The Deterioration of Mountain Environments

Ecological stress in the highlands of Asia, Latin America, and Africa takes a mounting social toll.

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An unusual meeting was convened in Munich, Germany, in December 1974. Any organizing principle, any common thread among the participants, would have eluded an outsider. The group included biologists, anthropologists, foresters, ecologists, economists, geographers, businessmen, and civil servants, and they had traveled to Munich from Europe, North and South America, Africa, and Asia. What drew this disparate group together was a shared concern for a problem that has scarcely been recognized as one deserving attention in its own right: the deterioration of mountain environments in the poor countries (*1*).

Mountains, in contrast with deserts—another sparsely populated, economically marginal portion of the earth—have been largely neglected by researchers and governments. A major international program of arid zone research was initiated by the United Nations as early as 1951, whereas coordinated interdisciplinary research on mountain environments is only now getting under way.

Highlands occupy about one-fourth of the earth's land surface, but provide a home for only a tenth of the world's people (*2*). Still, it is curious that mountain ecosystems have been ignored so long in comparison to other natural areas, for history has repeatedly shown that when ecological changes take place in the highlands, changes soon follow in the valleys and the plains. And while only 10 percent of the human population lives in the highlands, another 40 percent lives in the adjacent lowland areas, and their future is intimately bound to developments on the slopes and plateaus above.

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For all the diversity that characterizes the land and peoples of the three major mountain ranges of the developing regions—the Himalayas, the Andes, and the East African highlands—they present a rather uniform set of environmental and economic challenges. What strikes the casual observer of ranges like these is their stark immutability, their massive grandeur; but in fact they are among the most fragile ecosystems on earth. Steep mountain slopes can seldom sustain the degree of cropping, woodcutting, and grazing that is customary in flatter areas. Yet increases in all three practices are forced by rising populations throughout the mountains. And the inherent difficulty of adapting cultural practices to rapidly changing environmental circumstances is exacerbated by the tendency of mountain populations to be those with the least income, the least education, and the least political power in any country.

When the environment starts to deteriorate on steep mountain slopes, it deteriorates quickly—far more so than on gentler slopes and on plains. And the damage is far more likely to be irreversible. The mountain regions are not only poor in economic terms; many areas are rapidly losing any chance of ever prospering as their thin natural resource base is washed away. Degenerating economic and ecological conditions in the mountains, in turn, often push waves of migrants into the lowlands, leaving behind an aged, dispirited population incapable of reversing the negative spiral.

The net result of current trends, as evaluated by the international committee of experts recently established by Unesco to study mountain environments, is "accelerating damage to the basic life support systems" today in practically every mountainous region of Asia, Africa, and Latin America. "Within the last decade there has been a marked increase in the destructive clearance of forests, in flood damage and silting, in soil erosion and the explosive spread of pests.... In sum, human pressures on tropical high mountain ecosystems are increasing nearly everywhere..." (*3*).

Mountain regions often have great economic potential as sources of hydroelectric power, of valuable timber and minerals, and of scenic natural refuges which are in growing demand and diminishing supply. But one must take care to distinguish between the potential toward which societies need to work, and the present-day realities. For without a massive effort to preserve and restore the ecological integrity of the mountains, within a few decades they will not be idyllic vacation spots but, rather, barren eyesores that perennially present the lowlands with devastating torrents and suffocating loads of silt.

Tragedy in Shangri-La

There is no better place to begin an examination of deteriorating mountain environments than Nepal. In probably no other mountain country are the forces of ecological degradation building so rapidly and visibly. This kingdom of 12 million people is minuscule by Asian standards, but it forms the nucleus of one of the more strategic ecological nerve centers in the world. The Himalayan arc, stretching from Afghanistan through Pakistan, India, Nepal, and Bhutan to Burma, forms an ecological Gibraltar whose fate will affect the well-being of hundreds of millions. From the Himalayas flow the major rivers of the Indian subcontinent—the Indus, the Ganges, and the Brahmaputra—which annually bring life, and sometimes death, to Pakistan, India, and Bangladesh.

Nepal has an exotic facade of romance and beauty, but behind it are the makings of a great human tragedy. Population growth in the context of a traditional agrarian technology is forcing farmers onto ever steeper slopes, slopes unfit for sustained farming even with the astonishingly elaborate terracing practiced there. Meanwhile, villagers must roam farther and farther from their homes to gather fodder and firewood, thus surrounding most villages with a widening circle of denuded hillsides. Ground-holding trees are disappearing fast among the geologically young, jagged foothills of the Himalayas, which are among the most easily erodable anywhere. Landslides that destroy lives, homes, and crops occur more and more frequently throughout the Nepalese hills (*4, 5*).

Topsoil washing down into India and Bangladesh is now Nepal's most precious export, but one for which it receives no

compensation. As fertile soil slips away, the productive capacity of the hills declines, even while the demand for food grows inexorably. Some terraces are expertly managed and ecologically stable; others continue to be farmed despite their waning productivity, and others reach the point of no return and are abandoned. In the country's most densely populated region, the Eastern hills, as much as 38 percent of the total land area consists of abandoned fields (*6*).

While the acceleration of the heavy natural erosion is the chief threat, the declining fertility of the hills stems in part from another problem. Nepalese farmers have always assiduously applied the available animal manures to their fields as fertilizer, but in some regions the fields now receive less manure than in the past—well below the full amount necessary to preserve high fertility (*7*). This is partly because herd sizes have not grown as rapidly as the cultivated area; the hills are already overgrazed, and fodder of any kind, whether tree leaves or forage crops, is scarce. Even more ominously, farmers facing an unduly long trek to gather firewood for cooking and warmth have seen no choice but to adopt the self-defeating practice of burning dung for fuel.

The average hectare of arable land in Nepal's hills must now support at least nine people. This is a man-to-land ratio comparable to that in Bangladesh or Java, but those countries are blessed with far more fertile soils and a climate which permits several crops a year on the same land. And in the hills, the Nepalese government realizes that "there is absolutely no scope whatsoever for bringing new land under agriculture" (*5*).

If Nepal's borders ended at the base of the Himalayan foothills, the country would by now be in the throes of a total economic and ecological collapse. Luckily the borders extend farther south to include a strip of relatively unexploited plains known as the Terai, which is an extension of the productive Indo-Gangetic Plain of northern India. The Terai suffers seasonal floods and is heavily vegetated, and historically the high incidence of malaria precluded heavy settlement. Once an effective malaria eradication program got under way in the 1950's, however, a rush to colonize the region was inevitable.

The Nepalese government knows that the controlled settlement of the Terai is an essential step to help take some of the pressure off the hills, but it lacks the capacity to keep the land rush under any meaningful control. In the decade from 1964 to 1974, 77,700 hectares of Terai forest land were officially distributed by the government to settlers. But more than three times that amount was cleared illegally by migrants from the hills or, perhaps even more significantly, from India (*5*).

The presence of undeveloped arable land in the Terai does provide Nepal with some breathing space in which to reverse the downward spiral of population growth, land destruction, and declining productivity in which it is now caught. Yet the length of this reprieve is frequently exaggerated, both by outsiders and by some Nepalese. Analysis of satellite imagery indicates that less than half the remaining three-quarters of a million hectares of Terai forestlands will be suitable for cultivation (*8*). If migration down into the Terai continues at the pace of the last 10 years, all the good farmland will be occupied in little more than a decade.

Agricultural modernization—better seeds and innovative techniques, land reform, extension services, and so on—will quickly have to replace the extensive spread of farming to new lands if Nepal is to avoid an acute food crisis. The potential for raising yields may be greatest in the Terai, but the hills cannot be neglected any longer. Migration is a temporary palliative, not a long-term solution; a large share of the country's citizens will always live in the hills regardless of the quality of life they provide, and soon there will be no place for the people to go. Furthermore, the devastation in the hills is exacting a heavy, if as yet unmeasured, price on the potential productivity of the Terai. The incidence of flooding by swollen rivers coming down from the mountains is increasing, according to those who have lived near their banks for decades. Government soil conservation officials observe that the bed level of many Terai rivers is rising from 6 inches to 1 foot every year (*5, 9*). This not only guarantees wider floods from even normal volumes of water in the monsoon season; it is also causing the river courses to meander about, often destroying prime farmland as they go.

The cultures of Nepal have not historically faced a serious problem of land scarcity, and while terracing has always been necessary to farm the hills, the development of a national conservation ethic was never before essential to their survival. By now, however, the pace of destruction is reaching unignorable proportions, and this, in combination with the continuing efforts of dedicated individuals both in and out of the Nepalese government, is stirring new interest in the integrity of the environment. The country's influential National Planning Commission recently expressed its concern with an urgency unsurpassed by any party. Soil erosion, the commission fears, 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" (*5*).

Translating official awareness into meaningful programs on the ground is no mean task, particularly in a country with such limited resources and unique problems of transportation and communication. In August 1974, a Department of Soil and Water Conservation was finally formed within the Ministry of Forests. This department hopes to establish demonstration projects in villages scattered about the country, but in early 1975 the department included only 67 employees, of which fewer than a third had college-level professional training. According to national development policy, this department is slated to expand to 167 employees over the next 5 years—still far from adequate.

India's Worries

Faced with the inevitability of absorbing many of the consequences of ecological degradation in Nepal, Indian officials have encouraged the Nepalese to attack the problems and have even provided limited assistance in land management research (*6*). The Indians are worried about environmental trends in Nepal and with good reason, but the fact is that virtually identical problems plague even larger hilly expanses within India itself in such states as Himachal Pradesh, Uttar Pradesh, Assam, and Jammu and Kashmir. In large mountain regions in these states, the fertile valley floors have long been overcrowded, and cultivation is constantly pushed onto steeper slopes by population growth in the absence of nonagricultural employment opportunities. On millions of hectares there is no longer any topsoil at all, just a rocky substratum lacking organic matter or fertility. Forests are receding under the combined pressures of shifting cultivators; uncontrolled herds of goats, sheep, and cattle; and wood-gathering for home consumption or sale (*10*). In many areas, firewood is beyond the reach of village populations, so dung is burned instead.

Westward in the Himalayas, first in northern Pakistan and then Afghanistan, the outlook is hardly more encouraging. Both countries are mainly arid and desert-like, which means that the limited available forests in the mountains must bear an especially heavy burden. Pakistan today, for example, only classifies 3.4 percent of its land as forest, nearly all of which is concentrated in its hilly northern provinces. Large stretches in these hills have been visibly deforested within the last century (*11*). On top of the growing pressures from agriculture and overgrazing, the remaining for-

ests must satisfy the burgeoning national need for wood for construction, industry, furniture, and fuel. While farmers lop the branches off trees to provide their animals with fodder and their homes with fuel, timber concessionaires respond ,to some of the world's highest lumber prices in the cities below by clearing large stands of timber, often without concern for the environmental consequences.

Through these northern hills, after passing through India, flows Pakistan's jugular, the Indus River system. The water of the Indus and its six major tributaries is about all that stands between a bustling, densely populated civilization and a deserted, sandy wasteland. With erosion rampant in the uplands, the exceptionally heavy silt load carried by these rivers is rendering the country's expensive new reservoirs useless with startling rapidity and has become a favorite subject of editorials and political speeches over the last decade. Pakistani foresters are pressing ahead with an excellent series of forest resource and land management surveys in the mountain regions, but obtaining the funds and political commitment needed to act on their research findings is proving more difficult.

The barren, infertile landscape presented by most of Afghanistan, and by the Zagros and Elburz mountains farther west in Iran, is fair warning of what lies ahead for parts of Pakistan, India, and Nepal, if prevailing trends are not reversed. A United Nations team visiting Afghanistan in the mid-1960's found the country's river basins "remarkable for their sparseness of vegetation and the paucity of animal life. The upper catchments are often bare rocky mountains with almost no soil cover and very little vegetation." A German forester who worked 8 years in Paktia province, where most of Afghanistan's few remaining trees are standing, laments their imminent demise by writing, "In Afghanistan the last forest is dying—and with it the basis of life for an entire region" (*12*). Afghanistan was never blessed with ample rain and fertile soils; even many centuries back, the forests covered only a small area. By now, however, they have been reduced to less than 0.1 percent of the country.

Stress in the Land of the Incas

On the far side of the world from the Himalayas, dominating the west coast of South America, stand the Andes mountains. The longest range in the world, these mountains form what looks like the misplaced spine of an entire continent, stretching from Venezuela through Colombia, Ecuador, Peru, Bolivia, and Chile almost to Cape Horn. This massive ridge rises with remarkable rapidity from a deep trough in the Pacific, then just as quickly falls almost to sea level and the tropical forests in which the Amazon's tributaries begin their 5000-kilometer course to the Atlantic.

The major temperate zone mountain ranges, such as the Alps and the Rockies, have always been thinly settled in comparison with the surrounding lowlands. Just the opposite is true of the Andes and the Ethiopian Highlands, which have been densely populated for many centuries, and are bordered by sparsely populated tropical rainforests or deserts. Though rugged, the Andean uplands present a natural environment far more hospitable to permanent agriculture than the surrounding areas.

From Ecuador southward much of the narrow coast separating the Andes from the Pacific Ocean is a leafless desert, striped with the irrigated oases which surround each of the 60 or so rivers flowing down the westward side of the mountains. Some of these flow only seasonally, but most flow year-round, and for centuries have supported intensive agriculture and compact human settlements. Across the mountains to the east, in the jungle of the upper Amazon Basin which constitutes more than half of Peru and Bolivia and parts of Ecuador and Colombia, tropical diseases and the limited carrying capacity of tropical agricultural systems have kept the population low. Over the last few decades, however, this humid tropical zone has been on the receiving end of one of the great human migrations of the century: the movement of highland people throughout Latin America down into the humid lowlands. The spread of modern medicine to the jungles has been the prerequisite for this procession; its roots, however, lie in the slopes above. Most of its participants are best described as refugees from the deteriorating agricultural systems and the exploitative social systems of the mountains.

The pressure of human numbers on the environment is not a new phenomenon in the Andes, nor is knowledge of the farming techniques necessary to save the soil from accelerated erosion. Some Andean valleys doubtlessly provided sustenance for more people 500 years ago than they do today, and they did so at less cost to their long-term fertility than is exacted by present-day farmers. The unusual history of ecological deterioration in the Andes begins long ago, in the millennia preceding the European discovery of the New World.

By about A.D. 500 one of the major cultures of pre-Columbian America was emerging in the coastal valleys and upland plateaus and gorges of Peru. In relatively independent small settlements ruled strongly by priestly and warrior castes, the fruits of many centuries of technological and political development began to crystallize in societies able, like the earlier Egyptians and Sumerians in the Old World, to master the hydraulic cycle and thus create a large, complex civilization. These ancient Peruvians created an intensive agricultural system in the arid valleys of the coast, and on the slopes and plains of the mountains, by performing what McNeill has termed "extraordinary feats of water engineering," and building "terraces as elaborate as any the world has ever seen" (*13*). The terraces held down erosion, while fallowing was practiced to preserve the fertility of the soil.

Both hydraulic engineering and social regimentation reached a climax in the 14th and 15th centuries, when the Incas of the Cuzco Valley overran the city-states of the Andes and the coast to establish the empire of Ttahuantinsuyu, the Four Quarters of the World. These Indians of the mountains extended their rule over an area the combined size of France, Switzerland, Italy, Belgium, the Netherlands, and Luxembourg. Considering the rugged terrain in which they operated, which included parts of what are now Colombia, Ecuador, Peru, Bolivia, Argentina, and Chile, the Incas imposed an extraordinary centralization of political and economic control that historians have likened to that of the Pharaonic societies of Egypt.

The Inca Empire fell to Pizarro's invasion in 1532. It had successfully created, in a fragile environment, a sustainable agricultural system that minimized the damage to the productivity of the land. Yet by the latter years of the empire, there is some evidence that the pressure of population on the limited arable area was beginning to show.

Monheim, a German geographer, cites the very extensiveness of the costly irrigation, terracing, and artificial field elevation works, as well as the empire's food reserve policy, as evidence that by the early 16th century the carrying capacity of the land had been reached or even, in unfavorable weather years at least, perhaps surpassed. Even before this time, the central Andes were largely deforested and most mountain residents were dependent on the dung of llamas for cooking fuel (*14, 15*).

The extent to which land degradation actually was becoming a serious problem to the Incas is open to debate. More certainly, any threat of overpopulation quickly dissipated after the Spanish occupation. Historians disagree about the population of the Inca Empire at its height; estimates range from several million to more than 16 million. In any case, the combined influence of wars, forced labor in unhealthy silver and mercury mines, and European dis-

eases sharply reduced the population of the Andes—probably by as much as three-fourths in the first century of colonial rule (*14–16*).

While this decimation of the population obviously reduced any immediate pressures on the land it contributed, ironically, to the emergence of quite unfavorable conditions for land conservation in the following centuries. A low population and wide open spaces facilitated the establishment of huge European-owned estates, including cattle ranches on the highest plateaus and crop-growing haciendas in the middle and lower valleys. The former Inca system of central rule and labor tributes was replaced by one in which Spaniards favored by the Crown were given large landholdings and control over the Indian villages they contained. The estate owners extracted produce and labor from their Indian charges, while the government requisitioned further Indian labor for the mines, plantations, and cities. Although these conditions of virtual slavery passed with political reforms and the 19th-century emergence of independent nations, by the mid-20th century many of the Andean Indians remained in a state of near serfdom to great landed proprietors. And outside the large estates on which many have lived and worked are overcrowded, fragmented lands unable to provide adequate sustenance for their populations.

Unfortunately, the decimation of the Inca population and social order was accompanied by a disastrous loss of the conservation ethics and know-how of the former empire. With scarce labor concentrated in the mines and on the hacienda fields of fertile valley floors, most of the terraces and irrigation facilities constructed over previous centuries fell into ruin. Although in a few areas the very terraces constructed by the Incas are still in use today, this basic soil conservation technique has almost completely disappeared in the Andes (*15–17*).

If the population of the Andes had remained at the reduced level of the 17th century, the absence of conservation practices would not be so threatening. With land abundant, farmers could afford to exploit the slope for a year or two, watch its topsoil and fertility wash away, and move on to another hill. But over the last century, the population in the Andes has overtaken that of the Inca Empire, with devastating consequences for the land and those whose livelihood depends on it.

Peru's population was about 4 million at the turn of the century, 9 million by 1950, and 15 million by 1975. Colombia's population grew from about 3 million in 1900 to 11 million in 1950, and 26 million in 1975. The ecological and social consequences of this mounting pressure on the Andes become more apparent with each passing decade. Farmers are driven onto slopes so steep that erosion is a serious problem from the moment cultivation begins. Lands which need to rest for 8 years, 12 years, or longer to regain their fertility can now be left fallow for only a few years. Agricultural output is generally stagnant in the Andes, and in some areas is declining (*17*).

Land reforms in Bolivia since 1953, and in Peru since 1964, are benefiting many mountain residents by improving the ownership patterns in these two countries, but cannot, of course, create new land. Nor does land reform guarantee land-management practices that preserve the productivity of the soil, although it may be an essential first step. In the near feudal economic system that has characterized the Andes, land redistribution is certainly a prerequisite of improved farm productivity and modernized farming practices. But a look at Bolivia's mounting soil erosion problem in the decade and a half after the 1953 reforms suggests the necessity of safeguarding their benefits for future generations by also introducing new farming systems and curbing the pressures of population.

Overgrazing and overcropping have been depleting the fertility and vegetation of the Bolivian Altiplano, a treeless tundra, and surrounding valleys, at least since the beginning of Spanish rule; but fresh gulleys, increasingly frequent abandonment of once fertile fields, and a fall in crop yields on the steeper fields in recent years all indicate that the scale of damage has accelerated since the early 1950's. Preston argues that the increased access—for grazing, cropping, and firewood gathering—to areas once controlled by large landowners is an important cause of this acceleration in Bolivia, since this new access was not accompanied by a comprehension of soil conservation needs and practices (*18*).

Families in the more densely settled areas of Peru and Bolivia, such as the Lake Titicaca Basin, have as little as ½ to 2 hectares of land available for their use. This area does not provide enough food to meet even the modest needs of the family. Continual food shortages impel overexploitation of the soil and hence extensive soil erosion, and finally result in the abandonment of farms and seasonal or permanent migration (*17*).

In Colombia, erosion, landslides, and sedimentation—all natural problems now accelerated by the pressures of humans and livestock on the land—are major obstacles to national development. Cornell University engineers working in a representative area, the Cauca region of the southern mountains, have described the readily visible economic damage and heavy loss of life resulting each year from the deteriorating environment. "Landslides are so common that socially important slides occur every few months," they write. Sediment deposits regularly block the Cali and Canaveralejo rivers and cause major flooding problems in the city of Cali. The lower Anchicaya reservoir has filled with silt in only 7 years, and the multimillion dollar hydroelectric plant it was built to support now runs on the river flow alone—at one-third of its planned capacity (*19*).

Migration to City Slums and Tropical Lowlands

With life untenable for so many residents of the Andes, large-scale migration to other areas is inevitable (*20*). As usually occurs when human populations are forced to flee an impossible situation, the movement out of the mountains has given rise to many new social problems. Some migration has been seasonal and keyed to available jobs, with able-bodied family members finding work in plantations, mines, or construction jobs along the coast or in Argentina. But the mushrooming shantytowns of the major cities of the Andean region attest to the fact that many uprooted families face conditions in their new homes little better than those they left. Unemployment, poverty, and despair are widespread.

The eastward movement of settlers to the jungles of the upper Amazon Basin can appropriately be labeled anarchic. Every government has colonization programs which have met with varying degrees of success or failure, but for the most part, the evacuees of the highlands are ill-prepared to face the unfamiliar conditions of the humid tropics. The frequent result is double disaster: a costly depletion of lumber resources as trees are cleared without regard to the soil's suitability for agriculture, followed shortly thereafter by the abandonment of the unproductive farms (*17, 21*).

There is, of course, no doubt that further resettlement of mountain residents in the lowlands will be necessary over the coming decades, as will the expansion of nonagricultural employment throughout the Andean region. The questions to be confronted are: How many people can the jungles and cities safely absorb? And will the spread of roads, infrastructure, and technical know-how in the eastern lowlands catch up with a continuing flow of settlers? Already, suggests Peru's Office for the Evaluation of Natural Resources, the most

fertile agricultural soils of the country's vast jungle region are being cultivated. New colonists will have to settle on increasingly inferior soils (*17, 21*).

With the exception of Chile, which is more advanced economically than the others, the Andean countries have population growth rates among the highest in the world. At the current pace the populations of Peru, Bolivia, Colombia, Ecuador, and Venezuela all will double in size within three decades. Oil, copper, and tin will certainly continue to boost the economic development and diversification of the Andean countries. Yet, at this point, it is difficult to imagine where these unborn citizens will live, where they will work, and where their food will grow.

Deterioration in East Africa

Africa's principal mountainous zone, the highlands of the eastern side, present a topography quite different from that of the Andes. These highlands, which stretch southward from Ethiopia through Kenya, Uganda, Tanzania, and beyond, are not a sharply rising mountain range in the customary sense, but rather a wide bulky massif. The huge Amhara Plateau, which constitutes most of Ethiopia and is the most extensive mountain region of any African country, rises abruptly from the surrounding arid plains, and its general level is about 2000 meters above them. Yet the term plateau is also misleading in this case, for on these highlands are superimposed other mountains which rise to more than 4500 meters above sea level. Jagged, intricate, and fantastic, the Ethiopian Highlands share with the Himalayas and Andes the unfortunate distinction of being among the most erosion-prone areas on earth.

With a population estimated at 28 million in 1975, Ethiopia is the third most populous country in Africa, surpassed in numbers only by Nigeria and Egypt. The country's population growth rate of 2.4 percent annually is not so high as that of Tanzania, at 3.0 percent, and Kenya, at 3.3 percent. This is not due to a lower birth rate, but to one of the world's highest death rates—a rate surpassed only in Bangladesh, Mali, and Sikkim. Low agricultural productivity, and the need to give a high share of the land's produce to the landholding elite, chronically leaves much of the peasantry at a bare subsistence level (*22*). In the bad years, such as those that have visited the northern provinces of Wollo and Tigre in the early and mid-1970's, the line between bare subsistence and famine for tens or even hundreds of thousands of people is quickly crossed.

The Ethiopian plateau receives a good rainfall, and as much as three-fourths of the country was once forested. Clearing for cultivation, burning to create pasturelands, and tree felling to meet fuel and timber needs have reduced the forest area to a mere shadow of its former domain; significant stands of timber now cover less than 4 percent of the country. The tempo of destruction has quickened since mid-century, and by the early 1960's, reported an American research team, natural woodlands were disappearing at a rate of 1000 square kilometers per year. The country's major watersheds and steep mountain slopes are not being spared. "Even to the casual visitor to Ethiopia," a top-level soil conservation adviser recently wrote, "the extent of soil erosion seen in many parts of the country . . . will leave a lasting impression of desolation and impending disaster" (*23*).

The extent of deforestation and erosion varies by region according to population density and historical length of settlement. Leslie Brown, a prominent ecologist with decades of experience in East Africa, points out that one can observe the historical progress and results of land degradation in Ethiopia by journeying from north to south (*24*). In the oldest inhabited areas to the north, such as the provinces of Tigre and Eritrea, some of the steepest slopes no longer even carry grass or shrubs. People extract what produce they can from eroded, infertile patches. Many streams have dried up except during the rainy season, when they are prone to violent torrents.

Following the depletion of the soils and forests to the north, the center of Ethiopian civilization moved southward around the 10th century (*25*). The central highlands, including the region surrounding Addis Ababa, the nation's capital, have thus been increasingly exploited over the last millennium. Through much of this region the high forest cover has been replaced by bush, grass, and scrub; springs have often dried up and silty rivers flow erratically. Traveling farther to the south, where cultivators have more recently penetrated the forests, the streams tend to carry clear water and run constantly even in dry seasons.

A dramatic alteration in environmental quality in the hills surrounding Addis Ababa has been visible within the span of a single lifetime. When the capital was founded in 1883 by the Emperor Menelik II, it was still surrounded by remnants of rich cedar forests and reasonably clear streams. Deforestation and erosion were immediately spurred by the influx of humans. In the ensuing nine decades, virtually all the available land in the region has been cultivated, while charcoal producers cut trees within a hundred-mile radius for sale in the city. Only the widespread planting of eucalyptus trees to provide fuel has allowed Addis Ababa to survive. Now the waters of the nearby Awash River and its tributaries are thick with mud, and waterways are shifting their courses more markedly and frequently than in the past. A United Nations research team has expressed fears that the upper Awash Basin may become a "rocky desert" (*24, 25*).

Farther south in the Gamu Highlands, Oxford University geographers recently witnessed the incipient breakdown of a sustainable agricultural system. When they visited this area in 1968, erosion was not yet a serious problem. The steeper slopes had been saved for grazing animals rather than plows, and the people showed an awareness of the erosion hazard by terracing the hillsides and constructing drainage channels on slopes to carry off excess rain. Animal manure was carefully collected and applied to the fields, while crop rotations and fallowing also helped to preserve the soil's fertility.

Under the pressure of a mounting population, however, farmers have started plowing up lands formerly reserved for grazing. This has accentuated overgrazing and consequent erosion on the remaining pastures, and has also resulted in a lower population of cattle. Fewer cattle mean less manure, which, in turn, means lower yields and greater requirements for arable land, which will then necessitate further inroads into the pastureland, thus completing the cycle of degeneration. The villages in this area are violating their own land management rules and they know it, but they see no alternative (*26*).

Until the announcement of sweeping land reforms in early 1975 by the country's new military government, which had just unseated Emperor Haile Selassie, most of Ethiopia's best farmlands were owned by the Church, the Royal Family, or the powerful landed aristocracy. The land was worked by peasants in a state of bondage, whose daily lives were circumscribed by an elaborate castelike system of social and economic stratification (*22, 27, 28*). There is no question that the economic and political conservatism inherent in this land tenure system slowed the modernization of agriculture in Ethiopia, and reduced the incentive for the peasantry to manage soils properly. Whether the new regime will successfully carry out its announced reforms—and whether they will be accompanied by a new concern for soil conservation—remain to be seen.

The highlands of Kenya, Tanzania, and Uganda have fertile soils and a pleasant climate that have proved attractive to both Africans and Europeans. It is no accident that Nairobi, Kenya's capital in the heart

of the highlands, is the nexus of industry and economic development in East Africa. Above undulating plains, deep valleys, and numerous smaller mountain ranges tower Mt. Kenya and Mt. Kilimanjaro, Africa's highest peak.

These highlands include some of the most productive and densely settled farmlands of Africa. They are bounded by zones infested with the tsetse fly, which prohibits keeping the cattle so highly prized by most of East Africa's peoples, and to the north by semiarid lands best suited to grazing. The concentration of people on the more fertile lands, such as around Lake Victoria, on the slopes of Uganda's Mt. Elgon, and in the vicinity of Nairobi, is more than 200 per square kilometer; and in places it is double that. In the colonial era the pressure of the African population on available lands in Kenya was intensified by the reservation of a fourth of the arable area, including many of the most fertile portions, for use by whites only. Since 1960 these lands have been gradually resettled by Africans.

Between the efforts of land-hungry cultivators and charcoal makers, the East African highlands have been largely deforested except for the most inaccessible mountain areas and occasional government-protected reserves. Particularly where cultivators have moved up steeper mountain slopes, and where the combination of population density and traditional techniques has run down fertility, erosion is on the rise (*28, 29*). Not surprisingly, migrants from the fragmented, overcrowded farming areas are pouring into the cities of East Africa, where they frequently wind up subsisting on whatever occasional work can be found. The future of East Africa's magnificent game reserves is also jeopardized as the public pressure for new farmlands grows.

Technical Answers, Political Needs

All in all, little hard data are yet available on the true scale and the nature of environmental deterioration in the mountains. However, there is a rather broad consensus among the various scientists and governmental agencies cited above, as well as many others, about the general direction of prevailing mountain trends. On the basis of already available knowledge, it is no exaggeration to suggest that many mountain regions could pass a point of no return within the next two or three decades. They could become locked in a downward spiral from which there is no escape, a chain of ecological reactions that will permanently reduce their capacity to support human life.

This possibility is very real, but it is not inevitable. There is no major mountain problem for which technological solutions are not already known. If the existing negative trends are not abruptly reversed within the coming decades, it will be because human institutions have failed to adapt themselves to environmental necessity.

While every mountain zone has its peculiar problems and solutions, some general considerations with wide application can be noted. Undoubtedly, the most important need in virtually every case is an intensification of food production on the best farmland—in the lowlands, the valleys, and the gentler mountain slopes. Only when this occurs can the self-defeating pressure to move onto even steeper hillsides be countered. Reforms in land tenure and in the distribution of extension and credit services—political, not technical tasks—are in many cases the prerequisites of agricultural progress.

Where hillsides must be farmed, the adoption of soil conservation techniques is essential. Often erosion can be curbed markedly through the simplest of measures. In parts of Nepal, for example, many terraces are poorly constructed with an outward rather than inward slope and an inadequate buttress of stone to help them survive the annual monsoon deluge. In the Andes, a restoration of the lost art of terracing would bring immediate benefits to farmers, the land, and cities downstream. Terracing is not always the answer; soil experts in the Uluguru Mountains of Tanzania, for example, found that terracing encourages landslides there, and it exposes too much infertile subsoil. They did find that strategic tree planting, farming on the contour, and other simple changes in cultivation practices could greatly reduce erosion (*30*). Measures like these have not been widely adopted because farmers are either not aware that they are possible, or they are not convinced of the production benefits they bring. Many mountain farmers have never seen an agricultural extension agent.

Where population pressures do not permit a return of mountain slopes to forest, which might be the ecological ideal, the introduction of permanent tree crops like apples, apricots, nuts, or timber plantations may be a good compromise. Tree crops combine many of the ecological advantages of the forest with employment and incomes for the former farmers. An apparently successful United Nations watershed improvement project in Pakistan has utilized foreign-donated food aid as wages in road construction and planting activities to help tide farmers over until their new orchards start producing income (*23*).

More extensive reforestation programs are needed throughout the mountains of Asia, Latin America, and Africa. Trees are required not only to protect vulnerable slopes and soils, but also to provide firewood, and thus halt the spreading use of manures for cooking fuel. Putting manure back onto the fields will in turn help boost their productivity, reducing the pressure to spread cultivation onto unsuitable slopes. Virtually every government in the mountain regions has demarcated forest reserves in especially strategic locations such as above important rivers. But it is only when adequate food and fuel are available from other sources that these "protective forests" can be protected.

Greater opportunities to earn a living outside of agriculture can also reduce pressures on the land. Mining and related industries are already a source of jobs and money in the Andes. However, the environmental consequences of these operations must be carefully monitored and controlled, lest their impact be self-defeating. It has become something of an axiom in many quarters that the poor countries cannot afford the luxury of pollution controls on their industries; but the gap between environmental protection needs in the rich and poor countries may be narrower than many think. In Peru, a government agency points out that air pollution is killing vegetation on thousands of mountainous hectares surrounding mines and refineries, resulting in "truly spectacular" soil erosion (*21*).

Tourism, too, at once poses a great potential and a threat for the mountains. With their fascinating scenery and cultures, countries like Nepal, Peru, and Ethiopia clearly can expand their tourist trade severalfold. Yet planning will be essential to prevent the degradation of their natural resources by visiting sightseers. The soaring number of trekkers in the high Himalayas of Nepal over the last decade has created a booming firewood business for some mountain people, but it has grown at the expense of the forests and particularly fragile ecosystems of the upper slopes.

The central threat to the future of the mountains is the burden of the burgeoning human numbers they must bear. Planned migration to the less crowded lowlands will be important, but can only buy a brief reprieve. There is no escaping the need to rapidly bring population growth to a halt in the mountains; their limited carrying capacity will assert itself in no uncertain terms over the next few decades.

It is generally easy to recommend technological answers to ecological problems. Political and cultural factors are invariably the real bottlenecks holding up progress. Changing the relationship of man to land

in the mountains, as anywhere else, invariably involves sensitive changes in the relationship of man to man. Developmental funds and talents spent in the mountains are resources denied the cities and the plains. In the end, this may be the greatest challenge of all: how to convince the people of the plains that the future of the mountains cannot be isolated from their own.

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NEWS AND COMMENT

Third World: Science and Technology Contribute Feebly to Development

The military power of the Soviet Union and the tensions inherent in the widening gap between rich countries and poor are perhaps the two major foci of instability in the world as seen today from the United States. In both issues, science and technology play a primary role. They are the Danegeld in détente, and a decisive ingredient in development. But whereas the handover in the first case is simple, the transfer of science and technology to the developing countries has proved far less straightforward than was at first envisaged.

Organized knowledge is now recognized to be a major determinant of economic growth and to account for much of the disparity in living standards between developed and developing nations. Yet the truth about the state of science in many developing countries, to quote an article in the current issue of *Foreign Affairs*, "is so hard to bear that it does not easily pass the lips of the proud [inhabitants] nor of the courteous foreign expert enjoying the hospitality of a short visit." The authors, Michael J. Moravcsik of the University of Oregon and J. M. Ziman of the University of Bristol in England, severely criticize the scientific community, the AAAS included, for neglecting the plight of their Third World colleagues (see box). Behind the facade, they state, one often finds in developing nations "no more than the fragments of a scientific community, disorganized, disunited, of limited professional competence, poverty stricken, intellectually isolated, and directed toward largely romantic goals—or no goals at all."

Extreme though this view may seem to be, Moravcsik and Ziman's general diagnosis is quite widely shared by both scientists and economists familiar with Third World problems. The developing countries possess some two thirds of the world's population but conduct only 2 to 3 percent of its research and development. Not only do they spend little—typically 0.2 percent of GNP compared with about 3 percent allocated in advanced countries to R & D—but the returns on their investment are of dubious quality. The brain drain of scientists and engineers to advanced countries—a kind of reverse foreign aid that for several developing countries equals or exceeds the aid they receive—is in large measure the external symptom of an economy that cannot absorb such people.

According to the old strategy for development, there was no need for developing countries to reinvent the wheel. They could