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ENVIRONMENT AND DEVELOPMENT

Edited by
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Foreword

If war is too important to be left to the generals, the environmental concerns of poor countries are too important to be left entirely to the environmentalists. This module can help you identify many concrete environmental problems of development—problems that must be dealt with by program and project designers and managers, not just by environmental experts.

Unwitting environmental damage (damage to the lives and prospects of people) has resulted from well-intended development projects and programs in every part of the world. Irrigation has destroyed productive land as well as developing it, and spread disease as well. Technological fixes helped create the Sahel, no matter what the basic causes of that disaster. All sorts of unintended consequences lurk in interventions. Some have potentials for environmental disaster, in places where there is little enough to begin with.

All parties to the analysis of development problems and the design of interventions need a basic level of environmental awareness. They must know what to look for and what to be concerned about. They must decide if expert studies are necessary, and they must be able to judge the meaning—and the quality—of such studies (some have been quite bad). They have an obligation to help promote environmental understanding.

The United States Agency for International Development (AID) is committed to protecting the environments in which its projects run and to promoting environmental protection and enhancement in the countries where it works. This module presents a base-line introduction to the large environmental problems characteristic of many of these countries.

Sociologist Marion Levy once suggested that the world is more likely to end not with a bang but a breakdown. He calls it the "stupidity death," the result of our tendency to do things without adequately anticipating the consequences. In the field of development, some people can put others at risk of stupidity deaths. By the nature of things, development is a risky business. If risks and errors are compounded by casual inattention to established knowledge, it becomes an evil business too.

An imperative for all development efforts is to reduce the prospects and costs of error. Error's antidote is valid knowledge put to use. This material is one small assault against errors in dealing with the environmental contexts of developmental actions.

The articles that follow examine the problems of energy, health, and soil loss and their implications for the countries and peoples of the Third World:

A chapter from Erik Eckholm's book, *Losing Ground* deals with a particular energy problem of the Third World, firewood.

Andrew Kamarck portrays the most important diseases of tropical countries and their relationship to productivity and poverty.

Lester Brown examines land use, productivity, and their public policy implications in poor countries. In a companion piece, Eckholm considers the specific effects of irrigation practices on land productivity.

We conclude with an article on a large environmental perspective—*ecodevelopment*. There is no one best way to deal with environmental problems and opportunities except to carefully consider the consequences before beginning the action. Eco-development does not tell how, but it does put environmental concerns into a broad framework, useful in focusing on particular problems and specific solutions with due attention to their cultural and ecological aspects.

William J. Siffin
Director, PASITAM

Environment and Development

Some problems are difficult because there seem to be no sure solutions. Others are difficult because there is no consensus on their nature. Some of the most difficult and perplexing problems relate to the sensible use of the environment.

In certain development agencies, "concern for the environment" is official policy. It is more than just a procedural requirement. It is a commitment to environmental awareness by everyone involved in developmental design and decisionmaking.

A project designer may be uncertain about the relevance of environmental factors in particular situations. There is no single computational approach to help him or her. There are some useful assessment tools.[1] Project designers must decide which tools or approaches to use, what the results mean, and whether a set of environmental trade-offs is acceptable. Choice in these matters can be sharpened by familiarity with the environment as a system, by awareness of the commonest environmental issues, and by knowledge of the past.

Environmental issues are complex. We tend to define them in terms of our own outlooks. The 1972 UN Conference on the Human Environment began with a focus on environmental problems as seen by the industrialized nations. Representatives of developing countries brought up *their* concerns, a somewhat different set of environmental problems rooted in poverty: problems of energy, disease, and productivity that threaten not only the quality of life but life itself.

Part of the challenge facing project designers is to translate these broad concerns into well-defined problems. Meeting this challenge requires an understanding of the environmental dimensions of development. It also requires avoiding certain courses of action—such as "tacking on" environmental analysis after all significant project design decisions have been made. Viewing the environment as sacred and untouchable must also be avoided. Both extremes obscure useful ways of looking at the environmental dimensions of development.

The environment as a constraint: Arid environments, for example, are inherently unproductive, and some river basins in West Africa are dangerously unhealthy.

The environment as a vulnerable resource base: Because of soil structures and the ways people use the land, some soils are subject to high rates of degradation and loss. Because people need fuel to survive, vast amounts of wood and dung go up in smoke.

The environment as a set of latent resources: Alternative energy sources—especially biomass and solar—have been under-exploited in some developing countries.

The environment as a set of thematic problems of energy, health, soil, and water: These problems are dismayingly difficult. They have no easy technological fixes. But progress is being made. The unwitting spread of schistosomiasis in many regions is being matched by the slow, steady, and increasingly informed struggle against it. The worldwide resurgence of malaria has been balanced, in a sense, by the eradication of smallpox and efforts to control the tsetse fly. And we keep learning from experience.

It is unlikely that the interventions that contributed to the Sahelian disaster would go unchallenged today. There is a growing sophistication in our ways of thinking about and dealing with man and his environment. We know that trade-offs must sometimes be made, but maintaining environmental quality is beginning to be recognized as a prerequisite for sustained development.

I
Energy, the Environment, and Development

Wood is the poor man's oil. Throughout the underdeveloped world, men, women, and children spend a considerable portion of their time cutting trees, gathering twigs and branches, and tending fires to have the energy they need for cooking and a modicum of heat and light. Together with wood, animal dung, and crop residues, human and animal labor provide the barest of energy necessities for 50 to 60 percent of the world's people who live in the villages and small towns of Asia, Africa, and Latin America.[2]

Since 1973 the developed countries have faced an energy crisis. In the poor countries such crises have been building for a long time, exacerbated by the inefficient and often wasteful use of available energy. The Third World energy crisis is in many respects more serious than our own. They pay the same high costs for petroleum products, while rapidly expanding populations place greater demands on existing supplies.

Opportunities—limited but real—for more efficient energy use and for expanding supplies do exist. But they pose complex and difficult problems for LDC policymakers. For many individuals in these countries, the problems are neither abstract nor complex; they are elemental.

Erik Eckholm tells of a Pakistani woman being chided by a governmental official for stripping the bark from a tree.[3] Yet that woman's actions were entirely rational. She may be contributing to a future ecological catastrophe, but she is faced with the immediate need to cook or to stay warm. If she doesn't take the wood, someone else will.[4] She and the countless others who cut branches from trees, uproot saplings, and sweep the earth clean of leaves and twigs are inviting tomorrow's environmental disaster and its devastating effects on productivity, health, and the quality of life. For many of the world's poor, tomorrow has already arrived.

ENERGY USE IN POOR COUNTRIES

We tend to think that people in poor countries use little energy, especially in rural areas. It is true that total energy use by all the developing countries is one-quarter that of the industrialized nations. Even so, the amounts are considerable and are growing faster than in developed countries.[5]

Estimates of energy use are usually based on surveys of oil, coal, and hydroelectric power use. When other fuels, such as wood and dung, are taken into account (and there are considerable difficulties in measurement), they increase the estimate of poor country energy consumption by about two and one-half times.[6] But primitive methods of consumption and the low quality of energy inputs produce limited benefits from given amounts of energy. This is especially true in agriculture (see table 1). The problem is energy efficiency as well as energy quantity. For example, "total energy input per hectare" is roughly the same for all five countries noted in table 1. The difference in yields is striking.

"Non-commercial" fuels (other than oil, coal, or hydropower) play an important part in Third World agricultural processing, cottage industries, and service activities The demand for fuel is growing faster in the processing sector than among households.[7] Commercial food preparation, brick and ceramic manufacturing, tin smelting, and iron-making usually rely on locally supplied wood or charcoal. These activities account for between 2 and 15 percent of the total fuel use in Africa and Asia. In Tanzania, tobacco curing alone required an estimated 1.1 million m^3 of fuelwood in 1970. Rubber and tobacco preparation in Thailand used 300,000 m^3 of fuelwood in the same year.[8]

The complexity and diversity of energy use in poor countries is illustrated by data from rural India (see table 2). About 82 percent of all energy use in rural India is directly related to food production and processing.[9] Less than 11 percent of it comes from commercial fuels—this in a country with a relatively well-developed commercial fuel sector.

As Roger Revelle suggests:

From an energy standpoint, rural India [like other less-developed countries] can be thought of as a partially closed ecosystem in which energy derived by people and animals from the photosynthetic products of plants is used to grow more food, and so on in an endless cycle. The ecosystem is being disrupted by a rapid population growth.[10]

If people in LDCs are substantial but inefficient energy users, part of the fault lies in the available fuels. Poor countries consumed approximately 1,200 million m^3 of fuelwood in 1971, compared to 161 million m^3 in developed countries.[11] Wood accounts for nearly two-thirds of all energy used in Africa, one-third in Asia, one-fifth in Latin America, and about 6 percent in the Near East (see table 3). In the developed countries, the comparable figure is one-third of one percent.[12]

In the poor countries, 86 percent of all wood consumed is used as fuel, over 80 percent of it domestically. Wood, dung, and crop residue accounted for

TABLE 1
Energy Use per Hectare in Rice Production in Various Countries

Country	Installed horse-power hp per ha farm machines and draft animals only	Energy for farm operations million Btu per ha	Energy for irrigation and nitrogen fertilizers manufacture million Btu per ha	Total energy input per ha million Btu	Rice yield kg/ha	Energy intensity million Btu per ton of rice
India	0.7	20	6.5	26.5	1,400	19
China	0.7	20	12	32	3,000	10.7
Taiwan	0.5	10	22	32	4,000	8
Japan	1.6	10	25	35	5,600	6.2
U.S.	1.5	7	25	32	5,100	6.3

From *Energy and Agriculture in the Third World: A Report to the Energy Policy Project of the Ford Foundation*, by Arjun Makhijani and Alan Poole, p. 17. Cambridge, Mass.: Ballinger Publishing Co. Copyright (c) The Ford Foundation. Used by permission.

TABLE 2
Energy Uses in Rural India

Source of energy	Energy used (kcal)					
	Agriculture	Domestic activities	Lighting	Pottery, brickmaking, metalwork	Transportation and other uses	Total
Human labor	0.59×10^{14}	0.39×10^{14}		0.01×10^{14}	0.09×10^{14}	1.08×10^{14}
Bullock work	1.35×10^{14}				0.26×10^{14}	1.61×10^{14}
Firewood and charcoal						4.60×10^{14}
Cattle dung		6.78×10^{14}		0.75×10^{14}		1.86×10^{14}
Crop residues						1.07×10^{14}
Total from local sources	1.94×10^{14}	7.17×10^{14}		0.76×10^{14}	0.35×10^{14}	10.22×10^{14}
Petroleum and natural gas						
Fertilizer	0.35×10^{14}					0.35×10^{14}
Fuel	0.08×10^{14}		0.42×10^{14}			0.50×10^{14}
Soft coke		0.14×10^{14}				0.14×10^{14}
Electricity						
Hydro	0.03×10^{14}		0.01×10^{14}			0.04×10^{14}
Thermal	0.12×10^{14}		0.05×10^{14}			0.17×10^{14}
Total from commercial sources	0.58×10^{14}	0.14×10^{14}	0.48×10^{14}			1.20×10^{14}
Total, local and commercial	2.52×10^{14}	7.13×10^{14}	0.48×10^{14}	0.76×10^{14}	0.35×10^{14}	11.42×10^{14}
Daily per capita	1.57×10^{3}	4.55×10^{3}	0.30×10^{3}	0.47×10^{3}	0.22×10^{3}	7.11×10^{3}

From "Energy Use in Rural India," by Roger Revelle, in *Science*, vol. 192, June 4, 1976, p. 973. Copyright (c) by the American Association for the Advancement of Science. Used by permission.

TABLE 3
Estimated Use of Wood for Energy in 1971

	Consumption of wood fuel*		Energy from wood fuel	
	Total Million m³	Per caput m³	Coal equivalent† Million tons	Percent of total energy‡
Asia and Pacific				
Southeast Asia and Pacific	278	0.91	92	62
South Asia	267	0.38	88	43
China and other Asia	148	0.18	49	9
Total	693		229	29
Near East	13	0.15	4	6
Africa				
North Africa	55	0.50	18	41
West Africa	110	0.92	36	75
East Africa	117	1.14	39	75
Total	282		93	66
Latin America				
Central America§	33	0.36	11	9
South America	199	1.03	66	29
Total	232		77	20

SOURCE: FAO estimates of wood fuel; UN Statistical Yearbook, 1973.

*Fuelwood plus wood for charcoal.
†CE = coal equivalent; assumes one cubic meter of wood is equivalent to 0.33 ton of coal.
‡Total energy excludes organic fuels other than wood, and human energy and animal labor.
§Includes Caribbean.

From "Fuelwood and Charcoal in Developing Countries," by J.E. M. Arnold and Jules Jongma, in *Unasylva*, vol. 29, no. 118, 1978, p. 3.

nearly 56 percent of total energy consumption in India in 1970-71.

Wood is a relatively inefficient fuel with a high ratio of weight and bulk to caloric output, and it is usually consumed inefficiently (traditional stoves may waste over 90 percent of the heat value of wood).[13] Unlike other fuels, it can seldom be moved economically over great distances. In Africa, wood is rarely transported more than 100 kilometers, with 50 kilometers being the average.[14] So deforestation is severe, especially around population centers. Ouagadougou, Upper Volta, is typical. Virtually all trees have been removed up to 70 kilometers from the city.[15] Urban residents tend to use less wood per capita, but their aggregate demand is considerable.

Rural residents collect most of their fuelwood within walking distance of its place of use. This task is usually performed by women and children. In many parts of the world, it takes a full day's labor to acquire the amount of wood that used to be gathered in a few hours. In the Gambia, gathering a year's supply of fuelwood requires an average of 360 man days per household. When this much effort is expended on one activity, other tasks must suffer.[16]

Increased effort is only part of the cost. Firewood may consume as much as one-quarter of an urban family's income.[17] The cost of wood displaces other forms of consumption among people already living on the margins. As wood becomes scarce and expensive, some people turn to other sources of energy. In many cases, they have increased their reliance on dung and crop residues. Given the importance of these products to soil productivity, this is equivalent to "burning food in order to cook food."[18]

DEALING WITH THE ENERGY CRISIS

Technically, it is quite possible for people to use existing energy supplies more efficiently. A number of options are available.[19]

Wood

The most apparent answer to the firewood shortage is to grow more trees. But reforestation is not a simple task. First, large numbers of people must change their long-held attitude that wood is a "free" good and see it as a resource to be protected and renewed. Second, developing tree plantations requires that people curtail

immediate consumption—not an easy task for the Pakistani woman with no affordable alternatives. Formal prohibitions and sanctions have not been enough to force people to forego consumption.[20] In areas of high population density, where needs are most acute, there may be insufficient room for tree plantations, or plantations may run counter to established ownership, tenure, and usage arrangements.[21]

If wood is not the most efficient fuel, it is a desirable source of energy: Trees can be grown close to where wood is consumed. People are familiar with it as a fuel. Besides meeting the energy needs of the poor, trees help retain soil moisture, reduce erosion and flooding, act as windbreaks, and have aesthetic appeal.

To date, failures of reforestation efforts have outnumbered successes. The apparent success stories seem to share certain characteristics: intense local involvement backed by effective political and administrative arrangements.

Taking firewood reforestation efforts out of the public sector by encouraging commercialization may be one way to increase the wood supply. In principle, the increased value of firewood could help promote sustainable production and provide employment for rural residents. But it has not happened on a large scale.

The grievousness of the firewood and timber problem—and perhaps one possibility for dealing with it—is illustrated by the *chipko* movement in India.[22] The movement started in a village in Uttar Pradesh and has spread to other parts of the country. Chipko members hold fasts and demonstrations to focus attention on forest contractors who violate conservation laws. Their goals are to preserve the trees along India's rivers, to encourage the development of locally managed forest cooperatives, and to promote legislation to require commercial forest profits to be reinvested in forest areas.

Another way to address the wood shortage is to transform wood into a more efficient energy form—charcoal. It burns more slowly, produces less smoke, and has a higher combustion temperature. Charcoal has a calorie-to-weight ratio twice that of wood, enabling it to be transported over greater distances. Dispersed production of charcoal could satisfy some of the demand for firewood in areas surrounding population centers.

But charcoal is no easy answer. Present conversion methods waste 30 to 50 percent of the heat value of the wood. Large-scale charcoal production could result in even greater deforestation.

Biogas

Biogas, or methane, is a possible alternative to fuelwood in some circumstances. Biogas is produced by accelerating and controlling a natural fermentation process,

> performed by a mixture of micro-organisms in the absence of oxygen. In anaerobic digestion, acid-forming bacteria convert wastes into fatty acids, alcohols, and aldehydes; then methane-forming bacteria convert the acids to biogas. All biomass except wood can be anaerobically digested, and the process has been recommended for use in breaking down agricultural residues and urban refuse. Anaerobic digestion takes place in a water slurry, and the process requires neither great quantities of energy nor exotic ingredients. Anaerobically digested, the dung from one cow will produce an average of 10 cubic feet of biogas per day—about enough to meet the daily cooking requirements of a typical Indian villager.[23]

This process also produces "waste" slurry, a high quality fertilizer rich in nitrogen, phosphorus, and potassium, and free of the pathogens in the original materials.

About 50,000 *gobar* (cow dung) plants operate in India and, reportedly, over 4 million in China. Sudan is attempting to use an aquatic pest, the water hyacinth of the White Nile, as a fuel for biogas plants, though its commercial viability has yet to be determined.

Biogas plants are not without problems: The initial investment (approximately US $250) is not trivial. Frequent maintenance is required because the process is corrosive. The smallest economical plants require the dung of at least four or five cattle to provide gas for a family of five. In India, 70 to 80 percent of cattle owners have only one or two animals.[24] Collecting enough dung would require feeding and stabling additional cattle. Climatic conditions also affect productivity. Gas outputs drop dramatically in colder months unless complicated and expensive steps are taken to insulate or heat the chamber. The gas is produced at a relatively low pressure and [illegible]ly be used near the point of production, unless expensive and cumbersome tanks are used for transport. The process requires a considerable amount of water, presenting problems for villages in arid areas. And in some places, there is a strong social stigma to handling dung or human excrement.

Significant economies can be achieved by larger plants, but these require careful arrangements or the poor might "wind up without biogas and without cow dung."[25]

Solar Energy

The most abundant source of energy, the sun, is the most taken for granted. Technological improvements, plus the increasing cost of other fuels, have made solar energy attractive and economical. It can be used to heat or cool buildings, purify water, dry foods and lumber, and as a source of mechanical energy. Photovoltaic cells, which convert the sun's heat into electricity, are being tested as a source of power for educational television receivers and water pumps in Africa.

Solar cookers are relatively inexpensive to build and easy to operate. Tropical countries have plenty of sunlight, but solar cookers have not caught on because of a number of cultural factors. Solar cooking must be done during the day, which is alien to the preference of many people. In some cultures, people prefer to eat in the evening. Local custom may require women to cook food indoors, screened from public view. One proposed way to deal with these problems is the use of acid storage batteries to store solar heat for later use.

CONCLUSION

The failure of solar cookers to gain wide acceptance illustrates an important lesson: The greatest obstacle to dealing effectively with the energy crisis in poor countries is the tendency to define problems in narrow terms. Social systems, cultural preferences, economic circumstances, political realities, and habits are as relevant as technical issues. Technology is often the least important constraint.

Cost can be a major constraint. Really poor people may not be able to afford methane digestors—they can barely afford firewood. It is also easy to underestimate or to ignore the power of culture. No matter how elegant or "good" it is, a technology that runs counter to important social values will be ignored or resisted.

Social factors include the capacity to organize and maintain complex, novel, "artificial" arrangements and to distribute their products. With biogas plants, inputs must be collected, the plant maintained, and the gas and slurry allocated efficiently and equitably. In the case of forest plantations, men may prefer to have their women and children travel farther for wood than to work for a government or a local elite. Finally, governments may simply lack the trained personnel to supervise and maintain plantations.[26]

Political factors are also vital. People with status, power, and money will always find fuel. Urban centers are likely to receive greater attention than rural areas. And energy problems compete for attention against other important issues. Satisfying energy needs is a long-term problem. The absence of immediate, visible solutions frequently discourages action or skews it into quests for grand "modern" solutions.[27]

II
Health and the Environment

> Shangyanpan [China] . . . had a population of over 500 in 1920. By 1949, only 144 survived, including 115 who were languishing with infection. The village was known as the "Village of Widows," for schistosomiasis widows were found in almost every household, and many families included widows of 3 successive generations. In Tzeshih . . . the disease levied such a heavy toll on the inhabitants that 12,000 *mu* (*mu* = 1/6 acre) of fertile land, which once made the village famous for rice production, were overgrown with weeds. Scourged by famine, the people survived on seaweeds in spring, wild herbs in summer, husks in autumn, and handouts in winter. Many ended the nightmare of their existence by suicide.[28]

Some of the most confounding and pervasive environmental problems in poor countries concern health. In few other areas is the lack of options and the vulnerability of the poor so apparent. Millions suffer from chronic, often multiple infections with exotic, menacing names: *schistosomiasis, filariasis, kala azar*. If the terms are unfamiliar, the effects are all too real. In the poor countries these diseases

> . . . affect every aspect of human life from childhood onwards, and even when they don't kill they are debilitating: they can disable an entire population, prevent the planting or the reaping of crops, cause the abandonment of fertile and potentially productive land, and increase the effort required for survival.[29]

The health hazards confronting the poor cannot be reduced to a single, simple set of categories. Their relation to development can be viewed along two lines: *those conditions that constrain development and those that result from developmental efforts*.

The health-poverty-environment nexus is revealed in a set of basic problems. Because of climate, geography, or human impact, some environments support debilitating and disabling diseases. Endemic diseases make

certain river valleys in West Africa and the tsetse belts in East Africa bad places for people to live and work. As a consequence, people are forced to farm or to graze their animals on less productive land. Under conditions of poverty, human actions make other environments unhealthy. Unplanned settlements on the edges of many Third World cities are breeding grounds for a number of communicable diseases.

Developmental interventions can also create environmental health problems. The spread of schistosomiasis with the expansion of irrigation is the classic example. Even health interventions have created health problems when environmental relationships were overlooked or ignored. For example, in an otherwise effective malaria eradication program among the Dayaks of Borneo, DDT eliminated cats as well as mosquitoes. Without the cats, rats flourished and the Dayak people were exposed to sylvatic plague. An environmental equilibrium was restored when spraying was reduced and cats were reintroduced.[30]

We still don't know enough about the diseases and health hazards that afflict the poorest people in the world. And development planners and economists have often been insensitive to the implications of ill health. Development plans are usually drawn up by healthy officials, and decisions are made in comfortable offices in central cities. To succeed, these plans require cooperation and support from people who are often ill, malnourished, poor, and far less productive than the "average economic man."

As our understanding increases, our perspectives change. A worldwide program of basic and applied research is being initiated, and more attention is being directed to the major environmental health constraints affecting the poor. One of the most vivid of them is river blindness in West Africa.

RIVERS OF DARKNESS: DISEASE AS A CONSTRAINT

River blindness, *onchocerciasis*, affects as many as 20 million people. It is the most severe form of filariasis. Parasitic worms mature in body tissue and produce microfilariae or embryos that invade the lymph and circulatory systems.[31] Impaired vision or blindness is caused by the cornea clouding due to the death of microfilariae in the eye.

The parasite's life cycle depends on a chain of environmental factors: a host, principally man; a vector, the black fly; and a habitat in which to propagate, i.e., rapidly flowing fresh water rich in oxygen and nutrients. Man and fly compete for the same scarce resources in the river valleys of West Africa. The Volta River Basin is a potentially rich agricultural area of 700,000 sq. km. in an otherwise impoverished region. Yet those who farm this heavily infested area risk their health.

River blindness does not kill; it incapacitates. Thousands are affected in Ghana and Upper Volta, at high human costs. A Nigerian study found that those with impaired vision had fewer material possessions, such as domestic animals and household goods.[32] Heavily infected villages produced few cash crops (groundnuts, cotton, or rice) and tended to raise staple crops for survival. Infected people, even the totally blind, tried to farm; but blindness restricts mobility, and the infected were limited to areas adjacent to their compounds. They were often the beneficiaries of donated labor or outright gifts of grain and meals, imposing a significant burden on the healthy.

Infected regions experienced a population decline, even the abandonment of villages. Women from the uninfected uplands were loath to marry men from the infected regions or to settle there, so many young men from the lowlands moved away. In Upper Volta, river blindness stimulates the annual migration of workers to the Ivory Coast and Ghana.[33] It is difficult to isolate the causes of population migration, but it seems that disease—and river blindness in particular—has an important effect.

Mass curative efforts have not been very successful in dealing with river blindness. Control or elimination of the fly vector is the best approach; but the adult fly has a flight range of up to 150 kilometers, and a single female can re-infect a cleared area.

The most promising method is to attack the fly at its larval stage, before it is mobile. In 1966, Mali and Upper Volta established the *Organisation de Coordination et de Cooperation pour la Lutte Contre les Grandes Endemies* (OCCGE) and launched a massive campaign along these lines. Other West African nations, the World Health Organization, the World Bank, and AID have joined the program. Faced with 14,000 km. of potentially infected watercourses in the Volta Basin, the campaign has all the trappings of a military operation, using planes, helicopters, and boats to survey, identify, and spray often inaccessible fly breeding sites. The effort initially relied on DDT; other chemicals with lower toxicity are now being used. This program is expected to last 20 years, the life span of the

worm within an infected person, and to cost an estimated $120 million (at 1973 prices).[34]

Eliminating this health hazard could reduce land pressure on the less productive soils of the Mossi plateau, lessen migration, increase the productivity of rural families, and end the tragic loss of productive farmers. An estimated 65,000 km^2 of fertile land may eventually be brought under cultivation. In Upper Volta, the additional agricultural output could turn a food-deficit country into one with near self-sufficiency. The desperate need for this land is shown by the spontaneous movement of people into areas where the control program has just begun. By the time it is completed, as many as a million people may be resettled on fly-free lands.

The problems of settling the Volta Basin may make the difficulty of eradicating the fly seem simple. As the Dayak experience suggests, attacks on environmental health constraints can create other problems. So it will be in the case of river blindness. Land clearing, settlement, irrigation, and agricultural expansion could easily take environmentally damaging forms.

It is important to remember that eliminating a particular hazard creates obligations to manage and guide the consequences. Some countries in the Volta Basin have made progress in the orderly development of cleared lands. Upper Volta has established an agency to supervise resettlement. The program is not without difficulties, but it has gone a long way to provide for the sensible exploitation of this region.[35]

Tsetse

If the environmental implications of river blindness are considerable, they are dwarfed by the tsetse fly.[36] The tsetse has been called the "Guardian of Africa." It has influenced migratory patterns, social and economic arrangements, even colonial history. Currently, the emphasis is on eliminating the tsetse fly vector. Less attention is being given to the effects of success on land use, cattle population, fauna, and existing social arrangements.

Controlling the fly would open up an estimated 10 million sq. km. of land. This could cause an explosion of livestock numbers and the possibility of repeating the Sahelian cycle of overgrazing, erosion, and land destruction. Nomad pastoralists could lose their winter pasture to settlers. This scenario need not happen, but it could. Indeed it *may*, unless there are political and administrative mechanisms to manage the resources that will be created by eliminating the tsetse.

DISEASES OF DEVELOPMENT: THE HAND OF MAN

Disease hazards can be created or enlarged by human behavior. For example, enteric and other forms of communicable disease are spread through contaminated water supplies in over-crowded urban areas. Common human activities—swimming, drinking, irrigating, washing—expose people to risk in certain environments. Some development projects have magnified these hazards. The pre-eminent example is schistosomiasis, or bilharzia. Irrigation projects in infected areas have spread this disease among the very people who were expected to benefit.

Schistosomiasis has been identified with Egypt since Pharaonic times. It now affects approximately 200 million people worldwide. The disease is caused by small worms living in the venous blood vessels surrounding the intestines or bladder. Man, the primary host, shares the parasite with certain varieties of snails that inhabit slow-moving fresh water. In an infected person, the female schistosome enters a cleft in the male parasite's body (*schisto*/cleft; *soma*/body) to form a copulating pair. They produce up to thousands of eggs each day for as long as 40 years. These eggs work their way out of the body, lacerating the internal organs of the host, producing lassitude, fever or chills, and bloody urine and diarrhea—but sometimes no symptoms at all.

Man is the principal agent for spreading schistosomiasis.[37] In the past, man's contact with the disease was limited by his modest ability to control water resources. Powerful engineering technologies have changed all that.

When the Aswan Dam was built, primary emphasis was placed on the economic benefits of irrigation. As early as 1959, the World Health Organization warned the Egyptian government that unless sanitary improvements were included in the project, there would be a dramatic increase in schistosomiasis. Egypt faced a trade-off: "irrigation or malnutrition: malnutrition or schistosomiasis."[38] Egyptian decisionmakers opted for irrigation and schistosomiasis. "Intensified irrigation agriculture, large increases in suitable habitats for intermediate host snails, greater crowding of human populations and greater pollution of snail infested water by schistosome-infected people" provided the setting for a dramatic increase in the disease.[39]

A 1972 survey of the 500-mile stretch of river between Cairo and Aswan indicated that the incidence of urinary schistosomiasis ranged from 19 to 75 percent of

the populations in the area. In 1937, the average rate of infection had been about 5 percent.[40]

Diseases like schistosomiasis would seem to reduce productivity. Andrew Kamarck cites findings to this effect, but the connection is not entirely clear. A rigorous study on the island of St. Lucia failed to find a link between schistosomiasis and decreased worker productivity.[41] The researchers concluded that humans compensate for the disease by drawing on the body's "standby capacity." Whether such conclusions can be generalized is unclear.

But one thing *is* clear: It is easier to spread schistosomiasis than to control it. Control requires breaking the life cycle of the parasite. The most obvious way is to avoid contact with infested water, but this is not realistic for farmers working in irrigated fields. Providing safe water and sanitary facilities is one answer, but the cost would be staggering; and without education, their use could not be guaranteed.

Irrigation designers can help reduce man-snail contact. Lining canals to stop the growth of aquatic weeds or increasing the velocity of water can prevent snail build-up. Distributing irrigation water in pipes rather than in open canals discourages the spread of snails and has the added advantage of reducing the risk of malaria. These methods involve additional expense. Project designers and policymakers have to choose between the cost of the disease, which is difficult to calculate, and the cost of prevention.

So far, the chief method of dealing with schistosomiasis has been to use molluscicides to attack the snail directly. Conventional chemical treatment involves danger in application, toxicity to benign plants and animals, and the need for repeated treatments—but it does not require large numbers of people to change their habits. Now a new, relatively safe molluscicide has been found: *endod*, the soapberry plant. Its molluscicidal properties were discovered in Ethiopia when large numbers of dead snails were found downstream from where local people had washed their clothes. A field test was conducted with promising results: In five years, refined endod reduced the infection rate in one village by 15 percent; in an untreated village it had risen by 10 percent. Another promising experiment in Egypt involves growing a variety of ragweed that kills the eggs and larvae of the parasite as well as the snail along irrigation canals.[42]

Research has turned to the investigation of biological controls of this parasite. Promising experiments have been carried out in Kenya using a snail-eating fish. Other studies are testing the use of herbivorous animals, such as the manatee, to reduce the vegetation in which the snail lives. In Puerto Rico, researchers have identified a "killer snail" that feeds on schistosome eggs and the young of one of the intermediate snail hosts. Using this snail in conjunction with a health and sanitation program, Puerto Rican authorities have cut the cost of clearing one variety of schistosomiasis to one-fourth that of programs relying primarily on chemical controls. The University of Puerto Rico has established a training program to help Africans identify a similar snail suited to African conditions.[43]

Researchers in Puerto Rico are also testing a drug, oxamniquine, that kills the parasite in the human host. Unlike earlier chemotherapy treatments requiring close medical supervision, oxamniquine appears safe and easy to administer—one dose provides a cure. But the treatment is expensive—about $10 per person—and confers no immunity.[44] Even if this drug lives up to its expectations, it will not eliminate schistosomiasis as an environmental hazard.

China offers the most successful example of schistosomiasis control. In 1949, millions of Chinese were infected with a virulent form of the disease and many more were at risk. Today, according to Chinese data, the vast majority of people and irrigation systems are free of this parasite. The Chinese used all known control methods—molluscicides, chemotherapy, sanitation, and health education—backed by intense political commitment. With their most abundant resource—labor—and the knowledge that intermediate snail hosts cannot survive if their habitats are modified beyond certain limits, the Chinese embarked on a massive engineering program: straightening or constructing new canals and scraping infected mud from canal walls, burying it, and then spraying canals to prevent reinfestation.[45] Human feces were collected and stored to kill the schistosome ova, creating night soil that can be safely used as fertilizer.

The Chinese program cannot be transferred whole cloth. Few other nations can achieve the same degree of social mobilization. But as Dr. Letitia Obeng, an expert on water-related health problems, points out, it offers lessons about

> . . . the importance of ecological research into the habitats of the snail as a means of fighting it; the importance of sanitation and safe water supply systems; the importance of integrating the campaign against disease into the overall development program; and the importance of total government support and total involvement of the people.[46]

Schistosomiasis is not "dramatic." It does not kill directly, and it usually strikes the rural poor. Controlling schistosomiasis often comes into conflict with other important goals. In some places, there are inescapable trade-offs between increased agricultural productivity through irrigation and the risk of spreading the disease. Such choices should be explicit. They are made by default when decisionmakers view their interventions in narrow technical terms without regard for the larger environmental implications of their actions. Failure to anticipate a project's impact on health may result in substituting new problems for old.

ENVIRONMENTAL IMPLICATIONS OF DISEASE CONTROL

Research on diseases affecting the developing countries is modest in comparison to needs. The World Health Organization estimates that only about $30 million per year is spent on research on all tropical diseases.[47] But attitudes are beginning to change, and environmental health analyses are becoming accepted components of projects.[48] In 1976, the World Health Organization and the UNDP created a Special Program for Research and Training in Tropical Diseases. It seeks to link the biomedical knowledge and technical facilities of industrialized countries with research and clinical work in the countries most affected by these diseases. Over the next 20 years we may witness significant reductions in river blindness, a drug to cure schistosomiasis, the elimination of the tsetse, vaccines against malaria and leprosy, and inroads on other diseases.[49]

New vaccines and treatments may enable us to control or eradicate diseases that menace the lives of the poor. The reduction in personal suffering will be incalculable. But another result will be new problems. Accelerated population growth in Sri Lanka following the control of malaria in the late 1940s is an example of one way people may respond to the elimination of environmental health hazards.

There are no miracle cures for some of the diseases associated with poverty. Enteric diseases and other communicable illnesses will continue to be problems until urban housing and sanitation facilities are adequate. Nor will much headway be made against diseases of the rural poor until a health infrastructure is created that emphasizes prevention, education, and, where appropriate, the use of traditional medicine and practitioners. Here Tanzania may offer a model.

Following the Chinese example, Tanzania is giving its rural people access to basic, competent health services at the village level. At the base of this pyramid is a Village Health Worker. With six months of training he is able to diagnose and treat minor ailments and common diseases such as malaria, hookworm, and bilharzia. Though curative treatment is vital, the emphasis is on prevention. At the middle level, a group of Rural Medical Aids is specifically trained to deal with the majority of more serious or complicated cases for referral to a Rural Health Center. But ultimate success in dealing with the diseases of the poor will not depend solely on the ratio of practitioners to population; it will turn on improved standards of living.

Development that improves the quality of life for the poor, including health, education, and employment, is part of any basic strategy for dealing with problems of disease. Development efforts that produce growth at the risk of health are dubious. Yet in a world of limited resources, trade-offs will be made between productivity and disease prevention. We can never accomplish everything. But in dealing with the environment it is important to remember that we can never do just *one* thing. Change takes place within complex ecological systems. In the case of many health hazards, the need to protect the environment does not end with eliminating a disease. This is often the point at which environmental issues become more important and complicated.

III
Soil and Water

> The fundamental issue . . . is whether the farmer should be primarily concerned with feeding his *plants* or his *soil*. According to orthodox agriculture (orthodox over the last fifty years, at least), as long as the farmer gets nutrients into the plant, it doesn't matter too much what happens to the organic content of his soil. Some scientists in the agricultural schools are now taking the extreme position and arguing that "the soil is there simply to hold up the plant while the farmer feeds it nutrients." [The other position] is that if a farmer keeps his soil in good condition, the plants will pretty much take care of themselves.[50]

Keeping the land in good condition or making it better has been one of mankind's vital concerns since the beginning of settled agriculture some 15,000 years

ago. These concerns are even more critical today. There is an awesome amount of arable land—educated guesses put it at somewhere between a billion and a billion and a half hectares—that supply nearly three-fourths of the world's food. But this is only 11 percent of the total land area of the world. The remaining lands include the marginal soils of mountains, deserts, and unexploited rain forests.

In the short run, land is not a renewable resource. Except for some mountainous areas, the margins of some deserts, and unexploited rain forests, we can't add much to the total stock of available land—there are certain outer limits.[51] Yet there are tremendous possibilities for maintaining and enhancing the productivity of available land by adding resources such as water and energy.

Over the millenia, man's treatment of the land environment has been mixed. The remarkable irrigation systems of Mesopotamia, the complex adjustments of cultivators to the ebb and flow of the Nile, the slash and burn agriculture of the tropics, and the scientific and technological advances known as the "Green Revolution" represent attempts to manage and accommodate the demands of this vital ecosystem.

These efforts are remarkable, but the successes have often been transitory. Mesopotamia once supported 25 million people. The part that is now Iraq barely supports 10 million on some of the poorest land in the world. In Africa, the periodic flooding of the Nile valley has been checked, but the ultimate costs may exceed the benefits. In many places, traditional agricultural practices plus population pressures have helped destroy the quality of the land. Higher petroleum prices have challenged some of the benefits of the Green Revolution. Its social and ecological problems have become all too apparent.

Yet cultivators have achieved remarkable successes in preserving productive land. In the fertile Danube Valley, land has been continuously cultivated for nearly a thousand years with no apparent harm. In parts of the Ohio Valley, the land is probably as productive today as when it was first settled. In Japan, land under continuous cultivation for nearly 4,000 years produces enough rice to feed a population of 115 million with a surplus for export. The global record shows a large lesson: Man's relations to the soil are problematical. In some parts of the world, there are ominous problems, and they demand management that may or may not be possible.

These problems are as basic as the land itself. Their genesis lies in a single fact: Increasing numbers of people are placing greater demands on a finite resource. And as the demand for food increases, vast amounts of cropland are being lost through erosion, water-logging, salinity, and diversion to other uses. The U.N. estimates that the worldwide loss of soil over the next 30 years will be twice the amount of land added through reclamation (see table 4). If these projects hold, there will be even more people and less cultivable land. Of course, the balance between man and land will be restored at some point. Whether in a brutal manner, as in the Sahel, or through rational human action remains to be determined.

Apocalyptic scenarios are better at stimulating action than providing understanding. It is more helpful to examine some of the main trends of the times and their attendant problems. In the not too distant past, farmers could respond to declining soil fertility by moving. Except for some tropical rain forests, "extensification" is no longer an option. Most of the good land has already been taken, and some of the most fertile land is being lost to competing uses.[52]

The alternative is to intensify agriculture. In places like the American Midwest, intensified agriculture has produced remarkable yields—but not without some worrisome concerns. In much of the world, where traditional agriculture has in the past produced sufficient substance crops, intensification has created environmental problems.

INTENSIFICATION OF AGRICULTURE

The hypothetical effects of increasing productivity to the level of the United States have been estimated by Roger Revelle.[53] In the U.S. Midwest, the average corn harvest is usually more than 240 bushels per hectare—enough to satisfy the physiological needs of 24 people. At this rate, 170 million hectares of high quality farmland could satisfy the caloric needs of 4 billion people.

Such extrapolations are interesting but unrealistic. Under current conditions, the world's one billion-plus hectares of cultivable land fail to produce enough food. Much of this land is given over to non-food products, pasture, or fallow. But compared to the six metric tons produced in the U.S. Midwest, the average Indian or Pakistani farmer harvests little more than a ton of wheat or rice per hectare, often after investing more energy per unit of return. Innate fertility is different. So is the level of available technology and the supporting infrastructure.

If there is considerable margin for increasing productivity through agricultural intensification, there are

TABLE 4
Projection for the Period 1975-2000 Regarding Soil Loss and Reclamation

1975	Population	4,000 million
	Cultivated land	1,240 million hectares
	Cultivated land per person	0.31 hectares
1975-2000	Loss to urbanization	300 million hectares
	Loss to soil degradation (mostly erosion)	300 million hectares
	Potential land added to arable base	300 million hectares
2000	Population (medium variant)	6,253 million*
	Cultivated land	940 million hectares
	Cultivated land per person	0.15 hectares

*ECOSOC E/CN.9/324 (1977)

From "Report of the Executive Director," in *The State of the Environment: Selected Topics*, 1977, UNEP/GC/88 */, United Nations Environment Programme, March 14, 1977, p. 21.

also risks. Intensification often involves environmental simplication: bringing water from places of abundance to areas where it is scarce, monocultures, or pesticides to supplement natural resistance. Such practices may run counter to environmental needs.[54]

Diversification is one of the principal means by which ecosystems maintain their stability and adapt to changes and threats. It is the environment's way of hedging its bets against disaster. The United States is probably the best example of high-intensity agriculture. Spectacular yields of 200 bushels or more of corn per acre are realized, through ever more costly inputs of fertilizers, pesticides and herbicides, and sometimes irrigation. But sophisticated inputs have not eliminated the farmer's problems. He is subject to the risk of a gradual loss in soil fertility, particularly the depletion of organic soil material. Erosion has become a serious problem in some places. Hardpan has been reported as much as two feet thick.[55] One response has been to use heavier plows to break up this crust, compounding the problem. The increased weight of farm machinery has further compacted the soil and increased its vulnerability to erosion.[56]

Intensive agriculture suggests large-scale monoculture supported by expensive technological inputs. But for the traditional agriculturalist, intensification often translates into such environmentally damaging practices as overcropping or overgrazing. The results of such practices were evident in the American Dust Bowl in the 1930s and in the Sahel in the 1970s.

Some of the most serious problems of soil management in poor countries involve the deterioration of mountain environments.[57] Mountain ecosystems are extremely fragile and can rarely sustain the same degree of cropping, forest removal, and grazing that is practiced on the lowlands.

Nepal is a critical area. In the past, its farmers relied on a system of elaborate terraces, but population pressure has forced people onto steeper hillsides unfit for sustained farming. Overcultivation and deforestation are pushing the area toward ruin. Topsoil, Nepal's "most precious export," washes into India and Bangladesh at an alarming rate, and the remaining soil is declining in fertility. Nepalese farmers traditionally maintained fertility by applying manure to their fields, but this practice is declining. Faced with shortages of firewood, the Nepalese increasingly use dung as fuel rather than as fertilizer.

The Terai, a flat, fertile strip of land on the Ganges Plain, may provide an outlet for Nepal's population; but the frequency of flooding has increased there because of what has happened in the hills. Many riverbeds are rising six inches to a foot *each year*, causing the rivers to meander and destroy prime croplands. An uncharacteristically blunt report by Nepal's National Planning Commission concluded that soil erosion is "almost to the point of no return. . . . It is apparent that the continuation of present trends may lead to the development of a semi-desert type of ecology in the hilly regions."[58]

If Nepal is an extreme example of soil erosion, it is not unique. In East Africa, population pressures are forcing farmers to cultivate land traditionally used for grazing, moving herders onto ever smaller areas. In Korea, peasants virtually sweep the land clean of twigs and leaves, robbing the soil of important organic matter.

But there are also some success stories of halting soil loss and increasing productivity. After serious initial difficulties, the Soviet Virgin Lands program has achieved moderate success. The recovery of the American Dust Bowl demonstrated that, with adequate re-

sources and incentives, a virtual desert could be reclaimed. Well-known conservation practices—fallowing, strip cropping, terracing, contour plowing, and herd size limitations—can increase productivity. Some of these practices are being applied to the problems of the developing countries. And much can be learned from traditional agriculture.

Long considered primitive by Western standards, shifting agriculture is a sensible accommodation to certain environments.[59] Bush-fallow cultivation takes into account experience and tradition, the preferences of the people involved, and the likely returns from available resources. With many local variations, this type of cultivation involves three principal activities: burning or clearing vegetation, mixed cropping, and fallowing. Burning eliminates weeds and releases nutrients held in the vegetation cover. Though seemingly disorganized, a system of mixed cropping (different crops planted successively or simultaneously) spreads the risk of vulnerability to weather, disease, and pests. Fallowing restores fertility through recolonization.

During the fallow period, plants and trees function as "pumps" that transfer nutrients to the topsoil.[60] A lower soil temperature, particularly important in tropical areas, is maintained, and organic matter has a chance to build up. Finally, fallow's protective cover sharply reduces leaching and erosion. But bush-fallow cultivation involves extensive amounts of land; in stable traditional systems, as much as 85 to 90 percent of land is fallow at any one time. With population growth, there is simply not enough space to permit so much land to be withdrawn.

The Third World cultivator is faced with the same problem as the Midwest farmer: How to obtain higher yields on limited amounts of land without sacrificing fertility or destroying the soil base. But lacking resources to purchase inputs, the Third World farmer has no choice but to shorten the period between land clearings. Traditional agriculture can respond to new challenges and opportunities, but there are limits to its capacity to feed increasing numbers of people.

With rising population, traditional agriculture's disadvantages have begun to outweigh its advantages. Modifications have been proposed and implemented, but not always successfully. Efforts such as the East African Ground Nut Scheme, using seemingly sound technologies, failed to take root in new surroundings.[61] The fault lay less in the technology than in the manner of its transfer. Rather than treating such innovations as inputs into a complex system of social, political, and ecological relationships, they were presented as isolated answers or simple technological fixes.[62]

Evolutionary approaches to soil erosion and declining fertility that build on the knowledge of local people may prove to be more productive than radical interventions. As Hunter and Ntiri point out,

> there are no magical "packages" of aid, no easy shortcuts or overnight solutions, no miracles, and no panacea. The long-term goal must be environmental maintenance with sustained yield production. To achieve this end, the guiding principles should be those of the systems sciences that stress the dynamic inter-relatedness of cultural and biophysical phenomena.[63]

EXPANDING AGRICULTURE

Much of the unused land in the world is of marginal quality, requiring costly investments in irrigation, drainage, and leveling to become productive. Apart from the margins of some deserts, no greater unexploited region exists than the world's tropical forests. Nor does any other ecosystem so sharply demonstrate the difficulties and risks associated with development.

Of the tropical rain forests, the Amazon is at greatest risk. The world's largest tropical rain forest, it covers an area nearly two-thirds that of the United States. Seduced by what one observer has called a "counterfeit paradise,"[64] the Brazilian government, multinational corporations, and individuals are clearing its land at a rate with no parallel in history. One hundred million acres are earmarked for lumber exploitation, farming, cattle ranching, and settlement.

The forest's luxuriant growth conceals a fragile and poorly understood ecosystem. It is the home of an estimated 100,00 plant and animal species, but little is known about their relationships and dependencies. A relatively untouched reservoir of genetic diversity, their scientific and pharmacological value cannot even be estimated.

The forest pumps trillions of gallons of water vapor into the atmosphere daily. A vast load of nutrients makes the Amazon estuary a rich spawning ground for sea and land animals. Some of these nutrients are carried as far as the Grand Banks off Newfoundland. Scientists have generally discounted the notion that the Amazon is one of the "lungs" of the world producing vast amounts of oxygen, but significant changes in such a large ecosystem are bound to have profound effects.[65]

Prudence suggests a go-slow policy. Remote sensing surveys indicate that as much as 10 percent of the forest has already been razed—an area larger than Texas. Many square miles are being cleared by burning. *Correntoes*, giant chains pulled by tractors, are used to

uproot trees. Agent Orange, a toxic defoliant used in Vietnam and subsequently linked to health problems, is also used to clear vegetation.[66]

Beneath the vegetation cover lie relatively infertile soils. In 98 percent of the Amazon Basin the land (except for some alluvial soils) is thin, poor, and acidic. The lushness of the forest comes not from its soil base, but from the continuous cycling of nutrients through its flora and fauna. Everything that falls to the forest floor—plant debris, dead animals, etc.—is quickly decomposed and its nutrients absorbed by tree roots. Removing the trees breaks this cycle. Without a forest canopy, the soil is exposed to intense rainfall, and nutrients are quickly leached out. Sheet erosion is followed by gully erosion, and laterization[67] proceeds as soil temperatures rise.

How inevitable and unforgiving some of these processes are is shown by the experience of the Bragantina farmers:

> The largest and best-known example is the Bragantina zone around the city of Braganca at the eastern end of the Amazon region. The Maryland-sized area of tropical forest has been transformed into what one Brazilian scientist has called "a ghost landscape."
>
> Settled by European and Brazilian immigrant farmers around the turn of the century, the Bragantina area was first blessed with high yields. By the 1940s, however, the soil had been exhausted and crops replaced with coarse grasses and, eventually, by huge expanses of bare soil and rock unable to hold water.
>
> By the late 1940s, some of the Bragantina farmers were resettled by the Brazilian government at a colonization site along the Maderia River north of here. There, in the far western Amazon near the Bolivian border, their unhappy experience repeated itself in an even shorter time.
>
> Once again, the results from the first three years were promising. But within five years the once-dense jungle had been turned into what one study called "virtual pavements of rock," and today the colony is nothing more than a huge expanse of exposed and exhausted soil on which a few poor and desperate settlers eke out a meager living.[68]

Brazilians are aware of these problems and dangers, but they seem unable to contain the forces that may be creating a vast desert. Ironically, the people who suffer most are the Indians who live in harmony with the forest. Their environment will be radically changed and perhaps destroyed, and we shall lose an opportunity to learn how to wisely use the resources of the complex forest system.

WATER

In many ways the management of land includes the management of water. Water is essential to life, health, and productivity. There is enough water in the world to meet personal, agricultural, and industrial needs for the foreseeable future. Rough estimates place the total supply at 1.4 billion km^3. Ninety-seven percent of this is ocean, which could be an inexhaustable source of protein. The usable non-saline stock of water is about 0.3 million km^3 of ground water and 0.2 million km^3 of surface water—an amount that has changed little over geologic time.[69]

Yet about two-thirds of the world's people lack access to adequate supplies of water suitable for drinking, domestic use, and agriculture. "Water is rarely in the right place at the right time in the right quantity and quality."[70]

Agriculture accounts for about 75 percent of all water used. It takes 1,500 liters of water to produce a kilo of wheat, 4,500 for rice, and 30,000 for beef. High-yielding crop varieties typically require even greater amounts of water. Water intake may average more than one or two hundred times the dry weight of a plant during a single growing season.[71]

Irrigation is often the key that unlocks the potential of agricultural land. Like the slash and burn cultivator, the irrigator effects a profound change on the environment. He usually achieves immediate and spectacular results. Without care, these gains can be easily lost. Nutrients may be leached from soil or carried below the level of plant roots. If too much water is added—often the case among those unfamiliar with its use—it may penetrate below the root zone. Excess water is a waste, and a prospective cause of water-logging and salinization. When salts are already present in shallow surface soil, irrigation and even rainfall may concentrate them in a hardpan.

From ancient Mesopotamia to the 19th century British effort to create a Punjab Granary (where the problems of water-logging and salinity were "solved" by simply abandoning ruined land) to more recent efforts, the same fact has too often been ignored: Drainage must accompany irrigation. It would be difficult to find a more instructive example than Afghanistan's Helmand Valley.[72] What distinguishes the case is the rapidity with which water-logging and salinity occurred.

Before 1949, farmers in the Helmand Valley relied on inundation canals, wells, and *karez* (tunnels) for non-perennial irrigation. Then the Afghan government and a foreign construction firm created an elaborate irrigation system. The project has not achieved its expectations. The goal of settling large numbers of nomads proved illusory. Water-logging and salinity forced abandonment of some previously usable land. In some places, salt-tolerant grasses replaced wheat and

cotton. In some cases, crop yields dropped to pre-project levels.

The Helmand Valley project is not a disaster. In areas with sufficient drainage, where farmers are familiar with irrigation practices, the project has been effective. In some other parts of the valley, water-logging and salinity existed long before the project began. The greatest difficulties occurred in two important project areas, Nad-i-Ali and Marja, slated for reclamation and settlement by nomads. Here the water table rose 16 feet, to within a few inches of the surface, three to four years after irrigation became available. Seepage from unlined canals, the lack of drainage, and excessive irrigation by people unaccustomed to abundant water contributed to these changes. The basic problem was the shallow soil, underlain by an impermeable layer of dense gravelly subsoil. Under irrigation, topsoil was washed away or became saturated with salt. This should have come as no surprise; the soil characteristics were revealed during the construction of an adjacent irrigation canal.

Projects that promise great benefits often develop their own momentum. Halting or modifying grand plans is difficult. In Afghanistan, the government eventually did respond. It sought assistance from the International Cooperation Administration (ICA), a predecessor of AID. In 1959, ICA, in cooperation with the U.S. Bureau of Reclamation, commissioned studies that recommended remedies and improvements.[73]

Hans Singer has noted that

> the real objective of irrigation projects is to produce more and better food. Yet, when you concentrate your attention on the physical investment, your attention is concentrated on the engineering aspect. . . . The other part is taking the water to the farmer and following through into what the farmer does with the water . . . that is an involvement with nature and with people.[74]

In the Helmand Valley, it was incorrectly assumed that farmers would know how to use the water. Many farmers over-irrigated or applied water at the wrong time. A lesson that should have been obvious had to be learned again: Simply making water available was insufficient—farmers had to be helped to adapt to the new environment.

Thirty years and $200 million later, the promise of the Helmand Valley is not yet fully realized. The lessons learned there could—and should—have been learned from the Indus Basin, from the Imperial Valley in the Colorado River Basin, and from other irrigation schemes. With 200-300 thousand hectares of irrigated land being lost worldwide through salinization and water-logging each year, the luxury of such ignorance is too costly.[75]

IV
Conclusion

Protecting and developing soil capital is not just a physical problem. Social, political, and economic factors are as important as technical ones. They include market forces, costs of inputs, population pressures, land use policies and demands, and technologies such as irrigation. The issues are far from being simple, and narrow approaches or fixes will not suffice. We have examples both of successful adaptations to the environment and of horror stories.

The technical knowledge base for soil conservation and wise water use is better developed than the arrangements for using it. Technological know-how for the energy problems facing the Third World is more advanced than the institutional and political arrangements for its use. How to eliminate some of the major environmental health problems confronting the people of the poor countries is better known than how to create the political and administrative arrangements to deal with the opportunities and effects. The large lesson of this overview is that the basic problem is not to generate powerful technical knowledge, but to use such knowledge intelligently. Until environmental concerns are better integrated into developmental plans, technological interventions may defeat their own purposes.

If the environmental problems resulting from development activities were isolated "accidents of progress," it would be graceless to dwell on them.[76] But this is not the case. Some critics charge that the fault lies in the technologies themselves—witness the emphasis on "appropriate technologies." Others claim that the fault lies less in the technology than in the manner of its transfer. Perhaps the principal defect is a "reductionist" approach—the failure to systematically anticipate the impact of interventions on the complex web of relationships we call the environment.[77]

Too often our "solutions" have defined the problem rather than the reverse. We may define development as building a dam to provide energy, or initiating a disease control program, or introducing a specific cropping system. Such uni-purpose interventions may tend to ignore the systems into which they are placed. What happens to the people displaced by the dam? What are the effects of removing a particular disease constraint? How do farmers respond to the demands of a new cropping system? Only now are such questions being systematically asked.

The environmental problems of the poor countries demand action. But we must resist the impulse to act ahead of understanding or we risk "ecological backlash." Action must be informed by the human needs and environmental potentials of specific places, and by prudent, incremental approaches to complex and poorly understood systems. Otherwise, the roster of developmental horror stories will be increased.

—Paul Cunningham

Notes

1. Some of these are described in *AID and the Environment* (Bloomington, Ind.: PASITAM, 1979).

2. Arjun Makhijani, *Energy and Agriculture in the Third World* (Cambridge, Mass.: Ballinger Publishing, 1975), p. 1.

3. Erik Eckholm, *Losing Ground: Environmental Stress and World Food Prospects* (New York: Norton, 1976), pp. 102-103.

4. One way to look at the firewood shortage is as a problem of the "commons." The commons model suggests that individual rational behavior can in the aggregate lead to environmental disaster. In the commons, each individual is free to extract as many goods as he wishes. All the benefits accrue to the individual; any negative results are shared by all. Under this arrangement, it is rational for each individual to take as much as he can. But herein lies the "tragedy." Unlimited, unrestricted use of a finite environment brings ruin to all. The model can also be used when things are added to the environment—pollution into the air or water or cattle in the Sahel. For a detailed presentation of this model and an examination of the policy alternatives for dealing with it, see Garrett Hardin, "The Tragedy of the Commons," *Science* 162 (December 13, 1968): 1243-48.

5. Asit K. Biswas and Margaret Biswas, "Energy, Environment and International Development," *Technos* 5 (January-March 1976): 41-43. The authors estimate that the average annual growth rate in energy consumption was 7.5 percent in LDCs compared to 5 percent in developed countries.

6. Makhijani, *Energy and Agriculture*, pp. 18-19. Various sources, including World Energy Supplies 1960-70, *Statistical Papers*, Series J, no. 15 (New York: United Nations, 1971), estimate that non-commercial fuels account for about 25 million Btu per capita per year; commercial fuels account for 10 million Btu per capita per year in the underdeveloped countries.

7. J.E.M. Arnold and Jules Jongma, "Fuelwood and Charcoal in Developing Countries," *Unasylva* 29 (nd): 3. See also Keith Openshaw, "Wood Fuels the Developing World," *New Scientist* 61 (January 31, 1974).

8. Arnold and Jongma, "Fuelwood and Charcoal," p. 3.

9. Revelle, "Energy Use in Rural India," *Science* 192 (June 4, 1976): 973. See also P.D. Henderson, *India: the Energy Sector* (World Bank, 1975).

10. Revelle, "Energy Use in Rural India," p. 969.

11. Developed countries are defined as Australia, Canada, Europe, Israel, Japan, South Africa, the USSR, and the United States. Sources: *IBRD ATLAS 1973: FAO Yearbook of Forest Production 1973*, table 4. Cited in United Nations Environment Programme, "The State of the Environment: Selected Topics—1977," UNEP/GC/88* (March 14, 1977), p. 27. See also *Forestry*, Sector Policy Paper (World Bank, 1978).

12. Arnold and Jongma, "Fuelwood and Charcoal," p. 2.

13. H. Singer, *Improvement of Fuelwood Cooking Stoves and Economy in Fuelwood Consumption* (Rome: FAO, 1971), cited in UNEP's *State of the Environment: Selected Topics* (1977), p. 29. See also Ken Darrow and Rick Pan, *Appropriate Technology Sourcebook* (Volunteers in Asia, 1976) for a variety of stove designs and other energy saving devices.

14. Arnold and Jongma, "Fuelwood and Charcoal," p. 5.

15. Eckholm, *Losing Ground*, p. 104.

16. Keith Openshaw, "The Gambia: A Wood Consumption Survey and Timber Trend Study, 1973-2000" (unpublished report to the ODA/LRD Gambia Land Resources Development Project, Midlothian 1973). Cited in FAO, *The State of Food and Agriculture 1976*, FAO Agriculture Series, no. 4 (1977), p. 91.

17. Eckholm, *Losing Ground*, p. 102. There have been recent price increases as high as 300 percent in Nepal.

18. Ibid., p. 6. Arnold estimates that each ton of cow dung burned may mean the loss of as much as 50 kg. of foodgrain. Rough estimates of worldwide consumption of dung put the figure at about 400 million tons wet weight per year.

19. See *Energy for Rural Development, Renewable Resources and Alternative Technologies for Developing Countries* (Washington, D.C.: National Academy of Sciences 1976) for a comprehensive assessment of direct and indirect uses of solar energy. See also Darrow and Pan, *Appropriate Technology Sourcebook*, pp. 128-98.

20. Denis Hayes of the Worldwatch Institute reports that in southern Saudi Arabia, some tribes impose the same punishment for unauthorized cutting of trees as for killing a person. He does not indicate the effectiveness of this draconian measure. See Denis Hayes, *Rays of Hope* (New York: Norton, 1977), p. 192.

21. FAO, *The State of Food and Agriculture 1976*, p. 91, contains an extensive discussion of energy and agriculture. See also

FAO's earlier study "Energy for Agriculture in the Developing Countries," *Monthly Bulletin of Agricultural Economics and Statistics* 25 (February 1976): 1-8.

22. "Chipko" is Hindi for "to cling," after the practice of people clinging to trees to prevent them from being cut down. Marcus Franda, "Alternative Energies and the Renewal of India," *Common Ground* (an AUSF publication) 4 (Winter 1978): 27. This entire issue is devoted to energy alternatives for developing countries.

23. Hayes, *Rays of Hope*, p. 195.

24. C. R. Prasad, K. Krishna Prasad, and A.K.N. Reddy, "Biogas Plants: Prospects, Problems and Tasks," *Economic and Political Weekly* 9 (August 1974): 1360. See also Arjun Makhijani, "Energy Policy for Rural India," *Economic and Political Weekly* (Special Number) (August 1977): 1451-64.

25. Makhijani, "Energy Policy," p. 1458.

26. For some of the difficulties facing reforestation efforts see Erik Eckholm, "Forests for People," *Development Forum*, 7:2 (March 1979): 1, 4, and his longer *Worldwatch Paper No. 26*, "Planting for the Future: Forestry for Human Needs."

27. Brazil is apparently commited to such a path. It has recently undertaken a massive complex and expensive ethanol production program to supplement its gasoline needs by the 1980s. For an assessment of this program, see Norman Gall, "Brazil's Alcohol Program," *Common Ground* 4 (Winter 1978): 31-39. See also Allen L. Hammond, "Alcohol: A Brazilian Answer to the Energy Crisis," *Science* 195 (February 11, 1977): 564-66.

28. Tien-Hsi Cheng, "Schistosomiasis in Mainland China," *The American Journal of Tropical Health and Hygiene* 20 (1971): 27.

29. World Health Organization, *Tropical Diseases* (Geneva: WHO, nd), p. 3.

30. C. S. Holling and M. A. Golberg, "Ecology and Planning," *Journal of the American Institute of Planners* 37 (July 1971): 221-30.

31. For a somewhat dated but useful compendium of important diseases, see Jacques M. May, *Studies in Disease Ecology* (New York: Hafner, 1961).

32. A. K. Bradley, "The Effect of Disease on Rural Economy: Social Structure and Settlement; A Case Study of Onchocerciasis in the Hawal Valley, Nigeria," WHO/ONCHO/72.93 (Geneva: World Health Organization).

33. Andrew Kamarck, *The Tropics and Economic Development* (Baltimore: Johns Hopkins, 1976).

34. UNDP and IBRD, *Stemming the River of Darkness: The International Campaign Against River Blindness* (United Nations Development Programme and World Bank, nd).

35. Eileen Berry, Charles Hayes, and Earl Scott, "Onchocerciasis Clearance in West Agrica with Special Reference to Upper Volta," prepared for USAID Workshops in Environmental Investigation (Worcester: Clark University, 1978).

36. For an excellent examination of these efforts, see the recent WGBH-NOVA program, "The Tsetse Trap."

37. C. Sterling, "Superdams," *Atlantic Monthly*, and John Weir, "Bilharziasis as a Man-Made Disease," *World Health Organization Chronicle* 13 (1959): 19-25.

38. B. A. Wiesbrod, "Ways of Treating Many of the Major Diseases—Simply and Effectively—Have Yet to Be Found," *The Johns Hopkins Magazine* (Summer 1967), p. 9.

39. Joe L. Stockard, "Economic Justification for Schistosomiasis Control," in *Proceedings of the International Conference on Schistosomiasis*, ed. Dr. Ahmed Abdallah, vol. 1 (Cairo, Egypt, October 18-25, 1975), p. 6.

40. Henry van der Schalie, "Aswan Dam Revisited," *Environment* 16 (November 1974): 20

41. Karmarck, *The Tropics and Economic Development*, p. 63. See also Robert E. Baldwin and Burton A. Weisbrod, "Disease and Labor Productivity," *Economic Development and Cultural Change* 22 (April 1974): 414-35; and idem, *Disease and Economic Development: The Impact of Parasitic Disease in St. Lucia* (Madison: University of Wisconsin Press, 1973).

42. Aklilu Lemma, "Schistosomiasis: The Social Challenge of Controlling Man-Made Disease," *Impact of Science on Society* 23:2 (1973): 133-42; and "A Weed to Fight Bilharzia," *Mazingira* no. 8 (1979), p. 88.

43. "Third World Development Sets Back Bilharzia Probe," *To the Point*, October 27, 1978, p. 45.

44. "Bilharzia: New Drug Offers Hope," *To the Point*, April 13, 1979, p. 44.

45. Jane Stein, *Water: Life or Death* (Washington, D.C.: International Institute for Environment and Development, 1977), pp. 36-38. See also Cheng, "Schistosomiasis in Mainland China," p. 39.

46. Quoted in Stein, *Water: Life or Death*, p. 28.

47. WHO, *Tropical Diseases*, p. 17.

48. For examples of projects that include environmental health aspects, see Kamarck, *The Tropics and Economic Development*, p. 87 ff.

49. See, for example, Michelle Hibler, "Malaria: Return of a Deadly Foe," *The IDRC Reports* 4 (December 1978): 10. Walter Sullivan (New York Times News Service), "New Vaccine Developments Could Wipe Out Malaria," *The Herald-Telephone* (Bloomington, Ind.), December 28, 1978, p. 14.

50. William Tucker, "The Next Great American Dust Bowl . . . and How to Avert it," *The Atlantic Monthly* 244: 1 (July 1979): 48.

51. The concept of outer limits has been proposed as a useful way of avoiding the focus on rigid, global limits to growth. Instead, limits may be regional, national, or global. Their two basic determinants are: (1) the quantity of existing resources and the laws of nature; and (2) the way in which man conducts his activities with respect to this natural situation. The objective of not transgressing these limits implies achieving a condition of "sustainability" in meeting human needs. For an elaboration of this concept, see William H. Matthews, ed., *Outer Limits and Human Needs* (Uppsala: Dag Hammarskjöld Foundation, 1976), pp. 15-37.

52. As Lester Brown points out ("The Worldwide Loss of Cropland," *Worldwatch Paper* 24 [October 1978], p. 13, cities are voracious consumers of land. In most Third World cities and towns, reliance on local construction materials usually precludes construction of multi-story dwellings. What cannot go out must go up, frequently taking valuable cropland out of production. The same phenomenon occurs in the developed countries. In the United States, vehicle parking alone requires over 600,000 acres of land, and this does not include the land given over to roads and rights-of-way. See David Pementel et al., "Land Degradation: Effects on Food and Energy Resources," *Science* 194 (October 8, 1976): 149.

53. Roger Revelle, "The Resources Available for Agriculture," *Scientific American* 235 (September 1976): 174. Of course, Revelle

is too sophisticated an observer to conclude that this would be feasible, but it does make his point. This entire number is devoted to the problems of food and agriculture.

54. R.L. Smith, "Concept of the Ecosystem," in *The Ecology of Man: An Ecosystem Approach*, ed. Robert Leo Smith (New York: Harper and Row, 1972), esp. pp. 19-20. See also Ian Burton and Kenneth Hewitt, "Ecological Dimensions of Environmental Hazards," in *Human Ecology*, ed. Frederick Sarget II (New York: American Elsevier, 1974), esp. pp. 271-73. Kenneth E. F. Watt, "Man's Efficient Rush Toward Deadly Dullness," *Natural History* 81 (February 1972): 74-84.

55. Tucker, "The Next American Dust Bowl," p. 42. This extremely lucid article reports the growing interest in "organic" forms of cultivation among large-scale farmers in the Midwest as a commercially viable alternative to monocultures, chemical fertilizers, and pesticides. Among the new organic farmers, considerable attention is given to improving the quality of the soil by spreading manure, crop rotation, plowing under the residues of nitrogen-fixing alfalfa, soybeans, and clover, and minimum tillage.

56. In some parts of the Midwest, the reduction in organic matter in the soil has created serious problems of erosion. Of course, erosion is a natural phenomenon. (Soil has been called "rocks on the way to the sea.") Unfortunately, depletion occurs much more quickly than soil formation. Under ideal conditions, top soil is formed at a rate of about 1.5 tons per acre per year while the average loss of agricultural topsoil to erosion in the U.S. alone is estimated to be about 12 tons per acre per year. Pimental et al., "Land Degradation," p. 150. See also Luther J. Carter, "Soil Erosion: The Problem Persists Despite the Billions Spent on It," *Science* 196 (April 22, 1977): 409-411.

57. Erik P. Eckholm, "The Deterioration of Mountain Environments," *Science* 189 (September 5, 1975): 764-70. Much of the information on Nepal is from this article.

58. Ibid., p. 765.

59. Much of this information is from an excellent and comprehensive analysis by John Hunter and George Ntiri, of Michigan State University. See "Speculations on the Future of Shifting Agriculture in Africa," *The Journal of Developing Areas* 12 (January 1978): 183-208. The authors report that as late as 1957, an FAO paper termed shifting agriculture a "backward type of agricultural practice" of a "backward stage of culture" (p. 191).

60. On the role of trees as "nutrient pumps," see Gunnar Poulsen, *Man and Tree in Tropical Africa: Three Essays on the Role of Trees in the African Environment* (Ottawa, Canada: International Development Research Center, 1978).

61. Alan Wood, *The Groundnut Affair* (London: Bodley Head, 1950).

62. For a varied collection of essays that examine the environmental problems resulting from the application of technology, see M. Taghi Farvar and John P. Milton, *The Careless Technology* (Garden City, N.J.: The Natural History Press, 1972).

63. Hunter and Ntiri, "Shifting Agriculture in Africa," p. 207.

64. Larry Rohter, "Amazon Basin's Forests Going Up in Smoke," *The Washington Post*, January 5, 1979, p. A14, quoting American scientist Betty Meggers, "Environment and Culture in the Amazon Basin: An Appraisal of the Theory of Environmental Determinism," in *Environ/Mental: Essays on the Planet as a Home*, ed. Paul Shepard and Daniel McKinley (New York: Houghton Mifflin, 1971); Peter Bunyard, "Brazil: The Way to Dusty Death," *The Ecologist* 4 (April 1974): 89-93; and Robert Campbell, "A Timely Reprieve or a Death Sentence for the Amazon," *Smithsonian* 8: 7 (October 1977): 100-11.

65. Bunyard, "Brazil," p. 90.

66. Rohter, "Amazon Basin's Forests Going Up in Smoke."

67. There is some debate on the extent of latisols in the tropics and whether there is in fact a distinctive soil process of "laterization." See Charles Pearson and Anthony Pryer, *Environment: North and South an Economic Interpretation* (New York: Wiley, 1978), pp. 55 ff.

68. Rohter, "Amazon Basin's Forests Going Up in Smoke."

69. Andre van Dam, "Water Management in the 1980's," *Development Forum*, The Malaysian Center for Development Studies, 7 (December 1977): 10.

70. Noel Brown, Head N.Y. Liason Office, United Nations Environment Program, in Professional Studies and Career Development Division, USAID/PASITAM videotape, "Environment and Development."

71. van Dam, "Water Management in the 1980's," p. 11.

72. Material for this section is from Aloys A. Michel, "The Impact of Modern Irrigation Technology in the Indus and Helmand Basins of Southwest Asia," in *The Careless Technology*, pp. 257-75; idem, "The Kabul, Kunduz, and Helmand Valleys and the National Economy of Afghanistan" (Washington, D.C.: National Academy of Sciences, 1959); Louis Dupree, *Afghanistan* (Princeton, N.J.: Princeton University Press, 1973); Charles R. Maierhofer, "Afghanistan: Drainage and Related Problems," a report prepared for the U.S. Bureau of Reclamation (April 1961).

73. Maierhofer, "Afghanistan," p. 8.

74. Hans Singer, "Keynesian Models of Economic Development and Their Limitations: An Analysis in Light of Gunnar Myrdal's *Asian Drama*," The Asian Institute for Economic Development and Planning, *Occasional Papers* (Bangkok, December 1979), pp. 15-16.

75. UNEP, *The State of the Environment*, p. 23.

76. Commoner, "Summary of the Conference," p. xxi, in Farvar and Milton, *The Careless Technology*.

77. Commoner, "Summary of the Conference," pp. xxiv-xxvii.

/19/

The Other Energy Crisis: Firewood

Erik P. Eckholm

Dwindling reserves of petroleum and artful tampering with its distribution are the stuff of which headlines are made. Yet for more than a third of the world's people, the real energy crisis is a daily scramble to find the wood they need to cook dinner. Their search for wood, once a simple chore and now, as forests recede, a day's labor in some places, has been strangely neglected by diplomats, economists, and the media. But the firewood crisis will be making news—one way or another—for the rest of the century.

While chemists devise ever more sophisticated uses for wood, including cellophane and rayon, at least half of all the timber cut in the world still serves in its original role for humans—as fuel for cooking and, in colder mountain regions, home heating. Nine-tenths of the people in most poor countries today depend on firewood as their chief source of fuel. And all too often, the growth in human population is outpacing the growth of new trees—not surprising when the average user burns as much as a ton of firewood a year.[1] The results are soaring wood prices, a growing drain on incomes and physical energies in order to satisfy basic fuel needs, a costly diversion of animal manures from food production uses to cooking, and an ecologically disastrous spread of treeless landscapes.

The firewood crisis is probably most acute today in the countries of the densely populated Indian subcontinent and in the semi-arid stretches of central Africa fringing the Sahara Desert, though it plagues many other regions as well. In Latin America, for example, the scarcity of wood and charcoal is a problem throughout most of the Andean region, Central America, and the Caribbean.

As firewood prices rise, so does the economic burden on the urban poor. One typical morning on the outskirts of Kathmandu, Nepal's capital city, I watched a steady flow of people—men and women, children and the very old—trudge into the city with heavy, neatly chopped and stacked loads of wood on their backs. I asked my taxi driver how much their loads, for which they had walked several hours into the surrounding hills, would sell for. "Oh wood, a very expensive item!" he exclaimed without hesitation. Wood prices are a primary topic of conversation in Kathmandu these days. "That load costs twenty rupees now. Two years ago it sold for six or seven rupees." This 300 percent rise in the price of fuel wood has in part been prompted by the escalating cost of imported kerosene, the principal alternative energy source for the poor. But firewood prices have risen much *faster* than kerosene prices, a rise that reflects the growing difficulty with which wood is being procured. It now costs as much to run a Kathmandu household on wood as on kerosene.

The costs of firewood and charcoal are climbing throughout most of Asia, Africa, and Latin America. Those who can, pay the price, and thus must forego consumption of other essential goods. Wood is simply accepted as one of the major expenses of living. In Niamey, Niger, deep in the drought-plagued Sahel in West Africa, the average manual laborer's family now spends nearly one-fourth of its income on firewood. In Ouagadougou, Upper Volta, the portion is 20 to 30

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percent.[2] Those who can't pay so much may send their children, or hike out into the surrounding countryside themselves, to forage—if enough trees are within a reasonable walking distance. Otherwise, they may scrounge about the town for twigs, garbage, or anything burnable. In many regions, firewood scarcity places a special burden on women, who are generally saddled with the tasks of hiking or rummaging for fuel.

In some Pakistani towns now, people strip bark off the trees that line the streets; thus, meeting today's undeniable needs impoverishes the future. When I visited the chief conservator of forests in Pakistan's North West Frontier Province at his headquarters in the town of Peshawar, he spoke in a somewhat resigned tone of stopping his car the previous day to prevent a woman from pulling bark off a tree. "I told her that peeling the bark off a tree is just like peeling the skin off a man," he said. Of course the woman stopped, intimidated by what may be the most personal encounter with a senior civil servant she will have in her lifetime, but she doubtless resumed her practice shortly, for what else, as the chief conservator himself asked, was she to do?

It is not in the cities but in rural villages that most people in the affected countries live, and where most firewood is burned. The rural, landless poor in parts of India and Pakistan are now feeling a new squeeze on their meager incomes. Until now they have generally been able to gather free wood from the trees scattered through farmlands, but as wood prices in the towns rise, landlords naturally see an advantage in carting available timber into the nearest town to sell rather than allowing the nearby laborers to glean it for nothing. This commercialization of firewood raises the hope that entrepreneurs will see an advantage in planting trees to develop a sustainable, labor-intensive business, but so far a depletion of woodlands has been the more common result. And the rural poor, with little or no cash to spare, are in deep trouble in either case.

With the farmland trees and the scrubby woodlands of unfarmed areas being depleted by these pressures, both the needy and the ever-present entrepreneurs are forced to poach for fuel wood in the legally protected, ecologically and economically essential national forest reserves. The gravity of the poaching problem in India has been reflected in the formation of special mobile guard-squads and mobile courts to try captured offenders, but law enforcement measures have little effect in such an untenable situation. Acute firewood scarcity has undermined administrative control even in China, where trees on commune plantations are sometimes surreptitiously uprooted for fuel almost as soon as they are planted.[3]

Trees are becoming scarce in the most unlikely places. In some of the most remote villages in the world, deep in the once heavily forested Himalayan foothills of Nepal, journeying out to gather firewood and fodder is now an *entire day's* task. Just one generation ago the same expedition required no more than an hour or two.[4]

Because those directly suffering its consequences are mostly illiterate, and because wood shortages lack the photogenic visibility of famine, the firewood crisis has not provoked much world attention. And, in a way, there is little point in calling this a world problem, for fuel-wood scarcity, unlike oil scarcity, is always localized in its apparent dimensions. Economics seldom permit fuel wood to be carried or trucked more than a few hundred miles from where it grows, let alone the many thousands of miles traversed by the modern barrel of oil. To say that firewood is scarce in Mali or Nepal is of no immediate consequence to the boy scout building a campfire in Pennsylvania, whereas his parents have already learned that decisions in Saudi Arabia can keep the family car in the garage.

Unfortunately, however, the consequences of firewood scarcity are seldom limited to the economic burden placed on the poor of a particular locality, harsh as that is in itself. The accelerating degradation of woodlands throughout Africa, Asia, and Latin America, caused in part by fuel gathering, lies at the heart of the profound challenges to environmental stability and land productivity reviewed in this book—accelerated soil erosion, increasingly severe flooding, creeping deserts, and declining soil fertility.

The Dust Bowl years in the Great Plains of the thirties taught Americans the perils of devegetating a region prone to droughts. The images provided by John Steinbeck in *The Grapes of Wrath* of the human dislocation wrought by that interaction of people, land, and climate could easily describe present-day events in large semi-arid stretches of Africa along the northern and southern edges of the Sahara, and around the huge Rajasthan Desert in northwest India. Overgrazing by oversized herds of cattle, goats, and sheep is the chief culprit, but gathering of fuel wood is also an important contributor to the destruction of trees in these regions. Firewood is a scarce and expensive item throughout the Sub-Saharan fringe of Africa, all the way from Senegal to Ethiopia, but citizens in towns like Niamey are paying a much higher price than they realize for their

cooking fuel. The caravans that bring in this precious resource are contributing to the creation of desert-like conditions in a wide band below the desert's edge. Virtually all trees within seventy kilometers of Ouagadougou have been consumed as fuel by the city's inhabitants, and the circle of land "strip-mined" for firewood—without reclamation—is continually expanding.

In the Indian subcontinent, the most pernicious result of firewood scarcity is probably not the destruction of tree cover itself, but the alternative to which a good share of the people in India, Pakistan, and Bangladesh have been forced. A visitor to almost any village in the subcontinent is greeted by omnipresent pyramids of hand-molded dung patties drying in the sun. In many areas these dung cakes have been the only source of fuel for generations, but now, by necessity, their use is spreading further. Between three hundred and four hundred million tons of wet dung—which shrink to sixty to eighty million tons when dried—are annually burned for fuel in India alone, robbing farmland of badly needed nutrients and organic matter. The plant nutrients wasted annually in this fashion in India equal more than a third of the country's chemical fertilizer use. Looking only at this direct economic cost, it is easy to see why the country's National Commission on Agriculture recently declared that "the use of cow dung as a source of non-commercial fuel is virtually a crime." Dung is also burned for fuel in parts of the Sahelian zone in Africa, Ethiopia, Iraq, and in the nearly treeless Andean valleys and slopes of Bolivia and Peru, where the dung of llamas has been the chief fuel in some areas since the days of the Incas.[5]

Even more important than the loss of agricultural nutrients is the damage done to soil structure and quality through the failure to return manures to the fields. Organic materials—humus and soil organisms which live in it—play an essential role in preserving the soil structure and fertility needed for productive farming. Organic matter helps hold the soil in place when rain falls and wind blows, and reduces the wasteful, polluting runoff of chemical nutrients where they are applied. Humus helps the soil absorb and store water, thus mitigating somewhat the impact on crops of drought periods. These considerations apply especially to the soils in tropical regions where most dung is now burned, because tropical topsoils are usually thin and, once exposed to the burning sun and torrential monsoon rains, are exceptionally prone to erosion and to loss of their structure and fertility.

Peasants in the uplands of South Korea have adopted a different, but also destructive way to cope with the timber shortage. A United Nations forestry team visiting the country in the late 1960s found not only that live tree branches, shrubs, seedlings, and grasses were cut for fuel; worse, many hillsides were raked clean of all leaves, litter, and burnable materials. Raking in this fashion, to meet needs for home fuel and farm compost, robs the soil of both a protective cover and organic matter, and the practice was cited by the UN experts as "one of the principal causes of soil erosion in Korea." Firewood scarcity similarly impairs productivity in eastern Nigeria, where the Tiv people have been forced to uproot crop residues after the harvest for use of fuel. Traditionally, the dead stalks and leaves have been left to enrich the soil and hold down erosion.[6]

The increasing time required to gather firewood in many mountain villages of Nepal is leading to what the kingdom's agricultural officials fear most of all. For once procuring wood takes too long to be worth the trouble, some farmers start to use cow dung, which was formerly applied with great care to the fields, as cooking fuel. As this departure from tradition spreads, the fertility of the hills, already declining due to soil erosion, will fall sharply. In the more inaccessible spots, there is no economic possibility whatsoever of replacing the manure with chemical fertilizers.

And so the circle starts to close in Nepal, a circle long completed in parts of India. As wood scarcity forces farmers to burn more dung for fuel, and to apply less to their fields, falling food output will necessitate the clearing of ever larger, even steeper tracts of forest—intensifying the erosion and landslide hazards in the hills, and the siltation and flooding problems downstream in India and Bangladesh.

Firewood scarcity, then, is intimately linked in two ways to the food problem facing many countries. Deforestation and the diversion of manures to use as fuel are sabotaging the land's ability to produce food. Meanwhile, as an Indian official put it, "Even if we somehow grow enough food for our people in the year 2000, how in the world will they cook it?"

B. B. Vohra, a senior Indian agricultural official who has pushed his government ahead on numerous ecological causes, shook his head as we talked in his New Delhi office. "I'm afraid that we are approaching the point of no return with our resource base. If we can't soon build some dramatic momentum in our reforestation and soil conservation programs, we'll find ourselves in a downward spiral with an irresistible mo-

mentum of its own." Without a rapid reversal of prevailing trends, in fact, India will find itself with a billion people to support and a countryside that is little more than a moonscape. But the politicians, in India and other poor countries, will take notice when they realize that, if people can't find any firewood, they will surely find something else to burn.

The firewood crisis is in some ways more, and in others less, intractable than the energy crisis of the industrialized world. Resource scarcity can usually be attacked from either end, through the contraction of demand or the expansion of supply. The world contraction in demand for oil in 1974 and early 1975, for example, helped to ease temporarily the conditions of shortage.

The poor, like the rich, need to conserve energy. Millions of families cook over wood or charcoal stoves that are extremely inefficient in the use of heat. Millions more cook over open wood fires. The wide adoption of inexpensive, thermodynamically efficient wood and charcoal stoves could substantially reduce per capita firewood needs in every developing country.

Even if more efficient stoves are disseminated, however, future firewood needs in the developing countries will, in the absence of suitable alternative energy sources, be heavily influenced by population growth trends. Firewood scarcity will undoubtedly influence the urgency with which governments address the population problem in the years ahead.

Even if the demographers are surprised by quick progress on the population front over the next few decades, the demand for basic resources like firewood will still push many countries to their limits. Fortunately trees, unlike oil, are a renewable resource when properly managed. The logical immediate response to the firewood shortage, one that will have many incidental ecological benefits, is to plant more trees in plantations, on farms, along roads, in shelter belts, and on unused land throughout the rural areas of the poor countries. For many regions, fast-growing tree varieties are available that can be culled for firewood inside of a decade.

The concept is simple, but its implementation is not. Governments in nearly all the wood-short countries have had tree-planting programs for some time—for several decades in some cases. National forestry departments in particular have often been aware of the need to boost the supply of wood products and the need to preserve forests for an habitable environment. But several problems have generally plagued tree-planting programs.

One is the sheer magnitude of the need for wood and the scale of the growth in demand. Population growth, which surprised many with its acceleration in the post-war era, has swallowed the moderate tree-planting efforts of many countries, rendering their impact almost negligible. Wood-producing programs will have to be undertaken on a far greater scale than most governments presently conceive if a significant dent is to be made in the problem.

The problem of scale is closely linked to a second major obstacle to meeting this crisis: the perennial question of political priorities and decision-making time-frames. With elections to win, wars to fight, dams to build, and hungry people to feed, it is hard for any politician to concentrate funds and attention on a problem so multi-dimensional and seemingly long-term in nature. Some ecologists in the poor countries have been warning their governments for decades about the dangers of deforestation and fuel shortages, but tree-planting programs don't win elections. This phenomenon is, of course, quite familiar to all countries, not just the poorest. In the United States, resource specialists pointed out the coming energy crisis throughout the 1960s, but it took a smash in the face in 1973 to wake up the government, and, as of late 1975, the country still can hardly be said to have tackled the energy challenge head-on.

Despite these inherent political problems, India's foresters made a major breakthrough a few years back as the government drew up its five-year development plan for the mid-to-late seventies. Plans were laid for the large-scale establishment of fast-growing tree plantations, and for planting trees on farms and village properties throughout the country.[7] A program is going ahead now, but there have been some unexpected events since the projects were first contemplated two or three years ago: the quintupling of the world price of petroleum, the tripling in price and world shortages of grains and fertilizers, and the subsequent wholesale diversion of development funds to maintenance and emergencies in order to merely muddle through 1974 without a major famine and a total economic breakdown. India's development efforts have been set back several years by recent events, and forestry programs have not been immune to this trend.

Even with the right kind of political will and the necessary allocation of funds, implementing a large-scale reforestation campaign is a complex and difficult

process. Planting millions of trees and successfully nurturing them to maturity is not a technical, clearly defined task like building a dam or a chemical-fertilizer plant. Tree-planting projects almost always become deeply enmeshed in the political, cultural, and administrative tangles of a rural locality; they touch upon, and are influenced by, the daily living habits of many people, and they frequently end in failure.

Most of the regions with too few trees also have too many cattle, sheep, and goats. Where rangelands are badly overgrazed, the leaves of a young sapling tempt the appetites of foraging animals. Even if he keeps careful control of his own livestock, a herdsman may reason that if his animals don't eat the leaves, someone else's will. Marauding livestock are prime destroyers of tree-planting projects throughout the less-developed world. Even if a village is internally disciplined enough to defend new trees from its own residents, passing nomads or other wanderers may do them in. To be successful, then, reforestation efforts often require a formidable administrative effort to protect the plants for years—not to mention the monitoring of timber-harvesting and replanting activities once the trees reach maturity.

Village politics can undermine a program as well. An incident from Ethiopia a few years back presents an extreme case, but its lessons are plain. A rural reforestation program was initiated as a public works scheme to help control erosion and supply local wood needs. The planting jobs were given to the local poor, mostly landless laborers who badly needed the low wages they could earn in the planting program. Seedlings were distributed, planting commenced, and all seemed to be going well—until the overseers journeyed out to check the progress. They found that in many areas the seedlings had been planted upside down! The laborers, of course, well knew the difference between roots and branches; they also knew that given the feudal land-tenure system in which they were living, most of the benefits of the planting would flow one way or another into the hands of their lords. They were not anxious to work efficiently for substandard wages on a project that brought them few identifiable personal returns.[8]

In country after country, the same lesson has been learned: tree-planting programs are most successful when a majority of the local community is deeply involved in planning and implementation, and clearly perceives its self-interest in success. Central or state governments can provide stimulus, technical advice, and financial assistance, but unless community members clearly understand why lands to which they have traditionally had free access for grazing and wood gathering are being demarcated into a plantation, they are apt to view the project with suspicion or even hostility. With wider community participation, on the other hand, the control of grazing patterns can be built into the program from the beginning, and a motivated community will protect its own project and provide labor at little or no cost.

An approach like this—working through village councils, with locally mobilized labor doing the planting and protection work—is now being tried in India. There are pitfalls: Indian villages are notoriously faction-ridden, and the ideal of the whole community working together for its own long-term benefit may be somewhat utopian. But if it can get underway on a large scale, the national program in India may succeed. Once given a chance, fast-growing trees bring visible benefits quickly, and they just could catch on. The Chinese have long used the decentralized, community labor-mobilizing approach to reforestation, apparently with considerable success.

A new program of global public education on the many benefits of reforestation, planned by the United Nations Environment Program, will hopefully direct more attention to the tremendous global need for tree planting. Whatever the success of reforestation projects, however, the wider substitution of other energy sources for wood can also contribute greatly to a solution of the firewood problem. A shift from wood-burning stoves to those running on natural gas, coal, or electricity has indeed been the dominant global trend in the last century and a half. As recently as 1850, wood met 91 percent of the fuel needs of the United States, but today in the economically advanced countries, scarcely any but the intentionally rustic, and scattered poor in the mountains, chop wood by necessity anymore. In the poor countries, too, the proportion of wood users is falling gradually, especially in the cities, which are usually partly electrified, and where residents with any income at all may cook their food with bottled gas or kerosene. Someone extrapolating trends of the first seven decades of this century might well have expected the continued spread of kerosene and natural gas use at a fairly brisk pace in the cities and into rural areas, eventually rendering firewood nearly obsolete.

Events of the last two years, of course, have abruptly altered energy-use trends and prospects everywhere.

The most widely overlooked impact of the fivefold increase in oil prices, an impact drowned out by the economic distress caused for oil-importing countries, is the fact that what had been the most feasible substitute for firewood, kerosene, has now been pulled even farther out of reach of the world's poor than it already was. The hopes of foresters and ecologists for a rapid reduction of pressures on receding woodlands through a stepped-up shift to kerosene withered overnight in December, 1973, when OPEC announced its new oil prices. In fact, the dwindling of world petroleum reserves and the depletion of woodland reinforce each other; climbing firewood prices encourage more people to use petroleum-based products for fuel, while soaring oil prices make this shift less feasible, adding to the pressures on forests.

The interconnections of firewood scarcity, ecological stress, and the broader global energy picture set the stage for some interesting, if somewhat academic, questions about a sensible disposition of world resources. In one sense it is true that the poor countries, and the world as a whole, have been positively influenced by the OPEC countries, which, through price hikes and supply restrictions, are forcing conservation of a valuable and rapidly disappearing resource, and are not letting the poor countries get dangerously hooked on an undependable energy supply. In a world in which energy, ecology, and food were sensibly managed, however, the oil distribution picture would look far different. The long-term interest in preserving the productive capacity of the earth and in maximizing welfare for the greatest number of people might argue for lower prices and a rapid *increase*, not a halt, in the adoption of kerosene and natural gas in the homes of the poor over the next two decades. This, in turn, would be viable for a reasonable time period only if the waste and comparatively frivolous uses of energy in the industrial countries, which are depleting petroleum reserves so quickly, were cut sharply. It is not so far-fetched as it might first seem to say that today's driving habits in Los Angeles, and today's price and production-level decisions in the Persian Gulf, can influence how many tons of food are lost to floods in India, and how many acres of land the Sahara engulfs, in 1980.

Fossil fuels are not the only alternate energy source under consideration, and, over the coming decades, many of those using firewood, like everyone else, will have to turn in other directions. Energy sources that are renewable, decentralized, and low in cost must be developed. Nothing, for example, would be better than a dirt-cheap device for cooking dinner in the evening with solar energy collected earlier in the day. But actually developing such a stove and introducing it to hundreds of millions of the world's most tradition-bound and penniless families is another story. While some solar cookers are already available, the cost of a family unit, at about thrity-five to fifty dollars, is prohibitive for many, since, in the absence of suitable credit arrangements, the entire amount must be available at once. Mass production could pull down the price, but the problem of inexpensively storing heat for cloudy days and evenings has not been solved.[9] The day may come in some countries when changes in cooking and eating habits to allow maximum use of solar cookers will be forced upon populations by the absence of alternatives.

Indian scientists have pioneered for decades with an ideal-sounding device that breaks down manures and other organic wastes into methane gas for cooking and a rich compost for the farm. Over eight thousand of these bio-gas plants, as they are called, are now being used in India. Without a substantial reduction in cost, however, they will only slowly infiltrate the hundreds of thousands of rural villages, where the fuel problem is growing. Additionally, as the plants are adopted, those too poor to own cattle could be left worse off than ever, denied traditional access to dung, but unable to afford bio-gas.[10] Still, relatively simple and decentralized devices like solar cookers and bio-gas plants will likely provide the fuel sources of the future in the poor countries.

In terms of energy, Nepal is luckier than many countries in one respect. The steep slopes and surging rivers that cause so many environmental problems also make Nepal one of the few remaining countries with a large untapped hydroelectric potential. The latent power is huge, equaling the hydroelectric capacity of Canada, the United States, and Mexico combined. Exploitation of this resource will be expensive and slow, but will relieve some of the pressures being placed on forests by the larger towns of Nepal and northern India. On the other hand, cheap electricity will only partly reduce firewood demands, since the electrification of isolated villages in the rugged Himalayas may never be economically feasible.

The firewood crisis, like many other resource problems, is forcing governments and analysts back to the basics of human beings' relationship with the land—back to concerns lost sight of in an age of macroeconomic models and technological optimism. Aware-

ness is spreading that the simple energy needs of the world's poorest third are unlikely ever to be met by nuclear power plants, any more than their minimum food needs will be met by huge synthetic-protein factories.

Firewood scarcity and its attendant ecological hazards have brought the attitude of people toward trees into sharp focus. In his essay "Buddhist Economics," E.F. Schumacher praises the practical as well as esoteric wisdom in the Buddha's teaching that his followers should plant and nurse a tree every few years.[11] Unfortunately, this ethical heritage has been largely lost, even in the predominantly Buddhist societies of Southeast Asia. In fact, most societies today lack a spirit of environmental cooperation—not a spirit of conservation for its own sake, but one needed to guarantee human survival amid ecological systems heading toward collapse.

This will have to change, and fast. The inexorable growth in the demand for firewood calls for tree-planting efforts on a scale more massive than most bureaucrats have ever even contemplated, much less planned for. The suicidal deforestation of Africa, Asia, and Latin America must somehow be slowed and reversed. Deteriorating ecological systems have a logic of their own; the damage often builds quietly and unseen for many years, until one day the system falls asunder with lethal vengeance. Ask anyone who lived in Oklahoma in 1934, or Chad in 1975.

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Health Hazards

Andrew M. Kamarck

Recent economic literature reflects an amazing lack of consideration of the impact of disease on economic development. Even in so comprehensive a collection of essays as *Agricultural Development and Economic Growth,* D. M. Hegsted pointed out that "this volume has not considered the general problems of public health, sanitation and medical care. Ill people are obviously poor and inefficient producers. . . . Land use and agricultural development may be determined by parasitic and infectious diseases."[1]

It is probably entirely justified for most economists working on problems of the more developed countries to ignore the economic impact of human disease—it can be assumed that the average economic man is healthy and is in full command of his body and mind and that sickness, though not insignificant, is not normally a major factor in the growth and functioning of the economy. But this assumption is false in today's less-developed countries in the Tropics. Exactly the opposite assumption is more likely to be true. Lack of good health affects a person's attitude toward work, initiative, creativity, learning ability, energy, and capacity for heavy or sustained work or thought. In the less-developed countries a person who has not been or is not being substantially affected by poor health is the exception.

It is possible that, aside from sustaining an environment favorable to disease, the tropical climates also have a direct adverse impact on work efficiency, creativity, and initiative of humans and so, in this respect, are still another handicap to the economic growth of the less-developed countries. In his pioneering work, D. H. K. Lee concludes that "the problem of possible levels of activity has not been adequately studied, at least with the objectivity that science requires."[2] Lee believes that loss of mental initiative is probably the most important single direct result of exposure to tropical environment. While accuracy may be noticeably affected in the test results of poorly motivated persons, it is relatively unaffected in others except under extreme or unusual conditions.[3] In the nearly twenty years since Lee's book there has been but little further work on the subject. In 1962 the U.S. National Academy of Sciences did report:

> Laboratory studies on human performance in hot conditions show that there is a deterioration in performance somewhere between 81°F and 86°F effective temperature. [But] the tasks used in laboratory hot rooms are synthetic compared with those in industrial work and the social-psychological relationships of the subjects of the experiments are quite artificial.[4]

In 1970 Neville Billington, director of the British Heating and Ventilation Research Association, detailed some research results concerning human output and temperature ranges in a paper he titled "Human Performance":

Testing organization	Work	Temperature range in degrees Celsius	Change in output	Percentage of change for each degree Celsius
New York Comm. on Ventilation	Weight-lifting	20-24	−15	−4
Schweisheimer	Various tasks	about 27	−3 to −10	−2
Hasse	Mining	18-30	−25	−2
Mackworth	Telegraphy	26-36	—	−2

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It appears that a threshold temperature exists, varying for different jobs, and that, above this, increases in temperature bring about decreases in production.[5]

Basically, the problem with this subject is that there has been very little research on it and what there is has been done mostly on people in temperate climates, working under hot conditions. Even casual observation shows that productivity may suffer when a person is too hot—or too cold. The very existence of air-conditioning and space heating in homes, offices, and factories serves to prove this. What has not been demonstrated is that economic activity (outside of agriculture) in hot climates where air-conditioning is regarded as necessary is handicapped compared to activity in temperate climates where heating is necessary in winter. But agriculture is not air-conditioned and in most developing countries agriculture is the predominant economic sector. If tropical climates as such do adversely affect human productivity, initiative, and creativity, this would slow down the pace of economic growth in the tropical countries as long as agriculture remains an important activity.

A large number of factors influence the health of a population. Over the developing countries, as a whole, the most important causes of poor health undoubtedly, to my mind, stem from the prevailing poverty. Except in a few instances—perhaps river blindness in areas of western Africa—the argument cannot be made that the tropical climate is the decisive factor in this reinforcing relation between disease and poverty. But there is sufficient evidence that tropical climates make the problem of sickness sufficiently more difficult to handle to warrant the conclusion that less-developed countries in the Tropics have a harder task in this regard than countries in the Temperate Zones. This then is another reason why developing countries in the Tropics may lag behind in the world process of economic development.

The difference in average life expectancy at birth in the less-developed countries, 49 years, and in the industrialized countries, 70.4 years, indicates the differences in health conditions between the two areas.[6] But it does not sufficiently bring home the fact that the population in the developing countries typically has to adjust to living with disease. To illustrate: in Colombia, 89 percent of the individuals sampled in an intensive nutritional study were infested with some form of parasites; in Peru only 9 out of 122 men sampled in the armed forces had no parasitic infection; autopsy records in some areas of east Africa indicate that more than 90 percent of the persons examined were harboring beef tapeworms.[7] John D. Thomas has written that human beings are more heavily parasitized in the African continent than in any other part of the world, with an average two infections per man. Schistosomiasis is the dominant infection, affecting nearly half the population.[8] A study of six villages in the northeast of Brazil found the average person harbored two species of parasitic diseases and the hemoglobin content of his blood was less than half of what is medically regarded as normal.[9] On Ukara Island in Lake Victoria, Tanzania, only 0.6 percent of the population was found free of parasitic infection. Of adults over 40 years, the infection rates were 38 percent for hookworm, 38 percent for bilharzia, and 37 percent for filariasis.[10]

Research studies by a World Bank team in Indonesia found that of the workers on three construction sites tested 84 to 87 percent had hookworm, 50 to 67 percent had roundworm (*Ascaris*), and 44 to 58 percent had whipworm (*Trichiuris trichura*). Of the workers on the plantation sites tested, 88 percent had hookworm, 49 percent had roundworm, and 63 percent had whipworm. These infections resulted in iron deficiency anemia in at least 45 percent of the adult male workers, whose output was around 20 percent lower than that of nonanemic workers.[11] Helminth (intestinal worm) infestation rates in children six years old were 95 percent in Sri Lanka, 97 percent in Bangladesh, and 93 percent in Venezuela.

The greater incidence of disease in tropical compared to temperate climates stems from three basic sets of circumstances. First, tropical countries are subject to the diseases of the Temperate Zones and have in addition some diseases that the temperate countries do not. Next, the Tropics offer more hospitable conditions for some diseases than do the Temperate Zones. For example, most vector-borne diseases are easier to control in the Temperate Zones because winter kills the vector. Last, in some diseases, infected human beings can continue to function more effectively in a cool climate than in the Tropics. This is true of some cases of trichinosis and of amebic dysentery. Yaws, a disease caused by a spirochete, heals by itself when the patient leaves a hot and humid climate for a dry and cool environment.[12]

The pattern of causes of deaths roughly indicates differences between the health situation of industrialized countries in the Temperate Zones and that of the less-developed countries in the Tropics. The major differences are that infectious, parasitic, and respiratory diseases account for around 44 percent of the

deaths in the developing countries but only 11 percent in the developed countries, while cancer and diseases of the circulatory system together cause 19 percent of the deaths in the developing countries and 47 percent in the developed countries.[13]

Carl M. Stevens points out in a pioneering analysis that the relation between health and economic development may be very complex and that research is badly needed to establish the true relation better. In the short run, improved health is generally thought to result in an increased supply of labor, through increased productivity of the individual and therefore in increased income. However, much greater benefits of improved health may come rather in the long run and through the improvement of the health of the group or community. Improvement in one individual's health may have little measurable effect on production in agriculture, for example, because the existing organization modes and technology were set up within a framework of existing constraints, including the ill health of most farm laborers. A factory offers an even better example when the pace of the whole production process has been set to adapt to the poor health of the majority of the workers. As Stevens says: "It is reasonable to suppose that . . . ill health exacts its greatest toll on productivity [by] contributing importantly to the failure to adopt otherwise available innovations, both technical and organizational, which have a far greater impact on productivity than that to be had from labor augmentation in the context of the traditional techniques."[14] In the case of agriculture, farmers in poor health have insufficient physical energy both to do their traditional tasks and to invest labor in improved technology; they also lack the mental energy and attention span necessary to plan ahead and innovate beyond the well-worn grooves of custom. Similar considerations apply to nonagricultural pursuits. Sick children do not learn well in school. If students are sick, the resources allocated to education are partly wasted and schools do not produce individuals with as high a level of basic skills as they would with healthier students. The labor force is also less efficient because people with scarce skills are neither as effectively used nor as productive because of their high incidence of poor health.

As Stevens says, not only does the status of a person's health impact on productivity, it is in fact an important part of his welfare. Economic development does not mean only increase in personal incomes; personal incomes are rather a proxy for individual well-being. While not quantifiable as easily as money incomes, good health may be regarded as an important component of real income.

Among the major diseases influencing mortality patterns and affecting the productivity of people are bilharzia, malaria, river blindness, and a host of other parasitic diseases, such as sleeping sickness.

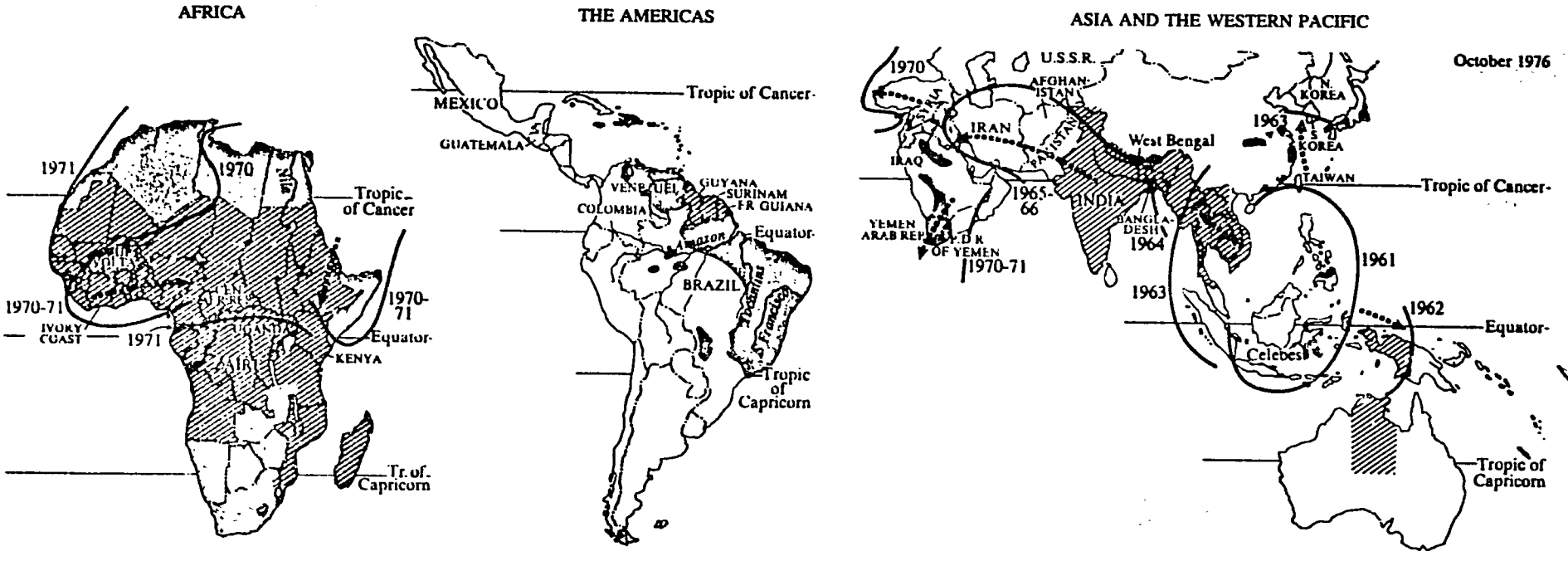
BILHARZIA

The debilitating disease bilharzia (schistosomiasis, sometimes called snail fever or liver fluke) affects some 150 million to 200 million people in Africa, the Middle East, and Latin America. Millions are afflicted in Mainland China, where the disease is widespread in the Yangtze valley and presumably in south China. According to doctors in Peking's Anti-Imperialist Hospital, it is China's most serious health problem.[15] In Egypt the countryside is almost saturated with the disease. The World Health Organization, in its Egypt 10 Project, found in six sample villages the incidence among humans was at least 50 percent, and in one village at least 70 percent. Bilharzia is considered by the World Health Organization to be the most important parasitic world health problem. The disease is still out of control and continues to spread to new areas as an unwelcome by-product of dam and canal construction with the migration of infected workers into new areas (see map 1).

Bilharzia is a cruel, debilitating, sometimes fatal disease. In its chronic stages, the disease may produce severe, irreversible liver damage, an enlarged spleen, and a bloated abdomen, while the rest of the body becomes emaciated. So far neither a generally applicable cure nor a system of control has been found. There has been some progress in recent years. Understanding of how to cope with the disease has increased. Chemical therapy is being developed. The available cures used to be almost as unpleasant as the disease: a new drug can effectively cure the disease with one injection, but it has side effects and cannot be used in a mass campaign.

There have been a few efforts to establish a cost-benefit analysis of bilharzia control, but the results are somewhat inconclusive. In areas where bilharzia is endemic it is difficult to separate out the economic effects of the disease alone, since the debilitating effects of the disease become associated with malnutrition and confused with the impact of other parasites and other diseases. What is perhaps the best study in the field found that the impact of one variety of the disease,

MAP 1
Geographical Distribution of Bilharzia, Leprosy, and Cholera



The boundaries shown on this map do not imply endorsement or acceptance by the World Bank and its affiliates.

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schistosomiasis japonicum, was estimated to cut working ability of patients from 15 to 18 percent in mild cases and 72 to 80 percent in severe cases.[16]

The agent of bilharzia is a parasitic worm, or schistosome, that is a quarter of an inch to an inch in length when fully grown. There are three main species: *Schistosoma haematobium*, which causes damage chiefly in the bladder and anal regions but often also affects the kidneys and the genital tract in women; *S. mansoni*, which affects the intestine, spleen, and liver; and *S. japonicum*, which chiefly affects the liver and spleen and which in a child can result in infantilism. The link between the worm and the disease was discovered in 1852 by Theodore Bilharz, but the complicated life cycle of the worm was not fully worked out until 1910.

The life cycle begins with a male and female schistosome mating within a human vein, in which the worm's thorned eggs are laid. The eggs of each female number in the thousands. These eggs work their way into the bladder or intestines, lacerating the host's tissues enroute. They damage the liver and produce a gradual internal poisoning of the victim, then cause hemorrhages in the intestines and interfere with the absorption of food or cause lesions of the bladder that may result in cancer. The eggs are then excreted. The eggs hatch into larval forms that to survive must find a suitable host snail—only certain species are acceptable hosts. Within the snail, the larva goes through a process of development that results in the production of thousands of minute cercariae. These leave the snail and enter the water of the lake, pond, stream, or irrigation ditch and swim about looking for a mammal host. When they find one drinking or bathing in the water, they easily penetrate the skin, reach a vein and travel to the liver or other host organ. Within four to six weeks the cercariae are mature worms; they mate and the cycle begins again.

A human body is sensitive to the invasion of the cercariae and the initial reaction is fever, chills, headaches, or extreme fatigue. The eggs as mentioned above cause substantial damage to the body on their way out. In all forms of bilharzia, there is a weakening of the body and decreased resistance to still other infections.

The disease has been known since antiquity, and in recent years it has become evident that the bilharzia is spreading rapidly in the developing countries and only Japan has succeeded in controlling it through strict sanitation measures.

Synthetic organic molluscicides are now available and effective in killing host snails under field conditions in irrigation channels. This also kills fish, however. Snail control in marshes and lakes is more difficult. A control program of killing snails in an area of over 340,000 hectares in Egypt with 750 kilometers of open drains was estimated to cost about $5 million in 1972.

It has been found that most snails in Egypt lose their infections in the winter (January, February, and March). The semitropical countries thus have a considerable advantage in trying to control the disease although so far this has not yet resulted in successful control of the disease in Egypt.

In the two International Development Association credits for rural development projects in Malawi and the Malagasy Republic extended by the World Bank in 1972, provision was made for bilharzia control. Farmers would be educated in methods of avoiding infection, bilharzia-free water supplies would be provided, and hospital and clinic facilities to cure those infected would be established. Close watch on the results of these projects will be kept to provide information as to how successful these measures turn out to be in both medical and economic terms.

MALARIA

Malaria is one of the most important reasons why development in the Tropics has lagged behind. Malaria probably originated in Africa and spread from there to the other Tropics, the sub-Tropics, and parts of the Temperate Zones during the later Roman Empire and the Middle Ages.

The cause of malaria is a protozoan microbe, one of four species of the genus *Plasmodium*. It may spend part of its life cycle in the human body and the rest in one or another of the sixty or seventy species of *Anopheles* mosquito. In the human body the microbes penetrate the liver and the red blood cells, multiplying in the process and destroying the cells. The different species of plasmodia behave somewhat differently in the body. The severest form is *Plasmodium falciparum*, but all can be fatal, all may prostrate the victim through regular recurrence of chills and fever at intervals of one, two, or three days, and all tend, if untreated, to hang on for months and sometimes years.

As winter kills off most of the mosquito vectors of the disease, malaria is more easily controlled in the

Temperate Zones. In fact, one of the principal vectors of malaria (and of filariasis), the mosquito *Anopheles gambias*, can only live in the Tropics.[17] The occurrence of malaria is now largely restricted to the Tropics and the poor countries of the world: most of Africa; parts of Central and South America; and west, south, and southeast Asia. The World Health Organization has estimated that (outside of Mainland China, northern Vietnam, and North Korea), in 1965, there were around 100 million cases of malaria in the world from which 1 million people died. This disease has probably had the greatest impact on history and economic development over thousands of years. Malaria's spread contributed to the decline of the Mesopotamian civilizations and of the Roman Empire. It is believed to have killed Alexander the Great and Oliver Cromwell at the height of their careers. It prevented the French from constructing the Panama Canal. Because Africans were more resistant to malaria, it stimulated the introduction and the spread of black slavery into the United States, the Caribbean countries, and Brazil. With yellow fever, it kept European settlers out of most of tropical Africa.

There has been little research on the economic developmental impact of malaria and what there is has not been followed up [18] In earlier centuries, malaria may have kept people out of areas subject to the disease, but this is no longer the case. Its main impact now is through an increase in number of deaths and a reduction in the efficiency of the labor force.

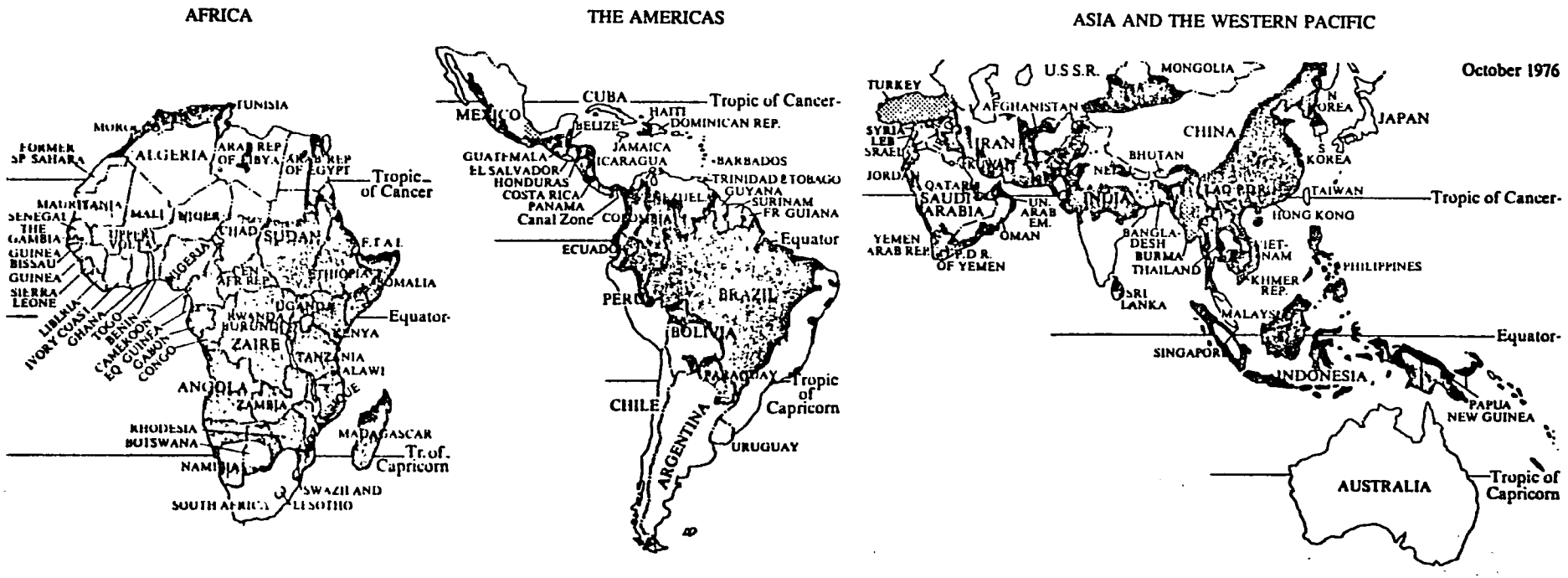
Children who contract malaria are more severely affected during their childhood—their learning years—than during their adult life—their working years. Still, the effect may be severe in both cases. Adults contracting the disease for the first time are more seriously ill than those who have had it since childhood and survived. Michael Colbourne estimates that it is likely at least one African child in twenty is killed by malaria, and possibly one in ten.[19] Most children affected are seriously sick in spells and their ability to learn is consequently damaged. As the victim gets older, attacks may be less severe but the occasion of an attack may still keep an adult from working. If attacks occur at a time of year when the soil has to be cultivated, the farm weeded, or the crop harvested, they can have a major impact on output. At other times, the disease may not keep the worker from working but it may affect his productivity.

The full economic impact of malaria is difficult to trace. For example, malaria-infected mothers find it difficult or impossible to breast-feed their children, thus leading to infant malnutrition as well as a lowered resistance to highly prevalent parasitic and viral infections. If infant malnutrition does impact on mental capacity later in life, this would be still another important economic effect of this disease.

The quick eradication of malaria through spraying, as was accomplished in 1947 in Ceylon (now Sri Lanka), may result in an acceleration of population growth—a large number of children continue to be born even though the need to offset losses to malaria is no longer present. It is not clear in such cases whether the economic costs of larger population growth offset the economic benefits from resources unspent in bringing up children who otherwise would have died prematurely from malaria. The gain in welfare and happiness is undeniable, both for those parents whose children survive and for the children who live without being periodically tortured by the disease. Among the other nonquantifiable benefits from eradication is the difference in human creativity and productivity between a person in good health and one who is ill, not to speak of the difference in attitude toward work and in individual initiative.

The nineteenth century saw malaria disappear from northern and most of western Europe and North America. Medicine's introduction of quinine treatment interrupted the transmission of the disease. In the colder temperate climates, frost already eliminated the vector carrying malaria, the mosquito, for part of the year. As many swamps were drained, the mosquito found fewer refuges during that period when it could survive in the temperate climates. Around the end of the nineteenth century, a combination of discoveries resulted in sufficient knowledge about malaria and how it is spread to make possible systematic attempts to roll it back further. After World War II, malaria was essentially eradicated from the American South and the northern shores of the Mediterranean, and brought under control in a few tropical areas such as Sri Lanka, Guyana, and to a large extent India. Malaria is spreading again in Sri Lanka and India. In 1963, only 17 cases were diagnosed in the whole of Sri Lanka, but over 300,000 cases were diagnosed in 1974. The number of cases reported in India climbed to 2.5 million in 1974. In Africa, in light malarious areas such as Rhodesia. Kigezi in Uganda, and some of the forest areas of Liberia and Cameroon, antimalaria insecticide spraying programs have satisfactorily interrupted malaria transmission. In

MAP 2
Geographical Distribution of Malaria



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other areas—the north of Cameroon, Tanzania, and the savanna country of west Africa—eradication campaigns were attempted but transmission has continued. So far, an effective and practicable method for stopping the transmission of malaria all over Africa has not been discovered.[20] Map 2 depicts areas subject to malaria transmission and areas where eradication of the disease is being consolidated.

In the absence of a completely effective method, there is some doubt whether partial eradication is worth attempting on large tropical land masses. The mosquitoes develop resistance to insecticides.[21] Some species of mosquitoes are even learning how to avoid insecticides. If the disease is only temporarily eradicated and it comes back again, the situation is worse than before: people who lose their partial resistance to the disease may become much more susceptible to severe attacks if they get it again. Since malaria eradication through the use of insecticides and drugs appears to have halted in recent years, the major hope for further progress may be in developing a vaccine against malaria. Some advance has been made in this effort but major problems remain: immunity against one form of malaria may not protect against the others, acquired resistance disappears in time, and it is not known whether a vaccine would merely suppress or could actually destroy the parasite causing malaria. The answer to malaria in most of the Tropics pending any new research successes appears to be combination programs including spraying, draining swamps, clearing of bush, and mass chemotherapy and chemoprophylaxis. Eradication of the disease requires, in other words, a substantial commitment of resources and cooperative effort.

RIVER BLINDNESS

River blindness (onchocerciasis) is a fly-borne infection that, according to World Health Organization estimates, affects approximately 20 million people. Most of those afflicted live in tropical Africa, in the big river valleys, but some are also in Yemen, and limited areas of Mexico, Guatemala, Venezuela, and Colombia (see map 3). River blindness causes partial or total loss of sight and fear of the disease keeps people out of considerable areas of fertile land.

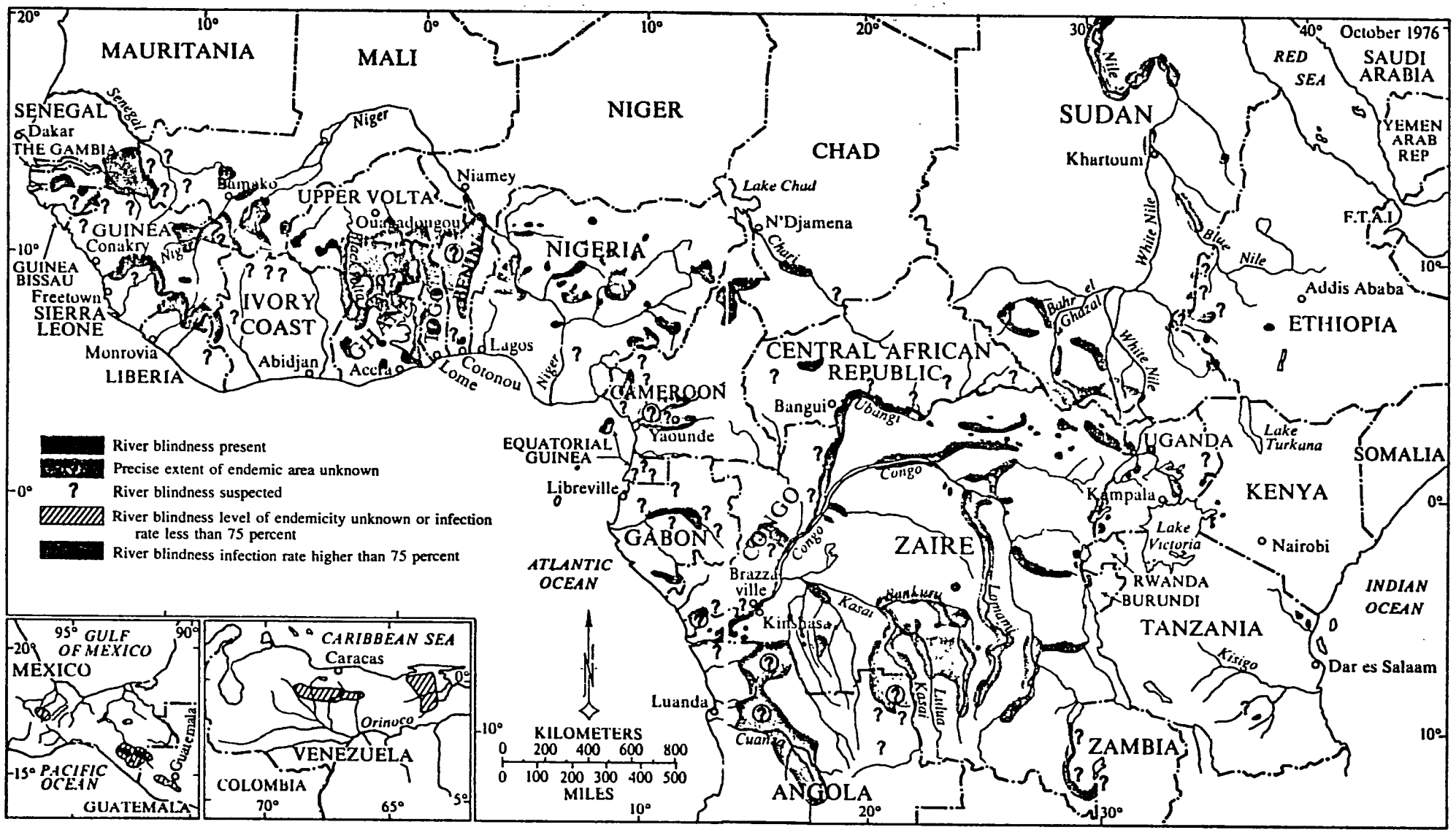
The greatest incidence of river blindness is usually in adult males. Since river blindness does not shorten life, the blind are not only subtracted from the economically active portion of the community but become a burden to it. Aside from the infection that various species of the Simuliidae fly may carry, their bites are so unpleasant that they make farming or other outdoor activity difficult. (One species of the fly, *Simulium venustrum*, inhabiting Maine, Siberia, and Canada, is known as the "curse of the north" because of the unpleasantness of its bite. But in these latitudes the fly cannot carry the river blindness infection because temperature has been found to be one of the major factors governing the duration of the parasite cycle in the vector.[22]) The complete extent of the tropical area that is affected by the disease-carrying black fly is still unknown. The most heavily infested areas are in parts of the larger African river valleys—the Volta, the Niger, the Congo, and the upper Nile.

Probably the most heavily affected area is the Volta River Basin in Upper Volta and Ghana. The World Health Organization has estimated there may be 100,000 blind from this cause alone in the area. In some villages of Upper Volta and Ghana, practically all male inhabitants are infected. The percentage of blindness reaches 13 to 35 percent and most of the other inhabitants have impaired vision. In many other villages of west and equatorial Africa, more than 50 percent of the inhabitants are infected; typically, 30 percent would have impaired vision and 4 to 10 percent are blind. In such areas, blindness often affects individuals in their twenties and thirties.

In addition to the cost to the community and the individual resulting from total blindness, the various degrees of impairment of vision suffered by others must also have a substantial impact on productivity. In Guatemala, for example, river blindness causes considerable loss of efficiency among workers on the coffee plantations, and there is a steady drain of public health funds to try to keep the disease under control. Another important economic impact of the disease is essentially the depopulation of the alluvial land of the river valleys. People are afraid to live and work on much of what little fertile land is available.

In Upper Volta, for example, the river valleys of the three branches of the Volta are practically deserted, although they are potentially rich for agriculture. The reason is the presence of river blindness. Over half the country's population live on less than one-fourth the country's area, the central plateau, which is on the whole the most poorly endowed with natural resources. With the present techniques of production, land availability for each active person in the central region is

MAP 3
Geographical Distribution of River Blindness



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insufficient to permit a satisfactory level of food production, considering the disturbing influence of variable weather conditions. Partly in consequence, at least 450,000 to 500,000 Voltaics out of a total population of around 5 million migrate for work to Ghana and the Ivory Coast—around 40 percent of the adult male population. In Uganda, to construct the Owen Falls dam where the Nile flows out of Lake Victoria, it was necessary to eradicate local concentrations of the disease-carrying fly. Fortunately this proved possible. Since then river blindness has been controlled in the area. This had the beneficial by-product of turning a considerable stretch of land in Bugere and the contiguous area of Butembe and Bunya into an important producing area of food and cash crops. Over 75,000 people have resettled there.

Like other parasitic diseases, human infection with river blindness is the result of a complex chain in nature. Although species of fly carry and spread the infinitesimal parasites, they do not produce them. Rather, the nematode, *Onchocerca volvulus*, essentially *causes* river blindness. The adult worms live mainly below the skin, where they may form visible nodules in which one or more worms are coiled. The female worm gives birth to millions of microfilariae during its fifteen year life span. These may move to the skin anywhere in the body and cause lesions or swollen glands. They also may penetrate the eyes where they cause lesions that impair vision or cause blindness. The heaviest infections are in those people who are most heavily loaded with parasites. In forest areas the disease is less severe than in the savanna regions and causes a lower rate of blindness.

Numerous species of black fly actually transmit the infection: the aptly named *Simulium damnosum* in most parts of Africa, *S. neavei* in east and central Africa, and *S. ochraceum*, *S. metallicum* and *S. callidum* in Latin America. The fly bites an infected person, taking up microfilariae that develop into infective larvae in a few days within the fly. These are liberated into the next human being the fly bites, and develop into adult worms.

For its life cycle the fly needs flowing or turbulent water that cools its egg, larva, and pupa stages. Waterfalls, rapids, and spillways providing abundant cool sprays are particularly favorable areas. The flight range of the fly can reach 150 or more kilometers, so its eradication with insecticides is not easy. Small dams constructed for irrigation in arid areas often create favorable breeding sites for these black flies. The spillways of large dams are also favorable, but they can be designed to avoid this and their reservoirs often drown out existing breeding areas.

Much research remains to be done on how to control river blindness. Eradication has been successful in a few confined areas such as the Victoria Nile in Uganda, Kenya, and the Congo River near Kinshasa but the disease was conquered by dosing the rivers with DDT to kill the flyvector in the early stages of its life. In the Murchison Nile in Uganda and Eastern Province in Zaire, control failed, presumably because the area controlled was not large enough and the fly reentered the area. No satisfactory methods of mass chemotherapy have yet been found to eradicate the worms and microfilariae from human beings. In Mexico and Guatemala the nodules containing the worms are cut out of people, but since all the adult worms may not be in the nodules, this acts only as a suppressive and not a complete cure. Aside from the need for more knowledge, a program of eradication would require much greater resources than most of the countries affected can handle. A successful program would have to be able to finance the training of staff, carry out programs of eradication with sufficient care over the large areas necessary, and (because of the long life of the worm) continue over a sufficiently long period of years to eliminate the possibility of reinfection.

PARASITIC WORMS

A large number of other parasites affect and debilitate human beings. Often people host two or more parasites at the same time. Roundworms, pinworms, and whipworms infect over 1 billion people throughout the Tropics and sub-Tropics. (These intestinal helminthiases are respectively the large *Ascaris lumbricoides*, the *Enterobius vermicularis*, and the *Trichuris trichiura*.) Hookworm disease—ancylostomiasis and necatoriasis—infects some 500 million people in these areas and causes anemia, apathy, and in children mental and physical retardation. There are about 250 million people throughout the world who have one or another variety of filariasis caused by two species of nematodes and spread by the bite of a mosquito. One of the more unpleasant varieties of this disease is elephantiasis. About 100 million people suffer this disease in Asia. Guinea worm, another nematode, affects 50 million to 80 million people in southeast Asia, India, Africa, and the Middle East.

A World Health Organization report surveyed intestinal worm infestations among school children in a sample of areas throughout the world and found high incidence in most cases throughout the developing countries. Perhaps the highest incidence was in El-Hadjira, Algeria, where 94 percent had hookworm and 34 percent had whipworm. In two villages in West Bengal, 75 percent of the Moslems and 89 percent of the Hindus had hookworm. In a semi-urban population in Brazil, 25 percent of the population had hookworm, 42 percent another variety of intestinal worm, and 17 percent and 11 percent still other varieties. Map 4 illustrates the distribution of hookworm disease throughout the world.

Hookworm is characterized by anemia, weakness, fever, and abdominal pain. Heavy infestation may result in mental and physical retardation in children and apathy toward work in adults. Before it was eradicated in the American South, hookworm was probably a main cause for the old stereotype of the Southerner as being lazy, irresponsible, and shiftless. According to one study, labor efficiency in parts of Syria was reduced by as much as 50 percent by heavy hookworm infestation.[23]

Among the most important filaria that are parasitic on humans is Guinea worm (*Filaria medinensis*). In 1947 the number of people having Guinea worm in Asia alone was estimated at over 30 million.[24] It is also widespread in Africa. Although the male is only about one and a half inches long, the female worm reaches a length of over three feet. The female settles in the tissues under the skin. When the worm breaks out, the eggs are scattered in water. These eggs develop in small crustaceans and eventually are taken by a human host in drinking water.

A number of other diseases are significant. Leprosy infects more than 12 million persons, mostly in Africa and south Asia, and most are not under treatment. It has been found recently that the "curative" drug is not as effective as formerly believed. Kala-azar (leishmaniasis or "oriental sore"), dengue ("breakbone fever"), trachoma, and cholera are also significant economic factors from time to time.

LEPROSY

Leprosy is now largely restricted to the Tropics. One theory explaining this geographic restriction is that leprosy is related to the many skin abrasions prevalent where insects cause innumerable bites.[25] An estimated 11 million persons are infected in the Tropics, of which almost 4 million are disabled. Only 2 million cases are getting treatment. In 1965 the number of cases was estimated at 6.5 million in Asia, 3.9 million in Africa, 400,000 in the Americas, 50,000 in Europe, and 30,000 in Oceania.[26] Current estimates raise the world total by about 2 million cases. The highest incidences in the world have been found in the Central African Republic (93 for each 1,000 population), Upper Volta (52 for each 1,000), and the Ivory Coast (50 for each 1,000) (see map 1).

Considerable progress has been made in finding drugs to arrest the progress of the disease and, if used in time, to prevent its disabling and disfiguring aspects. Recently, however, it has been discovered that the standard drug, a sulfone (dapsone or DDS), has limited effectiveness, and some patients develop resistance to it. The main alternative is a phenozine dye compound which discolors the skin. A great deal is still unknown about the disease: whether for example it is only transmitted through long and close association, through direct skin contact, or by breathing germs.

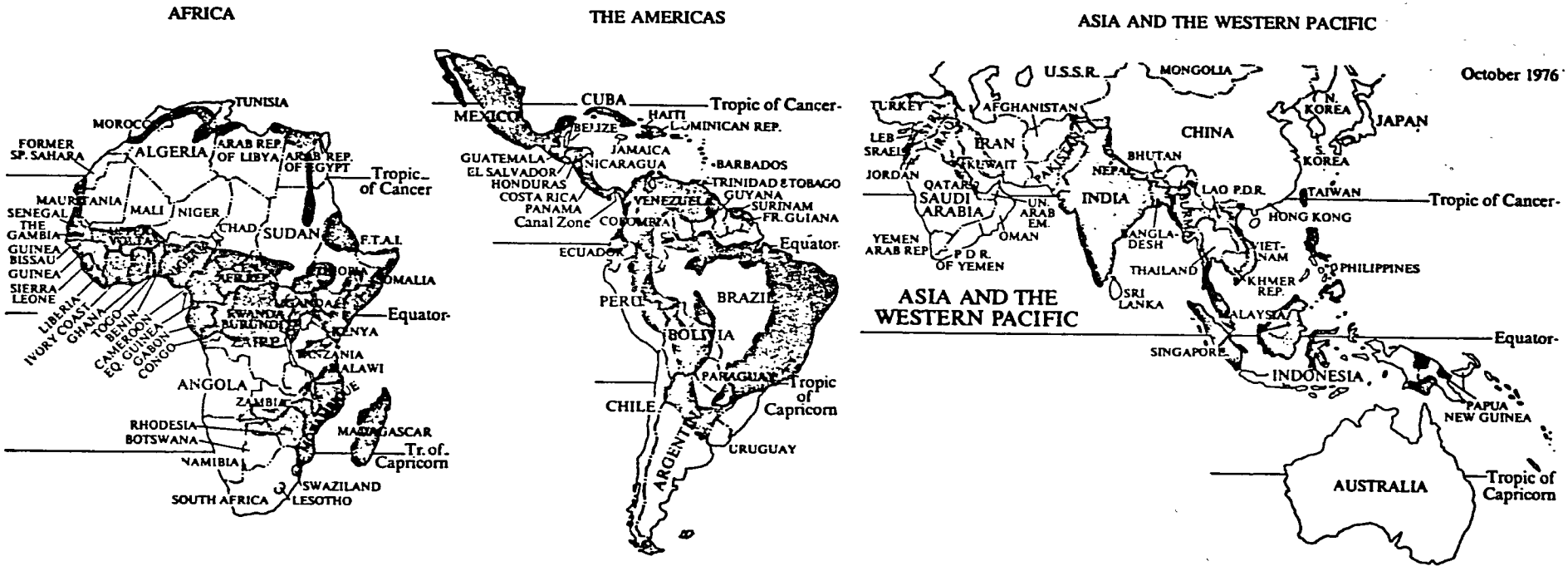
LEISHMANIASIS

Leishmaniasis is carried by flies and manifests itself either as a debilitating general affliction characterized by enlargement of the spleen, known as Kala-azar, or as a skin disease, known as oriental sore. In Asia, it is endemic in India—Assam, West Bengal, Bihar, Uttar Pradesh, and Madras—Bangladesh, some regions in Nepal, and the Middle East. Leishmaniasis is also present in east and north Africa. In Latin America there are only sporadic cases of the disease, but as man penetrates the rain forests a flare-up may occur.[27] Mainland China claims to have eradicated this disease. Leishmaniasis packed Chinese hospital wards and left "hundred of thousands of peasants" dead in the villages and fields, but doctors now say they see only one case in several years.[28]

YELLOW FEVER AND DENGUE

The conquest of yellow fever is today one of the few success stories of tropical medicine mostly because it was a major obstacle to the United States' development and expansion at the beginning of this century. Yellow fever, together with malaria, delayed construction of the Panama Canal and made American occupation of Cuba hazardous. (One example of the virulence of the

MAP 4
Geographical Distribution of Hookworm Disease



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disease before it was brought under control was the epidemic in Santo Domingo in 1802: it killed 29,000 of the 33,000 veteran soldiers and sailors sent by Napoleon to reconquer the island and garrison New Orleans and the Mississippi valley. This disaster helped induce Napoleon to sell Louisiana to the United States in 1803.) As a result of research by the U.S. Army and Public Health Service, the mosquito vector, *Aedes aegypti*, was found and, through sanitation measures, was brought under control in the Panama Canal Zone, Cuba, and the southern cities of the United States. An inoculation was later developed by the Rockefeller Foundation against the disease. The mosquito carrying yellow fever stops breeding when temperatures drop below 15°C to 20°C so its range north and south of the equator is determined by these limits. The disease does not now occur in Asia or the southern United States, although the mosquito vector is still present.

This species of mosquito also transmits another disease, dengue, or "breakbone" fever, throughout the tropical and sub-tropical regions including Asia. This disease has only recently been identified. While it is difficult to recognize among other diseases in its endemic phases, it can distinguish itself with epidemics that affect large masses of people in short periods of time. Dengue is not as deadly as yellow fever and the disease only lasts three or four days as it sweeps through a community. Climate particularly affects dengue: the viruses causing the disease are transmitted by the bite of the *aegypti* mosquito only when the temperature is above 20°C to 22°C, while another vector of the disease, the mosquito *Aedes scutellaris*, is restricted geographically to a narrow band of the Tropics.[29]

CHOLERA

Cholera is a bacteria disease transmitted through contaminated food. It can spread anywhere in the world, but its base is in the deltas of the Ganges and Brahmaputra rivers in south Asia and the island of Celebes in Indonesia, where it is endemic. Cholera is no longer a serious public health problem in countries with adequate medical facilities, that is, in more developed countries. With antibiotics and replenishment of body fluids, recovery is almost always swift, leaving no after effects. In the 1961-71 pandemic (see map 1), cases appeared in many parts of Asia, Africa, and a few cities of Europe. In 1971 there may have been more than 20,000 deaths from the disease. One of the main economic consequences of cholera was that, to protect themselves, many less-developed countries with inadequate medical facilities in some cases cut off trade with countries in which cholera appeared.

Notes

1. "Comment," in *Agricultural Development and Economic Growth*, p. 362.
2. *Climate and Economic Development in the Tropics*, p. 100.
3. Ibid.
4. *Tropical Health*, p. 385.
5. G. W. Reynolds [Cold International Limited] to A. M. Kamarck, May 30, 1973, Economic Development Institute, World Bank, Washington, D.C.
6. Timothy King and others, *Population Policies and Economic Development: A World Bank Staff Report* (Baltimore: Johns Hopkins University Press, 1974), p. 170. See also World Bank, *The Assault on World Poverty: Problems of Rural Development, Education, and Health* (Baltimore: Johns Hopkins University Press, 1975), pp. 348-50.
7. Marguerite C. Burk and Mordecai Ezekiel, "Food and Nutrition in Developing Economics," in *Agricultural Development and Economic Growth*, p. 340.
8. "Some Preliminary Observations on the Ecology of a Small Man-made Lake in Tropical Africa," in *Ecology and Economic Development in Tropical Africa*, ed. David Brokensha (Berkeley: University of California Institute of International Studies, 1965), p. 133.
9. Mentioned by Dieter Koch-Weser [Harvard Medical School] in the course of a discussion in November 1971.
10. William Laurie, "Survey before Service: Observations on Relations between Agriculture, Parasite Load, and Nutrition on a Tropical African Island," *The Lancet* 2 (October 16, 1954), pp. 801-802.
11. Samir S. Basta and Anthony Churchill, "Iron Deficiency Anemia and the Productivity of Adult Males in Indonesia," Staff Working Paper no. 175 (Washington D.C.: World Bank, April 1974), pp. 18, 29, 39.
12. May, *The Ecology of Human Disease*, pp. 5, 227.
13. Computed from United Nations, *Population Bulletin of the United Nations, no. 7, 1963* (ST/SOA/Ser.N/7), 1965, pp. 111-12.
14. "Health, Employment and Income Distribution," World Employment Programme Research Working Paper no. 21, provisional draft (Geneva: International Labour Organisation, 1975), p. 11.
15. Sally Reston, "Mao's Poem Urges Drive on Virulent Snail Fever," *New York Times* (July 30, 1971), p. 7. Mao Tse-tung had written of bilharzia's debilitating effects:

    Green streams, blue hills–but all to what avail?
    This tiny germ left even Hua
    To powerlessness;
    Weeds choked hundreds of villages, men wasted away;
    Thousands of households dwindled, phantoms sang with glee.

16. *Tropical Health*, p. 236.
17. John F. Kessel, "The Ecology of Filariasis," in *Studies in Disease Ecology*, ed. Jacques M. May (New York: Hafner, 1961), p. 58.
18. Among the pioneer works is Robin Barlow's *The Economic Effects of Malaria Eradication* (Ann Arbor: University of Michigan

School of Public Health, 1967); see also *American Economic Review* 57 (May 1967), pp. 130-48. Also useful are comments by George H. Borts and Peter Newman, reported with Barlow's *AER* article, pp. 150-51, 155-57; Michael Colbourne's *Malaria in Africa* (London: Oxford University Press, 1966); and Peter K. Newman's *Malaria Eradication and Population Growth* (Ann Arbor: University of Michigan Bureau of Public Health Economics, 1965).

19. *Malaria in Africa*, p. 34.

20. Ibid., p. 82.

21. The WHO Expert Committee on Malaria reported in 1967 that twenty-four species of the *Anopheles* mosquito had developed resistance to dieldrin or DDT; eleven had resistance to both.

22. Thomas A. Burch, "The Ecology of Onchocerciasis," in *Studies in Disease Ecology*, p. 74.

23. *Tropical Health*, p. 58.

24. Erwin H. Ackerknecht, *History and Geography of the Most Important Diseases* (New York: Hafner, 1965), p. 134.

25. May, *Ecology of Human Disease*, p. 146.

26. L. M. Bechelli and V. Martínez Domínguez, "The Leprosy Problem in the World," *Bulletin of the World Health Organization* 34 (1966), p. 811.

27. See the special issue on "Leishmaniasis" of the *Bulletin of the World Health Organization* 44, no. 4 (1971).

28. Reston, "Mao's Poem," p. 7.

29. See Charles L. Wisseman and Benjamin H. Sweet, "The Ecology of Dengue," in *Studies in Disease Ecology*, pp. 15-44.

41

The Worldwide Loss of Cropland

Lester R. Brown

INTRODUCTION

Ever since the beginning of agriculture, the relationship between people and cropland has been a critical one. When land is scarce, people often go hungry. When soils are depleted and crops are poorly nourished, people are often undernourished as well.

Pressures on the world's croplands have escalated since mid-century as our numbers have increased, raising doubts about long-term food security. In 1950 there were 2.5 billion people in the world. In 1975 there were 4.0 billion. By the end of the century, there will be 6.3 billion of us if current projections materialize.[1]

Growing populations demand more land not only for food production but for other purposes as well. As the demand for cropland is expanding at a rapid rate, more and more cropland is being converted to nonagricultural uses. In addition, the soaring world demand for food since mid-century had led to excessive pressures on the more vulnerable soils. This in turn has led to soil degradation and cropland abandonment.

Cropland deterioration and loss are not new problems. The Tigris-Euphrates Valley, once described as the Fertile Crescent, may have formerly supported more people than it does today. The food-deficit lands of North Africa were once the granary of the Roman Empire. What is new is the scale of cropland loss and soil deterioration, a problem that affects rich and poor countries alike. Natural soil fertility is now declining on an estimated one-fifth of the world's croplands.

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Direct evidence of the mounting pressures on the global cropland base is seen in accelerating soil erosion, the spread of deserts, and the loss of cropland to nonfarm uses. In the Central Sudan and Northwest India, sand dunes now occupy the land where villages once stood. In the midwestern United States, shopping centers occupy land that only a few years ago was planted to corn. Factories are being built in southern China on land that for generations yielded two rice harvests each year.

Indirectly, excessive pressures are reflected in falling crop yields, growing food deficits, and a greater instability in the world food economy. Crop failures are more frequent, as cultivation is extended onto land with less reliable rainfall. During the seventies, prices of wheat and rice have more than doubled in times of scarcity. After a quarter-century absence, famine returned in the seventies, claiming hundreds of thousands of lives in Bangladesh, Ethiopia, and the Sahelian zone of Africa. The food shortages that led to these deaths were initially blamed on poor weather, but weather was often the triggering event that brought into focus a more fundamental problem, the growing pressure on local land resources.

A valuable national resource, cropland is the foundation not only of agriculture but of civilization itself. Yet monitoring the condition of the global cropland base has been handicapped by a lack of data. Virtually all governments collect statistics on the land being brought into production through irrigation and drainage projects or through land-clearing, but relatively few systematically compile data on the land being taken out

of production. Fewer still attempt to measure topsoil loss through erosion.

Obtaining a complete picture of the changing world cropland situation is not possible because many key pieces of the global mosaic are missing. Nonetheless, enough pieces are now available to bring the overall picture into focus. Some bits of the mosaic are described graphically in the project documents in the files of the Agency for International Development (AID), the World Bank, and the U.N. Development Program. Dimensions of the unfolding land shortage are evident in the publications of the Food and Agriculture Organization (FAO). Evidence of excessive pressures on cropland can be seen in the computer printouts of national grain yield trends from the U.S. Department of Agriculture (USDA).

Scientific journals are beginning to carry detailed analyses of local cropland loss and deterioration. In recent years, *Science* has published several landmark articles on soil erosion and cropland loss, principally in the United States. Translations from Soviet scientific journals reveal the extent of official concern with soil deterioration. Improved access to information on China indicates an extraordinary effort to preserve the cropland base in the face of both the food and nonfood claims on land of some 900 million people.

In 1976, Erik Eckholm's *Losing Ground* detailed the extent of soil erosion, the deterioration of mountain environments, deforestation, the firewood crisis in the Third World, desertification, the silting and salting of irrigation systems, and the other forces undermining the inherent productive capacity of the world's soils. The first global overview of the complex forces affecting the cropland base, this book captured the grim dimensions of the threat to the world's cropland.

In response to growing international concern, the United Nations Environment Program in 1977 convened a world conference on desertification, one of the many threats to the world's cropland. The preparatory work for the meeting included the compilation of all available data on the spread of deserts and the human creation of desertlike conditions. At the conference, governments endorsed a World Plan of Action to halt the spread of deserts and to reclaim desertified land.

The information now available on the changing global cropland situation indicates a growing worldwide shortage of productive cropland, acute land hunger in many countries, and soaring prices for farmland almost everywhere. Despite the greater availability of information on soil erosion and deterioration, most governments take their cropland for granted. The loss of productive cropland is helping to drive food prices upward, thus contributing to inflation and creating troublesome political problems. Yet, many political leaders seem oblivious to these pressures, perhaps because the loss of cropland occurs in the countryside, while most political leaders live in the city.

THE HISTORICAL EXPANSION OF CROPLAND

The historical expansion of cultivated land has been closely related to the growth in human numbers. In response to population pressures, farmers moved from valley to valley and continent to continent, gradually extending the area under cultivation until, today, one-tenth of the earth's land surface is under the plow. By the mid-twentieth century, most frontiers had disappeared. Up until that time, increases in world food output had come almost entirely from expanding the area farmed. Increases in land productivity were scarcely perceptible within any given generation.

Historically, as the demand for food pressed against available supplies, farmers devised several techniques for extending agriculture onto land that was otherwise unproductive. Dominant among these techniques are irrigation, terracing, and fallowing. Irrigation enables farmers to cultivate land where rainfall is too low to support crops. In mountainous regions, the construction of terraces permits the extension of agriculture onto steeply sloping land that would otherwise be uncultivatable. Centuries of laborious effort are contained in elaborate systems of terraces in older settled countries such as Japan, China, Nepal, and Indonesia, and in the Andean regions once inhabited by the Incas.

In vast semiarid regions—such as Australia, the western Great Plains of North America, the Anatolian plateau of Turkey, and the drylands of the Soviet Union—where there is not enough rainfall and moisture to sustain continuous cultivation, alternate-year cropping has evolved. Under this system, land lies fallow in alternate years in order to accumulate moisture; all vegetative cover is destroyed during the fallow year, and the land is covered with a dust mulch that curbs the evaporation of water from the soil. The crop produced the following year thus draws on two years of collected moisture. In some situations, this practice would lead to serious wind erosion if strip-cropping were not practiced simultaneously: alternate strips planted to crops each year serve as windbreaks for the fallow strips. It

was the adoption of this cropping technique that permitted wheat production to continue in the western Great Plains after the Dust Bowl years of the thirties.

In the tropics—such as Africa south of the Sahara, Venezuela, parts of Brazil, or the outer islands of Indonesia—where more nutrients are stored in vegetation than in the soil, fallowing is used to restore the fertility of the soil. Stripped of the dense vegetative cover, soils in the humid tropics quickly lose their fertility. In response to these conditions, farmers have evolved a system of shifting cultivation, whereby they clear and crop land for two, three, or possibly four years, and then systematically abandon it as crop yields decline; moving on to fresh terrain, they repeat the process. These cultivators return to their starting point after 20 to 25 years, by which time the soil has become fertile enough to again support crop production for a few years.

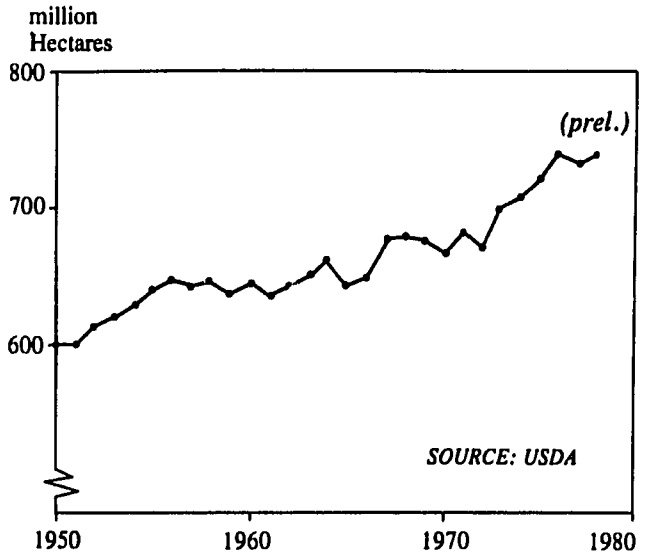
Over time, irrigation, terracing, strip-cropping, and shifting cultivation enabled farmers to produce food on land where conventional agriculture would not survive. Today, land farmed with these specialized techniques provides a large share of the world's food supply. Without them, the earth's capacity to feed people would be far lower than it is. Although these practices have withstood the test of time, in some areas they are beginning to break down under the pressure of population growth.

Agronomists have been aware of the mounting pressures on the world's cropland, but their efforts to measure the impact have traditionally been handicapped by the absence of reliable data on overall cropland trends. An alternative to using data on total cropland is to use data for cereals only. This sacrifices some comprehensiveness, but the greater availability and precision of data more than compensate for this loss. Cereals occupy some 70 percent of the world's cropland and are the dietary staple in virtually every society.

In addition, the USDA computer bank, the product of several years of painstaking effort, contains information on area, production, and yield for every cereal in all countries from 1950 through 1978. Fed by the worldwide network of agricultural attachés, it is an invaluable resource, providing new insights into changes in both cropland area and productivity.

Although rising cereal output per hectare has accounted for most of the growth in the world food supply since 1950, expansion of the area in cereals has also made a significant contribution. Between 1950 and 1978, the area in cereals expanded by 140 million hectares, or some 23 percent[2] (see figure 1). During this time there were two periods of rapid expansion. From 1951 to 1956, the area in cereals expanded by 10 percent, or 2 percent each year. Close to half of this increase was accounted for by the extension of grain production onto the "Virgin Lands" of the Soviet Union.

FIGURE 1
World Harvested Area of Cereals, 1950-78



Between 1956 and 1972, the area in cereals increased only 4 percent. This was a period of excess production capacity in the global food economy, a time when the world's farmers could produce more grain than the world's consumers could afford at prevailing prices. During most of this time, the United States, the world's leading food producer, idled some 20 million of its 140 million hectares of cropland.

The second period of rapid expansion occurred from 1972 to 1976 in response to a worldwide food shortage and soaring food prices. The Soviet wheat purchase in mid-1972 was the triggering event that brought the tightening world food situation into sharp relief. Over four years, some 50 million hectares were added to the world's harvested area of cereals, increasing the overall area nearly 8 percent. At least one-third of this increase was due to the return to production of U.S. cropland previously idled under government programs. A smaller share came from reduction of the land in fallow in the United States and the Soviet Union. The soaring prices encouraged expansion of the cultivated area in several developing countries—importantly, in Argentina, Brazil, and Nigeria.

As the food supply tightened in the early seventies, there was enough slack in the system to allow this increase of several percent in the land planted to cereals. Much of the increase, however, was due to special circumstances that cannot be repeated, including the return to production of idled cropland and the reduction in fallowed area.

During the third quarter of this century, world population increased by 1.5 billion, or 59 percent, while the area in grain expanded from 602 to 731 million hectares, a gain of 21 percent. This was almost certainly the first generation during which the growth in human numbers so greatly exceeded the growth in cropland. It led to a precipitous drop in area per person from .24 hectares to .18 hectares.[3] Such a drop did not pose any problems because the yield per hectare was rising rapidly throughout most of this period. Once that began to slow, however, as it did in 1972, a global food shortage developed.

CONVERSION TO NONAGRICULTURAL USES

As noted earlier, the increase in world population and economic activity means land is needed for much more than just the production of food. The principal nonagricultural needs are urbanization, energy production, and transportation. Each of these sectors is now claiming cropland in virtually every country.

Wherever national data are available, they usually show the growth of cities to be a leading source of cropland loss. Within the United States, cities are consuming cropland at a record rate. Land-use surveys by the USDA in 1967 and 1975 indicated that some 2.51 million hectares of prime cropland "were converted to urban and built-up uses" during the eight-year span. A study of urban encroachment on agricultural land in Europe (grasslands as well as croplands) from 1960 to 1970 found that West Germany was losing 0.25 percent of its agricultural land yearly, or 1 percent every four years. For France and the United Kingdom, the comparable figure was 0.18 percent per year, or nearly 2 percent for the decade.[4]

While data are available on the loss of agricultural land to cities in the industrial countries, there is little information on the Third World, where the most rapid urbanization is occurring. Scores of cities in developing countries, such as Lima, Ankara, and Manila, are growing by 5 to 8 percent yearly. Inevitably, some of this growth comes at the expense of cropland.

No one knows exactly how much cropland was claimed by cities during the third quarter of this century, and it is only possible to estimate how much cropland cities will cover by century's end. To get some idea of the future land needs of expanding cities, information is needed on the expected growth in urban numbers. According to the U.N. demographic division, the urban share of world population, which was 29 percent in 1950 and 39 percent in 1975, is projected to reach 50 percent by 2000 (see table 1). This means the urban population would expand from 1,547 million in 1975 to 3,127 million just 25 years later. If these projections do materialize, the absolute increase in urban dwellers during the final quarter of this century will be nearly double the increase from 1950 to 1975.

TABLE 1
The Urbanization of World Population, With Projections to 2000

Year	World Population (millions)	Urban Population (millions)	Urban Increase (millions)	Portion of World Urban (percent)
1950	2,501	725		29
1975	3,968	1,547	822	39
2000	6,254	3,127	1,580	50

SOURCE: Derived by the author from United Nations data.

To estimate the extent of urban encroachment on cropland, we need to know how much land each person will use and the share of that which will be cropland. Within the United States, each person added to the urban population between 1950 and 1960 required an average of .08 hectares, but between 1960 and 1970, a period of unprecedented urban sprawl, this figure increased to .13 hectares. Several estimates for Canada indicate that urban land requirements per person may be even greater than in the United States.[5] While the per capita land needs of city dwellers in Europe and the Soviet Union appear to be similar to those in North America, those in the Third World are probably less, given the crowding in Third World cities.

If it is assumed, perhaps conservatively, that the projected increase in world urban population of 1,580 million from 1975 to 2000 will need only .04 hectares per person, then the world's cities would occupy 63 million hectares of land by 2000. Assuming that 40 percent of this total is cropland, expanding cities will cover 25 million hectares of cropland between now and the end of the century.

Although this loss would amount to only 2 percent of the world cropland base, the share of world food output

involved is likely to be larger, for cities are commonly situated on the most fertile soils. A study of changing land-use patterns in Canada reports that "half of the farmland lost to urban expansion is coming from the best one-twentieth of our farmland."[6] But even assuming average levels of land productivity, this loss of 25 million hectares represents the food supply of some 84 million people.

All additions to the world's population require living space, whether they live in the city or in the countryside. In the Third World, where land is in critically short supply, cropland is lost each year to village growth. In an analysis of village spread using data over several decades for his native Bangladesh, Akef Quazi, a lecturer in science and technology at the University of Wales, concludes that growth in the number of families and growth in the area occupied by the village are closely related. One reason for this direct correlation is that homes are "made of locally available materials, such as bamboo, thatch, and corrugated iron sheets, and, as such, are never strong enough to hold an upper story." Quazi reports that "every new village homestead is being built on cropland."[7] While there are undoubtedly occasional exceptions, Quazi's general point is a sound one, since Bengali villages are usually surrounded by the fields on which they depend.

A similar situation exists in India, a country of 600,000 villages, nearly all of which are expanding. Living space requirements of the 14 million people added each year are at least partly met by homes built on cropland. In its report to the 1976 U.N. Conference on Human Settlements held in Vancouver, Canada, India estimated that between 1970 and 2000, nonagricultural land use would expand from 16.2 to 26.0 million hectares, an increase of 60 percent.[8]

Further east, China, the world's most populous country, is also losing cropland to cities and industry. USDA China specialist Alva Erisman reports that "water control projects, urban growth, and the appropriation of agricultural land for roads, railroads, airfields, industrial plants, and military uses have removed good farmland from cultivation." Dwight Perkins, Chinese scholar at Harvard, makes the same point, noting that the 10 percent growth in modern industry, with factories commonly sited on the edges of cities, has undoubtedly used up cropland. He believes Chinese planners are aware of this continuing loss of cropland, but that "there is no way around the fact that good farm land (flat, located near transport, et cetera) often makes an excellent factory site."[9]

Rivaling the urban sector as a claimant on cropland is the fast-growing global energy sector. During the final quarter of this century, as during the third, the consumption of energy is projected to increase more rapidly than that of food. Like the production of food, the production of energy requires land. Hydroelectric dams often inundate vast stretches of rich bottomland; electric generating plants can cover hundreds of hectares. More often than not, oil refineries and storage tanks are built on prime farmland along rivers and coastal plains. Strip-mining of coal and the diversion of irrigation water to the energy sector both tend to reduce the cultivated area.

No one knows just how much of the world's cropland lies under the reservoirs behind hydroelectric dams, but it surely numbers in the millions of hectares. Nigerian ecologist Jimoh Omo-Fadaka outlines the losses in Africa: "The modern Kariba Dam in Africa has put 29,000 farmers out of business. Some of Ghana's rich farmland lies beneath the Volta Dam, and prosperous cocoa and coffee farms in the Ivory Coast's Bandama Valley are dying as the waters rise behind the Kossou Dam, sealed in 1971."[10] Some hydroelectric dams, of course, have many purposes and may add to the irrigated area even while subtracting from the cropland base through inundation.

In the United States, the Senate's Committee on Interior and Insular Affairs studied the land requirements associated with the development of various energy resources and facilities. Among other things, they analyzed President Ford's 1975 State of the Union Address in which he asked for "200 major nuclear power plants, 250 major new coal mines, 150 major coal-fired power plants, 30 major new refineries, 20 major new synthetic fuel plants, and the drilling of many thousands of new oil wells" in the next ten years. The Federal Energy Administration estimated that the program would disturb land on 18 million hectares. The Senate Committee noted that "this amounts to a tripling of the amount of land currently devoted to energy thus far."[11]

Although the Senate Committee did not estimate the share of this land that would be cropland, some studies conducted at the local level have done so. One such study compiled data on the loss of cropland to the strip-mining of coal in Illinois, a state with some of the most productive land in the Corn Belt. It reported that "as of 1976, 202,422 acres [81,981 hectares] in 40 Illinois counties have been affected by surface and deep mining. Surface mining accounted for over 94 percent

(191,874 acres) of this affected acreage."[12] Although mining companies are now required by law to restore land to its original productive state, many people doubt that it will be possible in most situations. Given the rich, extensive resources of coal close to the surface in some 51 Illinois counties, the potential disruption is a matter of great concern.

Although there are no detailed surveys of the worldwide loss of cropland to strip-mining, it is safe to assume that the measured loss in Illinois is only a small share of the U.S. total and a minute percentage of the global total. While estimates of future cropland losses to urbanization are difficult, those of losses to the energy sector are even more so. The potentially large claims, however, emphatically underline the need for energy conservation programs. To conserve energy is also to conserve cropland.

All transport systems require land but some systems use much more than others. Automobile-centered transport systems are voracious consumers of land. An enormous amount of U.S. cropland has been paved over for the automobile. Millions of hectares are required just to park the nation's 143 million licensed motor vehicles. But even this is rather small compared with the land covered by streets, highways, filling stations, and other service facilities. Moreover, the automobile has encouraged other inefficient uses of land, such as urban sprawl.

Societies moving toward an automobile-centered transportation system should weigh carefully the sacrifice of cropland that is sure to be involved. Almost any other form of transportation requires less land. Societies with well-developed public transport systems are able to use land far more efficiently than those where most people rely on cars.

Just as rising income increases the per capita demand for cropland, so too it increases the land required for other purposes. In effect, high income man is a space consumer. All the principal nonfarm uses of land are greater among high-income groups than they are among those with low incomes.

The amount of cropland that will be paved over, built on, strip-mined, or flooded by a dam by the end of this century is unknown. However, if world population projections materialize, 2.3 billion people will be added between 1975 and the year 2000, a far larger increase than the 1.5 billion added during the preceding 25 years.[13] Given these population projections and the projected gains in income, every nonfarm claimant on cropland—urbanization, energy production, transportation—is certain to be greater during the last quarter of this century than during the third.

CROPLAND ABANDONMENT

Although the world demand for cropland is greater than ever before, the amount of cropland abandoned each year may also be at a record level. The reasons for cropland abandonment, usually the product of economic pressures interacting with ecological forces, include desertification, severe erosion, waterlogging and salinization of irrigated land, and the diversion of irrigation water to nonfarm uses.

Deserts are now expanding on every continent. Documents prepared for the U.N. Conference on Desertification detailed this expansion and the human creation of desertlike conditions. Some 630 million people, or one in every seven of the world's people, live in arid or semiarid areas. An estimated 78 million people live on lands rendered useless by erosion, dune formation, changes in vegetation, and salt encrustation.[14] Desertification has deprived these people of their means of production, of their livelihood.

Agronomists who specialize in the management of arid and semiarid croplands have been aware for some time of the mounting pressure on these fragile soils and of their progressive deterioration and loss of productivity. It was not, however, until the droughts of the late sixties and early seventies in the Sahelian zone of Africa that the social consequences of desert expansion became more evident.

Although public attention has focused on the southward spread of the Sahara, the desert is also marching relentlessly northward, squeezing the populations of North Africa against the Mediterranean. FAO agriculturalist H. N. Le Houérou estimates that the North African tier of countries—Morocco, Algeria, Tunisia, and Libya—are losing 100,000 hectares of range and cropland each year. The ever-growing Sahara is expanding westward into Senegal and eastward into the Sudan. Readings taken of the Sudan in 1958 and 1975 indicate the desert expanded southeastward by some 90 to 100 kilometers during the 17-year period.[15]

Fed by the human pressures on their fringes—overgrazing, deforestation, and overplowing—virtually all the world's major deserts are expanding. As human and livestock numbers multiply, the creation of deserts or desertlike conditions is accelerating throughout the Middle East and in Iran, Afghanistan, Pakistan, and northwestern India. Brazilian ecologist

J. Vasconcelos Sobrinho reports that the semiarid tip of Brazil's Northeast is being desertified; similar conditions are developing in the Argentinean states of La Rioja, San Luis, and La Pampa.[16]

Soil erosion is an even more widespread problem. Soil scientists classify erosion into two main categories—sheet erosion, and rill or gully formation. Continuous erosion is usually found on sloping lands that are farmed without soil conservation techniques such as terracing and contour planting. This leads to productivity declines in the short run, and to land abandonment over the long term. The difference between rills and gullies is one of scale: the depth of rills can be measured in inches, but that of gullies is usually measured in feet. Gullies usually appear where subsoils are also erodible.

Some countries have studied extensively the process by which their croplands are being degraded by gully formation. Soil scientists at the Soil Erosion Laboratory at Moscow University have analyzed gully formation in the south central Soviet Union—Kazakhstan, Central Asia, and West Siberia. They note that although in only 2 percent of the area is there now strong gullying, there could be medium and strong gullying on as much as 50 percent of the land as efforts to intensify agriculture proceed.[17]

A parallel Soviet study analyzing the present gully network in the Steppe and Forest Steppe regions of the European part of the Soviet Union concluded: "One factor that more than any other has fostered the spread of gullies has been the plowing up of the land. The annihilation of the natural vegetation cover, the systematic loosening of the soil, the network of dirt roads, plow furrow, etc., produce conditions that give rise to a dense network of gullies, especially on steep slopes." In examining the history of the process, the authors report that gully formation has probably accelerated as "good land reserves became exhausted and sloping land began to be plowed."[18]

Although severe gullying, leading to land abandonment, is now common in many parts of the world, it has received the least official attention in those countries where the process is most advanced. A U.N. report on soil deterioration and cropland loss in Latin America notes its serious dimensions in the Andean regions.[19] Throughout the Andean countries gullies are advancing through the steeply sloping countryside like the tentacles of a giant malignancy. As these gullies eat their way across fields, farmers who are already hungry for land continue to till what's left, right up to the edge of the gully. In so doing, they feed the gully, accelerating its progress across the land.

A report by the Organization for Economic Cooperation and Development (OECD) describes the extensive abandonment of farmland in Italy, noting that "it is generally agreed that in Italy two million hectares have been abandoned in the last ten years . . . the farming methods used on this marginal land have led to deterioration of the soil so that the land was consumed in the literal sense of the term."[20] Similarly, some of the decline in the harvested area of cereals in Yugoslavia and Bulgaria over the past two decades reflects the abandonment of eroded, worn-out soils in farm areas with rugged terrain.

A report from the U.S. Embassy in Jakarta indicates that "soil erosion is creating an ecological emergency in Java. A result of overpopulation, which has led to deforestation and misuse of hillside areas by land-hungry farmers, erosion is laying waste to land at an alarming rate, much faster than present reclamation programs can restore it." Similar pressures are building in the rainfed agricultural regions of Pakistan. An AID officer in the Punjab area reports the annual abandonment of several thousand hectares of cropland because of severe erosion and degradation.[21]

The irrigated lands that provide a disproportionately large share of the world's food are threatened both by ecological forces—waterlogging and salinity—and economic forces that divert water to competing uses. Waterlogging and salinity develop wherever surface water from rivers or streams is diverted to irrigate land that has inadequate underground drainage. This net addition to the natural underground water supply gradually raises the water table. Once the water table is within a few feet of the surface, the growth of deep-rooted crops is impaired and the early symptoms of waterlogging appear.

As the water table rises further, water begins to evaporate through the remaining few inches of soil, thereby concentrating the minerals and salt near the surface. Eventually the salt concentrations reach a level that prohibits plant growth. Glistening white expanses of heavily salted abandoned cropland are visible from the air in countries traditionally dependent on irrigation, such as Iraq and Pakistan.

The problem is as old as irrigation itself. Indeed, the decline of some early Middle Eastern civilizations is now traced to the waterlogging and salinity caused by their irrigation systems. Although the designers of the

earliest irrigation systems in the Tigris-Euphrates Valley did not understand the subterranean hydrology well enough to prescribe corrective action, modern irrigation engineers do. The problem is the cost: a recent U.N. report estimates average salvage costs at $650 per hectare.[22]

Worldwide data compiled in a 1977 U.N. report indicate some 21 million hectares of irrigated land were waterlogged—one-tenth of the total area irrigated. The productivity on this land had fallen by 20 percent. An estimated 20 million hectares was affected primarily by salinization, with a reduction in productivity estimated at roughly the same level as that due to waterlogging.[23] Although crude estimates, they imply an overall reduction in productivity of the world's irrigated land of some 4 percent.

There are signs of waterlogging and salinity in many countries. Although fully half of the world's irrigation capacity has been developed since 1950, waterlogging and salinity are already impairing the effectiveness of many systems. The agronomic literature of China is liberally sprinkled with references to the problem. Heavy investments in agricultural land reclamation and irrigation in the Soviet Union during the seventies have been aimed at improving drainage systems for the reclamation of irrigated land that has become waterlogged and salty. The more intensive irrigation in the Nile River Valley made possible by the Aswan Dam has upset the long-standing water balance in some areas, leading to the waterlogging and salinity of Egyptian soils that have historically been free of this problem.[24]

Governments in some Middle Eastern countries have been trying for some time to identify or develop crops that are salt-tolerant. A case history of the Greater Murrayeb Project in the Euphrates plain of Iraq reports that 50 percent of the soils in the region are now moderately to severely saline, with 16 percent severely saline. The consequences are "lowered yields, loss of irrigable land, and abandonment of some holdings."[25]

A U.N. survey found that in Argentina "some 2 million hectares of irrigated land have declined in productivity due to salinization and alkalinization."[26] In Peru, the survey reported that of 800,000 hectares of irrigated agricultural land in the coastal desert, 300,000 hectares are affected by poor drainage and salinization.

Salinization and waterlogging also plague irrigated soils in India. The progressive loss of productive land to salinization is a particularly acute problem in northwestern India. In one irrigated area in Rajasthan, 24 square kilometers of productive land have been lost through salinization, and a U.N. study predicts that "if the process continues, it may extend to another 40.3 square kilometers."[27]

In Pakistan, virtually all the irrigated land in some districts is plagued with waterlogging and salinity. In the Mona reclamation area, a project that began in 1901, about 90 percent of the soils were waterlogged by the early sixties.[28] Since that time, the reclamation effort has led to some improvement, but the rehabilitation of waterlogged soils is a time-consuming, capital-intensive process.

Salinization has also become a major problem in the southwestern United States and northern Mexico. American farmers have designed drainage systems that remove the salt from their irrigated fields, but, unfortunately, some of the salt ends up in river waters that eventually irrigate Mexican fields. The result has been salt concentrations so high that many Mexican farmers have helplessly watched the productivity of their land fall.[29] This unintentional salting presents a sticky diplomatic issue for the two governments.

In some regions, crop production is threatened not by too much irrigation, but by too little. The diversion of irrigation waters to other purposes is particularly a problem in arid areas with irrigated agriculture and with rapid urbanization and industrialization, such as the south central regions of the Soviet Union and the southwestern United States.

Soviet efforts to regain food self-sufficiency rest heavily on plans to expand irrigation. Consequently, investment in irrigation has been the fastest growing sector of the economy over the past 15 years. But irrigation plans and capital commitments may not be enough. Thane Gustafson, Soviet scholar at Harvard, reports that "the entire irrigation program is threatened because the southern half of the country is running short of water."[30] Barring the massive diversion of northward-flowing rivers to the south for irrigation purposes (an approach that is now officially questioned on environmental grounds), severe water shortages appear to be inevitable.

In the United States, the problem has been carefully detailed for some of Arizona's leading agricultural counties. The irrigated area in Maricopa County is shrinking steadily as water is being diverted to the rapidly expanding Phoenix metropolitan area. Between the late fifties and the early seventies, the irrigated area fell from 224,000 to 177,900 hectares. But even at this reduced level of water withdrawal, groundwater levels have been dropping by some 10 to 20 feet per year. In

Pinal County, another leading agricultural center in Arizona, the land planted in crops fell from 138,000 hectares to 93,000 hectares during the same span.[31]

A similar situation exists in California, though on a much larger scale. As thirsty Los Angeles requires more and more water, the demand can often be satisfied only by diverting water from irrigation canals. Irrigated valleys that were once lush green have now turned a dusty brown. Fields that were once among the most productive in the world have now been abandoned.[32] Urban needs, however wasteful or illogical, always take precedence over farm demands for water.

In the western Great Plains—Nebraska, western Kansas, Colorado, and Wyoming—the withdrawal of underground water now often exceeds the rate of natural recharge. As water tables fall, pumping costs rise, until eventually farmers can no longer afford to irrigate. Efforts to develop the extensive coal resources of the northern Great Plains and the oil shale resources of western Wyoming and Colorado will divert more water from agriculture.[33] In Montana, farmers are battling energy firms in the courts in an effort to retain water for their fields. And Denver's expanding water needs are being met by the diversion of water from central Colorado farms.

While waterlogging and salinity have long been claiming irrigated land, the problems associated with the wholesale diversion of water from agriculture are relatively new. During the final quarter of this century, the diversion of water to pressing municipal and industrial needs will continue. In a *Science* article assessing the world food prospect, Neal Jensen of Cornell University predicts that "western U.S. irrigated agriculture faces gradual elimination as the pressures for higher priority water needs become evident."[34]

Responding effectively to the threats to cropland associated with mounting food demands poses a dilemma for farmers and government planners alike. Both economic pressures and political instincts encourage a short-term focus, a desire to expand current output to satisfy immediate needs. But this pressure to wring more food out of the land can have devastating consequences for the soil.

THE THINNING LAYER OF TOPSOIL

Over much of the earth's surface, the topsoil is only inches deep, usually less than a foot. Any loss from that layer can reduce the soil's innate fertility. Forty years ago, G. V. Jacks and R. O. Whyte graphically described the essential role of topsoil: "Below that thin layer comprising the delicate organism known as the soil is a planet as lifeless as the moon."[35]

The erosion of soil is an integral part of the natural system. It occurs even when land is in grass or forests. But when land is cleared and planted to crops, the process invariably accelerates. Whenever erosion begins to exceed the natural rate of soil formation, the layer of topsoil becomes thinner, eventually disappearing entirely, leaving only subsoil or bare rock. Once enough topsoil is lost, the cropland is abandoned. But the gradual loss of topsoil and the slow decline in inherent fertility that precedes abandonment may take years, decades, or even centuries. Although this interim process does not affect the size of the cropland base, it does affect its productivity.

As population pressures mount, cultivation is both intensified and extended onto marginal soils. Some of the techniques designed to raise land productivity in the near term lead to excessive soil loss. In the American Midwest, the intensification of farming has led to the continuous cropping of corn, thereby eliminating the rotations that traditionally included grass-legume mixtures along with the corn. The transition to continuous cropping has been abetted by cheap nitrogen fertilizers that replaced nitrogen-fixing legumes. While these chemical fertilizers can replace nutrients lost through crop removal, they cannot make up for the loss of topsoil needed to maintain a healthy soil structure.

Although the strong world demand for U.S. grain has made the continuous cropping of corn profitable, it has also led to an unacceptable level of soil erosion in many parts of the corn belt. A 1977 report from Iowa State University Experiment Station notes that "the often unobserved thinning of productive topsoil by erosion gradually removes the basic resource that supports agricultural production in an area." The report, from one of the world's most productive farming areas, adds: "The 200 million tons of soil lost from Iowa's cropland each year, for example, simply cannot be replaced within our lifetimes or those of our children. The eroded soil is gone, depleting the fertility of the land."[36]

In other parts of the world, the doubling of demand for food over the past generation has forced farmers onto land that is either too dry or too steep to cultivate and is thus highly vulnerable to erosion. Explosive Third World population growth has forced farmers onto mountainous soils without sufficient time to construct

terraces. Once the natural cover is removed from unterraced mountainous land, the topsoil quickly washes into the valley below, silting streams and irrigation reservoirs and canals.

In the Andean countries of Latin America, skewed land-ownership patterns aggravate this problem. Wealthy ranchers use the relatively level valley floors for cattle grazing, forcing small landholders onto steeply sloping fields for the production of subsistence crops.[37] This peculiar inversion in land-use patterns is leading to severe soil erosion on the slopes, impairing the productive capacity of both the mountainside and the valleys.

In dryland wheat areas of the world, pressures to reduce the area in fallow could lead to widespread drying up of soils. This proved catastrophic in the U.S. Great Plains during the Dust Bowls of the thirties and in the Virgin Lands of the Soviet Union during the sixties. Except where land can be irrigated, the basic natural constraints on cultivation under low-rainfall conditions cannot be altered substantially.

Soil scientists have determined tolerable rates of erosion for various types and conditions of soil. This tolerance level—or T factor, as it is commonly referred to—equals the rate of new soil formation. As long as the soil loss does not exceed the T factor, the innate productivity and fertility of the soil can be maintained indefinitely. In a 1975 survey of Wisconsin soils, 70 percent were found to have a soil loss greater than the tolerable level. On those soils with a T factor of 3.6 tons, the actual loss was 8.4 tons, more than double the tolerable rate.[38]

The USDA Soil Conservation Service reports that farmers are not managing highly erodible soils as well today as they were a generation ago. The adoption of conservation measures is relatively easy when there is excess capacity in the system, but when grain prices are high and food is scarce, the temptation to forgo these essential measures is strong. A nationwide survey by the Soil Conservation Service indicated that "in 1975, soil losses on cropland amounted to almost three billion tons or an average of about 22 tons per hectare. Although this was excessive, it was far less than the estimated four billion tons of topsoil that would have been lost in 1975 if farmers had followed no conservation practices at all."[39] The report concluded that if U.S. crop production was to be sustained, soil loss would have to be reduced to 1.5 billion tons annually, one-half today's level.

The Council for Agricultural Science and Technology, supported by a consortium of midwestern universities, reported in 1975 that "a third of all U.S. cropland was suffering soil losses too great to be sustained without a gradual but ultimately disastrous decline in productivity." A summary document prepared for the 1977 U.N. Conference on Desertification reported that just under one-fifth of the world's cropland is now experiencing a degree of degradation that is intolerable over the long run. The U.N. report estimated that productivity on this land has now been reduced by an average of 25 percent.[40]

These broad global estimates become more meaningful when examined at the national level. In the Soviet Union, attempts to regain food self-sufficiency through heavy investments in agriculture are stymied by soils that have lost some of their inherent productivity. In an analysis of the government's agricultural plans, Thane Gustafson of Harvard notes that Soviet efforts must reckon with "50 years of neglect [that] have left a legacy of badly damaged soils."[41]

The Nepalese Government estimates that the country's rivers now annually carry 240 million cubic meters of soil to India. This loss has been described as Nepal's "most precious export." In Ethiopia, the deterioration of soils was brought into focus by a drought that culminated in famine in 1974. A foreign ambassador in Addis Ababa described the origin of the problem in graphic terms: "Ethiopia is quite literally going down the river." More recently, the U.S. AID mission reports that "there is an environmental nightmare unfolding before our eyes. . . . It is the result of the acts of millions of Ethiopians struggling for survival: scratching the surface of eroded land and eroding it further; cutting down the trees for warmth and fuel and leaving the country denuded. . . . Over one-billion—one billion—tons of topsoil flow from Ethiopia's highlands each year."[42]

According to U.N. estimates, erosion robs Columbia of 426 million tons of fertile topsoil each year.[43] Colombia's topsoil is relatively thin; given the poorly nourished condition of many of its people, the country can ill afford such a massive loss of this life-sustaining resource. In Pakistan, the progressive deforestation of recent decades has led to widespread soil erosion. At some point, these losses in Ethiopia, Colombia, Pakistan, and other severely affected countries may begin to sabotage farmers' efforts to expand output.

Few efforts have been made to precisely measure the relationship between the cumulative loss of topsoil and

the inherent fertility of cropland. Luther Carter writes in *Science* that "even where the loss of topsoil has begun to reduce the land's natural fertility and productivity, the effect is often masked by the positive response to the heavy application of fertilizers and pesticides which keep crop yields relatively high." The implications are, nonetheless, disturbing. David Pimentel of Cornell University cites three independent studies, all undertaken in the United States, indicating that, other things being equal, corn yields decline by an average of "four bushels per acre for each inch of topsoil lost from a base of 12 inches of topsoil or less."[44]

In a world facing an acute shortage of productive cropland, any loss of topsoil should cause concern, for such a loss is essentially irreversible in the short term. Even under normal agricultural conditions—including the heavy use of fertilizers and tillage practices that gradually mix subsoil into topsoil and that incorporate organic matter—creating an inch of new topsoil can take 100 years; if left to nature, it may take many centuries.

National political leaders and ministers of agriculture are faced with the task of adequately feeding an ever-expanding population without irreparably damaging one of the world's most essential resources—the soil. Mounting demand pressures, whether the subsistence survival efforts of Peruvian peasants or the response of American farmers to market forces, can have the same effect. In a great many countries, efforts to produce more food are now leading to a slow but gradual decline in the inherent fertility of soils.

LAND PRODUCTIVITY TRENDS

The ancients calculated yield as the ratio of grain produced to the seed that was planted. For them, the constraining factor was the supply of seed-grain. But as agriculture spread, and as seed became more abundant and land more scarce, the focus shifted from the productivity of seed to that of land.

From the beginning of agriculture until World War II, land productivity increased very slowly. For long periods of time it did not increase at all. Rice yields in Japan during the nineteenth century were only marginally higher than those during the fourteenth century. Corn yields in the United States during the 1930s were the same as those during the 1860s, the first decade for which reliable yield estimates are available.[45]

Following World War II, however, crop yields began to rise rapidly in virtually every industrial country. During the sixties, introduction of the fertilizer-responsive varieties of wheat and rice enabled yields in many Third World countries to also rise. From the end of World War II until the early seventies, the steady rise in cereal yield per hectare was one of the most predictable trends in the world economy. Between 1961 and 1971, there were particularly impressive gains.

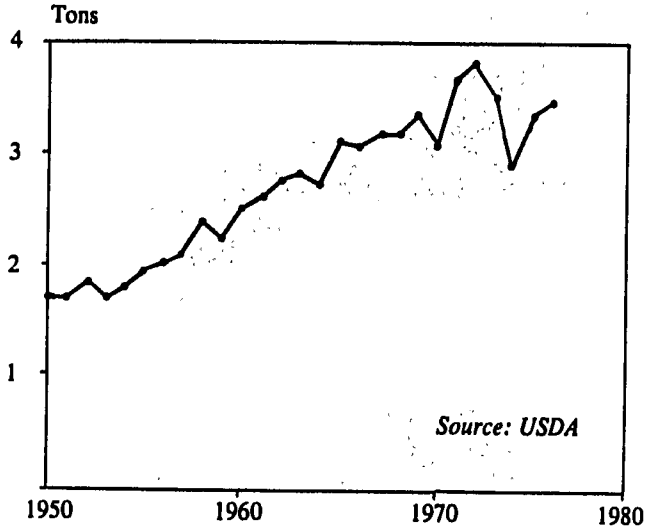
Since 1971, however, the increase has slowed; yields have become much more erratic and less predictable. From 1950 to 1971, the cereal yield per hectare climbed from 1.14 metric tons to 1.88 tons per hectare, or 2.4 percent per year. Between 1971 and 1977, the yield increased at only one-fourth that rate, or 0.6 percent per year. This marked slowdown was due to a combination of pressures, including the addition of marginal land to the world's cropland base, higher energy prices, a reduction in the land in fallow in the dryland wheat-growing regions, a shortening of the fallow cycle in areas of shifting cultivation, and the cumulative loss of topsoil in major food-producing regions.

Within the United States, the yield turned abruptly downward in 1973. While the yield of all cereals combined increased by a rather spectacular 4.0 percent per year from 1950 to 1972, it has actually declined since then. The 1977 yield was 6 percent below that in 1972. Per hectare yields of wheat, barley, oats, rye, and rice peaked in 1971; the yield of corn peaked in 1972 (see figure 2). As of 1977, none of these cereal yields had regained its earlier high level. The return to production of most of the 20 million hectares of idled U.S. cropland (nearly one-seventh of the cropland base) helps explain the initial fall in yields in 1973. Combined with uncommonly adverse weather, it contributed to the further decline in 1974. But it does not adequately explain the leveling off since then.

Another agriculturally advanced country that has experienced a yield downturn is France. Closely paralleling the U.S. experience, the cereal yield in France nearly tripled between 1950 and 1973, climbing from 1.6 metric tons to 4.4 metric tons per hectare; but after this impressive climb, it turned downward. During the four years since, it has fluctuated between 3.4 and 4.2 metric tons per hectare.

Egypt and China, two Third World countries with rather intensive agricultural systems, have also experienced a leveling off in per hectare cereal yield during the seventies. Egypt's yield nearly doubled between 1950 and 1971, but it has not increased since. China's

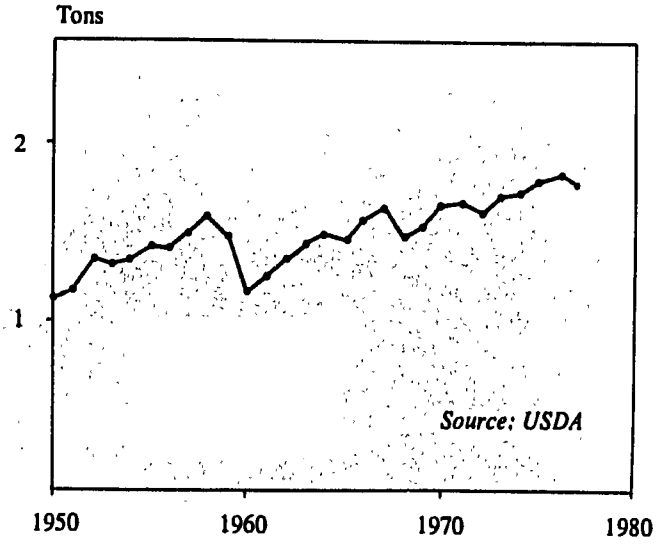
FIGURE 2
Cereal Yield Per Hectare,
United States, 1950-77



yield, more modest overall, has not increased at all since 1974 (see figure 3). Except for the sharp falloff in the aftermath of the 1958 "Great Leap Forward," China's cereal yield had been edging upward throughout most of the 1950 to 1974 period.

The reasons for the interruption in national yield trends are not precisely the same for all countries. The main contributor to the downturn in U.S. yield per hectare was undoubtedly the return to production of cropland previously idled under government programs. When participating in supply limitation programs, farmers invariably retire their poorest, least productive land.[46] Since the United States is the world's leading food producer, bringing this poorer quality land back into production obviously had an effect on the world trend as well.

FIGURE 3
Cereal Yield Per Hectare,
China, 1950-77



The high cost of energy has also influenced agricultural yields. The fivefold increase in the price of petroleum during the seventies slowed the growth of energy use in agriculture. This influenced fuel use not only in tractors and irrigation pumps, but also, indirectly, in the production of chemical fertilizer, an energy-intensive commodity. Fertilizer prices during the mid-seventies, influenced both by cyclical trends in the industry and by rising energy costs, soared to record levels.[47]

A third influence on the productivity of cropland is a shrinkage in the fallowed area in dryland farming regions. As world wheat prices rose during the seventies, U.S. summer fallow land dropped from 17 million hectares in 1969 to 13 million hectares in 1974. This decline led Kenneth Grant, head of the USDA Soil Conservation Service, to warn farmers that severe wind erosion and dust bowl conditions could result. He cautioned farmers against the lure of record wheat prices and short-term gains that would sacrifice the long-term productivity of their land.[48]

Stresses are evident in other dryland farming regions as well. The U.S. agricultural attaché in Moscow reports there has been a reduction in fallow land in the Soviet Union. During the late sixties and early seventies, the Soviets were consistently fallowing 17 to 18 million hectares in the dryland regions; but after the massive crop shortfall and heavy imports of 1972, the fallowed area was reduced by one-third to 11 to 12 million hectares, where it has remained.[49]

In tropical and subtropical regions, where fallowing has evolved as a method of restoring fertility, mounting population pressures are forcing shifting cultivators to shorten the rotation cycles. This in turn acts to reduce crop yields. Students of African agriculture refer increasingly to that continent's "cycle of land degeneration." In *Losing Ground,* Erik Eckholm noted that "where traditional technologies persist—due either to the lack of proven alternatives or to the failure to reach farmers with new methods—deterioration of the land begins as soon as human numbers in a local area surpass the level shifting cultivation can support."[50] As cycles are shortened, land productivity falls.

In Nigeria, where both the addition of marginal land to the cropland base and a shortening of the fallow cycle

are lowering cropland fertility, cereal yields have been falling since the early sixties. A World Bank study reports that "fallow periods under shifting cultivation have become too short to restore fertility in some areas."[51] In some locales the original cropping cycle of 10 to 15 years has already been reduced to five years. Since 1950, the harvested area in Nigeria has multiplied two-and-one-half times as marginal land has been added and fallow cycles have been shortened. Together, these two trends have led to a fall in the average productivity of land that has overridden the combined contribution of all advances in agricultural technology, including chemical fertilizers, improved varieties, and the expansion of irrigation.

Similar pressures on the land are evident in Latin America. According to FAO researchers: "There is abundant evidence in certain regions of Venezuela that, with growing population pressure, the fallow period is becoming increasingly shorter so that soil fertility is not restored before recropping. This leads to a fall in the organic content and the water-holding capacity of the soil. Soil structure deteriorates and compaction becomes more common. . . . In other words, with the population of modern times, formerly stable shifting cultivation systems are now in a state of breakdown."[52]

Pressures associated with the growing demand for food affect more than just the humid tropical and subtropical regions where the fallowing systems of shifting cultivation are breaking down. Although the process of soil erosion is not always highly visible, its cumulative effect on land productivity can be graphic. A U.N. study of Latin American agriculture ties the falling potato harvests to soil erosion in the Peruvian Andes, the region that gave the world the potato.[53]

German geographer Rober Schmid describes a situation in Nepal that is similar to Peru's: "During the last century man in search of more arable land had greatly extended the terraced fields. . . . Increasingly, the farmers had to be self-sufficient, and therefore marginal land was taken into cultivation. . . ." The farming of increasingly marginal land, Schmid goes on, combines with progressive deforestation, as trees are felled for wood and branches are lopped from remaining trees for use as animal fodder, until a cycle of soil erosion and deterioration is set in motion. "On the permanently farmed fields the soil showed signs of exhaustion and the yields declined slowly."[54]

Schmid's account resembles those of others who have witnessed the deterioration of hill agriculture in Iran, Pakistan, northern India, and Ethiopia. The experience of the last several years suggests there is relatively little fertile new land that can readily be brought under the plow. There are indications in several major countries, including the United States, Canada, Nigeria, China, and Brazil, that the falloff in the quality of cropland is rather steep.

In Canada, the inherent productivity of the cropland is being reduced by the continual substitution of marginal land for prime land. Land being lost to urbanization includes some of the most productive soils in the country, whereas that being added is far less productive. The Canada Land Inventory uses seven classes of land with classes one to three being considered arable. Almost all of the class one, two, and three land is now being farmed. An estimated 233 hectares of class four land, described as marginally productive, is required to replace 100 hectares of class one land.[55] The net effect of substituting lower-quality land for higher-quality land lost to nonfarm uses is a reduction in the average fertility.

An even sharper falloff in land quality is reported in China, where population pressures are far greater. Leslie T. C. Kuo, a specialist on Chinese agriculture, reports that "the use of one acre of cultivated land for construction purposes must be offset by the reclamation of several acres of wasteland."[56] Kuo goes even further, indicating that a sizable portion of the present cultivated land is so poor as not to be profitable for crop production. This suggests there are few opportunities for profitably expanding cropland area.

The sharp falloff in land quality is also in evidence in Brazil, the largest country in Latin America. Brazil has more than doubled its harvested area since 1950, but, despite heavy investments in fertilizer and other modern techniques, crop yield per hectare has not increased. The declining quality of successive additions of land appears to have offset advances in agricultural technology and the increased use of fertilizer.

Apart from assessing changes in the innate fertility of soils, there is also the question of the biological potential for continuing to profitably raise crop yield per hectare. Despite its importance, this issue has received little attention from the research community. Among the few to consider the issue are Louis Thompson, Associate Dean of Agriculture at Iowa State University, and Neal Jensen, Professor of Plant Breeding at Cornell University. For 1958 to 1972, Thompson has plotted the average corn yields recorded on several experimental stations in Iowa as well as those achieved

by farmers in the state. In the late fifties, there was a wide gap between average yields on the experimental plots and those on Iowa farms, but by the early seventies, this gap had virtually disappeared.[57] In effect, the backlog of technology available to farmers in Iowa had been largely used up.

Neal Jensen has analyzed the long-term historical rise of wheat yields in New York State and reached a conclusion even more sobering. Applying his findings to agriculture in general, he predicts that "the rate of productivity increase will become slower and will eventually become level for several reasons."[58] He believes that plant breeders and agronomists in the more advanced agricultural countries have already raised yields about as far as they can.

In summary, the outlook for raising cereal yields appears less hopeful now than it did at mid-century. A number of soil surveys and studies indicate that the inherent fertility of as much as one-fifth of the world's cropland is declining. At the same time, the backlog of agricultural technology waiting to be applied in the agriculturally advanced countries appears to be dwindling. Together, these two factors cast a shadow over the prospect of a rapid, sustained rise in yield per hectare during the final quarter of this century to compare with that of the third quarter.

THE CROPLAND PROSPECT

There is no simple way of projecting the cropland area for the remainder of the century, much less of assessing its adequacy. One way to gain some perspective on the cropland prospect, however, is to compare increases in population growth, harvested area, and yields for the third quarter of the century with those projected for the fourth quarter. Between 1950 and 1975, world population increased by 59 percent, or 1.5 billion. The harvested area of cereals expanded by 21 percent and average yield per hectare rose by 63 percent. Together, the area and yield gains increased world cereal output 97 percent, a near doubling.

In 1950, there were still substantial opportunities for adding to the world's cropland base. The potential for expanding the area under irrigation was impressive, particularly in the developing countries. And farmers had scarcely begun to exploit the potential for raising per hectare yields, even in the argiculturally advanced countries.

During the final quarter of this century, population is projected to increase by 58 percent; although slightly smaller in percentage terms, the expected addition of 2.3 billion people would be half again as large as the 1.5 billion added during the third quarter. As the final quarter of this century began, cropland was being lost to nonfarm purposes at a record rate. The abandonment of agricultural land because of severe soil erosion, degradation, and desertification was at an all-time high. The potential for substantial net additions to the world's cropland base was not good.

A review of the potential for expanding the world's cropland by geographic regions does not provide much ground for optimism. In North America, the cropland base has been shrinking for three decades. The OECD's Agricultural Committee reports that the opportunities for new land reclamation in Western Europe are negligible.[59] The countries of Eastern Europe have been hard pressed to maintain their cultivated land area over the last 15 years. In the Soviet Union, where farming has already extended into highly marginal rainfall areas, the prospect of further expanding the cropland base is not good.

In densely populated Asia, the prospect is not very bright either. There is little new land to bring under the plow in China; given the already extensive development of irrigation, the opportunities for further expanding the area multiple-cropped are limited. In India, the region's other leading food producer, the cropland area is expected to increase little, if at all. But there is room to expand the area harvested through multiple-cropping, since much of the irrigation potential, particularly on the Gangetic plain, is still to be developed. The one area in Asia that could sustain an increase in both cropland area and the intensity of cropping is the Mekong Valley and delta, assuming that local political conditions permit these agricultural developments.

Although there are a few areas in Africa yet to be developed, overall there is limited opportunity for greatly adding to the cropland of the continent. In the vast northern section, the Sahara is reaching in every direction, claiming land in nearly a score of countries. The one country with potential for markedly expanding the area harvested is the Sudan, since it has developed only part of its share of the Nile waters, reserved to it by treaty with Egypt. To the south, the principal hope for more farmland is in opening the tsetse-fly belt to cultivation—if a way can be found to eradicate the tsetse fly.

In Latin America, the cropland area can be expanded by plowing up some grasslands, as Argentina has been doing during the seventies. This would, of course,

reduce the scope for grazing livestock. The other major potential, often overrated, lies in opening new lands in the interior of the continent, mainly in the Amazon basin. The principal constraint here is the inherent poor fertility of the soil and its limited capacity to sustain cultivation over an extended period of time.

Whenever data are available, they invariably show a sharp falloff in the productivity of recent additions to the cropland base. This has been documented for countries as different as Canada and China. In effect, it confirms what some analysts have suspected—that the world's farmers have most of the productive cropland under the plow.

Although there will be numerous attempts to expand the cultivated area both through government efforts and the initiative of individual farmers, there will also be some offsetting losses. Outstanding among these will be the abandonment of millions of hectares of marginal land brought under the plow during the great push since mid-century to expand world food output. This land is on the sides of mountains in the Andean countries of South America, in the highlands of East Africa and the foothills of the Himalayas, and in the rugged valleys of Java. Well before the end of the century, the topsoil will be gone from many of these plots and they will have been abandoned.

The question of how much the world's cultivated area can be expanded has been hotly debated during the past 15 years. Some studies contend that it can easily be doubled, while others assume that the opportunities for adding new land will largely be offset by losses—leading to little, if any, increase in the base. The principal difference between such widely varying estimates is explainable in economic terms. The more optimistic projections omit economic constraints whereas the less optimistic ones include them.

Cropland projections that take economic factors into account do not show large increases in the world cropland base. One very rough set of projections by John McHale that incorporates both additions and losses concludes that the former will offset the latter, leading to a cropland base at the end of the century that is essentially the same as that today. A USDA model of the world food economy, which assumes a real increase in commodity prices of roughly 50 percent between the 1969-71 base period and the year 2000, shows an increase over the 1975 harvested area of cereals of only 6 percent.[60]

On balance, it is difficult to see how the world can achieve much more than a 10 percent increase in cropland area during the final quarter of this century without a dramatic rise in the price of food. This area increase would be much smaller than the one that occurred during the third quarter of this century. Prior to 1950, the world cultivated area expanded more or less apace with population, accounting for most of the increase in food output. From 1950 to 1975, the increase in cultivated area fell far behind that of population, accounting for only one-fourth of the gain in food output. The projected increase of 10 percent in the harvested area for the final quarter of this century represents an extension of this historical rate of decline.

Barring a pronounced rise in food prices, one that would make the cultivation of markedly less fertile soils profitable, a 10 percent net increase in the harvested area may represent the realistic upper limit. Combined with the projected growth in population during the final quarter of this century, such an increase would lead to a decline in cereal land per person from .184 hectares to .128 hectares (see table 2). In absolute terms, this per capita decline of .056 hectares is almost exactly the same as the .057 hectare decline of the third quarter-century, but in relative terms it is much larger. From 1950 to 1975, the area per person shrank by scarcely one-fourth, but during the current quarter the reduction would be closer to one-third.

TABLE 2
World Population and Area in Cereals, 1950 and 1975, With Projections to 2000

Year	Population (billions)	Area in Cereals (million hectares)	Area Per Person (hectares)
1950	2.50	602	.241
1975	3.97	731	.184
2000	6.29	804	.128

SOURCE: United Nations, U.S. Department of Agriculture, and author's projections.

If this cropland assessment is a reasonable one, it suggests some serious difficulty in satisfying the projected growth in world food demand for the final quarter of this century. Projections of world food demand by the FAO and the International Food Policy Research Institute indicate or imply that the world demand for food will roughly double between 1975 and 2000.[61] Assuming the modest growth in the cropland area of 10 percent, satisfying the projected growth in demand would require an even greater increase in yield per hectare during the final quarter of this century than was achieved during the third quarter.

Unfortunately, recent trends indicate the potential for a continuing rapid rise in crop yield per hectare may be much less than has been assumed in existing projections of world food supply. The postwar trend of rising yield per hectare has been arrested temporarily in the United States, France, and China, each the leading cereal producer on its respective continent. Aside from the biological constraints on raising crop yield per hectare, a combination of pressures to extract ever more food from the land and poor land management is leading to the slow but progressive deterioration of an estimated one-fifth of the world's cropland. For most countries, the mounting demand pressures are of domestic origin, but for food exporters such as the United States and Canada, it is the growth in demand from abroad that is pressing the land beyond its limits.

The evidence now available raises doubts as to whether it will be possible to get a combination of cropland expansion and yield increases that will satisfy the growth in world food demand projected for the remainder of this century. Evidence of the difficulty can be seen in the reduced rate of growth in world food supplies in recent years. Between 1950 and 1971, the modest expansion in world cropland area and the unprecedented rise in crop yield per hectare raises world grain production per person from 276 kilograms to 360 kilograms. Since 1971, per capita grain production has actually declined, averaging only 354 kilograms over the following six years.[62]

This review of the period from 1950 to 1977 indicates a clear loss of momentum during the seventies in the efforts to raise food consumption. Since 1971, output has failed to keep pace with population growth, much less with the growth in demand generated by rising incomes. The result has been rising food prices. If the cropland assessment is reasonable and if the projected increase in world population materializes, then steep rises in food prices in the years ahead may be inevitable.

The years from 1972 to 1976 were ones of insecurity and instability in the world food economy unprecedented in peacetime. During the late seventies, however, uncommonly favorable weather and stepped-up food production efforts may be lulling the world into a false sense of complacency. The dimensions of the emerging stresses are likely to come into focus the next time two or more of the major food-producing countries have poor harvests. Just as years of bad weather tend to bring a deteriorating situation into focus, so recent years of good weather have tended to obscure the long-term deterioration.

PUBLIC POLICY IMPLICATIONS

Few things will affect future human well-being more directly than the balance between people and cropland. If recent population and cropland trends continue, that balance will almost certainly be upset, leading to economic uncertainty and political instability. Avoiding large, politically destabilizing rises in food prices between now and the end of the century may not be possible without a mammoth effort to protect cropland from nonfarm uses, to improve the management of soils, and, most importantly, to quickly reduce the rate of population growth.

The lack of well-developed land-use policies is a legacy of an earlier era when land was relatively abundant and there were still frontiers to be pushed back, or when there was still a large unrealized potential for raising per hectare yields. Now the frontiers are gone and the loss of cropland is proceeding at a pace that threatens to undermine the balance between food and people.

Agricultural land can no longer be treated as a reservoir, an inexhaustible source of land for industry, urbanization, and the energy sector. Cropland is becoming scarce. In a world of continuously growing demand for food, it must be viewed as an irreplaceable resource, one that is paved over or otherwise taken out of production only under the most pressing circumstances and as a result of conscious public policy.

In some situations, adjustments are needed in land use within agriculture as well as between agriculture and other sectors of the economy. The prevailing social structure in several countries in Latin America that has led to grazing on valley floors and the plowing of mountainsides can be remedied with a thorough land reform program. In effect, existing social structures in some countries are simply not compatible with the wise management of land resources.

Historically, land in most countries was allocated to various uses through the marketplace, but unfortunately the market does not protect cropland from competing interests. As cropland becomes more scarce, it can be protected from competing nonfarm demands only through some form of land-use planning. Such planning can occur at the national level, the local level, or both. It can rely primarily on land-use restrictions in the form of legislation or government decrees, or it can rely on incentives such as differential tax rates. Each society will need to employ approaches suited to its own circumstances.

The OECD reports that Japan is the only country with comprehensive zoning nationwide. In 1968, the entire

country was divided into three land-use zones—urban, agricultural, and other. In 1974, the plan was further refined to include specific areas for forests, natural parks, and nature reserves.[62] Given the acute pressures on its land resources, Japan has faced the issue first and in so doing has developed a model for other countries to follow.

Within the United States, national land-use planning is still at a rather rudimentary level, confined largely to setting aside national parks, forests and wildlife reserves. Such zoning as does exist is usually at the local level, consisting largely of restrictions on land that can be used for commercial purposes. A number of states, including California, Massachusetts, New Jersey, and New York, are concerned about the need to protect agricultural land, but to date only a few have effectively done so.

During the sixties, several European countries—Belgium, France, Germany, and the Netherlands—passed legislation establishing national land-use guidelines, but left the actual planning to be done at the local level. In addition to protecting agricultural land as such, their laws also addressed such issues as the control of urban sprawl, the need for parks, and the establishment of urban green belts.[63]

Rivaling the loss of cropland to nonfarm uses is the process of gradual soil degradation through erosion. If the loss of topsoil and associated soil degradation are permitted to continue, they will lead to ever-higher food production costs. But the effort needed to halt the deterioration of the soils on which humanity depends is staggering, one fraught with complicating social factors.

The one source of cropland degradation and loss officially dealt with at the international level is desertification. The World Plan of Action to stop the spread of deserts, agreed to at the Nairobi conference, concluded that money spent now to halt and reverse desertification and the loss of cropland promised high returns, ones that were competitive with other forms of investment. The plan specified the levels of investment by national governments, the World Bank, the U.N. Development Program, and the Inter-American Development Bank that would bring the process to a halt within the next decade and a half. They estimated that "a net zero desert growth can be achieved within the next 10 to 15 years, provided that the measures are started promptly and are effectively and comprehensively carried out."[64] Achievement of a net zero desert growth will be possible only with prompt, concerted action by national governments that are, unfortunately, not usually noted for such efforts.

In many countries, the stabilization of soils is such a vast undertaking that it will require a strong national political commitment and a detailed plan of action. Such a program has been outlined for the United States by the Soil Conservation Service. In order to stabilize U.S. soils and bring the annual loss of topsoil down to a level that does not exceed the tolerance factor, the plan calls both for changes in cropping practices and for heavy investments in land improvements. The principal recommendations of the plan include an increase in the terraced land where farmers leave crop residues on the surface from 4.8 million hectares to 17.6 million hectares, an increase in the amount of strip-cropped land with minimum tillage from about 0.4 million to 14.0 million hectares, and an increase in the strip-cropped land with crop residues left on the surface from 3.2 million to 7.2 million hectares. For land where farmers rely on a combination of contour farming and minimum tillage to keep their soil in place, they recommend a 21-fold increase—from 0.8 million to 16.8 million hectares. The largest suggested increase of all is for land where contour farming and crop residues on the surface are used together—from 3.2 million to 22.4 million hectares.[65]

These prescribed changes in farming practices are monumental in scale, involving half of all U.S. cropland. Adoption of these soil-saving measures would often run counter to the immediate economic interests of farmers and consumers, since they would lead to a 5 to 8 percent increase in food production costs.[66] Some efforts to conserve soil and protect long-term food production might reduce food output in the short term as well.

While soil scientists can chart a national plan of action in detail, they cannot generate the political support needed to fund and administer such a plan. Public support on the scale needed will not be forthcoming without a broader understanding of the costs to society of failing to act. R. A. Brink and his colleagues, writing in *Science*, observe that "in our predominantly urban society, it may be difficult to gain the public support needed for funding an adequate soil conservation program." But they predict that "public opinion will shift with the worsening of the world food crisis."[67]

Brink wonders whether "as a result of mounting pressures on the land, the need for soil-saving measures is outrunning the capacity of conservation agencies as now financed to assist farmers in meeting it." If this

observation applies to the United States, one can only wonder about the future adequacy of efforts to protect cropland in countries that have far less to work with, both institutionally and financially. The alternative facing governments is to not respond to the deterioration, and then be confronted with long-term food scarcity as the cropland base progressively deteriorates.

The future balance between people and cropland is likely to be affected more by population policy than by any other single factor. Growth in human numbers not only generates a demand for more cropland, but it also simultaneously generates pressures to convert cropland to nonfarm uses. Thus far, policymakers have assumed that projected increases in population over the final quarter of this century will materialize. But the social costs of remaining on the projected demographic path may become too great.

For a great many countries, the future promises acute land hunger, food shortages, soaring food prices, and widespread social unrest. The signals indicating a need for changes in population policies will be strong. They seem certain to lead to a fundamental rethinking of population policies at the national level.

The changing food prospect may lead to the abandonment of pronatalist policies and the active encouragement of small families. Other governments may join those of China and Singapore in advocating a maximum of two children per couple and in making family planning universally available. With future rates of population growth bearing so heavily on the prospect of eliminating hunger, the fact that one-half of the world's couples do not yet have access to family planning services is not only socially irresponsible, but politically inexcusable as well.[68] If population growth is to be reduced to a socially acceptable rate, unprecedented changes in government policies and in individual attitudes will be required. Such changes are not likely to occur without a better understanding of the precarious balance between people and cropland.

The convulsive changes in the world food economy during the seventies are indicative of the growing pressures on the cropland base. They reflect the extension of cultivation onto marginal rainfall areas in the Soviet Union, the encroachment of deserts in Africa, and the flooding in Bangladesh aggravated by deforestation in the Himalayas. Unprecedented in peacetime, the worldwide food shortages and soaring prices of the early and mid-seventies should be regarded not as an aberration, but rather as a signal that the pressures on cropland are in some ways becoming excessive. They may in fact be advance tremors warning of the quake to come.

Threats to the world cropland base from the nonfarm sector are very real. Evidence that the soils on which we depend for our food are deteriorating is overwhelming. What is not nearly as evident is how political leaders will respond. But the time left in which to respond is measured in years, not decades.

The issue is not whether the equilibrium between people and land eventually will be reestablished. It will be. If the deterioration is not arrested by man, then nature will ultimately intervene with its own checks. The times call for a new land ethic, a new reverence for land, and a better understanding of our dependence on a resource that is too often taken for granted.

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The Salting and Silting of Irrigation Systems

Erik P. Eckholm

The first human civilization may well have emerged in what is now Iraq, on the plain of the Tigris and Euphrates rivers known as Mesopotamia. Here people learned, six or seven thousand years ago, to raise abundant crops in the desert by diverting river water onto their fields. The need to maintain irrigation works, in turn, provided strong impetus for cooperation among families and clans, while the new food surplus encouraged formation of the first non-farming classes—priests, administrators, warriors, merchants, craftsmen, and artists.

That Mesopotamia is possibly the world's oldest irrigated area is not an encouraging observation. The end result of six millenia of human management is no garden spot. The region's fertility was once legendary throughout the Old World, and the American conservationist Walter Lowdermilk has estimated that at its zenith Mesopotamia supported between seventeen and twenty-five million inhabitants.[1] One early visitor, Herodotus, wrote that "to those who have never been in the Babylonian country, what has been said regarding its production will be incredible." Today Iraq has a population of ten million, and on the portions of these same lands that have not been abandoned peasants eke out some of the world's lowest crop yields.

Rarely has the history of civilization been so directly linked to changing ecological conditions. Environmental modification has sometimes been the cause, and sometimes been the result, of the rise and fall of Mesopotamian states. Their history reveals lessons for irrigation-based societies everywhere, lessons only slowly being absorbed despite the visual aid of Iraq's wastelands.

The first recorded civilization, that of the Sumerians, was thriving in the southern Tigris-Euphrates valley by the fourth millenium B.C. Over the course of two thousand years Sumerian irrigation practices ruined the soil so completely that it has not yet recovered. The dissolved salts present in minute quantities in all water do not evaporate, so as water evaporates or is used by plants, the salt content of the remaining water grows. Irrigation waters unused by plants and not absorbed by the air may percolate down to the underground water table, which, in turn, may become increasingly salty over time. In Mesopotamia, in the absence of natural or artificial means of draining away extra water, the water table began to rise. Seepage from canals and periodic floods also added to the groundwater until it eventually reached root zones, where its brackishness stunted or prohibited crop growth. Even where the subterranean water was not too salty, it damaged or killed crop roots by cutting off the oxygen supply.

Once the water table was within several feet of the surface, water also began to move upward by capillary action, pulled by the dry air and soil above. As it reached the surface and evaporated, a thin deposit of salts was left behind—a familiar enough phenomenon to anyone who has seen a glass or dish from which salty water has evaporated. Centuries of repeated wetting and drying out left a thick white crust on the ground, rendering much of it all but useless for agriculture. Vast areas of southern Iraq today glisten like fields of freshly

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fallen snow; from 20 to 30 percent of the country's potentially irrigated land is unusable. Where salt concentrations are lower, farmers in much of Iraq are able to farm a given area only in alternate years, despite the availability of ample water. Irrigation water is applied to wash the salts downward into the ground a modest distance, a small crop of salt-tolerant barley is coaxed from the earth, and then the land is given over to deep-rooted weeds for a year, which help dry out the soggy soils. Until an underground system of drainage tiles is installed—an expensive, ambitious proposition—the situation will not improve; it may deteriorate further.

The progressive build-up of salt in lower Mesopotamia has been carefully chronicled by archaeologists. Barley tolerates saltier water and soils than wheat, so as salinization proceeded, barley has grown over larger areas. About 3500 B.C., wheat and barley were grown in nearly equal proportions. A thousand years later, wheat accounted for only one-sixth of the crop, and eight hundred years after that, by 1700 B.C., wheat cultivation had ceased entirely in most of southern Iraq.

More important than the shift in crops was the decline in productivity, a process which accelerated as irrigation grew heavier in the waning years of the Sumerian civilization. The declining yields were devastating for the towns, where large non-farming classes were dependent on farmers' surpluses for sustenance. Field records from 2400 B.C. indicate an average yield of 2,537 liters, or about two metric tons, of grain per hectare—respectable by current North American standards. By 2100 B.C. the yield had declined to 1,460 liters per hectare, and by 1700 B.C., as political and cultural dominance shifted northward to Babylonia, yields in Sumer had fallen to 897 liters per hectare. Many of the great Sumerian cities dwindled to villages or were left in ruins. While "probably there is no historical event of this magnitude for which a single explanation is adequate," write the pre-eminent historians Thorkild Jacobsen and Robert M. Adams, "that growing soil salinity played an important part in the breakup of Sumerian civilization seems beyond question."[2]

Successive Mesopotamian civilizations grew up in the north, where salinity generally did not emerge as a problem until many centuries later, and has never been as acute as in the lower reaches of the rivers. But as irrigation systems grew in size and complexity, another threat to food production eventually grew as well: the burden of silt carried by the river waters into irrigation canals. For the first four thousand or so years, irrigation in Mesopotamia was a simple affair in comparison to its later phases; silt was not yet a serious problem. Rather small human settlements concentrated along the banks of major water courses meant that short, easily maintained canals were the principal engineering works needed to supply fields with water. Often, river bank levees could simply be breached to flood low-lying fields.

After Alexander the Great's conquest in the fourth century B.C., Mesopotamia entered a new phase of urbanization and agricultural development. These trends peaked in the third through seventh centuries A.D., when the conquering Sassanians of Persia built an unprecedented, gigantic system of major and minor canals that crisscrossed the desert, allowing the exploitation of almost all the region's cultivable area. One ambitious canal, the Nahrwan, was three hundred kilometers in length with thousands of brick sluice gates along its branches.

The Tigris and Euphrates both carry heavy loads of sediment from upstream, loads that quite likely increased over time due to the growing use and misuse of the rivers' headwater areas for farming and grazing. The deposition of silt on floodplains, riverbeds, and at the rivers' delta on the Persian Gulf is a massive and never-ending process. Thus, over the last five thousand years a new layer of soil ten meters thick has been laid over the landscape in some parts of the Tigris-Euphrates Basin. In the earlier, simpler phase of irrigated agriculture and settlement in Mesopotamia, silting must have been an occasional nuisance when it clogged channels and ditches, but, on the whole, it was a blessing since, in the pattern of Egypt's productive floodplain agriculture, it meant an annual deposit of fertile topsoil on the land.

The new scale and complexity of agriculture in the Sassanian period, however, also meant a new vulnerability to any factor that might disrupt the workings of the extensive, finely-tuned water delivery system. The long canals quickly filled with sediment, and keeping the system working required continuous and backbreaking drudgery. Coordination of labor over a large area was required; no village acting in isolation could ensure its own survival. A powerful, centralized state was essential. That the system worked for many centuries is attested to by the huge mounds of silt, once cleaned from canals by slaves and laborers, that are still

a central feature of the landscape in parts of central and northern Iraq.

The region flourished so long as state power remained inviolate, and the Sassanian cities became cosmopolitan trade centers where Hebrew, Greek, and Syriatic were commonly spoken. But whenever cooperative canal maintenance was not forthcoming, whether due to internal social decay, a preoccupation with external military adventures, or hostile invasion, the system suffered catastrophic breakdowns that reduced the region's life-support capacity. A crisis of political authority in the late Sassanian period caused just such a breakdown, and, after a brief recovery following the Islamic invasion, the irrigation system fell into a state of disrepair in the twelfth century that has not yet been righted. Accumulating silt loads reduced the flow of the Nahrwan Canal to a trickle, and a leading world civilization to a few dusty villages. Most historians now agree that the Mongols, who invaded the region in the thirteenth century and have often since been blamed for its downfall, found scenes of devastation rather than opulence when they arrived in the legendary land of Mesopotamia.

A central lesson of Iraq's history, one that has been learned and forgotten repeatedly since the decline of the Sumerians, is that irrigation (providing water to thirsty crops) and drainage (removing excess water from the soil) are inseparable components of a single system. The need is not simply to locate water and wet the earth, though this goal alone has, understandably, preoccupied all desert societies, but to provide moisture at a level that maximizes crop growth and preserves the land's productive capacity over time. Often, this means providing underground or surface drains to draw away water unused by plants. Ironically, once water, the prerequisite of production, is obtained, getting rid of it eventually becomes nearly as crucial as assuring its continued supply.

Some irrigated regions are blessed with adequate natural underground drainage or an efficient flow of surface water out of fields. In Egypt, for example, the annual flooding of the Nile flushed salts out of the soil each year, which is why the Nile Valley, in contrast to Mesopotamia, has remained one of the world's most productive and densely populated areas for several thousand years. Egyptian irrigation projects outside the Nile floodplain have, over the last century, developed severe salinity problems. The Aswan Dam, which harnessed the Nile in the sixties, will allow further extensions of the irrigated area, but has eliminated the historic natural soil desalination process of the Nile Valley. Waterlogging and salinity, on both old and new farmlands, are becoming major headaches for the Egyptian government, and coping with them demands tremendous expenditures and technical skill.

Either too much or too little irrigation water can cause salinity problems. Where underground drainage is poor, as in Iraq, unused and unevaporated irrigation waters build up toward the surface, causing the dual problems of waterlogging and, as the water near the ground evaporates, salt deposits. But when water applications are too scanty, salt also builds up, since not enough water filters downward to flush the inevitable salt deposits below the root zone.

Under the right conditions, typified by Pakistan, the problems of too much and too little water can, in a sense, both exist at once. As the human population of Pakistan has multiplied over the last century, the irrigated area has also grown—but without a commensurate increase in the amount of water extracted from the country's rivers and underground aquifers. As a result, water is spread thinly and is often inadequate to satisfy the needs of crops, let alone the need to flush or leach salt downward out of the surface soils. At the same time, however, natural underground drainage throughout much of Pakistan is poor, and seepage from the country's extensive network of unlined canals, together with irrigation waters unused by crops, have brought the water table almost to the surface in many areas.

Pakistan, whose Indus Plain is by far the largest continuously irrigated region on earth and is thus a major world resource, presents many parallels to ancient Mesopotamia. It is a desert land where all civilization is founded on the waters of the Indus and its four major tributaries. Salt and silt challenge the survival of Pakistani society just as they did those of the Sumerians and Sassanians. One advantage the Pakistanis hold over the ancients is access to modern technologies that can probably keep irrigation sustainable on a permanent basis. A disadvantage is a population of seventy million that promises to double in twenty-five years, leaving little latitude for mistakes or disruptions in the water supply without tragic consequences.

Irrigation in Pakistan has a long history, stretching back to the Indus civilization of over four thousand years ago. Water diversions on a large scale, however, are relatively recent. Canal irrigation began at the end of the seventeenth century, primarily to furnish water

for the parks and gardens of the Moghul royalty. Though the obvious agricultural potential of these canals, most of which could only operate when river flows were high, was quickly perceived, farming was by and large still limited to narrow ribbons of land near the riverbanks. In the mid-nineteenth century the British undertook construction of the massive perennial irrigation system that was to make the area called the Punjab the breadbasket of the Indian subcontinent. Low dams called barrages were built to store water and channel it into canals with a total length of tens of thousands of miles, some of which carry nearly as much water as the Colorado River of the southwestern United States.

Almost as soon as these canals were built something unexpected began to happen: the level of water in wells began to rise. The new water courses were altering the equilibrium of the hydrological cycle, with as much as a third of the water they carried seeping down to the subterranean water table. Away from the riverbeds the water table was initially fifty to seventy feet deep, but over huge areas the table began to rise steadily, at a rate of one or two feet per year, until it was within ten or fifteen feet of the surface. At this point its rise slowed as the capillary rise and evaporation of water helped reduce the pace of build-up. But in some areas the water table eventually reached the surface, emerging as stagnant puddles. Well before the water reached the roots of the crops, damage to the land's productivity began occurring. Once underground water with a salinity content of one part per thousand—quite acceptable to crops—is within several feet of the surface, capillary evaporation residues will raise the salt content of the top three feet of soil to the intolerable level of one part per hundred in just twenty years.

By 1960 the problems of waterlogging and salinity were taking a deadly toll. An estimated area of over two million hectares, a fifth of the annually cultivated area of the Indus Plain, was severely affected; either yields were significantly cut by waterlogging and/or salinity, or production had ceased altogether. As many as forty-thousand additional hectares were falling into that category each year, a good share of them lost to cultivation altogether. And the productivity of many more millions of hectares was well below its potential level due to saline soils.[3] Pakistan was losing a hectare of good agricultural land every twenty minutes, but gaining a new claimant on that land by birth every twenty-four seconds. Pakistan's existence as a nation was being called into question by this process of human-caused ecological change, and the question could no longer be tabled.

Until 1954, almost nothing was done to counter the threat posed by waterlogging and salinity. Research efforts initiated in that year culminated in a comprehensive strategy for attacking the problem that was launched by the government in 1961. Warning that Pakistan had to act soon to avoid a "national catastrophe," and invoking the spectre of ruined hydraulic civilizations of the past, the government called for the construction of tens of thousands of miles of drains to draw surplus water away from the fields. But the heart of the new program, particularly in the Punjab, was the massive installation of tubewells, cylindrical shafts driven down to tap the water table.[4] Water drawn from underground could, engineers reasoned, replace or supplement river waters in irrigating the fields. Part of the water drawn up by the wells would seep back down, flushing salts downward, and enough would be lost to evaporation or plant consumption so that the dangerously high subterranean water would gradually sink lower. Where conditions were right, the introduction of properly spaced tubewells could not only help reverse the waterlogging and salinity trends, but could also provide a large, dependable supply of new irrigation water, allowing the adoption of higher-yield grain varieties.

Salinity-control project areas were given boundaries and thousands of wells were sunk. The results were significant, if sometimes below the expectations of the program designers. Tests in late 1964 in the initial project area indicated that in one year, despite unusually heavy rainfall, the groundwater level had fallen by eleven inches.[5] Overall, by 1970, it appeared to many observers that an important threshold had been crossed, with the land reclamation by then outstripping land losses.

But the processes that produce waterlogging and salinity continue without reprieve, while competing claims on the attention and resources of the government have left unrealized the salinity program's original goals for tubewells and drain construction. While the cost of the recently built Tarbela Dam on the Indus River climbed from the original estimate of $400 million to $1.2 billion, the civil war that resulted in the breaking away of Bangladesh also soaked up funds needed to fight salinity. Thus it would be premature to claim that the salinity problem has been conquered by Pakistan. As one leading foreign advisor to the government recently said, "The battle is far from won, but

at least it is now well underway. The country appears to be holding ground." In 1973 President Bhutto publicly recognized the shortcomings of the past effort. "So far we have merely toyed with the problems," he said, as he announced a new plan involving the anticipated expenditure of half a billion dollars over the next decade to hold down the losses to salinity.[6]

Irrigation in Pakistan, like that in ancient Iraq, is also hampered by the extraordinarily high silt load carried by the Indus and its tributaries—the product of easily erosive geologic conditions, exacerbated by the progressive deforestation of the Himalayas. The principal threat posed to Pakistan by silt is not the asphyxiation of irrigation canals, bad as that problem may be, but the shockingly rapid sedimentation of the country's expensive new reservoirs. Pakistan's topography offers dam sites that are poor by usual international standards, and, where feasible at all, dams will produce reservoirs that are extremely small in comparison with the size of the rivers they harness. The combination of small reservoirs and large rivers bearing heavy silt loads means reservoirs will have very brief life-spans.

The country's first big dam project, the $600 million Mangla Reservoir, began operations in 1967. It was constructed on the basis of feasibility studies showing a reservoir life expectancy of one hundred years or more. Sediment measurements after a few years of operation, however, indicate that most of its water-holding capacity will be gone in fifty-five to seventy-five years.[7] Even this estimate makes no allowance for a possible acceleration in silting as deforestation and overgrazing in the Jhelum River watershed continue.

The engineering lengths to which water-short, densely populated countries can be forced is suggested by Pakistan's Tarbela Dam, which was completed in early 1975. The largest earth- and rock-filled dam in the world, Tarbela was constructed with certain knowledge that its reservoir will be almost completely filled with silt in fifty years.[8] The reservoir's extraordinary expense is nevertheless outweighed in the calculations of the Pakistani government by its benefits in electric power and irrigation. As the original reservoir loses its water storage capacity, water will be diverted to nearby valleys, and eventually another dam may be built downstream. In the case of the Mangla Reservoir, plans now stand eventually to heighten the dam, thus adding to its storage ability and postponing the demise of the irrigation system it supports.

One generation of costly concrete and steel structures can be replaced by another, but as yet little has been done to attack accelerating soil erosion in the Indian and Pakistani headwaters of the Indus and its tributaries. Pakistan is paying an enormous price for land deterioration in the western Himalayas. Any reduction in the flow of soil into the Indus system would bring life-giving benefits to the country by prolonging the economic life of these reservoirs.

Continuously threatened by waterlogging, salinity, and siltation, Pakistan presents a striking juxtaposition of the primitive and the ultra-modern. Many of the world's poorest people subsist oblivious to advanced technologies, and their livelihood and habits are little affected by the decisions of seemingly faraway national governments. In Pakistan, however, the survival of an extremely poor, largely uneducated population is increasingly dependent on sophisticated technologies, elaborate regional cooperation, and huge, well-planned governmental expenditures. Fighting the salinity problem requires complex analysis using computers, and the careful control of pumping and irrigation practices over large areas by highly trained technicians. The country's huge irrigation projects demand centralized control and cooperation over wide areas; in the face of a system breakdown the individual farmer would be just as helpless as the Mesopotamian farmers were who lost their livelihood nine hundred years ago. Effectively replacing the new reservoirs as they fill with silt will require tremendous expenditures and technical skill. Should prolonged political disintegration or military conflict ever impair for long the government's ability to meet these problems forcefully, Pakistan's resemblance to Mesopotamia would leave little to the imagination.

Only a few decades back, it was sometimes debated whether the irrigation of desert lands, where evaporation is particularly high and natural drainage is often poor, could be considered a permanent enterprise. Today, most experts believe the technology is available to maintain soil quality indefinitely. Yet, right up to the present day, world irrigation development has been blemished by the frequent neglect of this knowledge in the planning and construction of new irrigation projects. Where drainage works have been provided at all, they have often been inadequate.

Insufficient provision for drainage in many countries is one aspect of a larger problem plaguing world irrigation development. Opening the initial stages of a project such as a dam or major canal is always a prestigious event, with high political payoffs for those responsible. These are visible, impressive achievements constructed

and thereafter managed by a small core of technological elites. But the extra steps required to make the grand projects meaningful and sustainable—the development of systems to deliver water on time and in proper quantities to the individual farmer, and the assurance of proper drainage at the farm level—are often overlooked. These steps are more difficult, requiring the cooperation not only of a few highly skilled technicians, but of all.

One explanation for this self-defeating trend is the mindset of many civil engineers, who sometimes plan and build dams with too little appreciation for the management needs of the individual farmer and for the long-term requisites of soil quality. Irrigation is too often viewed as an end in itself, rather than as the handmaiden of agricultural development. There may, furthermore, be an anti-drainage bias built into the process of project evaluation and adoption. Government officials and agencies competing for scarce funds and status, not to mention the consultants and contractors who will design and build the dams and canals, have a strong stake in keeping overall cost estimates as low as possible, and in magnifying a project's potential benefits. It is common at the planning stage to underestimate both the need for and the cost of the other side of the irrigation coin, drainage. Once irrigation projects are under construction and costs run over initial estimates, as they usually do, there are additional temptations to postpone even the planned drainage work. This is particularly easy since salinity and waterlogging usually do not start undercutting production for many years after the irrigation, with its dramatic initial returns, gets underway—and well after construction firms and bureaucrats have moved on to other projects, countries or positions.[9]

The legacy of this continued defiance of reality is a stupendous loss of global agricultural output. Two American analysts have estimated that the productivity of at least one-third of all the world's irrigated land is being undermined to varying degrees by salinity problems. The noted Soviet soil scientist V. Kovda goes further, estimating that 60 to 80 percent of all irrigated lands are, due to inadequate drainage or canal lining, becoming gradually more saline and, hence, infertile. By his calculations, twenty to twenty-five million hectares of land have been laid waste over the centuries after the introduction of improperly managed irrigation, and two hundred thousand to three hundred thousand additional hectares—out of a total worldwide irrigated area of nearly two hundred million hectares—pass from cultivation *each year* due to waterlogging and salinity.[10] Strangely, the awesome dimensions of this worldwide problem are generally unrecognized.

While Pakistan and Iraq present the most dramatic examples of the salinization threat, the problem is a critical one on every inhabited continent. Waterlogging and salinization are reducing yields to varying degrees in virtually every one of the thirty or so countries with more than half a million hectares of land under irrigation.

In Pakistan's neighbor, India, for example, over six million hectares—compared to a total national irrigated area of about forty million hectares—have been severely damaged by waterlogging and salinity and in many cases rendered unusable. Governmental and private tubewell installation has recently helped draw down the water table in parts of the Indian Punjab, but there and elsewhere, in the states of Haryana, Uttar Pradesh, Gujarat, Maharashtra, Orissa, and Rajasthan, the threat remains acute. After learning bitter lessons from past irrigation projects, the Indians are carefully minding drainage needs as the waters of the huge new Rajasthan Canal bring life to the desert, though some analysts still fear that salinity will harm the newly irrigated lands. China, too, has suffered from improper irrigation practices. Yields on at least a fifth of the irrigated area of some major regions are reduced by salinity, and tens of millions of hectares throughout the country are barren because of salt—some of it natural, some of it left by farmers in the past.[11]

Waterlogging and salinity plague nearly every country in the Middle East, not just Iraq. Salt-whitened sands are surpassed only by oil derricks as noteworthy human alterations of the landscape in that part of the world. As irrigation development escalates in the arid countries of the Middle East and North Africa, in part due to the new capital resources being shared with neighboring states by the oil exporters, salinity damage is sure to increase.

In the Euphrates Valley of Syria, above the Euphrates' entry into Iraq, from one-fourth to one-half the total agricultural area has been rendered unfit for cultivation by soil salinity and saturation. Average cotton yields in the valley's remaining farmlands dropped from 2.5 tons per hectare in the early fifties to about 1.5 tons per hectare by 1966. More than half of the combined irrigable lands of the Euphrates and Khabour Valleys, about 220,000 hectares, had been harmed or destroyed by salinity as of 1970. Nearly all this damage has occurred in the last twenty-five years since the

introduction of intensive, perennial cotton production.[12] The problem is certain to spread with the current expansion of irrigated area allowed by Syria's new dam on the Euphrates.

In 1970, less than a decade after Jordan initiated irrigated agriculture in the Jordan River Valley, salt and sogginess were affecting 12 percent of the project area, and the extent of the injury, according to the government, was "increasing every year." In Iran, officials say that "the majority of irrigated lands are saline and crop yields are depressed by the toxcity of salt." Iran is planning to bring vast quantities of water that is already moderately saline to large areas of land; only conscientious attention to drainage and leaching needs will permit these investments to fulfill their potential.[13]

Waterlogging and salinity problems also affect every country with major irrigation works in the Americas. By 1200 A.D., as the Incas of the mountains above were gaining ascendency over Peru's coastal cultures, some irrigated lands of the coastal desert had already been abandoned—due, some historians feel, to salinity and a rising water table. Today over two hundred thousand hectares along Peru's coast, almost a third of the cultivated area in this region, suffer from the same problems. Twenty to thirty percent of the agricultural lands in the Patagonian region of Argentina have been damaged by salt accumulation. In Northeast Brazil, at least half the irrigated land is affected by waterlogging and salinity, and the yields on some irrigated fields are actually lower now than they were before the advent of irrigation. Food and Agriculture Organization researchers have also identified salinity as an acute and growing problem in northwestern Haiti, a region suffering from drought and famine in mid-1975. As salt accumulates on the fields there, the cultivation of important food crops like peanuts and beans is impaired and then abandoned. More salt-resistant crops like cotton are substituted until their yields, too, begin falling; eventually the land is given over to cactus and thorny brush. Leaching and drainage could reverse this catastrophic trend, report the FAO analysts, and the battle is now getting underway.[14]

As a result of inadequate provision for drainage, and the attempt to spread irrigation waters too thinly, the tremendous expansion in this century of irrigation systems in Northwestern Mexico has been plagued by serious salinity problems.[15] In the Yaqui Valley, for example, forty thousand hectares were damaged by salts and fifteen thousand hectares had been retired from production by the mid-sixties. The problem is even worse in the large irrigated zone of the Colorado Delta, where four-fifths of the arable land was to some degree affected, and 14 percent was too saline for any cultivation by 1965. The Mexican government has recently initiated drainage projects in many salt-damaged areas, but another basic problem—the effort to farm too much land that is often alkaline with too little water—ensures that the salinity threat will not be countered easily.

Exacerbating the already difficult salinity problem in Mexico's Colorado Delta, the salt content of the lower Colorado River leaving the United States nearly doubled after 1961. In 1944 the precious waters of the Colorado were divided between the United States and Mexico, but no attention was given to the question of water quality. The river has a high natural salt content due to geologic deposits, and, as its waters have been increasingly diverted for agricultural uses and then drained back into the river, the salt concentration downstream has steadily risen. Since irrigation uses part of the water and speeds evaporation, the salt content in leftover waters rises.

The salt content of the river escalated dramatically when a pumping program was initiated in 1961 to lower the highly saline water table in the Wellton-Mohawk Irrigation and Drainage District of Arizona. Brackish water caused serious agricultural damage downstream in Mexico's Mexicali Valley, and became a major diplomatic irritant between Mexico and the United States. Protracted negotiations finally produced an agreement in 1973, under which the United States is building a desalination plant in Yuma, Arizona, to improve the quality of the water drained from the Wellton-Mohawk District.[16]

Though the 1973 accords were billed as a "final solution" to this international dispute over water quality, the problem persists. Irrigation development in the southwestern United States continues, and the expected diversion of upper Colorado waters for oil shale and coal exploitation promises to intensify further the salinity problems downstream.[17] Since the Colorado is the life-blood of much of the southwestern United States, there is little choice but to use and re-use the river waters, even though each additional diversion adds to the salt concentration of the remaining flow.

Already, despite elaborate drainage systems, some farmers in the rich Imperial and Coachella Valleys of California have suffered falling crop yields. The drainage facilities are not yet as developed in the Mexicali Valley, but the future of irrigated agriculture on both

sides of the border will be thorny in any case as the salt content of the river water rises, a process beyond the control of any single farmer or region. In the lower Colorado Basin, writes Harold E. Dregne, a prominent U.S. agronomist, "it is not hard to see the day coming when on-the-farm ameliorative measures are no longer sufficient."[18] Southern California, Arizona, and northwestern Mexico are gradually being boxed into a predicament with no easy answers. Either the river's salt build-up will have to be reversed in the coming decades—perhaps in part through massive, expensive desalination operations, but also by cutting off some of the upstream salt sources—or large areas of cropland will eventually have to be abandoned. There are limits to how many unnatural burdens can be heaped upon a single river, a fact whose implications many individuals now recognize, but which the affected state and national governments have so far been unable to reflect in practice.

Silt, like salt, is undermining irrigation systems on every continent. Heavy sedimentation of canals and other waterworks is a common problem, reducing the efficiency of irrigation systems and absorbing funds and labor for maintenance that are sorely needed for activities to increase production. The accelerated silting of reservoirs, cutting their effectiveness for hydroelectric-power generation, flood control, and irrigation, has huge annual worldwide costs that have never been totaled.

Silt in rivers and streams is, of course, one of the major end results of erosion on the land. The natural conditions of vegetation and soil structure in the watershed area, and of riverbanks and bottoms, are usually the major determinants of sediment loads carried by waterways. But human alteration of the landscape can also make a significant difference, giving once-clear streams a visibly muddy complexion. Excess sediment is the major form of human-caused water pollution in the world today, and exacts a heavier cost than any other water pollutant—possibly more than all other pollutants combined.

Sediment studies of the U.S. Department of Agriculture in sixteen Mississippi watersheds carried out in 1959-61 examined the potential impact of various human land uses on silt loads.[19] The studies were in a hilly region where, once the original forest cover is stripped away, soils are especially prone to erosion. The annual soil runoff from forested areas was only a few hundredths of a ton per hectare. Erosion from grassy pasturelands was much higher, though still not dangerous, averaging four tons per hectare. Lands cultivated for corn production, however, produced an average annual sediment yield of fifty-four tons per hectare. On the more skillfully managed fields, the erosion rate was eight tons per hectare, but on some farms it reached 106 tons. Where gullies had formed on abandoned farmlands, the average runoff of sediment was an astounding 450 tons per hectare. The numbers differ in every region but the basic relationships do not: as forests are cleared for agriculture, or are severely depleted by lumbering, grazing, or firewood gathering, the silt load of the rivers and streams below usually rises.

Siltation is especially dramatic in reservoirs that are small in relation to the river feeding them, such as the Mangla and Tarbela reservoirs in Pakistan. The water-holding capacity of the Tarbela Reservoir is only about one-seventh the annual flow of the soil-laden Indus, ensuring a short life. Lake Mead on the Colorado River, by contrast, holds more than twice as much water as the Colorado carries in a year, and will remain useful for centuries, despite the river's high sediment load.

The threat of siltation is frequently underestimated by dam builders, resulting in unhappy surprises later on for governments and farmers. When construction began on the Anchicaya Dam in Columbia in 1947, the consulting engineers reassured apprehensive officials that "tropical rivers carry little sediment," though the influx of farmers and roads to the surrounding slopes was then beginning. Imagine the bewilderment of these officials in 1957 when, only twenty-one months after the dam was completed, nearly a fourth of the reservoir's capacity had been lost to sediment![20]

Preliminary calculations for Taiwan's Shihmen Reservoir suggested a useful life of seventy-one years, but in one five-year period, from 1963 to 1968, 45 percent of its capacity was lost, provoking a new government program to halt unauthorized forest clearing and the rapid spread of farming onto steep slopes upstream. The Philippines' Ambuklao Dam, built to last sixty-two years, will be useful for thirty-two years—mainly because of excess logging in the Upper Agno River watershed.[21] The literature of world development activities is strewn with similar horror stories—and there will be more.

One of West Africa's most significant recent development projects, the Kainji Reservoir, which opened in 1969 on the Niger River in northern Nigeria, is intended to spur industrial and agricultural development in that arid zone by providing cheap electricity

and water. Unfortunately, satellite photographs analyzed by Paul Anaejionu of the American University, in Washington, D.C., suggest that the project will not meet original expectations. Deforestation, burning and overly intensive cultivation in Mali, Niger, Upper Volta, Dahomey, and Nigeria are apparently dumping far more sediment into the river than anticipated.[22]

Surveying twenty-two irrigation reservoirs, the Indian government recently discovered, to its consternation, that in many instances the annual inflow of sediment is at least four times as high as was assumed when the dams were built. In some cases, laments B. B. Vohra of the Ministry of Agriculture, "there are no alternative sites for reservoirs once these have been rendered useless. This means that even if we have the money to build fresh projects—and this is by no means certain—we shall not have the physical opportunities for doing so."[23] A good reservoir site is, in a sense, a non-renewable resource. Once exploited and then destroyed by silt, it can be replaced only at increased expense—and sometimes, as in some unlucky Indian provinces, it is irreplaceable.

A sample survey in 1941 indicated that 39 percent of the reservoirs in the United States had a useful life of less than fifty years. "Many of the reservoirs," write two prominent engineers, "were doubtless designed without consideration of the sediment load normally carried by the streams on which they were built." The total economic loss from reservoir sedimentation in the United States was estimated at fifty million dollars per year as of 1962.[24] Watershed conservation programs are not cheap, but they will often pay for themselves many times over in the extra farm output allowed by prolonged reservoir life.

Irrigation has played a key role in the evaluation of Southeast Asia, where wet-rice production has permitted the emergence of the world's most densely peopled humid tropical zones. Among Southeast Asian countries, irrigation agriculture is perhaps most advanced in Java, the island on which nearly two-thirds of the people of Indonesia live. Population growth is forcing other countries in that part of the world, such as the Philippines and Thailand, in Java's direction—toward more elaborate irrigation networks—while Java rehabilitates its long-neglected system in the effort to boost yields, and further extends the intricate circulatory network of canals that permits extra harvests each year on its scarce arable lands.

Many observers fear that Java is rushing inexorably toward an ecological nightmare. A few numbers sketch the problem. By 1975, Java, with a land area of 136,000 square kilometers, or about that of the state of New York, had a population of eighty-four million people, giving it an overall density of over six hundred per square kilometer (sixteen hundred per square mile). This compares with a density in the crowded Netherlands of about four hundred per square kilometer—and in some of Java's intensively farmed rural areas the density is more than double the island's average. Java's population is growing by two million per year, but there is no ecologically viable possibility of adding to the cultivated lands, which now cover 60 percent of the island.

Even if average fertility drops by one-fourth, reports Sumitro Djojohadikusumo, a leading Indonesian analyst, Indonesia's total population will increase from about 130 million in 1975 to 250 million at the century's end, and Java's from 84 to 146 million. This will give Java an *average* density of about eleven hundred people per square kilometer. As Sumitro observes, "this is greater than the present density in the most populated and urbanized centres of Western Europe."[25] Java is rapidly becoming the world's largest "island city." The resettlement of Javanese on Indonesia's more sparsely populated islands is desirable and necessary, but can hardly alter Java's basic prospects. Even if the government's goal of moving two million people during the current Five-Year Plan is met, Java's annual population increase will only be reduced by a fifth. There are basic logistical limits as to how many people can be resettled rapidly, particularly since they are moving to territories that are, in many cases, agriculturally untested and ecologically unfamiliar. The steady flow of destitute squatters into the shantytowns of Jakarta remains the country's most notable form of migration.

The term "island city" brings to mind an image of a fairly prosperous commercial center like Hong Kong or Singapore. Java, however, is an agricultural land where the vast majority must support themselves through farming if they are to support themselves at all. Simply finding housing space for the island's residents without encroaching on good farmlands will be a major challenge. Incredibly, Indonesia is not yet a massive food importer; limited progress in raising rice yields, and the wide sharing of inadequate food supplies among the rural poor, mean chronic undernourishment but, as yet, no huge import needs. And one can identify the theoretical means by which Java could continue to limp along with a nutritionally inadequate, but probably politically

tolerable, supply of food as its population doubles. The efficiency of the island's irrigation system can be increased greatly, and this, together with improved seeds and other practices, could bring major increases in crop yields. Fisheries development can help boost protein supplies, and the exploitation of as yet untouched arable lands on other islands of Indonesia may provide a surplus to help keep Java afloat.

But well before any theoretical agronomic limits are reached, Java could find itself sliding into an ecological crisis that undercuts their meaning. Farmers, out of understandable desperation, have *already* cleared forests well beyond the safe limits of agricultural sprawl, denuding hillsides on which farming is not sustainable for long. The negative consequences can be calculated in terms of disrupted stream flows and rising silt loads that jeopardize the efficiency of the island's essential water-delivery systems. Satellite pictures suggest that as little as 12 percent of this lush island now has tree cover, including plantations of teak and other species. In the watersheds of the vital Solo, Brantas, and Citarum river systems, forest cover is certainly well under 10 percent. An Indonesian ecologist, Dr. Otto Soemarwoto, has documented the acceleration of soil erosion in several watersheds, drawing special attention to a sevenfold increase in the silt load of the Citarum over a recent period of three years that is rapidly filling up Indonesia's largest reservoir downstream at Jatiluhur. In some areas around the upper Citarum, cassava and other root crops are now planted right up to the tops of smaller peaks that were covered by dense jungle in the 1950s.[26]

As Java's population grows, pressures on the ecosystem will mount, but as the irrigation system is refined, it is becoming more and more vulnerable to ecological disruption. Java's irrigation system might be compared to a fine watch. From some vantage points, one can see waters running in nine different directions and levels. Closely synchronized water movements from rivers or reservoirs to the individual field are essential; maximizing yields requires a precise amount of water at just the right time, and then its removal from fields.

Any factor reducing the efficiency of this intricately meshed system will pull down crop yields. A growing load of silt in canals and gates, like blood clots in human arteries, impairs their effectiveness. Declining river flows in dry seasons, and higher floods in the wet seasons, which are additional consequences of hillside clearing, further hamper the functioning of the system. An ominous long-term trend is the gradual building up of the level of fields and ditches as they receive a heavy annual sediment deposit, hindering the delivery and drainage of water to and from fields by gravity.

As other Southeast Asian countries expand and intensify their irrigation facilities to meet burgeoning food needs, moving in the direction of what might be termed the "Java model," their vulnerability to siltation and disrupted river flows will grow commensurately. The Philippines, for example, hopes to triple its irrigated area over the next decade. Yet the watersheds of several of the country's important rivers have already been ravaged by shifting cultivators and loggers. Satellite photographs indicate that deforestation is far more advanced than official statistics reveal, with the forest cover probably less than a fifth of the country's land area—a far cry from the 35 to 50 percent commonly assumed.

In mainland Southeast Asia, many of the same factors operate, but generally on a different schedule. The relatively crude irrigation system in the basin of Thailand's Chao Phya River has been vastly upgraded in the past decade, with large reservoirs on upstream tributaries and intricate water-delivery systems that permit two crops annually on much of the Central Plains area below. Hydrological data show little change in silt loads and seasonal water flows over the past decade, while aerial and satellite photos show more than 40 percent forest cover remaining in the Chao Phya watershed.

Yet some local observers calculate that the northern forests are being decimated at a rate of 5 to 7 percent a year. Most of the deforestation is occurring in the mountainous homelands of the minority ethnic tribes, especially in the "slash-and-burn" areas of opium cultivation—regions where the authority of the central Thai government is minimal. Superficially, the Thai situation appears relatively comfortable and well-balanced, like Java's in the 1930s. But if one projects a continued 3 percent annual rate of population growth, and a 5 to 7 percent annual deforestation rate, a crisis point is coming in the near future: intensive, controlled irrigation will be most needed just at the time when upstream erosion and irregularity of water flow will make downstream delivery and drainage facilities most difficult to operate and maintain. And this point will most likely coincide with greatly sharpened competition for Chao Phya water to serve agricultural, urban, industrial, and hydroelectric needs. A large river flow must also be maintained to keep ocean water from invading the low-lying coastal plains.

Though Java has a refined and intricate irrigation system already facing acute stresses, and Thailand a less pressured system with a grace period of perhaps fifteen years in which to undertake integrated planning, the basic lesson remains the same. The expected benefits of irrigation projects may never materialize, in Southeast Asia or elsewhere, if more heed is not paid to the overall ecological balance.

Each of the irrigation systems in ecological danger discussed in this chapter represents a serious local threat to a region or nation. Viewed together against world trends in irrigation development, they take on a far broader significance. One of the key factors permitting world food output to keep up with the surging postwar demand has been the historically unprecedented explosion in irrigation capacity. A total world irrigated area of eight million hectares in 1800 reached forty million hectares in 1900, 105 million hectares in 1950, and then 190 million hectares by 1970, thus growing faster than world population so far this century.

Unquestionably, considerable potential remains for further growth in the total world irrigated area, not to mention the vast improvements possible in the efficiency of water use. Large reserves of underground water remain untapped in the Indian subcontinent and elsewhere, and the Sudan has not come close to utilizing the Nile River waters accorded it by treaty with Egypt, to take two notable examples. Yet, on a global basis, there are clear indications that the rate of new irrigation development will slow markedly over the coming decades.[27] Most of the world's economically feasible opportunities for large-scale irrigation development have already been exploited. In some areas, such as the high plains of West Texas, the underground water supplies are being steadily depleted.

The great burst in world irrigation projects during the third quarter of this century cannot be repeated during the last quarter. Thus, though world irrigated area expanded by nearly 3 percent annually between 1950 and 1970, it will probably grow at little more than 1 percent a year in the remaining years of the century. As the need for fresh water grows faster than its availability, the insidious loss of irrigation capacity to salt and silt is sure to become more visible.

Notes

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Environment and Styles of Development

Ignacy Sachs

INTRODUCTION

After the anti-novel and counter-culture, zero growth. These are three symptoms, each quite different, of the re-examination of values by a society in search of new ideological responses to problems which have remained insoluble despite the spectacular progress of material growth, or which have arisen as a result of that progress: the generalized malaise of the young, the persistence of poverty, the aggression against the environment, the frustration of the Third World which today is wondering whether the very concept of development, founded upon efficiency, should not be replaced by that of liberation,[1] centred on social justice and the creation of a new man.

Only a profound sense of uneasiness can explain why the theme of zero growth should have so captured the public imagination and why it should have been taken up by public opinion within so short a time, despite the fact that it represents a complete reversal of the ideological outlook of the last two centuries and, still more, of the past fifty years. The frenzy of the mass media, the abuse of the computer to give credibility to this or that idea by investing it with scientific trappings, explain part of this phenomenon but not all. In a world traumatized by the crisis of the 1930s, the appearance of the socialist camp, and the emergence of the Third World, growth was in good standing with capitalists and revolutionaries, profit-makers and lovers of justice alike, and the only differences of opinion related to the methods and uses of growth. Today, however, the merits of growth are being questioned and—curiously enough—both the Left and the Right are dividing up into opponents and champions of growth.

The new awareness of environmental problems appears to be both one of the causes and one of the symptoms of this new outlook. True, the degradation of the environment is reaching unpleasant if not dangerous proportions here and there. But would this in itself have been sufficient cause for challenging the very objectives of society? Whatever the causes may be, the debate is now open.

Its oversimplifications, not to say mystifications, tend to be tiresome. Man is presented, now as the arrogant lord of creation and demiurge, now as the prisoner of a machine on a world scale in which production and pollution are conspiring to crush him and in which the only kind of history is natural history, in the sense that the depletion of energy introduces an element of irreversibility. For some, the quality of life is obtained at the price of limiting material production; for others it is, on the contrary, proportional to the abundance of products.

Beyond these clumsy efforts we should not fail to observe an emerging political practice which has several claims upon our interest: the long-term future is becoming operational, the notion of organizing possible futures and choosing a desired future is gaining acceptance, an approach to planning which is both

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global and normative at the same time is beginning to take the place of extrapolation, and the systems approach is replacing the sectoral method legitimized by Cartesianism. The hope of achieving continuous economic and social development hand in hand with rational management of the environment presupposes a redefinition of all objectives and all methods of action. The environment is a dimension of development, and must therefore be internalized at every decision-making level. Problems of resources, energy, environment, population, and development cannot, in fact, be correctly understood unless they are examined in relation to one another; and this implies planning within a unified conceptual framework.

For the poor countries the alternative presents itself more than ever in terms of original projects of civilization or of non-development, since to follow the path travelled by the industrialized countries appears neither possible nor, indeed, desirable. The rich countries will in future have to limit their wasteful use of resources, which are in process of relative exhaustion; price fluctuations will enforce this to some extent, but it would be dangerous to leave such matters to the hazards of the market. The elimination of waste and the confinement, within acceptable limits, of the pollution caused by the production or consumption of certain goods will also raise the problem of limiting the growth of material consumption while extending the range of social services (understood in the broadest sense) in order to arrive at a form of development which makes less intensive use of resources and is, at the same time, less harmful to the environment. Such restriction of consumption cannot be achieved without institutional changes more radical than is at present realized, starting with the redistribution of incomes and the reduction of social inequalities. In addition, there are a number of international problems: assumption of responsibility for the global environment, development of collective international resources regarded as the common heritage of mankind (e.g., the sea-bed), the impact of an international order capable of helping both to redefine their life styles.[2]

There is enough here to occupy a whole generation of social scientists. In fact, a new connection will have to be established between the human and the natural sciences in order to achieve a better understanding of the interaction between natural and social processes of which man is both the subject and the object: a subject, let us add, conscious of belonging to nature and of his own gradual growth. Beyond an excessively possibilistic human geography and an excessively deterministic ecology, there is a new synthesis to be made in which the contradictions between anthropology and history will be abolished,[3] and models of energy circulation will be linked with models of the production and circulation of matter and commercial goods. In the meanwhile, the charting of the future must be based on the practice of operational history in the Braudelian sense.[4] In order to learn to define possible futures we must start by dismantling the manifold models of the past, in which population, resources, energy, technology, environment, and social institutions are fitted together in a variety of fashions. In this context, *La Terre et l'Evolution Humaine* by Lucien Febvre[5] remains astoundingly topical after the passage of fifty years.

PLANNING WITHIN THE NEW ENVIRONMENTAL AWARENESS

How is the new awareness of environment problems affecting the planner's field of vision?[6]

Let us begin with a few necessary distinctions and definitions.

The term "environment" covers, on the one hand, the sum total of identified and identifiable natural resources existing in finite quantities on earth, and, on the other hand, the quality of the environment or, if one prefers, of the *milieu*, which constitutes an important element of the quality of life and which also determines the available amounts and quality of renewable resources. In fact, the dividing line between the renewable and non-renewable resources is not drawn once and for all. Renewable resources may in the end be destroyed by pollution, and recycling makes possible the repeated use of non-renewable resources. Generally speaking, however, the distinction between these two groups of resources remains valid and useful.

Let us now consider the environment proper. A more ambiguous concept has rarely been known. Of the multitude of proposed definitions, we shall set aside two which are largely complementary.

Definition 1. For the systems approach experts, the environment is made up of everything that does not form part of the purposive system under consideration, though it does affect the performance of that system.[7] As the system endows itself with environment policies, so the environment is less in evidence, and the success of these policies will consequently be measured by the disappearance of the very concept of environment, which will in the end be internalized by the system.

Let us now abandon the game of paradoxes, and draw attention to one operational advantage of the above definition. It invites us to identify better the ecological and societal impacts of the actions undertaken in order to achieve the explicit objectives of the purposive system constituted by development policies. Such an analysis should lead to a redefinition of development objectives with a view to more effective control of the ecological and social impacts of proposed action.

Definition 2. At a different level, UNEP speaks of the total habitat of man. This ecological definition of the human environment has the disadvantage of being too comprehensive. But it can be interpreted more restrictively.

Let us distinguish three subsystems within the environment.

1. The natural environment.
2. The man-made technostructures.
3. The social environment.[8]

Let us then endeavour to study the effects of each of these on the living and working conditions of the different social agents[9] and on the operation of enterprises (this corresponds, in an expanded form, to the problem of positive and negative externalities). The quality of the environment will be described by means of "objective" indicators and will, at the same time, be apprehended at the level of its perception by the different social agents. Hence the need for a set of indicators ranging from physical and chemical measurements of the quality of water or air to psycho-sociological surveys and including analyses of the availability and accessibility of collective facilities, housing, and social services, which will entail simultaneous recourse to statistics and to the time budgets of the various agents.

As already stated, the above two definitions of the environment are not mutually exclusive. The former stimulates the planner's awareness of the interrelations between natural and social processes. The latter concentrates on a more limited problem which is nevertheless of fundamental importance in the choice of development objectives—that of the quality of the environment properly speaking.

Let us now try to establish a relationship between the environment (E) and the population (Pn), techniques (T), natural resources (R), and the product (Pt) (see figure 1).

The development economist's traditional field of vision is represented in Figure 1(a). By means of the available techniques, the population transforms the resources into the appropriate product for purposes of consumption and social reproduction. The dialectic between demographic pressure and resources forms the subject of a large literature dealing with technological and social change. Is it a source of progress or of involution? Put in such general terms, the question cannot be answered. There is no single model to describe the numerous configurations of these variables. On the contrary, systematic efforts on the part of historians and anthropologists are called for to arrive at a typology of situations based on concrete data.

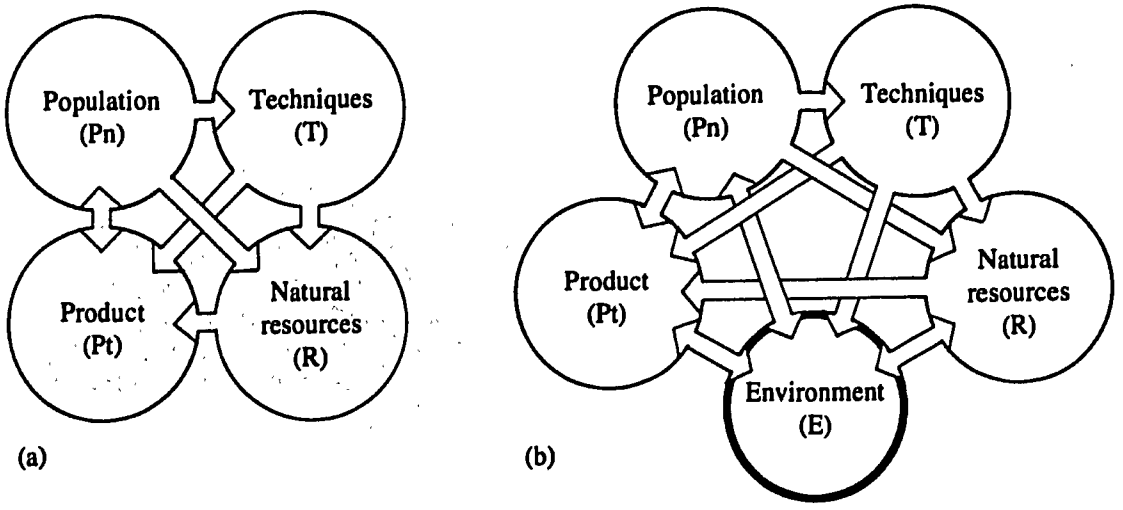
Let us now introduce the environment (E). Figure 1(b) indicates the relevant new relationships:

R → E, T → E	Effects on the environment of methods of utilization of the resources and of the production techniques employed.
Pt → E	Impact on the environment of the methods of consumption of products.
Pn → E	Impact of human settlements on the environment.
E → R	Degradation of natural resources due to pollution.
E → Pt	Conditioning of production through the quality of the environment.
E → Pn	Environment as a component of the quality of life.

Figure 1(b) does not, of course, set out to do anything more than point out the relevant relationships which, over and above the traditional factors used in planning, must be taken into consideration within the framework of a strategy aimed at making development compatible with the management of the environment. At best, the diagrams presented above have a heuristic value and will have to be modified in every concrete case. Likewise, it would be impossible to indicate once and for all the operational variables for such a strategy. On the other hand, it is possible to identify the critical levels at which action will take place. We distinguish six such levels, a brief description of which is given below:

1. *The consumption structure,* which, in turn, depends on the distribution of incomes and on the totality of values recognized by the society in question.

FIGURE 1
The Development Economist's Traditional Field of Vision
(a) and the Introduction of the Environment (b)



2. *The socio-political régime* and, more particularly, its manner of dealing with social charges; in market economies, the rule is to let enterprises internalize profits and externalize costs, while in socialist or mixed economies, the state may, in theory, change this rule of the game.

3. *The techniques employed,* where a distinction has to be drawn between, on the one hand, the adding of anti-pollution measures to the escalation of production and of the resulting nuisances and, on the other hand, the introduction of techniques which are not destructive of the environment, i.e., where the environment factor has been internalized.[10]

4. *The methods of utilization of natural resources and energy,* analyzed from the viewpoint of wastage of rare resources, possible recycling of waste products, and even of controlling the obsolescence rates of certain durable goods and equipment with a view to reducing the utilization of rare resources incorporated in them.[11]

5. *Land occupation systems,* since the same types of production and activities lead to very different effects depending on their localization.

6. Lastly, *the size, rate of growth, and distribution of the population,* it being understood that population size alone cannot serve as an indicator of its pressure on natural resources; by reason of their high per capita consumption, the few hundred million inhabitants of the rich countries exercise much more pressure than the thousands of millions of inhabitants of the Third World.

In a view of the complexity of the subject and of the many ways in which the relevant operational variables can be fitted together, there can, of course, be no question of proposing a single development strategy. Thus we come back once more to the search for alternative futures.

GUIDELINES FOR ECODEVELOPMENT

The foregoing general considerations have led to the formulation of the concept of ecodevelopment.[12] This concept aims at defining a style of development particularly suited to the rural regions of the Third World, though this does not mean that it cannot be extended to include towns, as we shall see in the case of New Bombay.

Its main features or guidelines are as follows:

1. In each ecoregion, efforts are made to develop those of its resources which are specifically needed for the satisfaction of the basic needs of the population in regard to food, housing, health, and education, these needs being defined realistically and independently so as to avoid the undesirable effects of copying the consumption style of the rich countries.[13]

2. As man himself is the most valuable resource, ecodevelopment must above all contribute to his fulfillment. Employment, security, the quality of human relations, respect for the diversity of cultures—or, if one prefers, the development of a satisfactory social ecosystem—are all part of this concept. A certain symmetry is discernible between the potential contribution of ecology and social anthropology to planning.

3. The identification, exploitation, and management of natural resources[14] is conducted from the standpoint of a forward-looking solidarity with future generations.

Depredation is strictly prohibited and the exhaustion of certain non-renewable resources—which is inevitable in the long term—is mitigated by the dual approach of avoiding wastage and making the greatest possible use of renewable resources which, if they are correctly used, should never be exhausted.

4. The negative impact of human activities on the human environment is reduced by resorting to procedures and forms of organizing production which make it possible to take advantage of complementarities of all kinds and to use waste for productive purposes.

5. In tropical and subtropical regions in particular, but everywhere else as well, ecodevelopment relies on the natural capacity of the region for photosynthesis in all its forms. Since guideline number 1, as applied to energy, tends to attach great importance to the use of local energy sources and to give preference to means of transport other than the private automobile, one result should be a reduction in the consumption of energy from commercial sources (and in particular hydrocarbons).

6. Ecodevelopment implies a particular technical style, since the above guidelines cannot in most cases be applied without the development of appropriate techniques.

There are two comments to be made here.

The development of ecotechniques will play a very important role in ecodevelopment strategies for the obvious reason that it is at this level that compatibility can be achieved between various objectives—economic, social, and ecological—since technical change would appear to be the principal multidimensional variable in planning.

It would be wrong, however, to assimilate ecodevelopment merely to a technological style. It calls for certain social-organization procedures and a new education system.

7. The institutional framework for ecodevelopment cannot be defined in the abstract without regard to the specific features of each case, any more than can forms of rural institutions proposed by the World Bank for achieving some success at last in the attack on absolute poverty in rural areas and for exploiting the potential of the impoverished masses of the Third World by providing the small peasant with production equipment and techniques suited to his economic and ecological conditions.[15] We can, however, state three basic principles.

Ecodevelopment calls for the establishment of a horizontal authority which is: (a) capable of looking beyond the interests of particular sectors; (b) concerned by all the facets of development; and (c) able constantly to control the complementarity of the different activities undertaken.

Such an authority cannot be efficient without the effective participation of the populations concerned in the realization of ecodevelopment strategies. This participation is essential for the definition and harmonization of actual needs, for the identification of the productive potential of the ecosystem and for the organization of the collective effort to develop it.

Lastly, it is essential to ensure that the results of ecodevelopment are not impaired by any plundering of the populations concerned, by intermediaries acting as contacts between the local communities and the national or international market.

These principles can be applied without too much difficulty in areas of the Third World where agrarian reform has been undertaken, and also in every case where living community structures have survived.

8. One necessary complement for the machinery of participatory planning and management is preparatory education. This argument applies *a fortiori* in the case of ecodevelopment, where it is essential also to make people aware of the environmental dimension and the ecological aspects of development. Lastly, as we have already said, it is essential to internalize this dimension and thus to change the system of values and predominant attitudes to nature or, conversely, to preserve and strengthen the respect for nature which is still a characteristic of certain cultures.[16] This result may be obtained by either formal or non-formal education. The Chinese experience is very instructive in this connection. The ecotechniques developed in China do not differ appreciably from those which other peasant societies have known and practiced; but what is new is the education which precedes and accompanies their application,[17] and determines their scope.

In brief, ecodevelopment is a style of development which, in each ecoregion, calls for specific solutions to the particular problems of the region in the light of cultural as well as ecological data and long-term as well as immediate needs. Accordingly it operates with criteria of progress which are related to each particular case, and adaptation to the environment, as postulated by the anthropologists, plays an important part. Without denying the importance of exchanges—and we shall revert to this matter later—it tries to react against the predominant fashion of allegedly universalist solutions and panacea-type formulas. Instead of placing too

much emphasis on external aid, it relies on the capabilities of human societies to identify their problems and devise their own original solutions to them, though drawing on the experience of others. It rejects passive transfers and the spirit of imitation, and gives pride of place to self-reliance.[18] It avoids the pitfalls of extreme ecologism, and suggests on the contrary that a creative effort to benefit from the margin of freedom offered by the environment is always possible, however great the climatic and natural constraints may be. This is amply borne out by the differences between cultures and human achievements in comparable natural environments. But success depends on a knowledge of the environment and on the will to create a lasting balance between man and nature. The setbacks and disasters in which certain societies have foundered offer equally eloquent evidence of the high price which has to be paid for inability to organize the relationships between man and nature.

APPLYING ECODEVELOPMENT STRATEGIES

With the assistance of some examples taken from the fields of production, food, housing, energy, industrialization of renewable natural resources, conservation of resources and organization of social services, we now propose to illustrate the scope of application of ecodevelopment strategies, with special reference to ecotechniques.

Food

The "green revolution," at least in its first phase, is based on a universalist and diffusionist philosophy of development which places too much emphasis on the virtues of transfers of technology and the widespread use of certain "miracle" varieties of wheat and rice. We are unable here to examine the complex and controversial subject of its results, and we shall therefore merely mention that many analyses insist that there are limits to its applicability, since it assumes that the problem of irrigation is solved and it also calls for extensive industrial inputs. In addition, it has contributed to an increasing social polarization and an even more inequitable distribution of income in the countryside. Lastly, it involves ecological risk both because of the reduction of genetic variety and because of the extension of single-crop farming, which is more vulnerable to epidemic disease than mixed farming.

Is it necessary to conclude from this that cultural borrowing and "modern" agriculture should be ruled out? Though certain champions of so-called biological agriculture may not agree with us, we reject this conclusion. The mere list of the plants originating from America which are now being cultivated by the rest of the world is enough to demonstrate the absurdity of such an approach, quite apart from the fact that the abandonment of chemical fertilizers and insecticides would lead immediately to a decline in production with very serious consequences. Nevertheless, it is possible and desirable to take a stand against the views embodied in the "green revolution," and to stress the specific potentialities of each ecoregion in regard to food production.

This leads us to draw attention, first of all, to the importance of ethnobiological research in order to take advantage—if only as a point of departure—of local knowledge of the natural environment, that "practical science" of primitive peoples and peasants the richness and accuracy of which are constantly surprising anthropologists and ethnobotanists.[19]

The striking diversity of types of agriculture and cultural habits in the world may be analyzed from the standpoint either of their adaptation to natural ecosystems or of the transformation of these systems. A classic study by Clifford Geertz draws a comparison between the irrigated terraces of Java—veritable aquaria fashioned by man for rice cultivation—and nomadic agriculture practiced on patches of burnt soil which constitutes an imitation of the tropical forest.[20] These are two extreme cases in many respects—the degree of artificiality, and supportable population densities (that of the rice fields is as much as 2,000 inhabitants per km^2); they are also two cases of felicitous adaptation to very different sets of ecological conditions. They reflect two very different orientations for agronomic research, the one relating to highly labor-intensive methods of production involving massive populations living in a small area, the other pointing to the development of mixed farming based on the "Chacras" of the Amazonian Indians and the gardens of the indigenous population of Polynesia. In the view of many experts, the apparent disorder of the latter conceals a profound rationality.[21]

In general, we have insufficient knowledge about agriculture in humid tropical areas; and priority should therefore be given to ecotechniques applicable in this area, on which a reasonable development pattern for Amazonia will to a large extent depend. This in itself is a highly controversial theme. Should Amazonia be developed or should it, on the contrary, be kept as a "reserve," as certain people advocate?

In view of the programs already undertaken and the existence of mineral wealth in this region, this question is rhetorical, particularly since the argument that the Amazonian forest is one of the "lungs of the world," producing oxygen, is scientifically unsound. The only real problem is how this development will be effected (and what is to happen to the last of the Indians). Will the development be effected by traditional techniques which involve cutting down the forest[22] in an impossible attempt to transform it into artificial pampas and open fields—or, on the contrary, will it be effected by ecotechniques that respect and are adapted to the forest although they draw profit from it? The results will depend on this basic choice and the ability to create in Amazonia a new "plant life" civilization. (Can it be that the pessimism of Betty Meggers[23] is due perhaps to the fact that she does not believe in the second possibility, while the optimism evident in the last writings of Gourou reflects precisely a genuine act of faith in human creativity in planning?)

Whatever the case, it will of course be necessary, here as everywhere else, to make use of methods that are already known and belong within the range of "classical" solutions, even though they may not have been adequately used hitherto. By way of example, we may mention the use of cassava or stripped sugar cane as fodder. But the bulk of the effort must be based on new approaches, of which we shall mention only a few.

First of all, there is forest-farming, which the British call three-dimensional forestry, using the forest as a source of industrial materials and also of animal fodder and human foodstuffs.[24] A glance back to the European Middle Ages will show that forests were long used as "a cattle fodder yard of unequalled quality," in the words of a Burgundy chronicler of the fourteenth century, quite apart from the role which they have long played as a source of energy. For a long time past, Germans have spoken of the *Nährwald*—the forest as a source of fodder—whose value is calculated in terms of the number of pigs it can feed.[25] The same evidence is provided by the study of certain primitive societies. One example is the astonishing case of the inhabitants of Ukara Island on Lake Victoria in Tanzania, which has a dense population of livestock breeders whose animals are kept in yards and fed on a mixture of leaves from specially planted trees and from aquatic plants.[26] This opens up prospects of research on trees which can produce human foodstuffs, either directly or indirectly through animal fodder. This research is regarded as essential for the future of agriculture in humid tropical areas, since tree cover seems to be the best cover for the soil in these regions.[27] We may note in passing that forest rehabilitation will call for a change in some ideas profoundly rooted in European civilization, which has grown accustomed to regard forest-clearing as synonymous with economic progress.[28] The rational management of the fauna and the taming of certain species may, in certain conditions, constitute a counterpart and a valuable extension of forest-farming.[29]

Next, we may mention aquaculture or the "blue revolution" (as opposed to the "green revolution") in all its aspects: the cultivation of aquatic plants and the breeding of fish and animals in fresh water, lagoons, and the sea, instead of a continuous fish-kill. There are abundant examples of this, starting with the familiar case of fish breeding in ponds, where a judicious combination of cultivation practices and fertilization produces very high yields with ecotechniques which require practically no capital investment.[30] Mention may also be made of the possibilities of breeding milk-fish in brackish-water lagoons. From certain lagoons fertilized by sewers in Indonesia it is possible to obtain a yield of 5,000 kg/ha/year. In Taiwan, fish breeding with fertilizers produces yields of 2,000 kg/ha/year; and it has been calculated that in South-East Asia 350,000 km^2 of water are suitable for breeding milk-fish. If these waters were used, they could produce 70 million tons of fish at the Taiwan productivity rate, or the equivalent of the world fish catch.[31] One more difficult but also promising field is the taming of certain species of aquatic mammals which feed on plants. The most notable example might be the sea-cow, which unfortunately is almost entirely extinct. In tropical regions where the soil is ill-suited for the creation of meadows, aquatic plants offer great possibilities as fodder for buffaloes and other animals.

Going on a step further, we come to the production of proteins from leaves of various kinds,[32] including weeds.[33] Under certain conditions, the plants infesting certain lakes could likewise become raw material for the extraction of proteins, and eutrophication could be prevented in this way.[34]

It goes without saying that both biological pest-control methods and genetic research on local species suitable for exploitation fall naturally within the framework of an ecodevelopment strategy.

Most of our examples have been taken from the humid tropical zones. The problem is quite different for the arid and semi-arid zones, though it is possible to imagine ecodevelopment strategies for these areas as

well. Recent studies have pointed to the possibility of developing plants which are particularly suitable for photosynthesis in areas where there is a lot of sunshine, high temperatures, and lack of water.[35] It is true that the development of deserts may call for ecotechniques with a high capital-intensiveness, but capital is not lacking in the petroleum-producing countries. A Japanese research project which was originally undertaken with a view to desulphuring the petroleum of the Persian Gulf points to the use of asphalt injected beneath the surface of the desert to prepare certain areas for the hydroponic cultivation of plants genetically suited to the brackish waters existing in the region. It is also worth stressing the political importance of studies of this kind, as a possible contribution to solving the Middle East conflict by developing the resources of the desert. The national aspirations of the Palestinians and Israelis could be satisfied more easily if the ecology of the region were changed; the "Great Petroleum Scare" and the subsequent sharp rises in prices have made it possible to envisage machinery for financing such an enterprise through a small surtax on petroleum, long-term loans advanced by the petroleum-producing countries, and the conversion of the military aid provided to the two opposing camps into a desert development fund.

Housing

Every year, the housing shortage on the world scale increases by some 4 to 5 million units in urban areas alone.[36] The situation in the countryside is far from being satisfactory. Yet, paradoxically, this is a field in which over the centuries human societies have created dwellings of varying types according to the locality and culture, and well adapted to the ecosystem and the climate,[37] but in which misunderstood modernity has led to such ravages that it has become necessary over recent years to re-invent "eco-dwellings" reflecting a high degree of ingenuity in the choice of materials, the use of solar and wind energy, water recycling, etc.[38] Housing within the framework of ecodevelopment has three closely linked aspects:

1. The use of building materials of local origin, which are abundant and cheap, ranging from bamboo to mud: this is a problem that has been studied in some detail, but much remains to be done in practice, starting with the rejection of an alien system of values according to which an aluminium roof or a steel and cement house imported at great expense is regarded as a symbol of modernity, even in the bush.

2. The adaptation of the dwelling itself to ecological conditions: as we have already noted, this is the field *par excellence* for the cultural creativity of man, in which it is necessary to take a deliberate step backwards to re-examine traditional housing and possibly draw some inspiration from it. A rigid attitude of reverence for tradition is, of course, undesirable; but architects should pay more attention to anthropology and move beyond the false universalism with which their discipline is at present tainted.[39]

3. Lastly, the integration of ecology and anthropology with urban thinking and with the elaboration of structural plans for towns and all other human settlements: this is by far the most difficult task and the one which has so far been least studied. Hence the importance of the pioneering efforts made by the creators of the New Bombay plan. This city of 2 million inhabitants is to be built with a minimal allocation of resources for housing proper, since the housing is to be provided by self-construction on very small plots; but a very careful plan for the occupation of the ground (which has been made possible by prior purchase of land by the authorities) and rapid collective transport by railway will together provide the inhabitants with living and working conditions which will be very reasonable compared with those in other towns in India.[40]

Energy

The debate on the importance of non-classical sources of energy is highly charged and we have no intention here of taking a position on this controversial subject. It is enough merely to observe that the recent increases in petroleum prices have already upset many hard-and-fast ideas. We shall not say anything of the possible solutions to the problem of large-scale energy production but, in the context of ecodevelopment strategies, we must refer to the importance which might be attached to the elimination of the energy wastage which occurs so often in the consumption style of the industrialized societies, and to the possible contribution which might be made—in the case of domestic energy uses and small production units—by solar energy (for example, for pumps, kitchen stoves, and water heaters), wind energy (for the local production of electricity), small dams, and even the production of methane from organic sources.[41] These various procedures are justifiable in the conditions of isolation which exist in many rural regions; and they also have the advantage that they can be applied on an even more

reduced scale, for example on a single farm. The possibilities of using geothermic energy should, of course, also be carefully assessed where they exist.

Industrialization of Renewable Resources

One way of combating the possible shortage of certain non-renewable resources might be to restore pride of place to the "plant life civilizations" which are so well described by P. Gourou and whose importance is so evident in Far Eastern cultures.[42] We do not advocate a pure and simple return to the past as do the partisans of the so-called intermediary and "soft" techniques, but would rather propose some detailed research on the possible use of plant life as an industrial raw material, both for building materials and for chemical products. The rise in petroleum prices makes this all the more necessary, and it increases the urgency of devising techniques for the rational management and exploitation of tropical forests and waters. We believe that a special place should be reserved to "mixed techniques," i.e., transforming the qualities of a product by highly technical processing, as the terminal stage in an otherwise traditional production procedure that provides much employment. All forms of processing and impregnating timber and plant fibers, based on the latest advances in modern chemistry and offering new outlets for certain products of tropical forests and agriculture, provide a good illustration of this concept.

Conservation of Natural Resources

As we have already indicated in regard to the definition of ecodevelopment, the care for natural resources in the name of a forward-looking solidarity with future generations is an integral part of the ecodevelopment strategy. It seems that it is also an excellent field for "human investment,"[43] since many soil and water conservation activities, reafforestation, etc. are suitable for the use of highly labor-intensive techniques. Also, as labor capacity is often available, at least outside the season of major agricultural activity, it is possible to envisage natural resources conservation programs which would not to any large extent diminish the capacity of a country to undertake other development enterprises. This is one opportunity which should not be missed, as the example of China eloquently demonstrates.[44]

Social Services

If, as has been suggested, the social environment is to be considered part of the global environment concept, when taken as meaning the total habitat of man, then an ecodevelopment strategy must naturally include forms and techniques for providing social, educational, and cultural services that are adapted to the specific conditions existing in the rural areas of the Third World and that also call for as little capital as possible. Many recent studies and the experience of certain countries prove that such techniques already exist at the level of para-medicine and rural education. In these conditions, Third World countries should be encouraged to attach much more importance to these activities than they are given in the thinking of planners in the industrialized countries, since the possibilities for developing these services are best at a time when social workers' salaries—like all others—are still low. In other words, the poor countries have a comparative advantage in creating many social services, which also offer employment possibilities that are more valuable to society than the traditional tertiary sector (domestic services and small business). Paradoxically, it is the countries of the Third World which have the best chance of creating genuine welfare states.[45]

CONCLUSION

The concept of ecodevelopment is intended to be operational. It constitutes a guideline for action (or, if one prefers, a philosophy of development) whose value can be judged only in the light of practice. Is it merely a return to the illusions of community development? Not necessarily so since, by comparison with the community development schemes for the rural areas of the Third World, it is richer in two respects: first, it is a critical reflection on the failure of those schemes and thus an attempt to do better, particularly at the institutional level, and second, it represents an opening on to natural and social ecology which is revolutionizing the habits of thought of development workers.

The application of the concept does, however, require a sustained research effort accompanied by pilot activities subject to critical review, so that permanent feedback is established between practice and action-oriented research.

In particular, we must promote the collation and circulation of information on ecodevelopment experiments, as identified and described by anthropologists, historians, and human geographers, and also on ecotechniques developed and applied by different indigenous popular cultures and, to an increasing extent, by certain research laboratories. The purpose of this will be threefold: to inspire the imagination of research workers and persons responsible for regional planning;

to assist in the training of ecodevelopers; and, occasionally, to suggest experiments in adaptation, particularly between similar ecozones. This will require a vast program of comparative and interdisciplinary research and journeys in space and time, undertaken through a network of scientific collaboration in which our colleagues of the Third World will have primary responsibility, since encouragement must be given above all to exchanges within the Third World on a South-South axis, by insisting on cooperation between ecoregions which are similar but situated in areas geographically distant from one another.

On the basis of these exchanges, supported by specific case studies, it would be possible to define points of interest to serve as focuses for the collaboration of biologists, technologists, and planners: three professions which in the past have had too little contact with one another. Their exchanges would lead to the formulation of research priorities on ecotechniques and organizational forms of ecodevelopment.

Without waiting for the results of all these exchanges, it is possible even now to undertake certain pilot activities, designed to show that regional or micro-regional development strategies would be improved if they were oriented in the direction of ecodevelopment. The elaboration of ecodevelopment scenarios would make it possible, in a first stage, to take stock of actual knowledge—or gaps in knowledge—on this matter, to test the participatory and unified approach to planning and to train ecodevelopers. In a second stage, it is conceivable that the ecodevelopment concept will simply be assimilated by the regional planners and will thus be generally used to contribute to the identification of development styles appropriate to each specific case; in the long term, the internalized environment as a permanent dimension in the field of vision of the planner is destined to vanish as a specific field of action.

NOTES

1. D. Goulet, *The Cruel Choice–A New Concept in the Theory of Development* (New York, 1973), pp. xii-xxi.

2. See in this connection the report of the United Nations Symposium on Population, Resources and the Environment (Stockholm, September to October 1973).

3. This social metascience is postulated and practiced by M. Godelier. See *Horizon*, "Trajets Marxistes en Anthropologie," (Paris, 1973), pp. 13-82.

4. See in this connection our article "Histoire Globale et Prospective du Tiers Monde," *Diogène*, no. 73.

5. L. Febvre, *La Terre et l'Evolution Humaine* (Paris, 1922).

6. The present piece of work partly represents our study "Ecodesarrollo: Un Aporte a la Definición de Estilos de Desarrollo para América Latina" prepared for the Economic Commission for Latin America (ECLA) in July 1973.

7. W. Churchman, *The Systems Approach* (New York, 1968).

8. The human environment is of course made up of men (see T. Maldonado, *Environnement et Idéologie* [Paris, 1972], p. 15).

9. In this respect F. Engels' work on the conditions of the working class in England stands out as a classic of the literature on the environment.

10. The category of non-destructive environmental technologies is broader than that of "soft technologies," defined as inflicting no damage to the environment, as not calling for a great deal of capital or for high qualifications and able moreover to be applied on a small scale. See in this connection: P. Harper, "'Soft Technologies' and the Critique of the Western Model of Development," in *Perspectives* 3:2 (1973), and our article published in the same review under the title "'Techniques Douces,' Projets de Civilisation, Développement."

11. One cannot over-emphasize, in this context, the importance of setting up a patrimonial accounting system for nature in order to be in a position to detect the consumption entailed by the irreversible whittling down of the capital of nature or, if one prefers, the rate of exploitation of the environment (for this last concept see R. G. Wilkinson's fine book, *Poverty and Progress. An Ecological Model of Economic Development* [London, 1973], and also M. F. Dasmann, *Ecological Principles for Economic Development* [London, 1973]).

12. Maurice F. Strong, former Executive Director of the United Nations Environment Programme, launched the idea of ecodevelopment at the first meeting of the administrative board of the program, held in Geneva in June 1973.

13. As the Pakistani economist and World Bank Policy Planning and Program Review Director Mahbub ul Haq has rightly written, "the developing countries have no choice but to turn inwards, in much the same way as Communist China did twenty-three years ago, and to adopt a different style of life, seeking a consumption pattern more consistent with their own poverty—pots and pans and bicycles and simple consumption habits—without being seduced by the life style of the rich" ("Crisis in Development Strategies," *World Development* 1:7 [1973]: 29).

14. It should never be forgotten that the very concept of natural resources depends on culture; as C. O. Sauer has said, natural resources are a civilization's estimates of its environment (quoted by P. Gourou, *Pour une Géographie Humaine* [Paris, 1973], p. 240).

15. See in this connection the address by Robert S. McNamara, President of the World Bank, to the Board of Governors, Nairobi, September 24, 1973, and the work of the United Nations Committee for the Planning of Development and the United Nations Research Institute for Social Development (UNRISD) on the unified approach to planning.

16. Development as it is traditionally defined always signifies ascribing an unconditional priority to culture over nature. However, as is stressed by Claude Lévi-Strauss, among primitive peoples the relation between culture and nature assumes a certain ambiguity: the latter is at one and the same time pre-culture and sub-culture, but, above all, it contains a supernatural component (*Anthropologie Structurale*, vol. II [Paris, 1973], p. 374).

17. See in particular J. B. R. Whitney, "Ecology and Environmental Control in China's Development Experience," special issue of the *Annals of the American Academy of Political and Social Science* 31:1 (March 1973): 95-109.

18. This English term consecrated by Emerson, used again in the context which is of interest to us by Gandhi, and more recently again by Nyerere (*Ujamaa: Essays on Socialism* [Dar es Salaam, 1968]) has connotations which the usual French translation, "développement autocentré," renders very imperfectly.

19. See, among others, C Lévi-Strauss, *La Pensée Sauvage* (Paris, 1962), pp. 3-47, and J. Barrau, "Plantes et Comportements des Hommes Qui les Cultivent. L'Oeuvre Ethnobiologique d'André Haudricourt," *La Pensée* 171 (October 1973): 37-46.

20. C. Geertz, "Two Types of Ecosystems," in *Environment and Cultural Behavior*, ed. A. P. Vayda (New York, 1969), pp. 3-25.

21. See for instance for the "chacras" of Indians, B. J. Meggers, *Amazonia: Man and Culture in a Counterfeit Paradise* (Chicago, 1971), and S. Varese, "Au Sujet du Colonialisme Ecologique," *Les Temps Modernes* (April 1973); for the gardens of Polynesia, R. A. Rapaport, "The Flow of Energy in an Agricultural Society," *Scientific American* (September 1971).

The International Rice Research Institute has begun a research program on "multiple cropping" conceived as a carry-on from the "green revolution," keyed to the humble peasant who lacks capital and access to irrigated lands, but could grasp perfectly well a new technique which would depend essentially on his labor and on knowledge of the environment and would afford him a possibility of increasing and diversifying his production (see G. Conway and J. Romm, *Ecology and Resource Development in Southeast Asia* [The Ford Foundation Office for Southeast Asia, 1973]).

22. Naturalists can be found who justify the cutting down of the forest by pseudo-scientific arguments. Has not Henrique Pimenta Veloso, adviser to the Brazilian Government, explained that the Amazonian forest is in the process of growing dangerously old and of degenerating beneath the weight of the liana and that 30 percent of it must be cut down before it is too late (*O Estado de São Paulo* [4 September 1973])? His statements called forth a caustic commentary from the *Jornal do Brasil* suggesting that the erudite ecologist had the soul of a lumberjack and of a cattle-breeder.

23. The book already referred to by Meggers bears the significant subtitle of counterfeit paradise. Gourou, whose assessments of the virtual possibilities of Amazonia have greatly evolved, writes in a recent work: "It is more realistic—and more scientific—to think that it is on account of the lack of farming techniques and adequate backing technologies that it has not been possible for a permanent and abundantly productive agriculture to be established in Amazonia. If an ingenious civilization had risen up in Amazonia, there would be no lack of people to say that it had been favoured by the vast expanse of arable land, by the abundance and regularity of the rains and by an admirable navigable network, unique in the world" (*Pour une Géographie Humaine*, p. 95).

24. See by way of example the excellent article by James Sholto Douglas, "Agrisylviculture to Increase Nature's Food Production," *Impact of Science on Society* (Unesco) 23:2 (1973).

25. See P. Deffontaines, *L'Homme et la Forêt* (Paris, 1969), pp. 37 and 44. See also, for examples of the role played by the forest in providing food during the early Middle Ages and the integration of agriculture, stock-raising, and sylviculture, Georges Duby, *Guerriers et Paysans, VII–XII Siècles* (Paris, 1973).

26. P. Gourou, *Lecons de Géographie Tropicale* (Paris, 1971), pp. 160-61.

27. See R. Revelle, "Population and Natural Resources—Land and Water Resources," document prepared for the United Nations Symposium on Population, Resources and the Environment, Stockholm, September 26 to October 5, 1973.

28. In this connection European culture is in opposition to that of the Moslem East, as has been rightly noted by J. Le Goff: "A great mantle of forests and heaths interspersed with cultivated clearings of varying degrees of fertility, such is the face of Christendom—like a negative of the Moslem East, a world of oases in the midst of deserts. Here wood is scarce, there it is plentiful, here trees are civilization, there they are barbarism. The religion which rose up in the East in the shelter of palm trees made its appearance in the West at the expense of the trees, the refuge of pagan spirits, which were mercilessly cut down by monks, saints and missionaries. All progress in the medieval West took the form of land clearance, of fighting and vanquishing the brushwood and bushes or, if it was necessary and if technical equipment and courage made it possible, the woods, the 'gaste forêt' of Percival, the *selva oscura* of Dante" (*La Civilisation de l'Occident Médiéval* [Paris 1967], p. 169).

29. The great English biologist Julian Huxley reached a similar conclusion with regard to the African savannas. See "Riches of Wild Africa" in *Essays of a Humanist* (Harmondsworth, 1966), pp. 177-201.

30. H. Dickenson describes Chinese practices whereby up to 8,000 kg of fish are obtained yearly for each hectare of pond subject to a very sophisticated management, involving the feeding of fish with snails, the chrysalises of silkworms, and the leaves of sweet potatoes, and enriched by pigs' dung (*Rural China*, report published by the School of Engineering Science [University of Edinburgh, 1972], p. 133). In Peruvian Amazonia we visited an example of experimental pisciculture where the fish were fed on termites, which opens up possibilities of managing the trophic chains in a new way. For an exhaustive overview of the problems of aquaculture, see J. E. Bardach, J. H. Ryther, and W. O. McLarney, *Aquaculture. The Farming and Husbandry of Freshwater and Marine Organisms* (New York, 1972).

31. P. Gourou, *Pour une Géographie Humaine*, p. 27.

32. See the studies carried out by N. W. Pirie, a pioneer in the field, and in particular the following volume (edited by him): *Leaf Protein: Its Agronomy, Preparation, Quality and Use* (Oxford and Edinburgh: Blackwell Scientific Publications for the International Biological Programme, 1971).

33. See S. B. Gore and R. N. Joshi, "The Exploitation of Weeds for Leaf Protein Production" in *Tropical Ecology with an Emphasis on Organic Production* (Athens, GA, 1972), pp. 137-46.

34. Thus at the eleventh International Great Dam Congress, held at Madrid in June 1973, the Soviet delegation announced the construction in the Ukraine of a factory for the extraction of proteins from the plants which infest the artificial lakes.

35. See O. Björkman and J. Berry, "High-Efficiency Photosynthesis," *Scientific American* 229:4 (October 1973): 80-93.

36. *World Housing Survey* (doc. E/C.6/129) (New York: United Nations, 1973).

37. See in this connection: A. Rapaport, *Pour une Anthropologie de la Maison* (Paris, 1972); P. Deffontaines, *L'Homme et Sa Maison. Géographie Humaine* (Paris, 1972); and, with regard to the Arabic house, Hassan Fathy's excellent book, *Construire avec le*

Peuple (Paris, 1971). Gilberto Freire has studied the adaptation to the ecosystem of the Brazilian colonial house in *A Casa Brasileira* (Rio de Janeiro, 1971).

38. As one example among others, mention may be made of the experimental house built at McGill University in Canada: sulphur, a by-product of oil refining, was used as material, wind energy was harnessed to produce electricity, solar energy was used for cooking and heating water. The creativity of the designers showed itself above all with regard to water husbandry: separation of three qualities of water in terms of use, recycling and purification with the aid of solar energy, collecting of rain-water, condensation of air humidity, choice of simple, and judicious methods of sprinkling for washing, etc. (A. Ortega et al., *The Ecol Operation* [Montreal, 1972]).

39. Let us refer once again, by way of example, to Hassan Fathy's fine work.

40. See Charles Correa's excellent study, "Self-Help City, the Internal Organization of Metropolitan Areas," submitted to the United Nations Symposium on Population, Resources and the Environment, Stockholm, September 26 to October 5, 1973.

41. Either on the basis of algae, or on the basis of dung, as is already being done in India; in the latter case, this constitutes important economic progress, for cow-dung traditionally serves as fuel, wood being scarce; the new process makes it possible to extract fuel, to meet the needs of the village, by means of a simple device, and also to obtain manure.

42. See P. Gourou, "La Civilisation du Végétal," *Indonésie*, no. 1 (5) (1948); and, by the same author, *La Terre et l'Homme en Extrême Orient* (Paris, 1972), in particular pp. 26-29.

43. See in this connection E. Raynaud's work, *Investissements Humains: Illusions et Réalités* (Paris and The Hague, 1969).

44. See in this connection the article, already mentioned, by J. B. R. Whitney, "Ecology and Environmental Control" and the study made by Chang Kuang-tou, Chen Chun-ting, Li Kuei-fen, and Liu Ling-yao, *Construction of Dams for Water Conservancy* (Peking, 1973); and for a general formulation of possibilities with regard to the application of labor-intensive methods for the conservation of resources, see our contribution to the Founex Symposium of 1971: "Environmental Quality Management and Development Planning: Some Suggestions for Action," in *Development and Environment* (The Hague and Paris, 1972).

45. For further details, see our article: "A Welfare State for Poor Countries," *Economic and Political Weekly* 6:35 (January 1971).