introduced technologies like irrigated agriculture and farm machinery. It also introduced state-controlled pastoralism and brought the beginnings of industrialization. Mobile herding techniques generally endured–even improved in some ways–during this period.

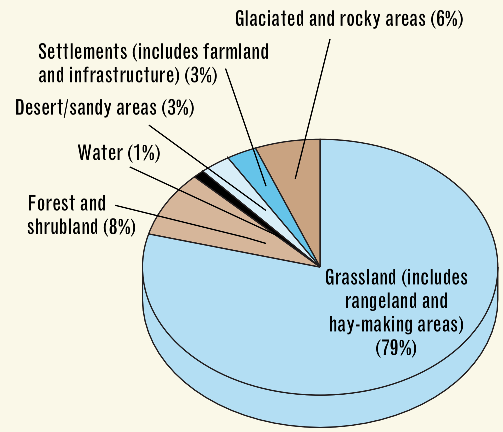
One of the first steps of the Soviet-style government was to organize herders into collectives. Early attempts at collectivism were so unpopular they had to be abandoned. However, in the 1950s, Mongolian pastoralists were organized as wage workers employed by about 250 *negdels* or collective farms and about 50 state farms, each managing pastoral or agricultural activity in a rural district or *sum*. A *sum* consisted of a central settlement of a few hundred households and a large area of grassland used as pasture by the herder households, most living in mobile felt *yurts* and herding the collective or state farm livestock and a few personal animals. Although the new *sum* districts were generally smaller than the earlier *banners*, most pastoralists continued to rotate pastures throughout the year and make use of *otor.* However, in some regions the distance of seasonal moves was reduced (Humphrey and Sneath 1999:233–264).

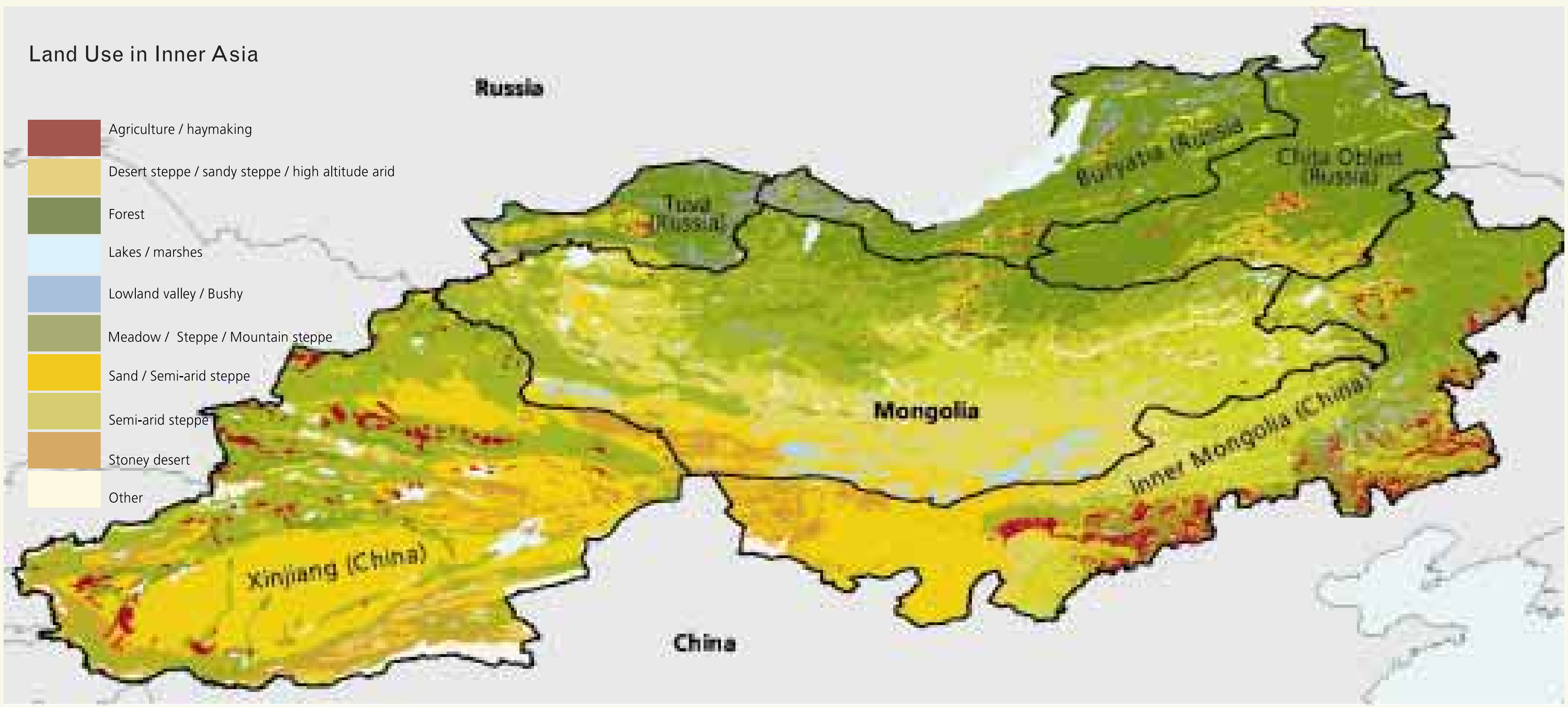
This "collective" system actually enhanced mobile pastoralism in some ways. The collectives maintained machinery

Box 3.18 Land Use in Inner Asia

The Asian steppe, including Mongolia and parts of China and Russia, support the most extensive natural grasslands in the world (WCMC 1992:280-292). The climate is harsh; on some regions of the steppe, snow can cover the ground for 5–8 months of the year. Extreme heat and drought are possible, too, particularly in the southern desert regions that cut off Mongolia from Tibet. In effect, much of Inner Asia is not readily adaptable to most economic activities; large areas of the Russian Federation, for example, consist mostly of high mountain ranges.

But livestock have thrived on the steppe for centuries. In fact, most of Inner Asia that is accessible is used for livestock grazing. Agriculture is also a significant land use, although less than 1 percent of Mongolia's land area is classified as arable (Mearns 1991:26). Thus, the way of life for many is rural, and the importance of herds as sources of food, wool, and transportation is paramount.



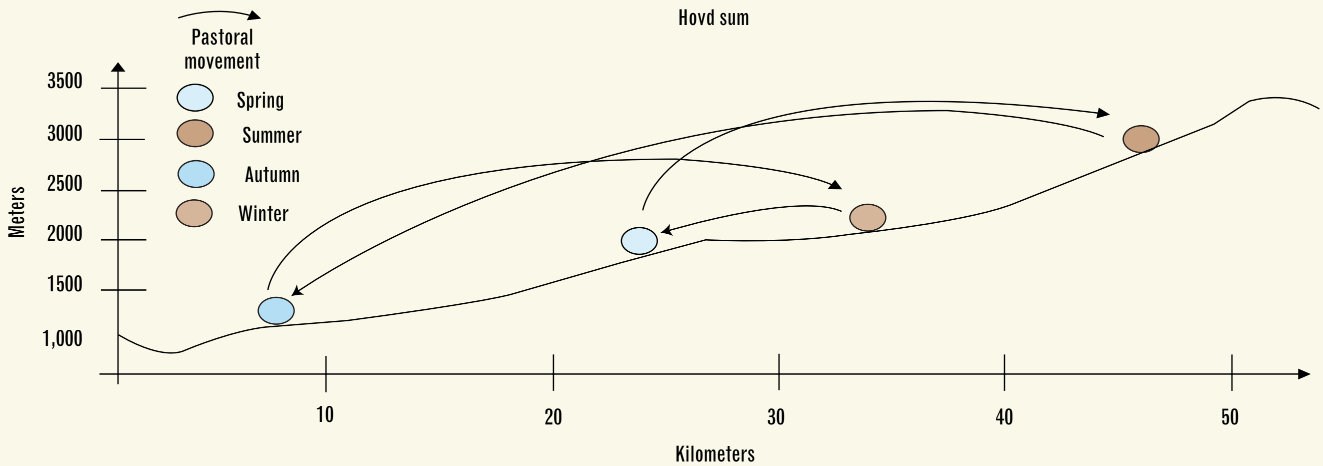


Source: MacArthur Environmental and Cultural Conservation in Inner Asia Project (MECCIA) 1995.

Box 3.19 Pastoral Movements

A variety of pastoral systems are practiced in herd movements in Inner Asia, depending on environmental, social, and economic conditions. In one area of Mongolia (Hovd *sum,* Uvs *aimag*), for example, most pastoralists use pastures that are high in the mountains in the summer—areas above 2,400 m. In autumn pastoral households move down near the lakes, at around 1,600 m. Winter is spent higher on the mountain slopes, at around 2,200 m, and the spring pastures are at a slightly lower elevation—2,000 m. In another, less mountainous area of Mongolia (Dashbalbar *sum*, Dornod *aimag*), the pastoral population generally spends the winter and spring in low areas in river or stream valleys and move to pastures in higher altitudes in the summer and autumn. The average movement in this area is about 25 km (Humphrey and Sneath 1999:236–247).

Cross-section Showing Pastoral Movement



Source: Figure is adapted from Humphrey and Sneath 1999:237.

for transportation and hay-cutting services. Herding households were moved on long legs of the annual migration by collective trucks; and hay deliveries helped feed livestock during the winter and early spring. Recalled one herder, "In the collective period . . . *otor* was very good. The services provided to the herdsmen were excellent. Also, the making of hay [for fodder] and the repair of *hashaa* [enclosures and sheds] was done well" (Humphrey and Sneath 1999:39). Herding households were encouraged to work together. State loans were supplied for infrastructure improvements that would benefit pastoralists, such as boring wells, purchasing hay-making equipment, and constructing winter animal shelters.

But collectivism discouraged individual initiative. Noted the same herder, "Herdsmen had hay and so forth provided for them, and were instructed where and when to move, so they did not choose places to pasture the livestock themselves. They worked only at the command and direction of their leaders . . . cutting and making hay, shearing sheep . . . dipping the animals, all these things the brigade or groups did together. So [during collectivism] people . . . just followed instructions and waited to be told what to do" (Humphrey and Sneath 1999:39–40).

Still, Mongolia basically retained its mobile herding system and a relatively low livestock-to-pasture ratio. This pattern of land use does not appear to have caused much pasture degradation (Asian Development Bank/PALD 1993).

Chinese and Russian Experiences with Grassland Management

A comparison of Mongolia's grasslands to neighboring Chinese and Russian grasslands during roughly the same period (1920–90) underscores the pitfalls of abandoning large-scale, mobile herding techniques. Even in areas of Mongolia where livestock densities are comparable to neighboring regions of China and Russia, the Mongolian regions tend to be far less degraded, according to estimates and herders' perceptions. This may be because Chinese and Russian central governments placed more emphasis on settled pastoralism. Russia also relied heavily on highly mechanized farming methods.

In Russia, most herders were organized into collectives by the 1930s. Within a few decades, livestock in some parts of Russia were kept relatively immobile on fenced pastures. Heavy machinery and chemical fertilizers were used to cultivate fodder crops and grain.

In China's Inner Mongolia in the 1950s, families were similarly settled into "People's Communes." The communes centered on a village in a district with local government facilities, while herding families on the steppe were organized into production "brigades." The brigades retained some mobility and herded the commune livestock on seasonal pastures as directed by officials, along with the small number of personal livestock that households were allowed to own. The decrease in pasture rotation, however, required an increase in haymaking facilities and winter animal sheds.

China, like Russia, dictated a drastic expansion of agriculture in the 1950s and 1960s. Large-scale irrigation projects enabled fodder to be grown, so pastoralists no longer had to move livestock to different seasonal pastures.

Even the remnants of the former specialized herding systems in China's Inner Mongolia disappeared by the 1990s. The new post-Maoist government, as part of its economic reforms, dissolved the communes. Because the government's recent experience in allocating agricultural land to farming families in the rest of China had been relatively successful, the administration sought to apply a similar policy to pastoral regions. Livestock were distributed to pastoral households and quotas for animal production were phased out. Haymaking fields also were allocated to households. By the 1990s grazing land was divided and allocated to individuals and groups of households using long-term leases (Humphrey and Sneath 1999:165).

These 20th century political and economic changes brought benefits to Chinese and Russian pastoralists, but also introduced new inequalities and ecosystem problems. Growth in production was one benefit. In China's Inner Mongolia, the number of livestock rose from about 17 million head in 1957 to more than 32 million in 1980 (Inner Mongolian Territorial Resources Compilation Committee 1987:519–520). These increases were largely the result of a shift to fast breeding sheep and goats and away from larger livestock such as horses, cattle, and camels. Herders also gained rudimentary electrical service, roads, and wells provided by the central government. In Buryatia, Chita Oblast, and Tuva in Russia, farms provided members with guaranteed wages, living accommodations, pensions and insurance, medical facilities, kindergartens and schools, shops, central heating, fuel and firewood, clubs, libraries, and recreational facilities (Humphrey and Sneath 1999:79).

With economic reforms and the beginning of a market economy in the 1980s, living standards in China rose from the extremely low levels that had prevailed in the People's Communes. Some herders became wealthy; those who had better access to markets or who were able to buy machinery and vehicles usually were those who could obtain low-interest government loans through ties to the local administration. Those households could hire labor to look after large herds and could invest in hay-cutting machinery and other assets. Some could pay for special access to high-quality areas of pasture in addition to the minimal pasture allocated to each herding household. Those with the financial means fenced these formerly common lands, limiting the mobility of others to use or move across them.

Thus, benefits were brought at high cost to cultural traditions and ecosystems. Large-scale pastoral movements between seasonal pastures have been largely eliminated by the land allocations, and there has been a corresponding decline in the use of the pastoral technique of *otor*. The effect has been to increase the amount of hay cut to feed livestock, to increase the tendency for livestock to graze in one location all year, and to intensify the concentrations of animals in certain areas. Individual herders can no longer graze different species of livestock on a range of accessible, suitable territories. For example, riverside pastures that had been available to cattle from the whole district might today be divided among different households. Locals have identified deterioration of pasture in intensively grazed areas in Russia and China's Inner Mongolia, especially around water sources and households.

Where static herds do not have access to natural water sources year round, water must be trucked to those pastures; and vehicular traffic damages the fragile surface of those pastures. The need to increase production of hay and fodder to feed the settled livestock also damages the thin steppe soils. In the substantial areas of Inner Asia where soil cover is weak and the climate harsh, converted pastures supply low crop yields while exacerbating erosion and desertification (Humphrey and Sneath 1999:91); plowed grasslands rapidly lose topsoil to strong winds and soil moisture decreases.

Other problems include reduced production of grass in hay-making pastures each year, since people routinely cut in the same places. Herders in China's Inner Mongolia have been known to plow the spring pastures to plant hay and grain because they cannot afford the high price of grain sold in markets. Grassland specialists in Xinjiang estimate that it takes 15–20 years for plowed land to regain its previous productivity as pasture (Humphrey and Sneath 1999:106) because plowing destroys the extensive root system that supports perennial grasses.

Another issue is the introduction of foreign livestock breeds. Merino sheep, for example, were crossbred with Mongolian sheep starting in the 1950s to increase the productivity and quality of livestock products. Many of the "improved" breeds were weaker and slower moving than indigenous breeds, thus requiring heated sheds to survive the winter, further reducing herd mobility (Humphrey and Sneath 1999:239). In Buryatia in Russia, researchers noted that foreign breeds indirectly affected forest ecosystems. Building winter sheds and supplying fuel and housing for newly settled herders requires timber. As a result, forest areas along the Russian border have been heavily exploited. By comparison, most Mongolian herders still use *yurts* for shelter and burn dried dung for fuel; wooden houses are generally found only in central villages. Thus, forest pressures from Mongolia's pastoralists are lower (Humphrey and Sneath 1999:12).

A decline in nomadic practices brings cultural advantages and disadvantages. Interviews with herders from various parts of Inner Asia suggest that many still prefer a mobile life, particularly middle-aged and older herders. Others recognize that nomadism is essential for pasture health but can be a hard life. Time spent in *otor* is time cut off from other people and, often, from social services like formal education, health care, and postal services. Static farming and livestock rearing let families cultivate vegetables, drink water from wells, and access markets more readily (Yenhu 1996:21).

Mongolia after Socialism: Parallels to China and Russia

In 1990, Mongolia began a transition toward a free-market economy. In some ways, the lives of its herders and its economic climate show parallels to China and Russia. There are more sedentary living complexes, divided pastures, and pressures on grasslands and other ecosystems. As a consequence, overgrazing and soil degradation have increased. Records show that the number of dust storms in Ulaanbaatar, the Mongolian capitol, have increased from 16 per year on average during 1960–69 to 41 per year during 1980–89 (Whitten 1999:11). Mongolia's National Environmental Action Plan warns that desert in the country's southern region may be advancing northward by as much as 500 m per year (Government of Mongolia 1995:27–28).

INCREASE IN LIVESTOCK NUMBERS

Mongolia has dissolved its collectives, and most of the livestock and other agricultural resources have become the members' property. As in China's Inner Mongolia in the 1980s, this move toward privatization and markets has promoted rapid growth in Mongolian livestock numbers. That growth occurred as herders first sought prosperity through larger herds, then as they sought to at least earn subsistence income as the economy took a downturn. From 1990 to 1998, Mongolia's national herd increased by more than 20 percent, from 26 to 32 million head (Statistical Office of Mongolia 1993:28; Ministry of Agriculture and Industry of Mongolia 1998:2).

DECREASE IN COMMON PROPERTY GRASSLANDS

To date, the Chinese have progressed farthest in the transition from collective use of pastures to individual use, though Russian Buryatia and Chita are not far behind (Humphrey and Sneath 1999:97). Now Mongolia is following suit. All pastureland remains "common" land under the jurisdiction of provincial and district-level authorities, suggesting that Mongolia still has some of the largest areas of common grazing land in the world (Mearns 1996:308–309). In practice, however, access to and control of common grasslands is not clearly defined. Ownership and use of public land is a controversial topic in Mongolia, with active debate in the Mongolian parliament about the merits of private rights to land and how to ensure that the rich do not acquire all the best pastures. With ambiguous use rights and declining use of collective management, some herding families have begun to rotate their herds less, fearing that others may use the best pastures if they vacate them.

Furthermore, the dissolution of the motor pools of the old collectives and the increase in the cost of gasoline is making seasonal movement difficult for many pastoral families. Where they once used trucks, they now rely on animal transport. The organization of *otor* movement and the regulation of access to pasture, which had been overseen by collective and state farm officials, have declined.

INCREASING DEPENDENCE ON PASTORALISM

During the breakup of the state collectives, livestock were allocated to its former members–to herders and to those who performed other jobs, like veterinarians, drivers, and canteen workers. In some districts the majority of the population became directly dependent on their allocation of livestock for subsistence. The number of registered herders nationwide was 135,420 in 1989–less than 18 percent of the national workforce. Since the economic reforms of the 1990s, that total has more than tripled to 414,433 in 1998 (National Statistical Office of Mongolia 1999:95,45; Statistical Office of Mongolia 1993:6).

Many of these "new herders" maintain permanent dwellings in the district center and are less familiar with or guided by the traditional mobile grazing systems than the households who were part of the specialized herding brigades of the collectives. Some have part or all of their livestock herded by relatives or friends with access to more distant pastures. Others who have migrated from urban areas to take up herding are treated as outsiders and resented for what locals see as increased grazing pressures on local pastures. The presence of these migrants weakens the potential to successfully manage common grazing areas (Mearns 1996:328).

ECONOMIC CRISIS

In the collective era, Mongolia exported 25,000–40,000 tons of meat, 25,000–30,000 tons of livestock, and more than 60,000 horses each year. The vast majority of these products went to the Soviet Union and other members of the socialist trade bloc. With the collapse of the socialist trade bloc, those export markets almost disappeared. Mongolia's meat exports in 1998 amounted to just 7,500 tons, and livestock and horse exports were insignificant (National Statistical Office of Mongolia 1999:144). At the same time, Mongolia's access to affordable imports was undermined; pre-1990, Mongolia spent one-third of its GDP on imports from the Soviet Union, including all petroleum products, 90 percent of imported machinery and capital goods, and 70 percent of consumer goods (Mearns 1991:30).

Accordingly, there has been a collapse in living standards and a declining level of public services like veterinary services and provision of farm machinery. The economic crisis also has lowered agricultural output. The area under cultivation, yields per hectare, and overall production for staple crops like wheat and cereals all have decreased since the end of central planning. Many farmers cannot afford to buy machinery, seeds, and fertilizers (Economic and Social Commission for Asia and the Pacific 1999:336).

In retrospect, many herders stress the relative wealth, security and convenience that the collective period offered, in comparison with the shortages and uncertainty of the current transition to a market economy. Some pastoralists have tried to establish "cooperatives" by pooling their shares of the old collectives to take ownership of its assets, or to share transportation and other costs. However, most of these cooperatives have gone bankrupt as the economy has failed to improve.

INCOME INEQUALITY

Although economic liberalization has enabled some individuals to make money, those in the agricultural sector have struggled to realize any profit. Similar to China's Inner Mongolia, Mongolia is experiencing a growing difference between the living conditions of rich and poor herders. Today, about 37 percent of livestock-owning households struggle to subsist

Box 3.20 Livestock Density in Inner Asia

Densities of livestock in Inner Asia are significantly higher in parts of Inner Mongolia and Xinjiang compared to neighboring Mongolia. But it is not necessarily the case that high livestock densities mean reduced grassland productivity. In fact, researchers studying pastoralism in Inner Asia found that the mobility of the herd and the herd structure seem to be stronger determinants of degradation. For example, records from the 1930s suggest that Inner Mongolia supported about the same quantity of livestock (when calculated in terms of a standard unit of livestock) as it has in the 1990s—the equivalent of about 70 million sheep (Sneath 1998, citing Chang 1933). But in the 1930s, the herds contained a much smaller proportion of sheep and goats and the system of pastoralism was much more mobile. Environmental problems are perceived where herders have shown a tendency to graze their herds year round in specific areas. Pressure on grasslands is exacerbated when some of the best natural pastures are converted to hay making and agriculture.

Livestock Density in Inner Asia

Source: MECCIA 1995.

on the income from less than 50 animals, and 11.5 percent had less than 10 animals in 1998 (National Statistical Office of Mongolia 1999:96). This situation is likely to have worsened during the harsh winter of 1999–2000 when more than 2.2 million livestock died of starvation (UNDP 2000).

One benefit of the emergence of a small stratum of wealthy livestock owners is the potential for them to reestablish some larger pastoral operations that can benefit from economies of scale and the old systems of extensive pastoral movement. The number of households in Mongolia that owned more than 1,000 animals rose from seven in 1992 to 955 in 1998; 33 of these owned more than 2,000 head of livestock (National Statistical Office of Mongolia 1998:96; *Zasagyn Gazar Medeel* 1992). The richest employ neighboring households to help herd livestock and can maintain trucks, jeeps, and wider systems of pastoral movement than most other households. Poor herders cannot afford such moves and, with smaller herds, have less incentive to do so. Their more meager flocks can survive on pastures around their fixed dwellings (Humphrey and Sneath 1999:254).

Poor herders also face more labor and education challenges now than they did under collective systems. For many it has become more economical to remove children from school to stay home and help with herding rather than employ laborers to look after herds (Ward 1996:33).

RELIANCE ON HAY AND FODDER CROPS

Unlike neighboring China and Russia, Mongolia has largely continued to use local breeds that can graze on natural pastures year round. But hay supplies are still critical in winter and early spring (Humphrey and Sneath 1999:236). In fact, the loss of the hay provision the government once supplied to Mongolian

Population and Livestock Density in Selected Districts

Country/Village	Population Density (person/km^2)	Livestock Density (SSU[a]/km^2)	Percentage of Useful Land[b] Cultivated	Percentage of Pasture[c] Considered Degraded
China				
Chinggel Bulag	0.70	54	0	54.4
Hosh Tolgoi	2.10	56	0.3	?
Handgat	3.25	54	0.44	12
Hargant	1.40-	36	0	22.9
Russia				
Argada	11.30	270	33	88.3
Gigant	4.00	125	18.8	76.9
Sholchur	1.80	65	0.9	1.5
Mongolia				
Hovd sum	0.96	48	0.008	0.07
Dashbalbar	0.40	22	0.17	0.03
Sumber[d]	1.56	36	1.2	2

[a]SSU, standard stocking unit: sheep = 1, goat = 0.9, cattle = 5, horse = 6, camel = 7.

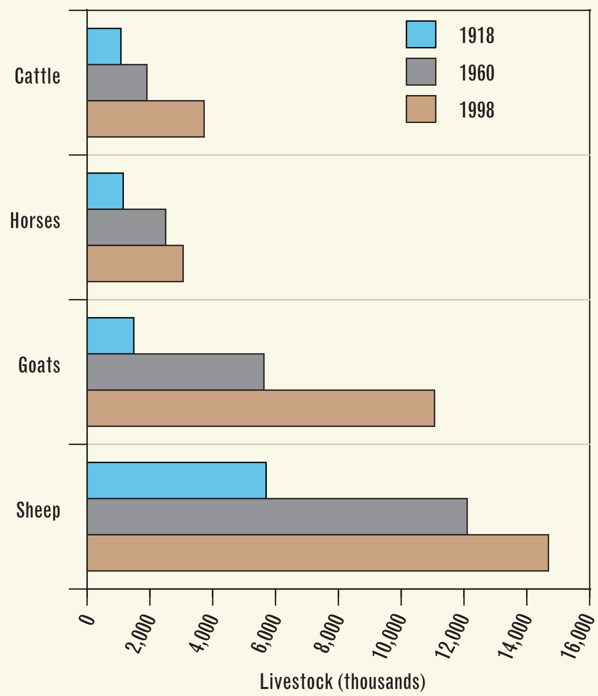
[b]"Useful land" is all land not specifically unusable for farming economy as a whole. It includes arable and hay-making land.

[c]"Pasture" is land specifically designated for pasture.

[d]Data do not include the administratively separate town or Choir.

Source: Humphrey and Sneath 1999:77.

Growth in Mongolian Livestock Populations



Source: Humphrey and Sneath 1999:44–45.

collectives seems to be harming livestock nutrition, especially as pastoralists make shorter and less frequent moves.

The lack of adequate hay production leaves flocks vulnerable to starvation, as evidenced during the winter of 1999–2000. Thousands of hectares of pasture were buried under heavy snow into the spring, yet the government was unable to provide supplementary feed because of limited funds, lack of hay stocks resulting from prior drought, and transportation problems (FAO 2000).

Another problem is that some of the pasture used for hay production is not ecologically suited for it. Perhaps 10 percent of the 1.34 million ha under cultivation in 1990 is now affected by erosion (Whitten 1999:14).

Mongolian herders have noted the negative impacts of recent trends. Remarked one man, "In the 1970s all the households used to go on *otor*, and the households were spread out at a distance from one other. But now most of the households do not move from their winter camps, so in the winter and autumn pastures the animals have eaten all the vegetation. So there has been significant pasture damage and reduction in vegetation" (Sneath 1993).

Modernization and Mongolia's Future

Looking at China's Inner Mongolia, some already foresee the passing of the era of mobile pastoralism. Economics could encourage production systems in which calves and lambs are shipped to farming areas for fattening, rather than raised on grass. For some herders, benefits of such a transition could include increased income, more leisure time, and greater economic security (Humphrey and Sneath 1999:93, citing Li et al. 1993).

It is too soon to tell if such a scenario is inevitable for Mongolia, or if the country can find a way to balance the old herding techniques of pastoral mobility with the new forces of urbanism and market economics. On one hand, old techniques of pastoral mobility still exist even in China's Inner Mongolia, with livestock raised to full weight on the steppe. On the other hand, the herding patterns that collectives used had retained some aspects of the older systems of land use, but the dissolution of these institutions brought a decline in large-scale pastoral operations and expanded the herds kept for use by individual families.

Currently, grazing land in Mongolia remains a public resource despite attempts to introduce legislation for its private ownership. However, without support, the poorer households with small numbers of livestock and limited domestic labor will have difficulty maintaining systems of wide pastoral movement, even where pasture land is not divided among individuals. A more sedentary life does not inevitably lead to pasture degradation, but the movement of the herds in relation to available pasture does appear to matter to herders. For example, in Dashalbar, Mongolians have a relatively settled way of life, with houses in the district center, but herders with a vast area of pasture at their disposal still make use of seasonal movement and occasional *otor* (Humphrey and Sneath 1999:212).

Other complicating influences include a tripling of the human population in Mongolia in the last 60 years and projected high growth rates for several more decades. This adds pressure to expand the pastoral economy and animal herds, although the number of livestock may be approaching the maximum level that Mongolia can support with the resources currently available to the pastoral sector. The desire to live near roads, markets, schools, and modern services also will draw people and their herds to populated areas where degradation is already a problem.

With current high inflation, debt, and depressed trade, it seems unlikely that local or central governments will be able to encourage large pastoral enterprises by renewing the government-supported motor pools and machinery for hay production. Yet such investments and government leadership may be essential if large-scale pastoral movement systems that include the majority of herders are to be retained. District governments might be able to coordinate labor for the maintenance of public resources such as wells and hay production, for example. Or, small farms and associations could be combined in scaled-down versions of collectives for more specialized and mobile livestock herding, even if households are more settled.

It is possible that wealthy Mongolian herd owners will accumulate sufficiently large livestock holdings to establish intermediate-scale pastoral operations, using labor from poorer households. However, decades may pass before such operations become large enough to encompass the majority of grazing land, and there would still be need for district authorities to coordinate herding and land use.

Significant investment in improved transportation services for herders could bolster environmentally sustainable systems of large-scale pasture rotation and might also benefit livestock processing industries by facilitating their purchase of livestock products at competitive prices. In China, at least, the close presence of markets and relatively high demand for pastoral products has enabled some herders to make a good living. But in Russia and Mongolia, the distance to markets, the high cost of production inputs like fuel, and low demand all depress the livestock economy. In Russia and Mongolia, the prices for livestock products like meat, cheese, and wool are very low; sugar, tea, flour, and other foods are expensive (Humphrey and Sneath 1999:75).

Market failures may cloud Mongolia's ability to see the short-term benefit of preserving large-scale herding patterns. This is especially true in the face of some farmers' increased wealth and the lack of policies that support and encourage mobile herding and collective action. But where herders' lives become highly settled, the grasslands appear to be overused. Pastoralists recognize the threat to the future productivity of their livestock operations. Herding populations from Tuva to western Mongolia and Mongol-inhabited parts of Xinjiang are deeply concerned about the environment. Whether that local awareness will translate into political change and sensitivity to ecological vulnerability, or what path "modernization" will take, is difficult to gauge.