PROTECT AND PRODUCE

putting the pieces together

REVISED EDITION

FOREWORD

That human life should depend for its existence on less than a metre of mixed organic and inorganic debris may come as a surprise to modern man. Yet it is so. Our planet's soil, together with the atmosphere and the oceans, comprise what is known as the biosphere, a thin layer around the Earth in which all living things exist.

The soil is the most complex of these three constituents. It is also the most easily destroyed. One thoughtless action by one human being can remove for ever tens of tonnes of soil from each hectare that he or she farms. In a few days the legacy of thousands of years of patient natural recycling can vanish for good. It is terrifying to consider what is at stake.

Without soil, there would be no food apart from what the rivers and the seas can provide. In the developing countries, where nearly three-quarters of the world's population now live, the soil also provides most of the fuel—in the form of firewood—which is used in the home, and a great deal of the fibre which is needed to make clothes, ropes, sails and other essentials. The soil is the world's most precious natural resource. Yet it is not valued as it should be. Gold, oil, minerals and precious stones command prices which have led us to treat soil as mere dirt.

If famine and malnutrition are to be defeated, the value of soil has to be reassessed. We are losing, through soil degradation of one form or another, nearly as much new land as we are now bringing into production every year. Since farming began, we have lost about 2000 million hectares of crop land to soil erosion.

Yet, as this publication makes clear, farming itself is not to blame. It is possible to farm good land, produce ample crops and still maintain and improve the soil. Indeed, the better land is farmed, the healthier and more prolific its soil becomes. But when the wrong techniques are used, or the wrong crops are grown, a chain reaction of disaster soon begins: falling production is associated with increased erosion, which leads to yet lower production and even more erosion. Crop land becomes wasteland.

There is no need for this. The solutions to soil erosion are not hidden in the research laboratories. We know the answers, and we know the causes. One of the most important of these is poverty. When the poor cause soil erosion, they do so because they have no alternative but to exploit the soil. Soil erosion is closely connected with the problems of rural development. Yet, without soil, rural development is impossible.

The first version of *Protect and Produce*, published in 1983, proved so popular that, after printing nearly 40 000 copies in five languages, we decided to revise it. This new edition has been updated to cover more recent information in the field, and is produced in colour.

I hope that this latest version will continue to convince FAO's member countries of two things: that soil erosion is one of the most serious threats confronting mankind; and that this threat can be confronted and defeated. Indeed, FAO's experience in a number of countries is already proving exactly this. The battle against soil erosion can be won. And it must be won.

Edouard Saouma
Director-General
Food and Agriculture Organization
of the United Nations

CONTENTS

PART I: THE VANISHING SOIL

PART II: PREVENTION AND REPAIR

PART III: A NEW APPROACH TO SOIL CONSERVATION

LAND RESOURCES

In 1990 the population of the developing countries was just over 4000 million. More than 500 million of them—about one in eight—were seriously undernourished. Yet by the end of the century the population of the developing countries is expected to increase by 25 percent—to about 5000 million. How are the increasing numbers of people to be fed and will there be enough land to support them?

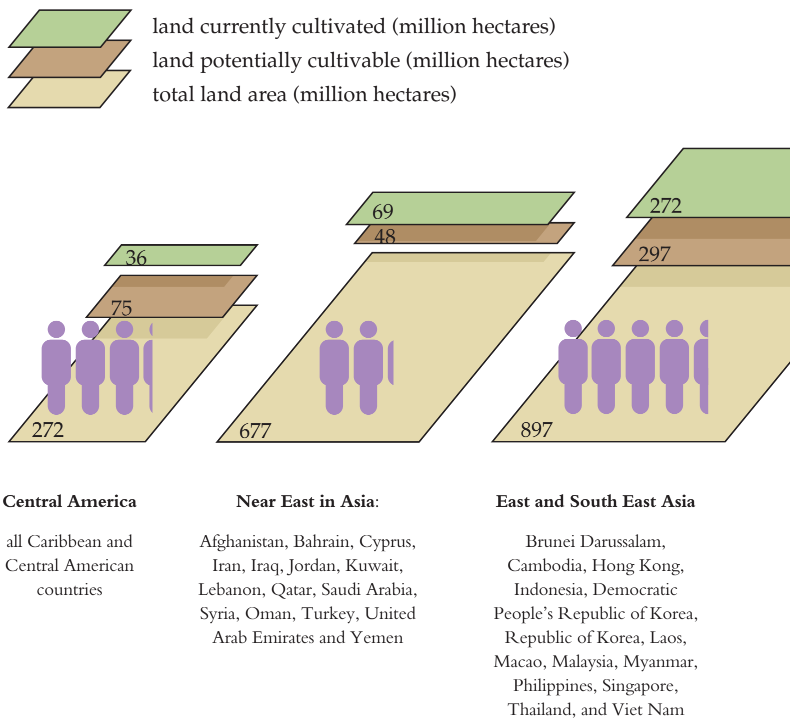
Very little of the Earth's land surface—only 11 percent, about 1500 million hectares (ha)—is currently suitable for agriculture. Land can often be improved: arid areas can be irrigated and waterlogged ones drained, for example. Even so, the world's potentially cultivable land amounts to only around 2800 million ha. In the developed countries, 77 percent of that land is already in use; in the developing countries, 28 percent of it is in use. But the situation varies greatly from region to region: in South Asia, 90 percent of cultivable land is being used while the figure for South America is only 23 percent.

The Food and Agriculture Organization of the United Nations (FAO) has made a detailed study—called *Agriculture: toward 2000*—of the future of world food problems in 90 developing countries. It points out that in 17 of these countries, in which half the population lives, more than 90 percent of potentially cultivable land is already in use. 'By the end of the century', the report concludes, 'shortage of land will have become a critical constraint for about two-thirds of the population of the developing countries.' Between 1980 and 2000, the amount of arable land available in these countries was expected to fall from 0.37 to 0.25 ha/head.

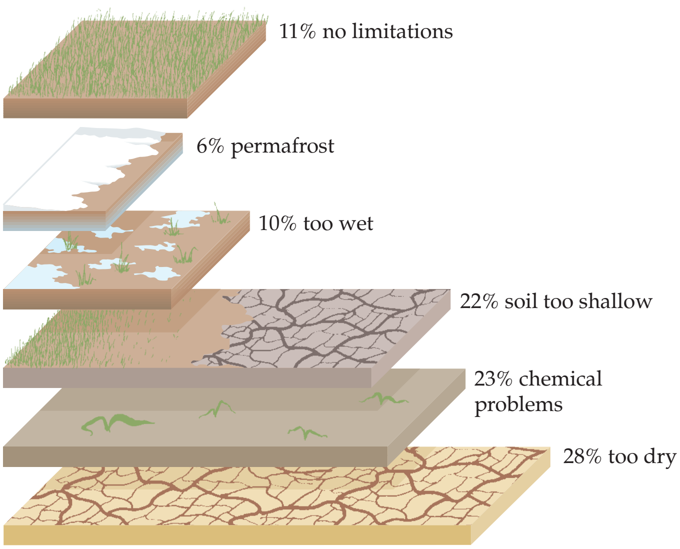
The report was first published in 1981, when it concluded that agricultural production could be doubled in these 90 countries by the year 2000. If so, malnutrition would be greatly reduced, though still not eliminated. About 14 percent of the increase would have to come from cropping land more often, 60 percent from improving yields and 25 percent from bringing 150 million ha of new arable land into production. This would have meant increasing the area of cultivated land by 20 percent, from 750 to 900 million ha.

If this rate of expansion were continued until the middle of the next century, 'virtually all the potential arable land would be cultivated. Only 18 of the 90 developing countries, containing 5 percent of their total population, would have any significant areas still to be brought into arable farming'.

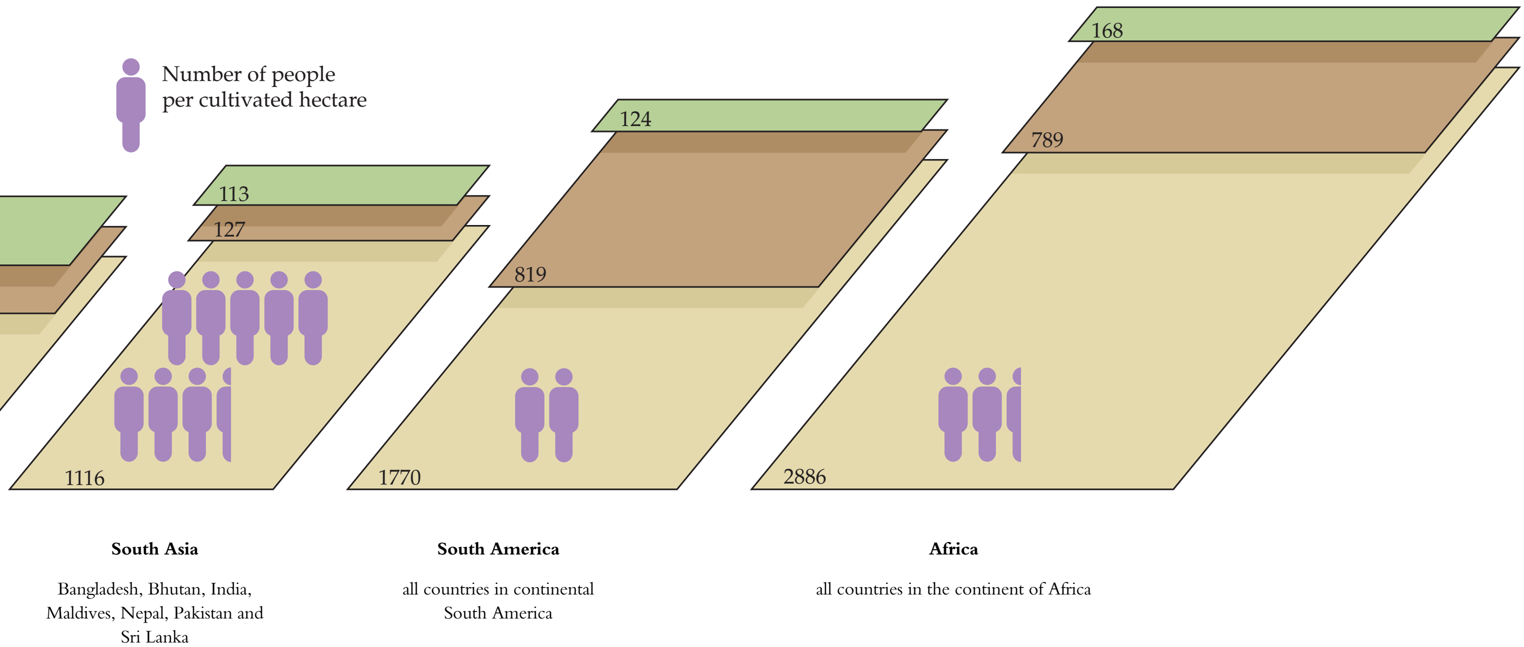
Land use and population in developing countries



How world soil conditions limit agriculture



Only 11 percent of the world's land area—some 1500 million hectares—is currently suitable for agriculture. However, with drainage and irrigation almost twice this amount, some 3000 million hectares, could eventually be brought into production.



Such is the pressure of increasing demand for food and fibre on land resources. The situation is in fact worse than even this scenario suggests because no mention has yet been made of what is the critical factor: land degradation.

According to one estimate, the various forms of land degradation—soil erosion, chemical poisoning, salinization and loss through building or mining—could deprive the world of one-third of its arable land by the end of the century. This may be excessively pessimistic. But a reliable estimate is that we are currently losing between 5 and 7 million ha of good land a year because of degradation. Even assuming that the current rate of land degradation does not increase, this amounts over 20 years to a loss of between 100 and 140 million ha of land—a figure comparable to the amount of new land which needs to be brought into cultivation over the same period.

This means that we are running fast to stand still. A major new effort to combat land degradation is therefore urgently required. FAO, with its International Scheme for the Conservation and Rehabilitation of African Lands, has made a start in Africa where a new approach is being tried out.

Some regions in the developing countries—Africa and South America—are still using only a relatively small proportion of the agricultural land available to them. Most regions in Asia, however, are approaching their limits and the Near East in Asia is already cultivating land unsuitable for agriculture.

This approach is underpinned by two ideas: first, that the prevention of degradation carries with it its own motivating force—the increase in production that accompanies well protected land; and, second, that land users themselves are not only willing to take the necessary measures but that they can and will organize and implement them themselves, given a little catalytic help.

These ideas give new hope that the pace of land degradation can be reduced and, eventually, halted. As the first edition of this publication commented: 'The alternative is famine'.

THE CAUSES OF LAND LOSS

Land degradation is an insidious process—rarely is land in full production one year and out of production the next. Instead, crop yields begin to fall as degradation proceeds. Eventually, the use to which the land is put also changes—arable land becomes pasture, pasture becomes scrub, and finally the scrub becomes barren. The end result is indistinguishable from a simple loss of land.

Much good crop land is currently being converted to non-agricultural use. Urban expansion and roadbuilding are the biggest culprits but mining, industry and recreation also play a part. Unhappily, it is the best crop land that usually disappears. During 1967–75 the United States alone built on 2.8 million ha of crop land.

There are four other ways in which land is degraded:

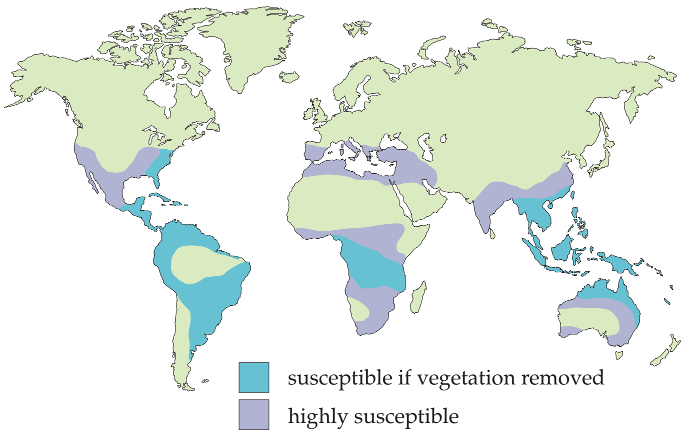
1. **Build-up of salts**
   If topsoil becomes too saline or too alkaline, its productivity falls. This can happen when poorly drained land is irrigated in hot climates. The sun evaporates the surface water, leaving behind the salts. At the same time, inadequate drainage causes the water table to rise, bringing salt water into contact with plant roots. In the mid-1970s, FAO estimated that 952 million ha of land were affected by salt. Salinity problems are often associated with waterlogged soils and the area of land currently being abandoned every year owing to salinization and waterlogging is roughly equal to the amount of land being reclaimed and irrigated. Worldwide, about 40 million ha out of a total of 200 million irrigated ha are either waterlogged, affected by salt, or both.

2. **Physical and biological damage**
   Soil may be physically damaged when it is repeatedly worked with heavy equipment in wet weather, or when it is compacted around water holes in pasture land. It is difficult to return compacted soil to full productivity and deep-rooting crops may have to be selectively planted to break up the 'pan'. Biological damage occurs when soils are deprived of their essential fertilizers, organic matter or humus content. The former can be replaced by artificial fertilizer, the latter cannot. Crop rotation and good farming practices are the solution.

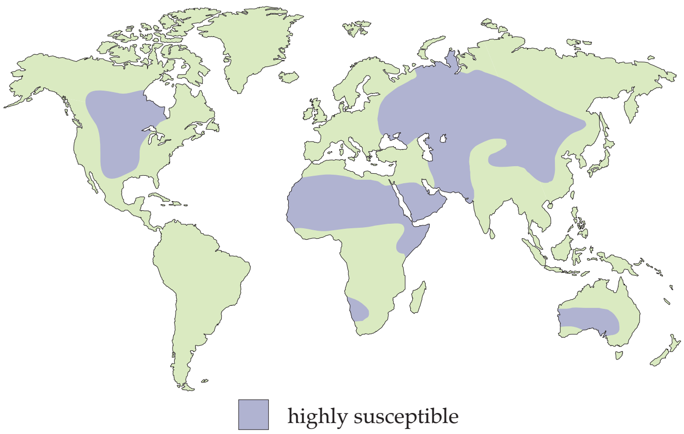
3. **Wind erosion**
   Large areas of the world are affected by wind erosion, one of the key causes of desertification. Wind erosion occurs when soil is left bare of vegetation and is particularly severe in arid and semi-arid areas following over-stocking and overgrazing. According to an FAO/United Nations Environment Programme (UNEP) study on soil degradation, 22.4 percent of Africa north of the Equator and 35.5 percent of the Near East are affected by wind erosion. Not only can the wind strip topsoil from good land but it causes extra damage by burying land, buildings, machinery and fences with unwanted soil. Under the worst conditions, as much as 150 tonnes of soil can be

Vast areas of the world are susceptible to wind and water erosion. When land is left bare of vegetation, the area which may be affected by erosion is greatly increased.

Water erosion



Wind erosion



blown off one hectare of land in an hour.

Wind erosion created the dust bowls in the Great Plains of the United States in the 1930s, laying waste millions of hectares of good land. A four-day storm in May 1934, for example, transported 300 million tonnes of soil an estimated 2500 km, darkening the skies in New York for five hours and muddying the decks of ships 500 km out in the Atlantic.

4. **Water erosion**

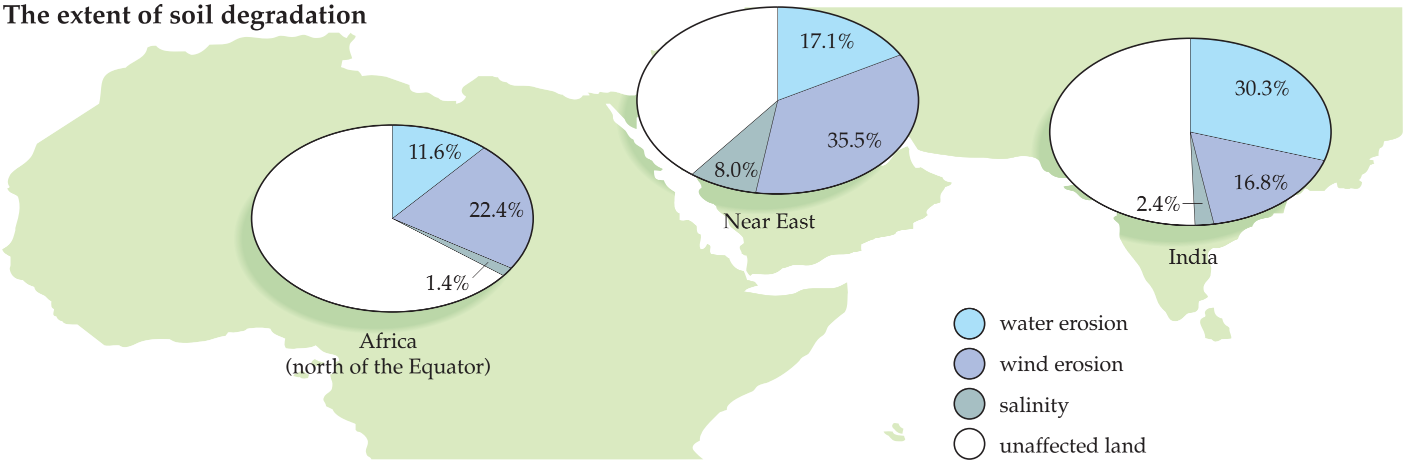
   The commonest form of erosion, it is causing massive damage in nearly all developing countries. It is found where steep land is being unwisely farmed and where gently sloping land is left exposed to the effects of heavy rain for any length of time.

Worldwide, about 25 000 million tonnes of soil are being washed away each year, ending up in the rivers and finally the oceans. China's Huang River—the most sediment-laden in the world—dumps 1.6 billion tonnes of soil a year, mostly from the heavily eroded Loess Plateau, into the East China Sea. The FAO/UNEP study estimates that 11.6 percent of Africa north of the Equator and 17.1 percent of the Near East are subject to water erosion. So are 74 million of India's 297 million ha. In the United States, the annual loss of topsoil from crop land still averages 12 tonnes/ha and some 50 million tonnes of plant nutrients are lost every year—nutrients which must be replaced with expensive artificial fertilizer. The United States has lost about one-third of its topsoil since farming began.

Gully erosion caused by shifting cultivation on steep slopes in Haiti.

FAO studies have shown the extent of the three main types of soil degradation—water erosion, wind erosion and salinization. Overall, more than 60 percent of land in the Near East is affected by at least one form of degradation.

The extent of soil degradation



HOW EROSION HAPPENS

Soil is a country's most precious natural resource, aptly described as 'the bridge between the inanimate and the living'. It consists of weathered and decomposed bedrock, water, air, organic material formed from plant and animal decay, and thousands of different life forms, mainly micro-organisms and insects. All play their part in maintaining the complex ecology of a healthy soil.

In the humid tropics, starting from a sandy base, a soil can be formed in as little as 200 years. But the process normally takes far longer. Under most conditions, soil is formed at a rate of 1 cm every 100–400 years, and it takes 3000–12 000 years to build enough soil to form productive land.

This means that soil is, in effect, a non-renewable resource. Once destroyed, it is gone for ever. Although soil erosion does occur naturally, the process is slow. Man has increased the rate of natural erosion by at least 2.5 times and, over the centuries, has destroyed an estimated 2000 million ha of land. There is good evidence that past civilizations, in the Mediterranean and in Central America, collapsed as a result of soil erosion following the cutting of forests on steep slopes and other destructive practices.

Soil erosion occurs primarily when land is exposed to the action of wind and rain. Unprotected by a cover of vegetation, and the binding action of roots, each raindrop hits the naked soil with the impact of a bullet. Soil particles are loosened, washed down the slope of the land, and either end up in the valley below or are washed out to sea by streams and rivers.

Wind erosion occurs when the land surface is left bare in regions that are arid enough to allow the soil to dry out and flat enough to allow winds to work their mischief over several consecutive days. Land may become susceptible to wind erosion through grazing animals, which eat the protective vegetative cover, and whose hooves break up the soil—especially around watering areas. Deforestation in much of Africa, where the need for fuelwood is becoming desperate, also produces erosion-vulnerable land. Once wind erosion starts, the moving soil particles accelerate the process, acting like a sand-blaster on what might otherwise have been a stable soil surface. The effects of wind erosion are evident in much of North Africa, the Near East, parts of southern and eastern Asia, Australia, southern South America, and the arid and semi-arid parts of North America.

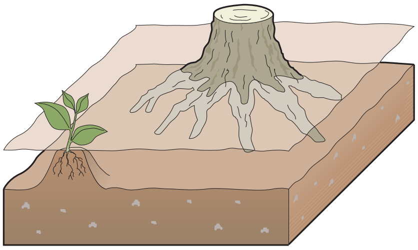
The most insidious form of erosion is called sheet erosion and occurs when the whole surface of a field is gradually eroded in a more-or-less uniform way. The process is insidious because it is not immediately obvious that soil is being lost. The only evidence of sheet erosion may be that the roots of trees or crops or the bottoms of fence posts become increasingly exposed. Yet by the time a farmer notices such things, he or she may have lost tens of tonnes of soil per hectare. On an average field, a farmer who loses just 1.5 cm of topsoil—barely enough to notice—will have lost about 190 tonnes of soil per hectare.

Rill erosion can occur on steep land or on land that slopes more gently. Because there are always irregularities in a field, water finds depressions in which to settle and low-lying channels through which to run. As the soil from these channels is washed away, rills or miniature gullies are formed in the field. Their presence is not always obvious because they are small enough to be ploughed or harrowed back into the land. Rills can develop into gullies but even as rills they represent a serious loss of soil.

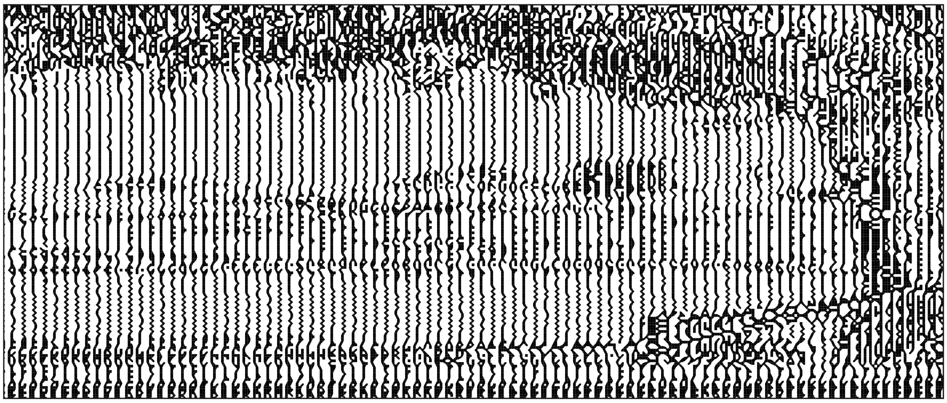
On steep land, there is often danger of gullies forming. Water running downhill cuts a channel deep into the soil; a gully head, where there is a sudden fall, forms at the lower end but gradually works its way back uphill. As it does so, it deepens and widens the scar that the gully makes in the hillside. Eventually, what started as a trickle of water, often down a path used by men or animals, can turn into a chasm metres deep and tens of metres wide. In India, gully erosion causes a land loss of about 8000 ha a year. Gully erosion is related to stream-bank erosion, in which fast-flowing rivers and streams progressively cut down their own banks.

Water erosion causes two sets of problems: an 'on-site' loss of agricultural productivity; and a downstream movement of sediment, causing flooding, loss of river navigability and the silting of reservoirs.

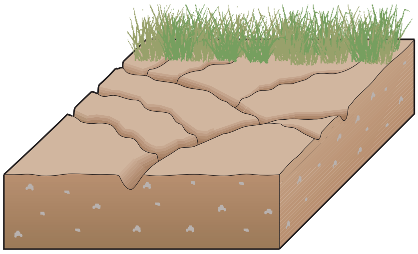
sheet erosion…



…is the more or less uniform erosion of the whole surface of a field. The roots of plants, tree roots and fence posts are increasingly exposed.

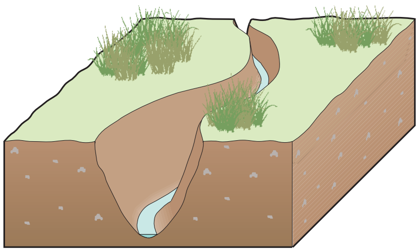


rill erosion…



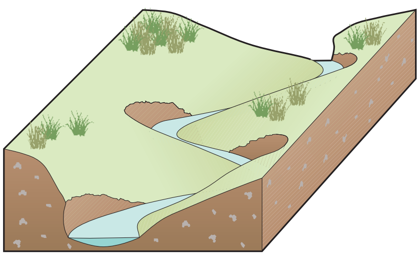
…is the accentuation of natural depressions caused by surface run-off. While normal cultivation often hides the damage, much fertile soil is still lost.

gully erosion…

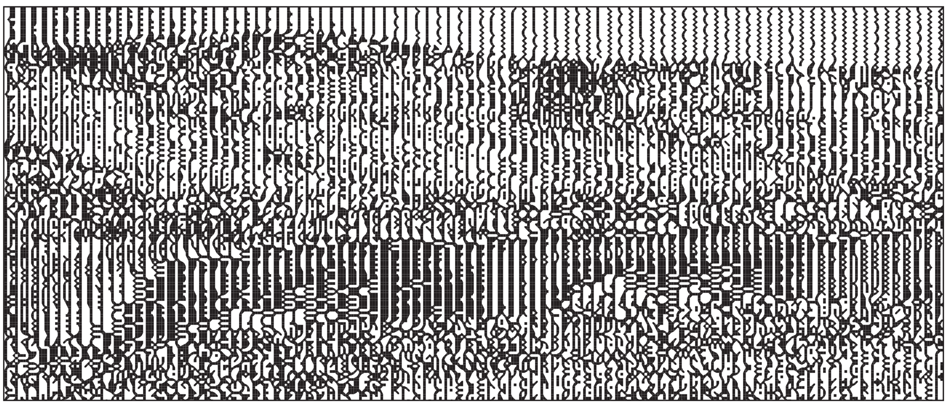


…causes deep fissures in otherwise cultivable land. If left unchecked, gullies eat their way progressively back into the hill.

streambank erosion…



…converts deep, fast-flowing streams into wide and sluggish meandering watercourses with extensive mudbanks. It can cause serious loss of cultivable land.



THE CAUSES OF EROSION

While heavy rainfall, prolonged drought or high winds may be the direct cause of soil erosion, they are not the real problem. A landscape can remain stable under all these conditions, whether it is in a natural state or being sensibly farmed. Erosion occurs when farming practices are used that fail to take account of the ease with which soils can be washed or blown away.

For example, over-stocking and overgrazing have caused untold damage in much of Africa and Asia in the past few decades. In arid areas, soil is compacted around water holes, the vegetation is stripped and dies, and erosion sets in. Too often the land ends up as desert, the ultimate result of soil erosion and degradation. If erosion is the sickness of a land, desertification is its death. In 1987 UNEP estimated that desertification threatened 48 million km^2—about one-third of the Earth's land surface—and affected the livelihood of at least 850 million people.

About 30 percent of the world's exploitable soils are still under shifting cultivation in Africa, Asia and Latin America. The technique is practised by more than 30 million people in Africa alone. Formerly, this use of land served to conserve fertility, as it allowed a long fallow period during which soil fertility would build up to its previous level. Today, population pressure and the struggle to produce more are cutting the fallow period back to virtually nothing. Under such conditions, the soils soon lose their fertility and begin to erode. Essentially, this is because the land is being farmed beyond its capability. The solution involves much more than erosion control, for the way of life and traditions of millions of people are involved.

Other examples of inappropriate farming techniques that cause erosion include deep ploughing land two or three times a year to produce annual crops, lack of crop rotation, the divorce of arable farming from livestock production, and planting crops down the contour instead of along it.

It is nearly always exposed land that erodes while land covered in vegetation is stable. The process often starts high in a watershed, on the steep slopes that are traditionally

Sheep race towards a water hole in Kenya's Rift Valley Province. The ground they are running on is badly eroded as a result of overgrazing. In some parts of Africa, all vegetation has been removed for 20 km around water holes.

Ethiopian woman carries fuelwood near Dhera, in the Arsi region.
Deforestation is one of the most serious causes of soil erosion.

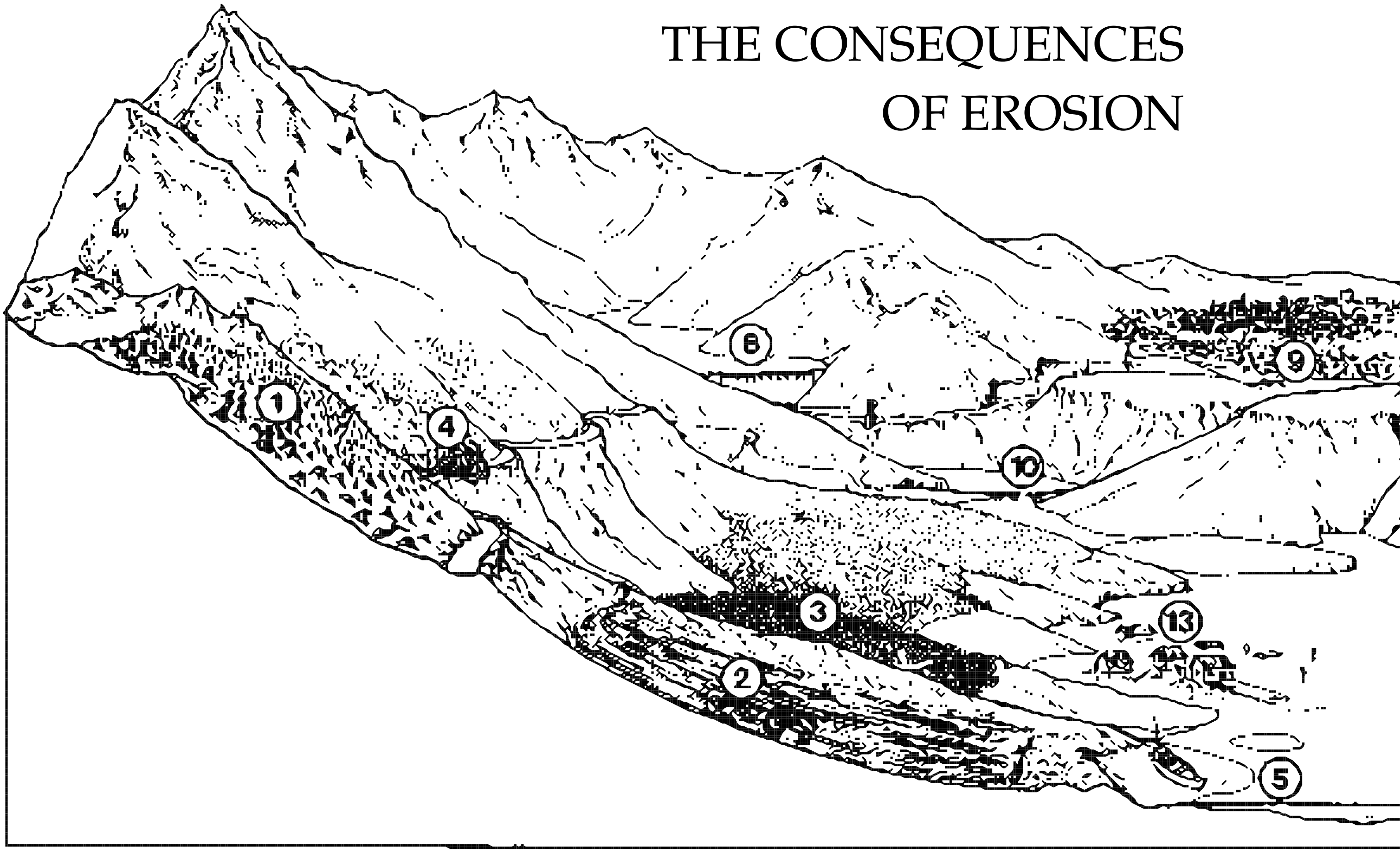
forested. But over the past few decades, there has been mounting pressure on fuelwood resources. Rural people have been forced to travel farther and farther to find their energy supplies, and to cut wood from higher and steeper ground. Many tropical forests have also been cleared for agricultural development. Between 1975 and 1980, 37 million ha of forest were destroyed in Africa, 12.2 million in Asia and 18.4 million in Central and South America.

Crops can be grown on soils that are thin and susceptible to erosion, provided farming methods are used in which the land is either not ploughed at all, or tillage is kept to a minimum. But attempts to grow annual crops on land that slopes steeply and was formerly covered with forest invite disastrous erosion. Such land is best reforested or put down to permanent crops, such as grass or tree crops of fruit and nuts, after it has been terraced.

This is one example of how incorrect land use—the wrong crop in the wrong place—causes erosion. There are many others. In some countries, an increasingly critical balance of payments situation has forced governments to plant more and more cash crops. If no more arable land is available, the new crops have to be planted in marginal land, previously pasture, which is brought under the plough for the first time. Much of the thin soil may be lost in the first heavy rain that occurs when the field surface is still bare. During a short storm in the United Republic of Tanzania a few years ago, scientists found that a field they were studying lost 5 cm of topsoil over its whole surface in just a few hours; and rills had cut down to a depth of 15 cm.

The problems of soil conservation are closely connected to those of rural development and rural poverty. A farmer who has to struggle to grow even enough food to feed his or her family cannot devote weeks or months to terracing his land or learning new farming techniques. As Dr R. Dudal, the former Director of FAO's Land and Water Development Division, has written: 'Poor people pass on their suffering to the land'. It follows that successful rural development is an essential precursor to eliminating soil erosion.

THE CONSEQUENCES OF EROSION



The Mayan civilization flourished for 1700 years until around 900 AD in what is present-day Guatemala. The cause of its downfall has been much debated, but recent studies suggest that a decline in agricultural productivity caused by soil erosion was at least partly to blame. As population pressure increased, the Mayans began to cut trees from steep hillsides to expand their farmland. The land became seriously eroded, the Mayans' ability to feed themselves was impaired, and their civilization collapsed.

The effects of soil erosion in today's far more complicated world can be just as severe, for they touch on nearly every aspect of survival and development. Erosion starts off a chain reaction of events, of which the first sign is a decline in crop yield. Then, as soil is lost and gullies deepen, the use to which land is put must be changed. crop land becomes pasture, pasture turns to scrub. Eventually, the land goes out of production altogether. Food becomes dearer and scarcer, and malnutrition more common.

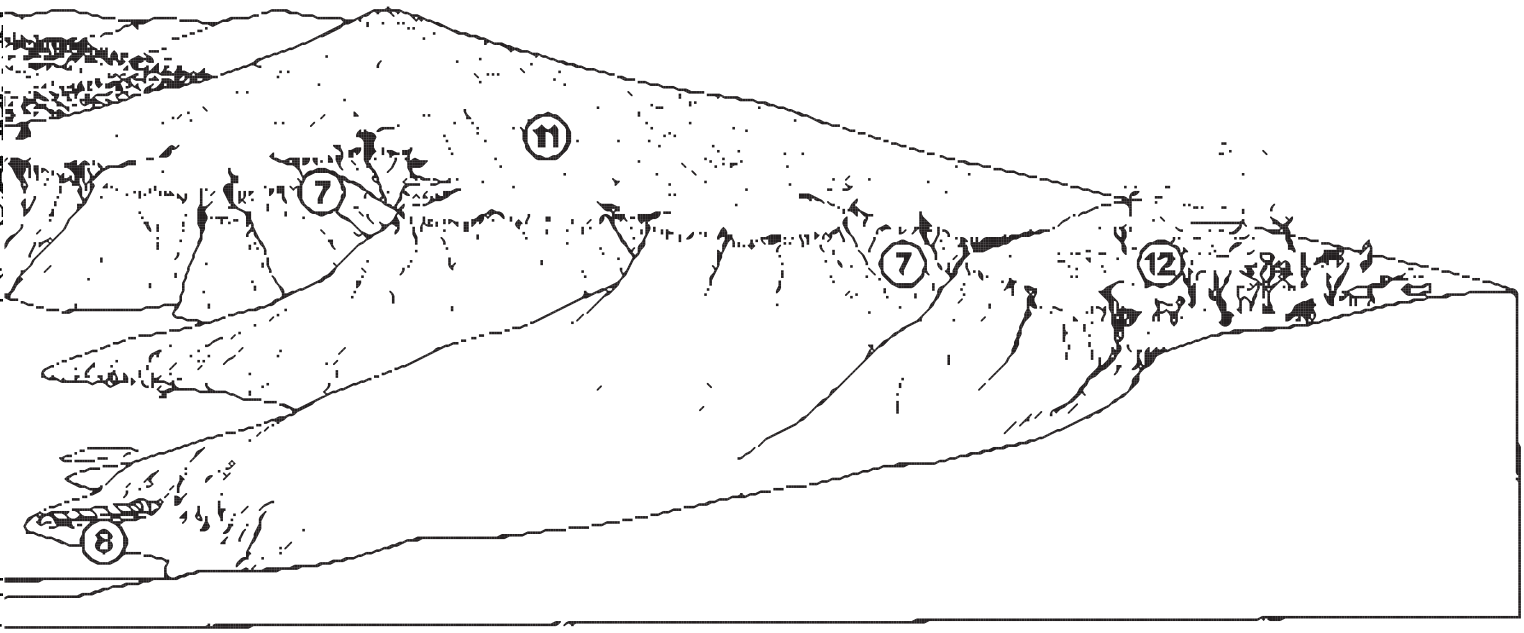
In many developing countries, a loss of agricultural revenue means more than food shortage. Because the agricultural sector is so important to the economy, national plans for development may be delayed and industrialization held back. The balance of payments situation may worsen if the country depends on cash crops. The rural population finds life increasingly hard and seeks a better life in the cities. The latter, often incapable of providing adequate services for the populations they already have, can offer little to the new arrivals except a place to build a primitive shelter in a shanty town. Social unrest and political discontent soon follow.

Meanwhile, the urban areas begin to suffer directly from the downstream effects of erosion. The soil that was once the natural resource of the farmers becomes the mud and silt of the valleys below. Huge quantities of it fill up the rivers, drastically reducing the amount of water they can carry. As rivers silt up, navigation begins to suffer; what were once highways for traffic and a productive source of high quality protein can become no more than meandering streams threading their way between enormous mud banks.

When heavy rains come, these rivers overflow and flood farmland and cities indiscriminately. Damage can be colossal. In Brazil and Argentina in 1983, floods covered an area approaching 100 million ha, destroying roads, railway lines, houses, crops and livestock. In Brazil alone, the cost of this flood was estimated at more than $1000 million.

Costly irrigation, flood control and hydroelectric schemes may also be wrecked as reservoirs designed to last many

1. deforested land
2. steep land being cultivated down the slope
3. monocrops grown over large areas
4. landslide blocks road
5. fish catch is reduced in shallow waters
6. silt in reservoir reduces lifetime of hydroelectric plant
7. gully erosion eats into crop land
8. mud banks reduce navigability of rivers
9. urban slums grow as rural population migrates to the city
10. bridge destroyed by floods
11. crops grown on large unprotected fields
12. badly managed pasture suffers from wind erosion
13. frequently flooded village becomes deserted



decades fill with silt in little more than a decade. In Colombia, the capacity of the Anchicaya reservoir—built to store water for a 64-megawatt hydroelectric power plant—was reduced from 5 million m^3 to 1 million m^3 in just 12 years, effectively reducing the reservoir to a river. A single flood alone deposited 60 000 m^3 of sediment in the reservoir overnight. Deforestation of the upper slopes of the watershed was the principal cause.

The economic result of downstream erosion is a rise in the cost of energy, water, food and goods formerly transported by river. The chances of further development schemes downstream are also eliminated.

It is extremely difficult to quantify the effects of unchecked soil erosion when so much is at stake but its direct effects on agriculture, however, are easier to understand. For this reason, FAO has been involved in a series of global studies related to land degradation. The first of these was the joint preparation with the United Nations Educational, Scientific and Cultural Organization (UNESCO) of a detailed, l0-volume, *Soil Map of the World*.

This was followed during 1976–79 by an FAO/UNEP/UNESCO project to develop better ways of assessing soil degradation. As a test of the new method, two series of maps were produced—at a scale of 1:5 million—for Africa north of the Equator and for the Near East. One set of maps shows the present degradation rate and state of the soil, and the other assesses future risks of soil degradation. Both treat the three main types of degradation—wind erosion, water erosion and salinization—separately. As a follow-up, FAO has been cooperating with UNEP and the International Soil Reference and Information Centre in producing a world map on the status of human-induced soil degradation at a 1:10 million scale.

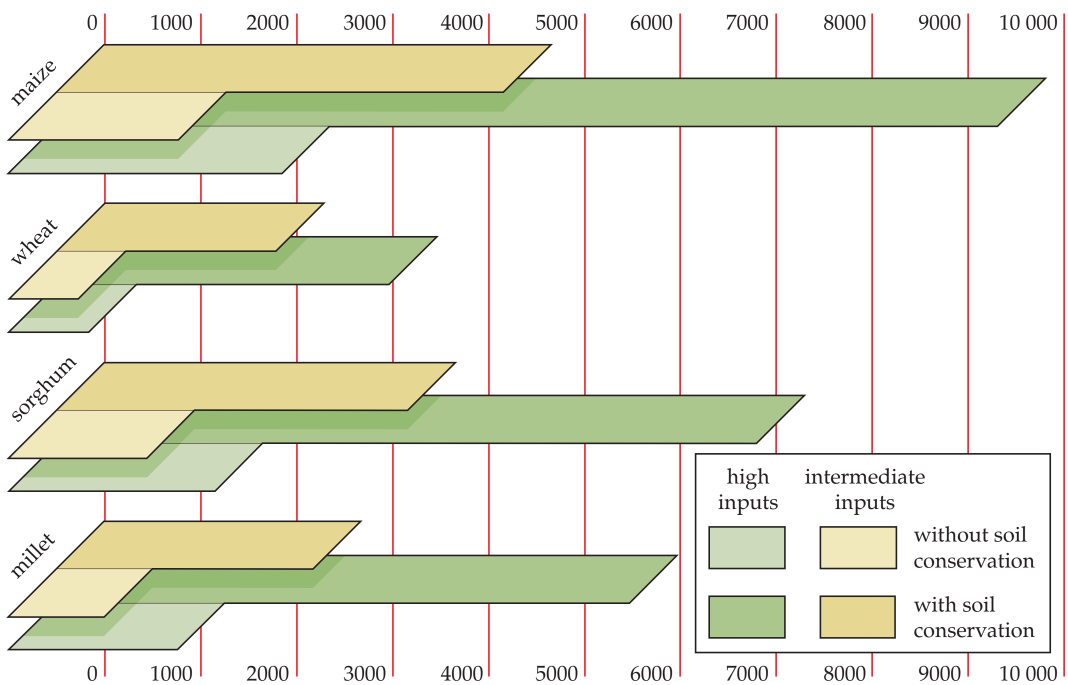
The *Soil Map of the World* indicated that if land were used optimally, and resources shared, there would be plenty of food for everyone for a long time to come. But the world does not work that way in practice. FAO has therefore been investigating the production potential of rainfed agriculture in developing countries in more detail. This Agro-ecological Zones project provided an assessment of land suitability for 11 main crops by combining soil data with information on climate and length of growing period. To simplify the calculations, two sets of results were produced, one assuming a low level of farming technology, involving only simple hand cultivation, with no agricultural chemicals or improved crop strains; and the other assuming a high level of farming technology, involving mechanical cultivation, high-yielding crop varieties, chemicals, and good management and conservation.

The data generated led to a joint FAO/United Nations Fund for Population Activities/International Institute for Applied Systems Analysis study: *Potential population-supporting capacities of lands in the developing world*. Using data on potential crop production from the Agro-ecological Zones project, it calculated the total population each country could expect to support, in 1975 and in the year 2000, from its own resources, given certain assumptions about the level of farming technology used and a number of other factors. The study shows that, even in 1975, some 55 of the 117 countries studied—32.5 percent of the developing world—could not support their populations using low levels of technology, leaving about 270 million people dependent on imported food.

One of the most important considerations is what, if anything, is done about soil conservation. This study produced important information on the quantitative effects of soil conservation on agricultural production. Among the major conclusions are that if no soil conservation measures are taken at all, the area of rainfed crop land in the world will decrease by 18 percent between 1975 and 2000. However, the production of rainfed crops drops by much more, by 29 percent, reflecting the fact that erosion not only destroys crop land but also reduces yield over much of the crop land that remains. Total production from rainfed and irrigated crops, and from grassland, would be reduced by 19 percent between 1975 and 2000 if no soil conservation measures were taken.

This work has also enabled FAO to calculate what effect efficient soil conservation might have on the number of people different regions in the world could support from their own resources in the future. As the map on the right shows, efficient soil conservation would enable many areas to support populations more than 50 percent larger than if soil erosion were allowed to continue unchecked. There is no more dramatic illustration of the positive value of soil conservation. Caring for the soil increases agricultural production in the short term and ensures the survival of future populations in the long term.

Kenyan crop potentials for the year 2000 (thousand tonnes)



Bar charts left show how soil conservation could increase crop potentials in the year 2000 in Kenya. The effect is most pronounced on agriculture that uses high levels of inputs.

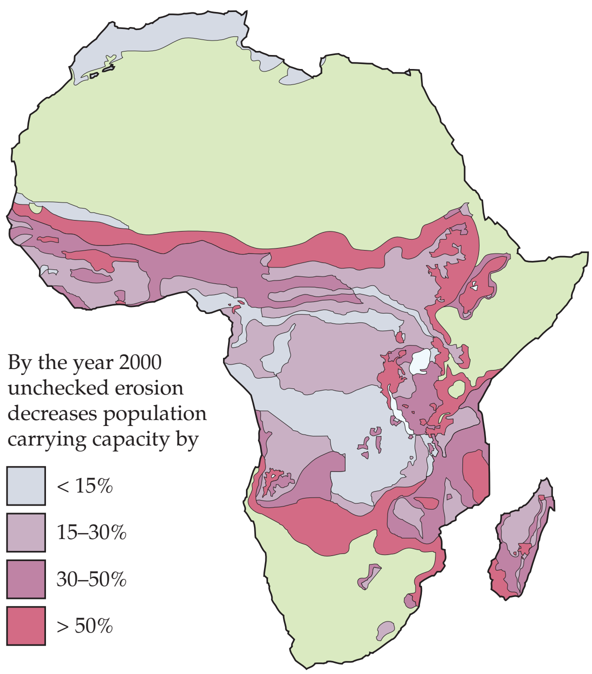
How erosion affects population-carrying capacity

A joint FAO/UNFPA/ IIASA study has assessed the capacity of land in the developing countries to support populations now and in the future. The study is based on the combined effects of such factors as the level of farming employed, length of growing season available, the crop mix which is used, the nutritional requirements in different areas and the amount of soil conservation carried out. It shows that by the year 2000, a number of countries, particularly in Africa and South West Asia, will be unable to support their populations from their own resources unless they use high-technology farming, the correct crop mix and carry out extensive soil conservation.

The map shows the effect that soil conservation could have in Africa. For example, with extensive soil conservation measures the areas shown in colour could support populations 50 percent higher than if no soil conservation were carried out. The map is based on the assumption that only a low level of farming technology is used: no artificial fertilizers, pesticides or herbicides, and only simple hand tools. The calculations include production from both rainfed and irrigated crops, and assume an optimum crop mix.

Worldwide, unless soil conservation measures are introduced on all cultivable land, 544 million hectares of potentially productive rainfed crop land will be lost during 1975–2000.

Population-carrying capacity map of Africa



RECLAIMING THE LOESS PLATEAU

China's Loess Plateau—the 530 000 km^2 watershed of the Yellow River in the northwest Shaanxi Province—is one of the most severely eroded areas in the world. Intensive cultivation on steeply sloping hillsides, using outdated techniques, has meant an estimated 1.6 billion tonnes of the fine, yellowish silt being washed away every year, seriously reducing the area's productivity.

The Chinese authorities addressed the problem in 1979 by setting up an experimental erosion control station at Mizhi, in the north of the province. They requested further assistance from the United Nations Development Programme to improve land use. Over the next eight years, the UNDP contributed US$1.2 million through FAO which provided international experts, modern equipment and training.

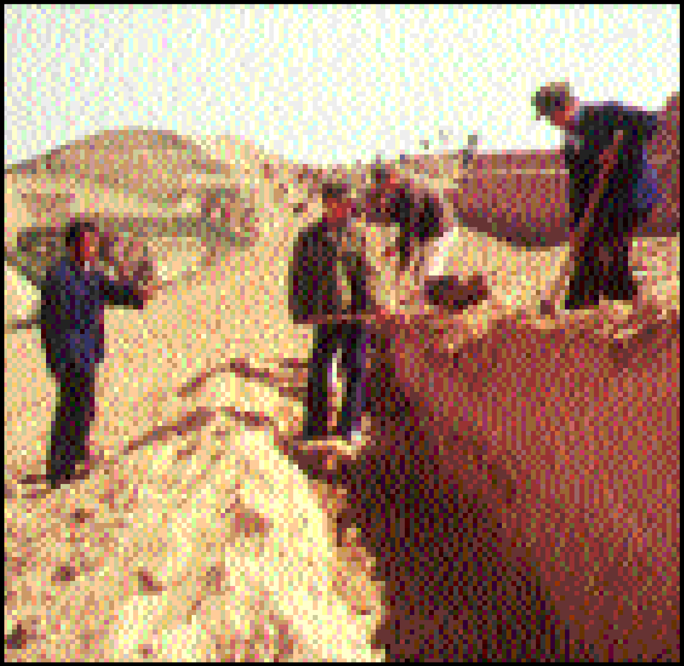
Mizhi County provides a good example of the conditions prevalent in the Loess Plateau: more than 60 percent of the area has slopes of more than 20 degrees, and the average annual soil losses caused by extreme gullying have been as high as 12–15 000 tonnes per km^2, most of which occur during the summer rainy season, after the winter wheat has been harvested and the ground is left bare.

The project centred on a 100-km^2 pilot watershed, shared by three villages, and aimed to assess the area and devise comprehensive land-use and management solutions to

- increase the yield of the field crops;
- increase the productive value of forestry and animal husbandry;
- restore farmland for trees and pasture;
- control water and soil erosion; and
- improve the standard of living.

The range of treatments tested included converting steeply sloped farmland to permanent vegetation; terracing additional land; controlling gully erosion; and introducing new crop varieties and small animal breeds better suited to the area.

Introducing perennial forage crops was particularly important for the success of this project as their presence on



Finished terraces in northern Shaanxi Province (left) provide basic farmland for such crops as sorghum, millet, potatoes and groundnuts. Photo right shows the terraces being prepared.

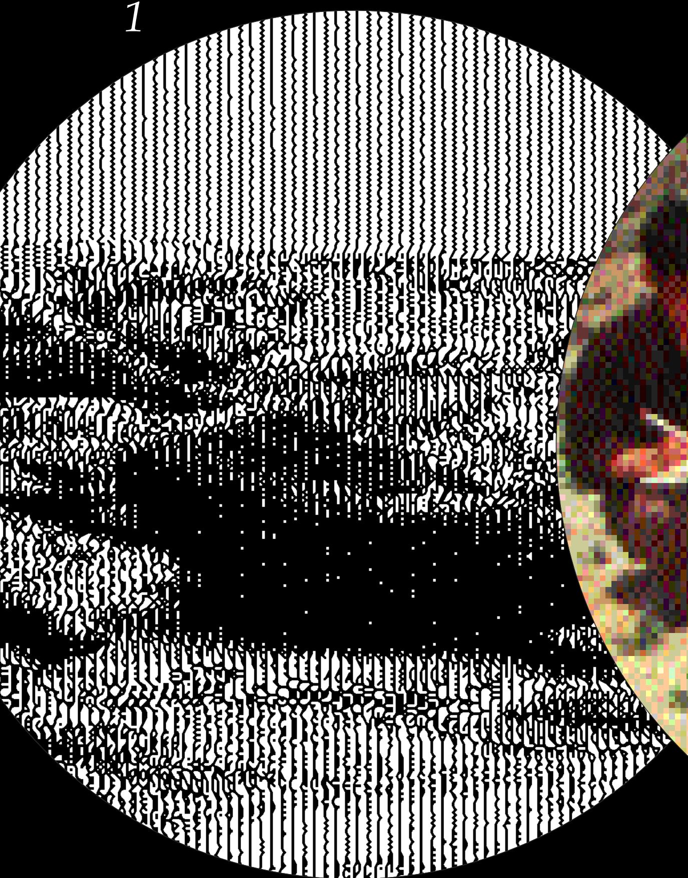
the characteristically steep slopes in the area could control erosion (unlike cultivated annual crops, such as potatoes), while also encouraging farmers to diversify away from annual crops and into small animal husbandry. After testing more than 200 forage grasses and legumes, large-leafed alfalfa proved the most productive and popular. Alfalfa planted in contour drills reduced the amount of soil lost from crops from about 4.5 to 1.82 tonnes/*mu*/year (1 *mu* is about 650 m^2). Such simple biological measures, which give an obvious economic return, are more acceptable to farmers and therefore more likely to be maintained. Other plants tested successfully for productivity and suitability for growing on terraces include asparagus, blackcurrants, raspberries and mulberries.

Animals successfully introduced to the area include fine-wool sheep, Angora goats, and rabbits for fur and meat. By crossing the local breeds with high-quality imports, reproducing by embryo transfer and artificial insemination, and improving management practices, the sheep- and goat-breeding programme has helped diversify production into a high-value, non-perishable product—wool—that can be transported without damage from this remote area.

Although planting forests was generally not welcomed by farmers—because the growth rate was inadequate for timber

Conservation in Mizhi Country begins with the exchange of ideas between farmers and extension workers (1). Technicians then experiment with different cultivation techniques for groundnuts (2) and fruit trees (3). 'Pit planting' of trees (4) is one of the techniques that has proved particularly successful in the area. A farmer proudly displays a sample of his groundnut crop (5).

1



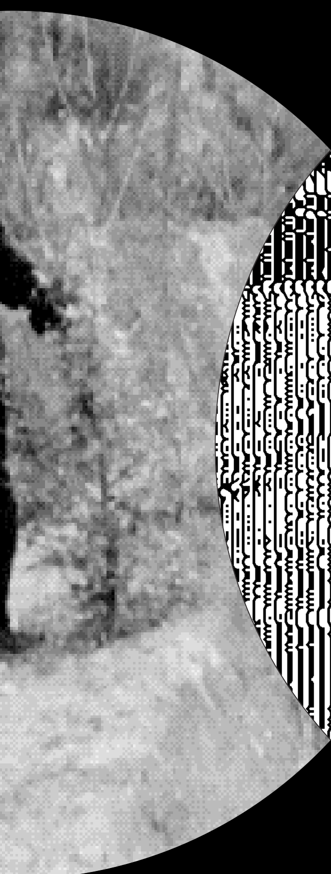
2

3

production, and thus financial gain—growing fruit trees was more successful. When planted on terraced slopes, improved varieties of apple, pear, peach, apricot and jujuba trees helped to control soil erosion and run-off, while opening up new possibilities for profitable fruit production.

The project has thus successfully achieved most of its objectives. The land area used for food production decreased by more than 50 percent, basic stable farmland increased by more than 50 percent, and grassland and forest now comprise 47 percent of the total land area. Although the aim of increasing food crop yield so that 2 *mu* of land produces enough food for one person's annual needs has not yet been met, total food production increased by about 70 percent, despite the decreased cultivated area. By 1988, 2.5 *mu* of stable land could fulfil this aim—and efforts continue to bring this average closer to the target figure.

The Loess Plateau project has proved beyond doubt that integrated land-use planning increases production, reduces erosion and raises living standards. The project further illustrated the success inherent in involving the individual farmer. The results demonstrated by the model watersheds were so encouraging that the same soil-conservation techniques and land-use practices are being extended throughout Shaanxi Province (through the World Food Programme) and in parts of the Yulin Prefecture.



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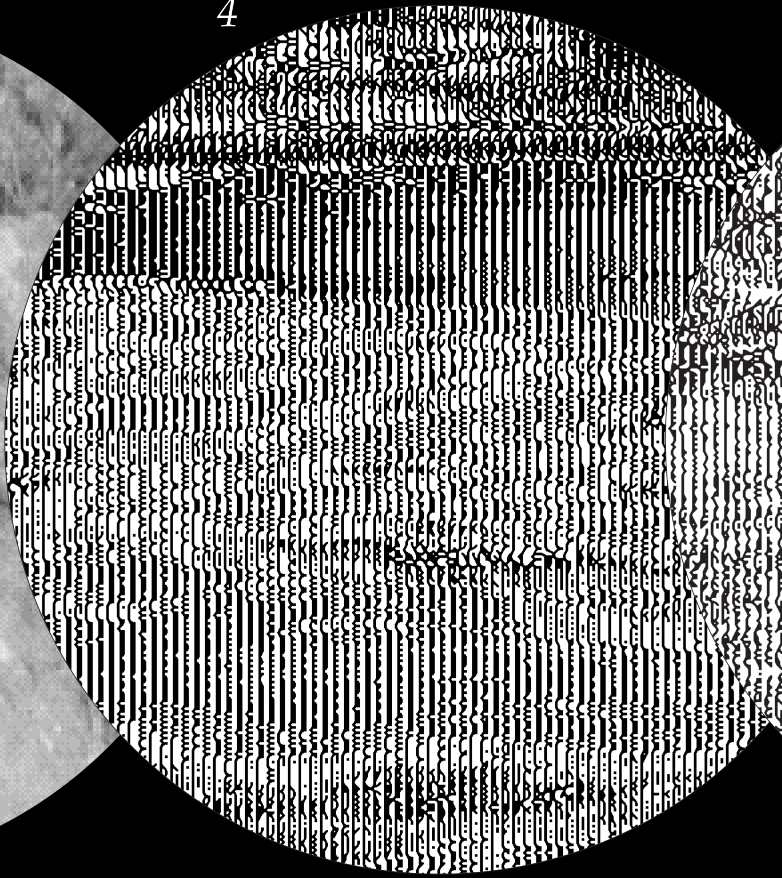

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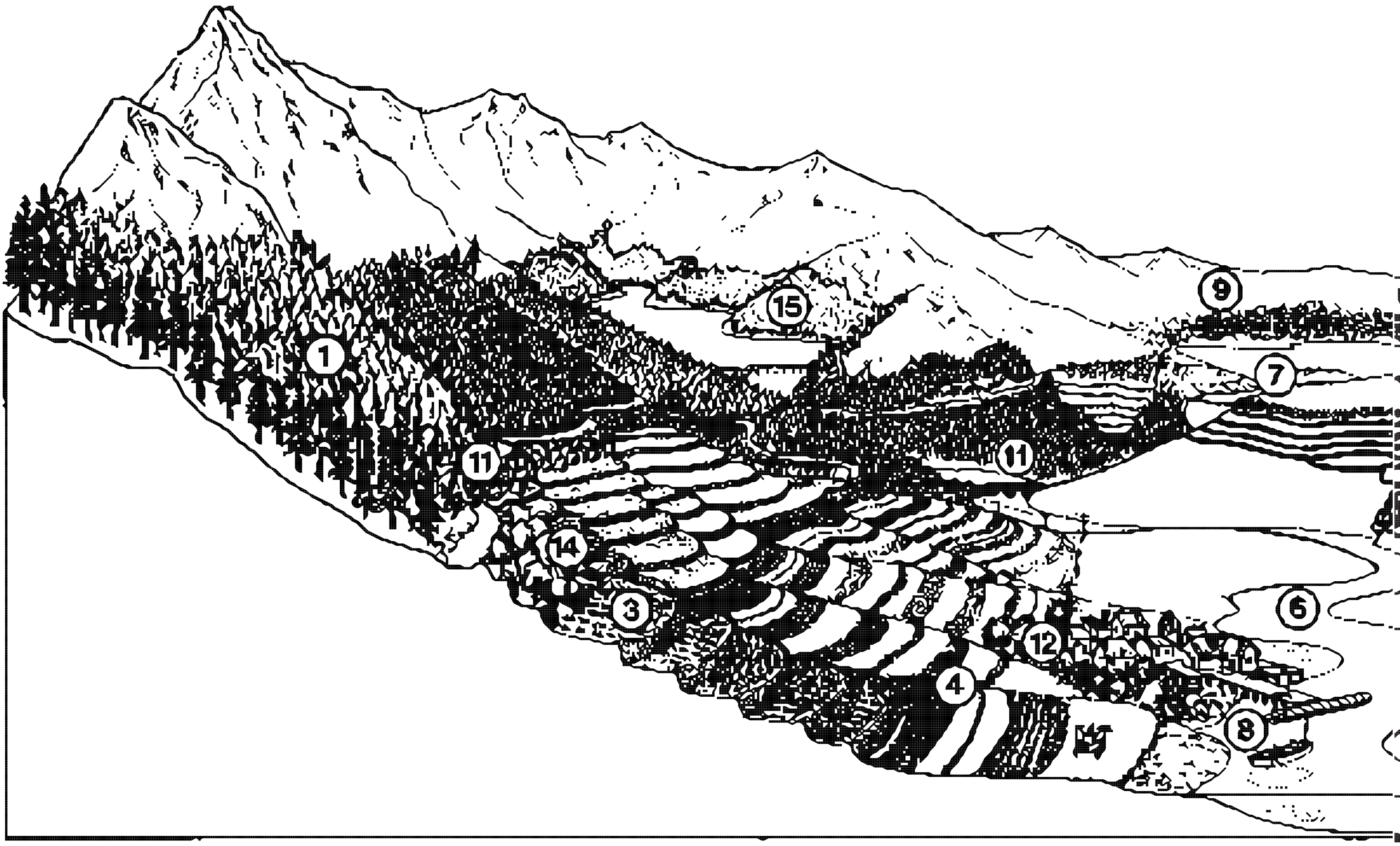
WHAT CAN BE DONE?



Soil conservation is not a negative activity, involving huge expenses and small returns. Soil conservation is positive: even in the short term it results in substantial increases in agricultural production and, in the long term, it ensures the continued productivity of the most important natural resources.

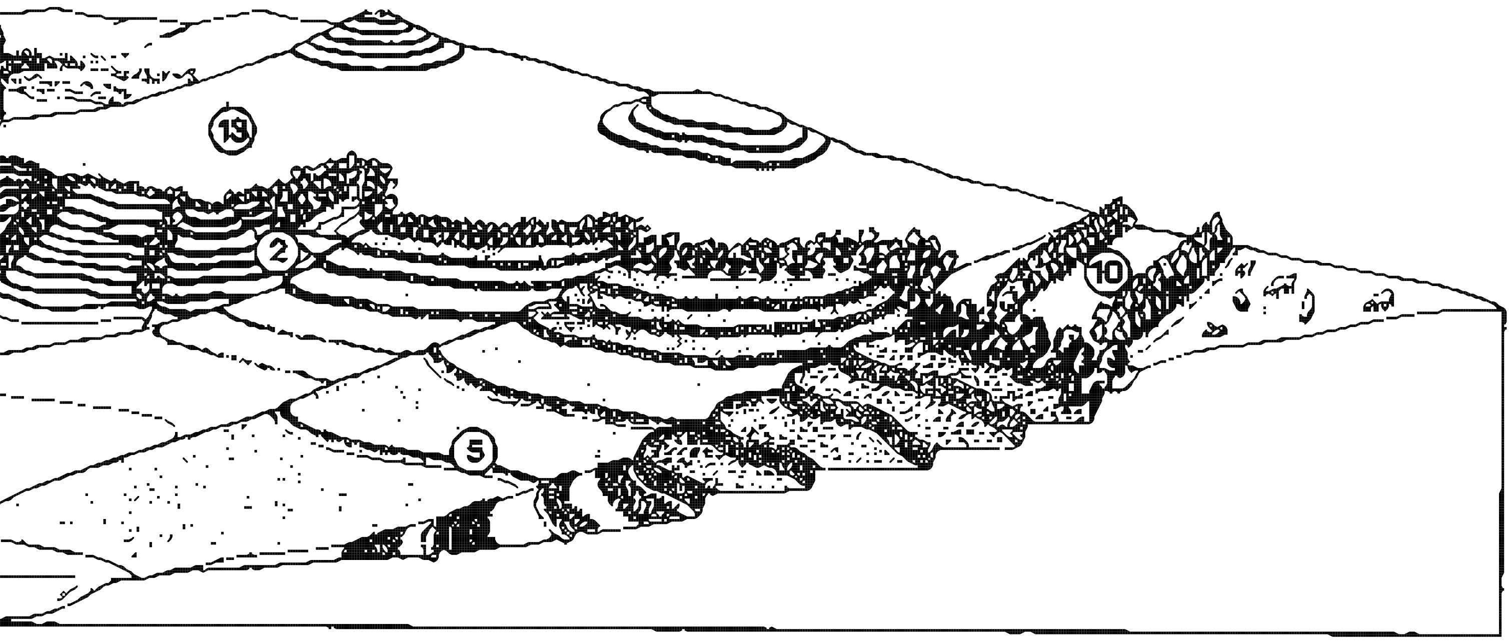
Without human intervention, soil erosion is usually extremely slow. Rapid erosion, of the kind prevalent in many developing countries, is caused by land-use patterns and farming techniques unsuited to the land in question. Perhaps the land is being worked beyond its capabilities; perhaps the wrong crops are being grown; or perhaps the farming techniques are inappropriate for the soil type.

Whatever the case, inappropriate land use has two results. One is that agricultural yield is inevitably below the maximum that could be obtained. The second is that erosion soon follows and accentuates the problem. In other words, these three factors—erosion, yield and land use—interact in a vicious circle. When the wrong crop is selected, or the wrong farming technique chosen, yield inevitably drops. Erosion follows, and reduces yield still further. Finally, the land is degraded and goes out of production.

It follows that as soon as the causes of erosion are corrected, two results ensue: erosion stops and yields increase. There can be no more encouraging conclusion, for both planners and farmers. In conservation, getting things right pays double dividends.

Fortunately, getting things right is not as difficult as it is in other areas of development. The causes of soil erosion are well known. So are the techniques with which to combat it. Soil conservation has been regarded as an important science since the devastating effects of wind erosion became apparent

1. reforested land
2. gully erosion halted by check dams, trees planted on gully banks
3. steep land is bench terraced
4. contour cultivation practised on lower land
5. bunds are built to control surface run-off
6. as erosion stops, flooding is reduced
7. new reservoir supplies power to nearby villages
8. river navigation improves, fish catch increases
9. urban services improve as population migration stops
10. shelter belts reduce wind erosion, pastures are improved or upgraded
11. absence of landslides and floods improves road communication
12. rural services improve as villages expand
13. crop rotation practised in strips along contours
14. tree crops grown on eyebrow terraces on steep land
15. forested slopes prevent siltation of reservoirs



in the United States in the 1930s. Over the decades, the battery of techniques available to control erosion has been steadily developed and expanded. These techniques fall into two categories.

The first comprises biological techniques of erosion control. They have little to do with engineering. Instead, they involve a fundamental assessment of the suitability of the crops being grown and of the techniques being used to farm them. Very often, getting both these things right will bring erosion under control by itself. Even if not, it will certainly reduce the amount of expensive physical work that has to be done.

The second category is the physical techniques, such as the many different forms of terracing that now exist, methods of gully control, dams for controlling flood water and siltation, and overall watershed management. The physical techniques are not cheap, either in terms of manpower or its mechanical equivalent. However, as the illustrations on these two pages show, their effects extend far beyond the immediate terrace or gully dam being constructed.

Successful erosion control affects everyone from the mountain shepherd to the coastal city dweller. Ultimately, national development plans can succeed or fail according to the success achieved in controlling erosion. A nation without soil is effectively bankrupt. A nation with appropriate land-use patterns and farming techniques, where erosion has been controlled and contained, is poised on the springboard of development.

A PROPER USE FOR LAND

The biological techniques of erosion control amount to two simple concepts: growing the right crop on the right kind of land and growing the crop in a way best suited to that land. The first is primarily a question of good land-use planning, the second a matter of good farming management.

Biological techniques of erosion control are always the first and most important issues to be considered. If the land is being used incorrectly, or if farm management techniques are wrong, no amount of physical work to combat erosion—the building of terraces, drainage channels and the like—will succeed. Furthermore, planting the right crop and growing it in the right way are a much cheaper alternative than expensive physical protection schemes, which may involve huge amounts of manpower and are often slow to carry out.

The first stage in land-use planning is assessing growing conditions and choosing the right crop. Ideal growing conditions are governed primarily by the climate and the nature of the soil. The FAO Agro-ecological Zones project has determined the areas in the developing world where 11 of the major crops can be grown most successfully: pearl millet, sorghum, maize, wheat, soybean, phaseolus bean, sweet potato, white potato, cassava, cotton and rice. Detailed country assessments are now being made at the request of several governments.

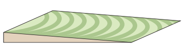
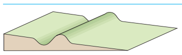
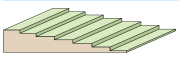
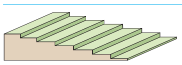
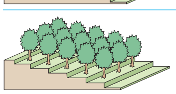
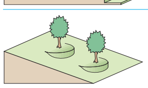
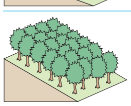
But other considerations also come into play. How easily is the soil eroded? This will depend both on the nature of the soil and on the slope of the land. And how erosive is the climate? Regular, gentle rainfall of the kind found most often in temperate zones is far less erosive than infrequent but torrential downpours that occur throughout the tropics.

Fortunately, there are simple but general rules to help planners. In the humid tropics, for example, slopes of up to 3.5 percent can be used to grow any crops, although they should be cultivated along the slope of the land and not down it. Slopes of 3.5-12 percent can also be used for any crops, but ridges or bunds will be needed to impede the flow of surface run-off. Land with a slope of 12–27 percent will also support most crops but bench terracing may be needed.

When the slope is more than 27 percent, the choice of crop is more limited. Close-cover crops and semi-perennials can be grown on slopes of 27–36 percent but step terraces or hillside ditches will be needed to help control erosion. Slopes of more than 36 percent are best suited for perennial crops, mainly tree crops with ground cover in which no cultivation takes place. If the slope is 47–65 percent, orchard terraces or tree platforms will be needed. Finally, land with a slope of more than 65 percent is suitable only for forest and will not generally be terraced at all.

An FAO project in Costa Rica helped to establish a national soil conservation service (SENACSA)—complete with training manual for professional and technical staff—to execute a conservation plan, carry out demonstration projects and promote improved land-use practices. This could serve as a model for similar institutions throughout Latin America.

Slope, crops and conservation in the humid tropics

maximum slope (%)	minimum soil depth (cm)	conservation treatment	type of crop
 0–3.5	—	contour cultivation	any
 3.5–12	—	ridges or bunds	any
 27	100	bench terraces	any
 36	50	step terraces or hillside ditches built by small tractor	close-cover crops and semi-perennials cultivated by small tractor
 47	50	step terraces or hillside ditches built by hand	tree crops with ground cover cultivated by hand
 65	25	orchard terraces or platforms	tree crops with ground cover (no cultivation)
 65+	—	none	forest only

Costa Rica: a model site for conservation

Like other countries in Central America, Costa Rica has recently suffered from declining productivity. Intensive cropping has robbed much soil of its fertility, while deforestation and overgrazing have damaged watersheds and provoked the serious soil erosion that now affects more than 12 000 km^2 of farmland.

Following a government request in 1984, FAO provided US$2.4 million and the services of 14 advisers to help establish the Servicio Nacional de Conservación de Suelos y Aguas (SENACSA) in November 1988, responsible for formulating and executing a plan for soil conservation, carrying out demonstrations and promoting improved land use. This new organization was divided into units for soil mapping, planning and construction, agro-conservation and data information; it was then integrated into the nation-wide technical assistance services of the Ministry of Agriculture.

By June 1989, an international consultation had drawn up a draft action plan. In the meantime, Costa Rica's soil and water resources were being assessed and the results used to draw up a 1:200 000-scale soils and watersheds map which indicated that 42 percent of the country's agricultural land was subject to severe erosion and needed reforesting or other forms of protection.

A natural resources database—containing soil, weather and socio-economic data—was compiled to allow SENACSA staff to determine land production capacity using such parameters as slope, degree of erosion, drainage and soil texture.

Soil conservation and management measures were developed and tested using demonstration areas. After analysing the main causes of soil degradation in the area, a catalogue of 53 land-use recommendations was drawn up and adopted by SENACSA.

Evaluating one rural area showed that the recommended measures boosted maize production from 2760 kg/ha to 3680 kg/ha without increased fertilizer. A vegetable farmer cultivating the volcanic soils of the northern Cartago region could expect to recover the cost of anti-erosion works within three years.

It is hoped that the technical expertise and training provided by FAO will enable SENACSA not only to continue conserving Costa Rica's soil resources, but also to serve as a model for similar institutions throughout Latin America.

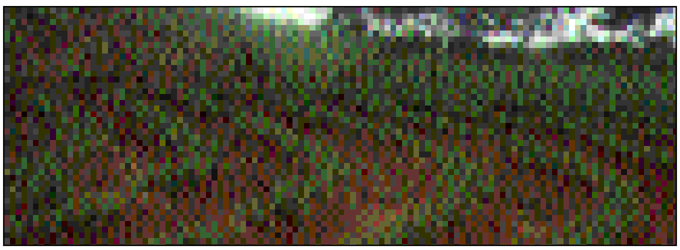
MANAGING THE CROP

Proper crop management is the single most effective means of controlling erosion. It can reduce the rate of soil erosion by a factor of 20, bringing it down from, say, 100 to only 5 tonnes/ha. This kind of saving is about 10 times larger than any that can be made using physical conservation measures.

Even the very simple management technique of ploughing along—instead of across—the contour can make a substantial difference, reducing erosion by half on slopes of two to seven percent, and by somewhat less on steeper land.

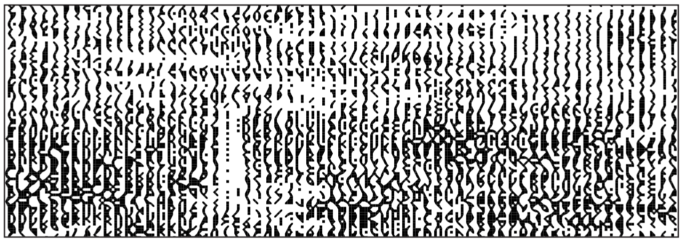
Strip cropping, in which strips of crops are grown side by side in bands along the contours, is also highly beneficial because it greatly reduces the length of slope down which water can run without interruption. Ideally, some of the strips are best put down to grass.

Encouragingly, farmers rarely need to sacrifice yield to conserve the soil. On the contrary, farming techniques that minimize soil loss tend to improve yield. Experiments in central Africa have confirmed this. Two fields were planted with maize. In one, the crop was grown using traditional techniques; in the other, a higher planting rate and more fertilizer were used, and the residue of the previous crop was ploughed back into the land. The second technique not only doubled the yield—from 5 to 10 tonnes/ha—but also reduced erosion from 12.3 tonnes of soil per hectare to just 0.7 tonne/ha, a 17-fold reduction.



Contour planting in Malawi—a simple way of cutting erosion by as much as one half.

Another key to good management is crop rotation, a practice which does much to improve the structure of the soil and its organic content. Both factors are useful in keeping erosion at bay and, of course, both make for higher yields. Crop rotation is one of the ways in which the land and soil can be kept healthy: uninterrupted monocultures are a sure way of inviting pests and diseases. If crops such as



Hillside terracing in Indonesia, with mixed cropping of palm trees and food crops, reduces the length of slope down which run-off can flow without interruption.

maize and grass are alternated, the soil structure is improved, allowing water to drain away more freely. In the tropics, however, the effect is short lived: grass improves the soil's resistance to erosion quite quickly but, after ploughing, the improvements last only a year or two.

One of the secrets of good crop management is to keep the ground covered for as much of the year as possible. Experiments show that ground cover can reduce soil erosion very dramatically. Two small plots of land were kept hand-weeded for 10 years; the first was left bare and the second was covered with a fine-mesh gauze, which effectively broke up the raindrops and prevented them from eroding the ground. Over the 10 years, the first plot lost soil equivalent to 1265.7 tonnes/ha, the second only 9.4 tonnes/ha, more than 100 times less. Covering soil with a grass crop produces a comparable improvement. But planting crops more densely and growing them prolifically using plenty of fertilizer, as in the maize example just mentioned, can be almost as effective, providing the bare period following planting does not coincide with heavy rains.

A refinement of these techniques is to practise zero or minimum tillage. Experiments in Nigeria have shown that in tropical countries zero tillage has much to offer. One of the best techniques is to kill off the old crop with a herbicide, and then immediately plant the new seed, together with fertilizer. Not only is erosion minimized, but yields are increased and a great deal of time and fuel are saved because fewer passes have to be made over the land. Minimum tillage techniques are growing greatly in popularity in developed countries: they were successfully used on 30 million ha of crop land in the United States during the 1980–81 season.

Brazil:
terraces are not enough

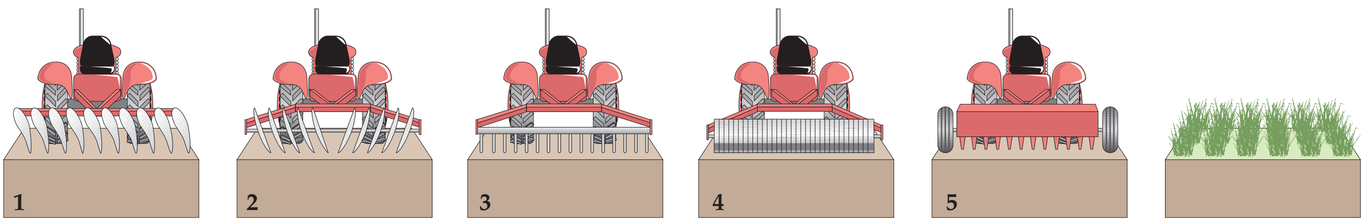
In the mechanized farming areas in the southern states of Brazil, soil erosion is threatening agricultural production, the future of hydroelectric power stations and continued easy transport on the region's rivers. The solution to the problem can come only from changing the way the land is farmed.

For instance, measurements have shown that one region near Santa Barbara has lost 30 cm of soil in just seven years. The prime cause is the farming system in which wheat is grown in the winter and soybeans in the summer. The land is ploughed and disc harrowed, using tractor-drawn equipment, for both crops, and the soil suffers in two ways. First, the clay in the soil is worked down deeper and deeper into the soil profile, eventually forming a compacted, non-porous subsoil. Secondly, the upper layers of the soil tend to be washed away during rainstorms because the soil is so often exposed. The sediment produced then causes silting of rivers and reservoirs. The huge Passo Real reservoir in Rio Grande do Sul now has sediments as deep as 2.2 metres and has lost 18 percent of its original volume in less than 8 years. This is threatening to reduce the lifetime of a 530-megawatt hydroelectric plant to less than 30 years. Sediment is also beginning to interfere with the shipping that uses the region's rivers.

Studies have shown that although terraces have long been known in the area, the system itself needs to change. Minimum tillage dramatically reduces soil loss and improves moisture infiltration. Furthermore, as productivity increases, production costs decrease. Crop yields can be maintained, and as much as 71 percent of the diesel fuel previously needed to work the land can be saved. Returning the wheat straw to the land increases the soil's organic content, and reduced tillage controls soil erosion.

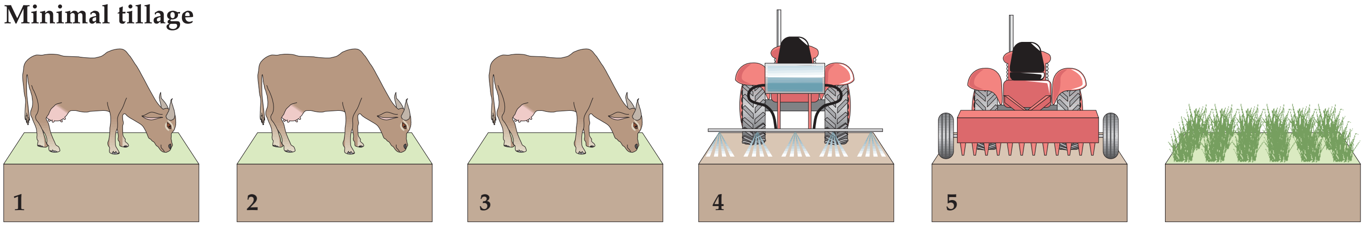
Farmers rapidly adopted the practices demonstrated; their use is now widespread, having been assisted by a recent series of major loans from the World Bank.

Conventional tillage



Conventional tillage practices vary widely but typically involve ploughing (1), disc harrowing (2), harrowing (3), rolling (4) and combined sowing and fertilizing (5). The process often leads to serious erosion and is expensive in time and fuel

Minimal tillage



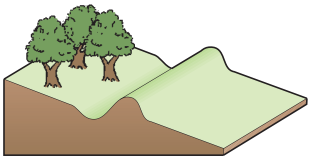
Minimum tillage techniques involve only two passes: spraying for weed control (4), and the simultaneous injection of seed and fertilizer directly into the undisturbed soil (5). Livestock can be allowed to graze (1, 2 and 3) until spraying begins

WORKING WITH CONTOURS

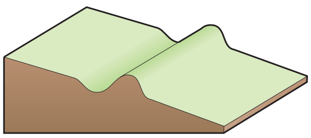
Strip cropping and contour farming are the first two ways in which farmers can work with contours. If their land is almost level, this may be all that is required. But on steeper slopes, some degree of physical protection against erosion will almost certainly be required, particularly in tropical conditions where the erosion risk is high.

Most of the main types of physical protection are included in the illustrations below.

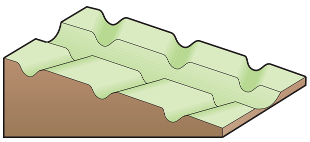
It is essential that all forms of physical protection against erosion be regularly and carefully maintained. Failure to do this can result in sudden, catastrophic damage that may be worse than if the work had never been carried out. Blocked diversion ditches, overflowing grass waterways and broken terracing are often a cause of huge land loss in developing countries.



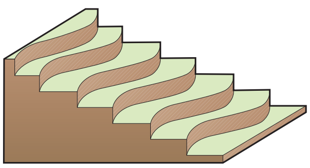
1. Storm water or diversion drains are used to separate higher, non-arable land from flatter crop land. They run along the contour and intercept the run-off from the higher ground that might otherwise seriously erode the relatively unprotected arable ground.



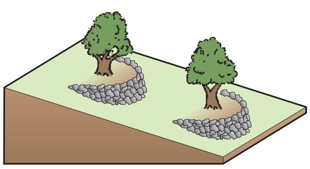
2. Ridges and bunds are small banks of earth built along the contour to brake the downhill flow of water. On arable land, they are used below diversion drains to lead off the water that actually falls on the crop land. They can perform a similar function higher up on erosion-prone hillsides which may be forested or planted with tree crops.



3. Grass waterways are built down the slope, to carry away the run-off from diversion drains and bunds. They must be covered in thick, hardy vegetation and be deep enough to cope with storm water.



4. Bench terraces are the oldest form of mechanical protection against erosion and have been in use for centuries, particularly in Asia. Their construction requires prodigious amounts of labour because sloping land is actually converted into a series of large steps, the nearly vertical riser usually being constructed out of stone or earth covered with clinging vegetation, such as a creeping legume. The terrace bed may be built flat, sloping slightly forward or slightly backward, into the hill. The latter construction is used, for example, in irrigation terraces for growing lowland rice. A lip is built on the front of the terrace, enabling the whole terrace to be flooded when required.



5. Platform, eyebrow or orchard terraces are the cheapest form of terracing because they are discontinuous. They are built as small platforms in the hill to take individual trees. The terraces are built along the contour and the slopes between them must be covered in vegetation.

Ethiopia: winning the battle to save a land

The effects of the Sahel drought in Ethiopia in the 1970s were greatly amplified by declining agricultural production. Too many cattle and too many people using inappropriate farming techniques had eroded the land—the country was losing an estimated 1600 million tonnes of topsoil a year—and nearly destroyed the forests. Much of the damage was in the Central Highland Plateau, a region of mostly sloping land that supports 70 percent of the population and contains 47 of the country's total 80 million cultivable hectares.

In an effort to halt land degradation, the World Food Programme (WFP) contributed 'Food for Work', which provided each worker with a family food payment of 3 kg of wheat or maize and 120 g of vegetable oil in exchange for a day's work on conservation projects. But there was a problem because Ethiopia had few trained soil conservationists to plan and supervise this big and important programme. The government therefore asked FAO for assistance and UNDP agreed to provide funding. As a result, US$7.4 million has been spent on the programme since 1979.

Some of the funds have been used to equip the soil conservation service, provide transport for field staff, purchase survey and drafting instruments, import seeds and plants to control erosion, and establish new nurseries. FAO experts have worked with local technicians to develop procedures for planning, supervising and monitoring the field work. Conservation practices that accord with local conditions and farming systems have been developed and tested, and manuals produced to guide field staff.

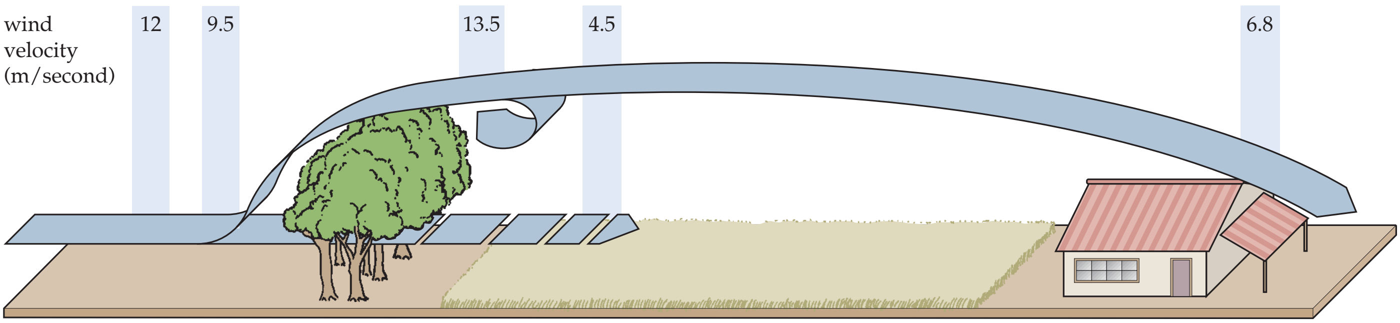
The main feature of the programme has been training. By the end of 1991, 56 Ethiopians had been sent overseas for advanced studies, some at Ph D and M Sc level, and a further 51 sent on short-term study tours. Thousands of technicians, extension workers and farmer representatives have also been trained.

Ethiopia still suffers from serious erosion but, thanks to this programme, it now has the staff and experience needed to tackle the problem.

Photo: members of a peasant association digging contour bunds in an erosion control scheme in Harar Province.

DIVERTING THE WIND

Shelter belts



Shelter belts generally protect land from the wind up to a distance of at least 20 times the height of the trees. However, if the trees are planted too close together, and the wind fails to penetrate them at all, eddies may be set up close to the shelter belt. A cover crop also acts as a kind of shelter belt for the soil by increasing the thickness of the layer of still air which exists at ground level.

Water erosion affects only sloping land but all land—if the climate is dry enough—may be prone to wind erosion. And wind erosion tends to reinforce itself: once it starts, it is likely to get worse.

The mechanics of wind erosion are quite complex. The lightest soil particles are lifted into the air by the wind and carried away. Slightly heavier ones are bounced along the soil surface. Heavier ones still only creep or roll, usually as a result of being hit by the lighter particles. Eventually, the heavier, less fertile particles end up against obstacles such as fences, roads and buildings. But on their way there they have bumped and rubbed against even bigger particles, breaking them down by abrasion, so that they too eventually begin to creep and roll.

Wind erosion thus sorts the fine, fertile particles from the heavier, sandy ones left behind. Once erosion starts, the soil soon becomes less fertile, and the crops growing on it less healthy: as the ground cover diminishes, so erosion increases. Anything that helps the wind break the ground up into smaller particles—repeated tillage, vehicle tracks and the hooves of grazing stock—tends to increase the rate of wind erosion.

The best shelter from the wind is a good cover crop. Where conditions are bad, mechanical protection must be used to provide enough shelter to allow the vegetation to make a start. Shelter belts of trees—which can also provide fuelwood—are often an ideal answer but should not be so thick that they are completely impenetrable to the wind, in which case turbulent areas will be set up quite close to the trees. Shelter belts generally protect an area the length of the belt and at least 20 times the height of the trees. After the dust bowls of the 1930s, officials in the United States planted 220 million trees—as ‘nets to catch the wind’—in areas prone to wind erosion.

A different problem arises where airborne soil or sand settles in sheltered areas. Roads in arid regions are frequently covered by drifting sand. Work in Morocco has shown that shaping roadside banks can actually cause sand to be blown clear of the road. Properly harnessed, it seems, the wind can be a friend.

FAO work in Tunisia has also demonstrated this. There, sand dunes are encouraged to grow large enough to act as shelters. A barrier—usually palm leaves—is erected along the crest of a small dune. Sand then blows up against the barrier, which is soon buried. A new one is built, and the height of the dune raised again. The process is repeated until the dune is high enough to provide the protection required; it is then stabilized by ‘chequerboard planting’ (*see opposite*).

The principles applied to treating water erosion also apply to wind erosion. Crops should be grown in strips at right angles to the wind. And where wind erosion is persistent and damaging, it may be foolish to try to continue to grow arable crops. The land may be safer—and in the long term more productive—as grazing land. Although wind erosion has been largely overcome in the central plains of the United States, a further 5.6 million ha of what is currently arable land may still have to be returned to grazing. Similarly, where grazing land has been downgraded, the best answer is often to rest the land for a period to allow the vegetation to return, and provide protection against wind erosion.

Morocco: turning back the sand

overgrazing and cutting sparse vegetation for fuelwood led to severe problems in southern Morocco in the mid-1970s, when wind-blown sand threatened palm plantations, villages and roads. In some areas, as much as 50 ha of irrigated palm plantations were lost every year. The sand also threatened costly irrigation works, such as the $20-million Mansour Eddhabi dam. Just keeping the principal irrigation canal from the dam free of sand was recently costing more than $60 000 a year.

In 1980, at the request of the Moroccan government, a four-year FAO/UNDP project began to investigate methods of stabilizing sand dunes in the southern provinces. This has been remarkably successful: sand advancement has been completely halted in many of the worst trouble spots.

Three techniques were used. The most successful involved marking chequerboard patterns in the sand using palm branches; inside the squares, where there is some protection from the wind, vegetation is then either allowed to regenerate spontaneously or local shrubs, trees and grasses are planted out. Several types have been bred for improved wind resistance.

The second technique involved erecting fibro-cement sheets in the sand to act as windbreaks.

Finally, a novel way of protecting the main roads was developed, which involves sculpting the sand on the windward side of roads with earth-moving equipment until it has an aerodynamic shape akin to that of an aircraft wing. This accelerates the flow of air over the road so that the sand, instead of settling, is carried away.

By the end of 1982, some 17 km of sheet fencing had been erected and 100 ha of chequerboard fencing had been marked out. Another 24 ha were planted out without protection. A research programme to improve the genetic qualities of *Tamarix* species began. Two nurseries were established, each capable of producing 100 000 plants a year.

As a result, 14 villages, 7 palm plantations and many irrigation canals, roads and railways in the area were freed of the threat of encroaching desert and a substantial amount of land was reclaimed for agriculture. At Tinfou, for example, a school has been built under the very dune that only recently threatened to engulf the village. For the first time for many years the villagers can, as they say, 'drink tea without sand'.

Photo: chequerboard planting is used to stabilize sand dunes in Morocco. Dead palm branches are often used to mark out the squares, the area within them being planted with drought-resistant grasses, shrubs or trees. Sometimes the vegetation will regenerate spontaneously in these protected areas.

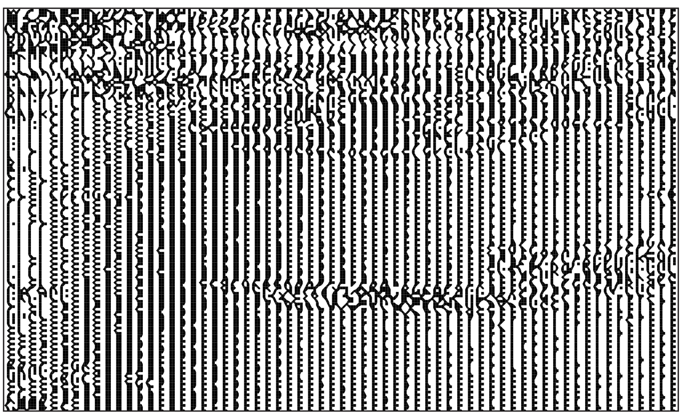
REPAIRING THE DAMAGE

Preventing soil erosion is a great deal easier than curing it: soil that has been washed off fields and carried to the valleys below can never be economically returned. But once erosion has been controlled, it is usually possible to restore fertility to the land and increase its productivity.

Steep slopes that have been deforested can certainly be replanted—and fast-growing species such as the ipil-ipil tree (*Leucaena leucocephala*) are likely to provide a greater return than the original tree cover. FAO now has considerable experience in helping to get community reforestation projects off the ground. In countries such as Nepal and Peru, where deforestation and erosion are almost equally severe, replanting is now proceeding apace.

Trees may also be the best crops in gullies and along stream-banks; though this land may formerly have been of arable quality, no amount of work will return it to crop land if erosion has been heavy. Furthermore, fuelwood is in such short supply that forestry is now a highly appropriate use for heavily eroded land.

Unfortunately, repairing gully erosion is rarely economic. It is usually better to spend limited funds on stopping old gullies from lengthening and preventing new ones from forming. Wherever possible, biological methods are preferable to physical ones—a bag of fertilizer, as one conservation engineer has put it, is worth more than a bag of cement. If vegetation can be established, it may slow down water speed sufficiently for some sediment to be deposited. As vegetation grows on the new deposit, the gully begins to fill up; eventually, it may disappear altogether.



Reforestation in the São João desert in the State of Rio Grande Do Sul, Brazil.

Check dams, such as this one being built in a gully in Kenya, can be used to trap sufficient sediment to give vegetation a chance to grow.

Temporary gully dams, made of brushwood or timber, are often needed to give vegetation an undisturbed start. In more severe cases, semi-permanent brick or concrete structures must be built, and occasionally large-scale dams and silt traps will be needed where the amount of water and silt carried is large and the risk is high.

Damaged pasture land can be repaired more easily. In many cases, resting the pasture for a year or two may be sufficient. Thereafter, grazing will have to be controlled or a ‘cut and carry’ system of fodder collection popularized; in Nepal, the buffalo is now commonly fed by this system, which is allowing new trees in mixed forestry/fodder plantations a chance to reach maturity.

However, damaged pasture can also be developed to a point where production is higher than it was before erosion set in. This requires an active rangeland development programme in which some areas are reseeded with forage plants that are hardier and more nutritious than those previously grown. If conditions are right, the new vegetation will spread spontaneously to other areas.

Crop land can be similarly restored. The important thing is to build soil fertility up to the point where vegetation flourishes again. After that, deep-rooted plants can be introduced to break up compacted soil and increase the rate of water infiltration. Finally, a cycle of fertility improvement can be started in which, for example, cover crops are ploughed back to increase humus content, crop rotation is re-introduced and a fallow period practised. FAO projects in Lesotho, Ethiopia, the Comoro Islands, Costa Rica and Saudi Arabia are helping to show how this can be done.

Comoro Islands: a natural recipe for repair

The archipelago of the Comoro Islands (four main islands and many small ones) covers 2236 km^2 between Africa and Madagascar.

Anjouan is the second largest island, with slopes of 60–130 percent covering half of it. More than 80 percent of the population depends on agriculture but plantations took over the good land early on, forcing most people to clear hill slopes and mountain tops, which are now severely degraded.

Traditional farming systems are still used: shifting cultivation using low inputs and basic tools, such as machetes and digging sticks. This was not a problem in the past but the current high birth rate and consequent pressure for land means that fallow periods are either non-existent, or the fallow plots are used as common grazing land.

Land tenure is very complicated (due to polygamy and matriarchal succession); cash crops, such as ylang ylang, vanilla, cloves, pepper and coconuts are suffering from marketing price structures; and there is an acute shortage of agricultural technicians.

In 1987, the intensive development site (SDI) was introduced to conserve soil as an integral part of sustained crop production and rational land use. Thanks to a series of FAO/UNDP projects, there are now 19 such model sites on the island. Each concentrates all activities in contiguous blocks of farmland of 50 ha or more, and involves an increasing number of participating farmers.

Perhaps the project's most successful innovation has been live-pole fencing, which involves planting fresh cuttings of fast-growing leguminous trees at 25–50-cm intervals along field boundaries. These fences unofficially mark individual plots of land, while also serving as animal barriers, shade, windbreaks, and sources of fodder and firewood. The enclosures also encourage more intensive development —in the form of vegetable gardening, for instance.

New annuals and perennials are being planted to break up the rice monoculture; stake-grazing is widely practised to manure plots before sowing; and many terracing, ridging, row planting and mixed cropping techniques are being tested.

As training and extension are critical bottlenecks in any conservation plan, it is essential to delegate as many techniques to the farmers as possible, instead of tying up technical and agricultural experts who could be carrying out more productive tasks. Lower-level field technicians have been taught simple technologies such as using the A-frame to mark contour lines.

Many farmers, apparently surprised by the yield increases of the past two seasons, are applying the same techniques to their other fields, to the interest of neighbours. Crop surpluses and the psychological security of tenure due to live fencing has allowed farmers to buy more land and cattle. Farmers' families appear to have varied and improved their diets through greater crop diversity and growing vegetables.

By convincing farmers that the SDI package is more economically advantageous than their traditional land-use practices, soil erosion on Anjouan has been controlled almost as a secondary—but nevertheless crucial—objective.

Photo: contour-ridging—the technique of making a physical barrier along a contour—aids water infiltration and ensures that organic matter is retained in the furrow to fertilize the next ridge.. Living-pole fences (background) are used to delineate plots.

CONSERVING AND REHABILITATING AFRICAN LANDS

Africa's major problem—how to feed its people—is not insurmountable But if African land, which is environmentally delicate and easily damaged, continues to be abused and degraded through practices forced upon farmers by increased populations and consequent land scarcity, problems of food scarcity and malnutrition are bound to worsen.

According to the 1986 FAO study *African agriculture: the next 25 years*, the continent could produce enough food, fibre and fuel to support a population far larger than the 500 million there now, but that this would require developing a continent-wide conservation strategy.

Sustainable agriculture—which maintains soil fertility and reduces erosion and other forms of land degradation while enhancing food production—is the key to restoring Africa's agricultural potential. In 1980, less than one-third of Africa's 840 million potentially cultivable hectares was being farmed. But 50–70 000 km^2 of productive land go out of production every year, primarily because of degradation caused by overgrazing and the clearing of trees and brushwood for fuel.

Traditional systems of using land—such as shifting cultivation and nomadic grazing—worked well for centuries, when good land was more abundant than those living from it. The amount of cultivated land available per person in rural areas fell from 0.71 ha in 1960 to 0.57 ha in 1980. Today, there is no longer enough land to allow long fallow periods, more animals compete for forage, and farmers have had to expand to marginal land, destroying forest and pasture in the process. With the population growing an average three percent a year, Africa will have to support 872 million people by the year 2000. This is impossible with old systems of land use and will require new farming systems to increase sustainable production.

Unfortunately, few African farmers have the time or the means to adapt to problems of land scarcity; degradation resulting from poor land management is proceeding faster in Africa than anywhere else.

- More than one-third of Africa suffers from desertification, caused mainly by animals stripping vegetation and breaking up the exposed soil with their hooves, as well as by intensive fuelwood collection. Although droughts do not help, land mismanagement causes the problem.
- Deforestation is occurring 30 times faster than

reforestation. An estimated 4 million ha of forest are being lost each year.

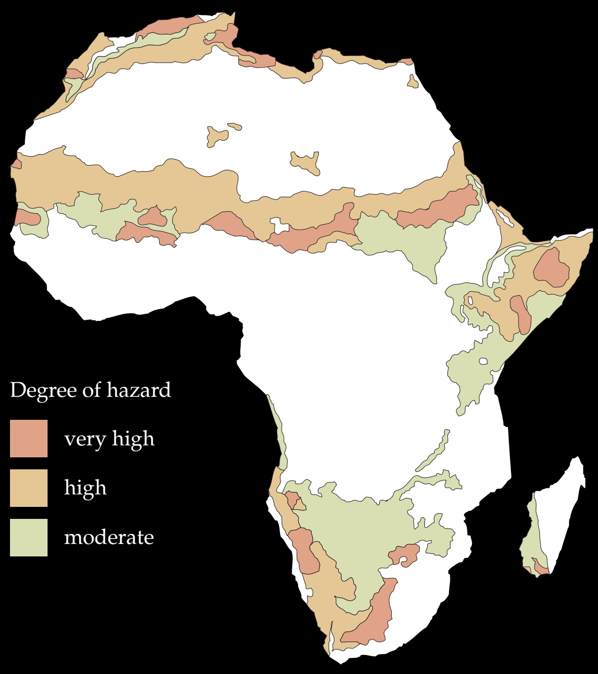
- With less vegetative cover, less rain infiltrates the soil, increasing run-off and flooding. This, in turn, encourages erosion and results in sediment-laden rivers and waterways, silted dams and damaged hydroelectric plants.
- More than 35 percent of the land north of the Equator is affected by either erosion or salinity.

It was the scale of land degradation in Africa that convinced FAO to mount a major effort, called the International Scheme for the Conservation and Rehabilitation of African Lands, to help African countries improve their soil and restore their productivity. The scheme mobilizes local, national and international resources, promotes sound land-use principles from the bottom (that is, the land user himself or herself) up, and increases yields and profits at the same time to encourage participation. Although physical conservation measures are still necessary, more emphasis is being placed on increasing and maintaining vegetative cover and introducing sound management principles to protect the land from wind and water erosion and increase soil fertility and organic matter content.

The scheme is catalysing national action on the part of government and non-government organizations to identify the causes of and suggest solutions to land degradation. It encourages governments to become facilitators, rather than agencies that implement specific conservation projects. At present, most African governments spend less than 10 percent of their total expenditure on agriculture, although it provides more than 50 percent of the GNP of many countries. Increased research and advanced training are needed if land degradation is to be overcome. Because African nations face severe financial constraints and generally lack the trained workers and inputs for programmes of the scale required, the scheme provides a bridge that enables African governments to work in partnership with technical assistance and financing agencies.

Most regions in Africa suffer from several forms of environmental degradation. Photo left shows severe gully erosion, now a common sight on African farmland . Map right shows the degree of desertification hazard that exists on the continent, and the types of hazard that are most common.

Desertification in Africa



LESSONS FROM THE PAST

Considering how much money, manpower and time have been spent on conservation over the past 50 years, it would seem that we still cannot consistently protect the soil. Despite the US government having spent an estimated $18 000 million since the 1930s—and currently spending about $1000 million a year—6000 million tonnes of topsoil are still being lost annually. The story is similar in Australia, and far, far worse in Africa, where governments do not have the billions of dollars to spend.

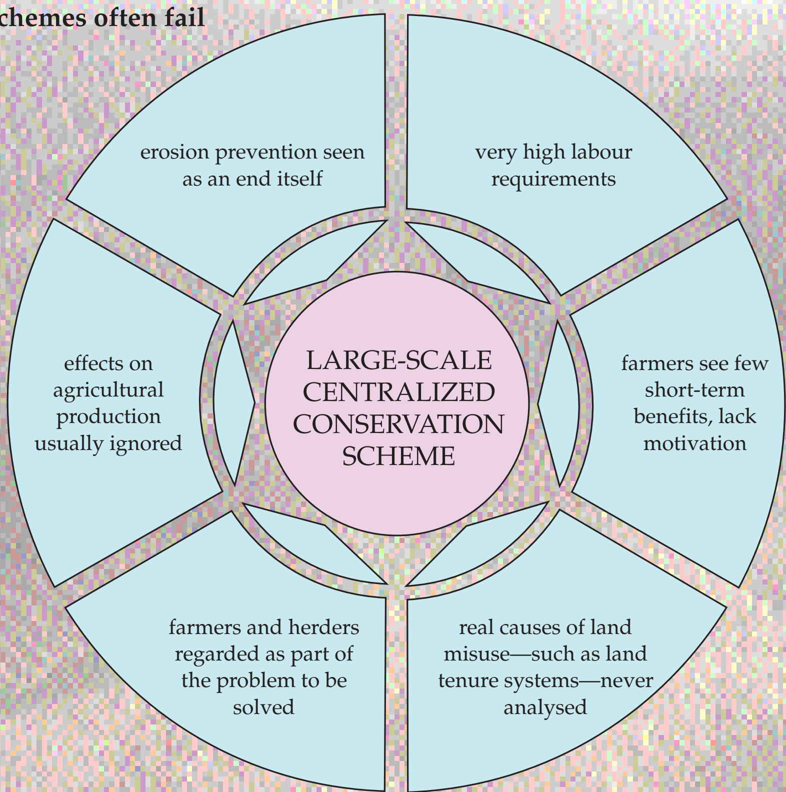
Although not all the programmes and projects have been unmitigated disasters, the success stories are rare enough to be notable. But why?

When traditional land-use systems began to break down under the strain of rapidly increasing populations, solutions tended to be directed at physically preventing or reducing soil loss, rather than seeing the problem as a consequence of poor land management and a lack of vegetative cover. The approach followed by most countries was modelled on one developed in the United States in the 1930s and consisted of three basic steps: identify the problem, plan control measures and implement the plan.

Erosion was usually only recognized after it had become serious enough for a bridge to be washed away, or a new dam to be filling with silt. By this time, much topsoil had already been lost and the land's productivity impaired. Plans for physical measures to slow down the rate of degradation were then drawn up; most of these patch-up schemes depended heavily on constructing bench terraces, contour banks, check dams and similar works. Thus, they addressed the symptoms*, not the cause,* of the problem. The real reasons behind land misuse were never analysed—keeping the soil in place was the only objective.

Farmers, pastoralists and others who lived from the land were rarely involved in the engineering plans—they were

Why conservation schemes often fail

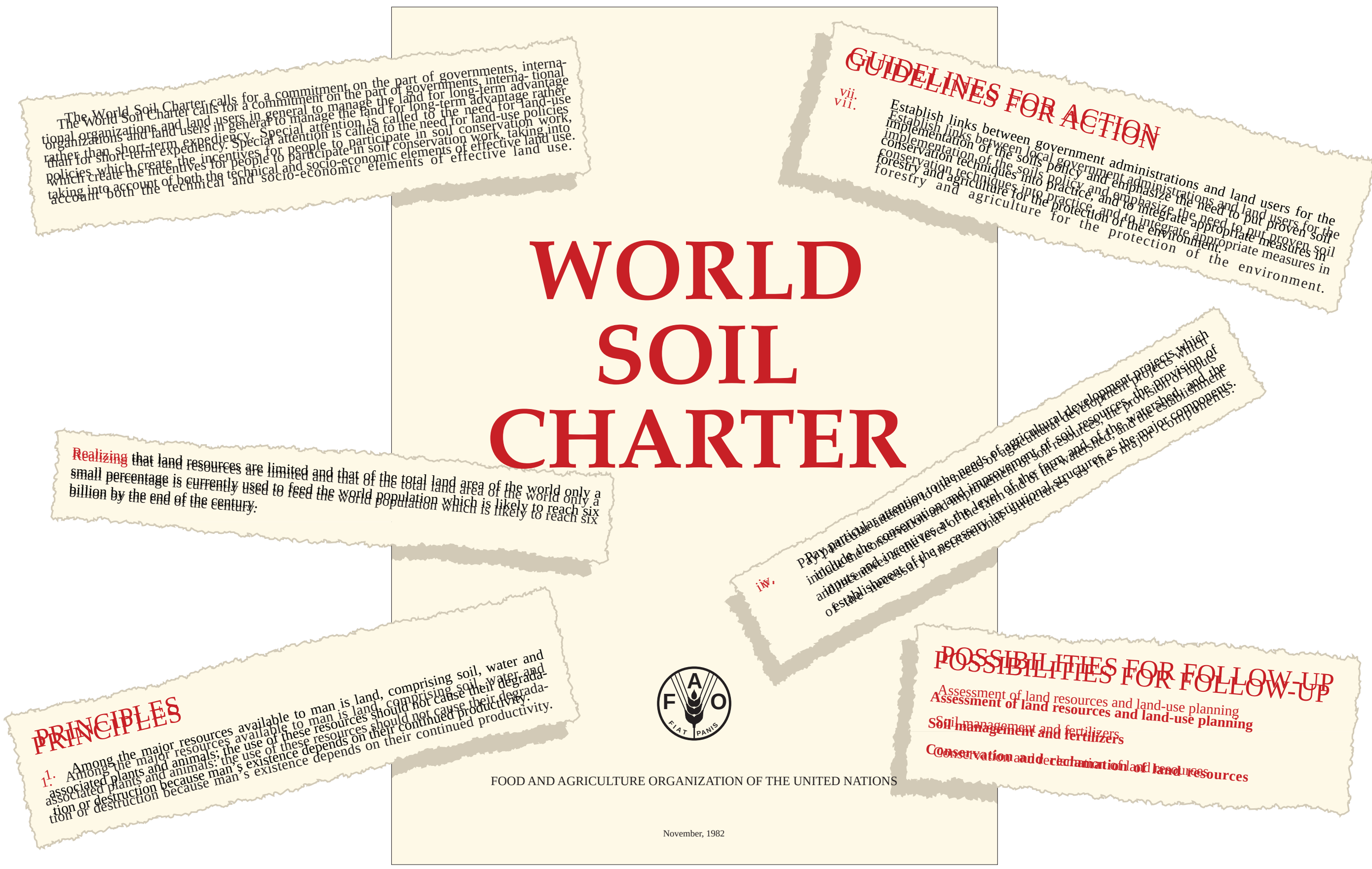


sometimes even regarded as part of the problem. Because of this lack of involvement, little interest was generated, and few were willing to maintain the work once the planners had left the area. They could not see the day-to-day effects of soil degradation, were probably unimpressed by scientists' statistics on the subject, and had little incentive in the way of immediate benefits to adhere to the rules. The harsh penalties imposed on some African farmers during the colonial period if they did not carry out the required work made conservation—unsurprisingly—extremely unpopular. In East Africa, conservation laws were taken up as a cause leading to the fight for independence: local politicians encouraged farmers to break them to oppose the colonial administration. This is hardly the desired effect of any soil conservation scheme.

It seems that the general approach to soil conservation has been faulty. Large-scale, top-down, government-run programmes have rarely been effective enough in the past to warrant their enormous cost, particularly in Africa. In addition, little has been done to develop long-term policies or sound strategies for soil conservation. Most countries simply rely upon short-term 'quick fixes' when the problems arise and when funds permit.

So what should be done? A first step was the adoption of FAO's World Soil Charter in 1981 (*see below*) which encouraged a long-term commitment to land resources.

FAO's World Soil Charter was adopted by the 21st Session of the FAO Conference in November 1981 and has been enthusiastically received by member-states. It establishes a set of principles for the optimum use of the world's land resources and calls for a commitment to manage land for long-term advantage rather than short-term expediency.



ACTION FOR THE FUTURE

If land degradation is to be stopped and the soil reclaimed, a new approach is clearly needed. FAO's 1990 blueprint for successful soil conservation is outlined in *The Conservation and Rehabilitation of African Lands*, an international scheme that grew out of the desperate need to improve Africa's agricultural potential. The scheme outlines the main steps required regionally, nationally and internationally, and is broad enough to serve as a model for conservation worldwide.

- The first step towards righting the effects of land degradation must be to identify and remove the factors responsible for poor land use. Just as cleaning up an oil spill would be a waste of time unless the oil source had first been cut off, there is no point in pouring money into conservation projects that only fix damage already done without first tackling its causes.

  Although farmers rarely deliberately degrade land—why would they damage their sole means of survival?—ignorance or economic, social or political pressure may force them to exploit it. The reasons behind such exploitation must be analysed and, if possible, removed. For example, in the case of land being abused beyond its population-carrying capacity, an extreme solution may be to relocate some of the farmers or to help them develop alternative sources of livelihood.
- New conservation schemes must recognize that the key to success lies in participation of the land users themselves. The millions of farmers, herders and foresters who live from the land are the ones who can make or break any programme. Properly motivated, these people have the ability to bring about desired change in land use and so should be directly involved from the start.

  Because most land users do not have the time nor the inclination to adopt new, and perhaps risky, practices to tackle problems that they probably cannot even see, the emphasis must be placed on measures that not only conserve the soil, but that also offer short-term, tangible benefits—such as increased yields or easier work—to farmers.

To achieve these two objectives, the scheme outlines a general framework of action that can be adapted and followed in any country. The burden of responsibility falls on national governments, which are the key to facilitating, promoting, encouraging, guiding and making possible more productive and sustainable forms of land use. With a strong national network, regional and international action will be easier to coordinate.

I. National

- *Improving land use*

  Every country should first inventory its land resources, combining all available data to form a 'picture' of the state of the nation's soil. Then specific problem areas can be targeted to identify the reasons behind poor land use.

  Once the causes have been identified, the way is open for government to make the necessary changes. Whatever changes are planned should be carefully thought through to determine their effects on land-use patterns and rates of degradation. Such action, depending on the reason behind land misuse, may include reforming agricultural strategies, for example by subsidizing certain crops; introducing new strains of crops and better technologies; encouraging the use of farm inputs to increase production; investing in a land tenure reform system to give farmers security of ownership; diversifying rural incomes by providing farmers with alternatives such as bee-keeping or furniture making; and, when all else fails, perhaps relocating land users to less degraded areas.

- *Encouraging participation*

  The critical role of land-user participation cannot be over-emphasized; without it, any soil conservation programme will fail. The ideal conservation project neither pays land users for their labour, nor invites them to join 'food for work' schemes; it helps them to plan and carry out their own solutions for their own benefit.

  Benefits must be immediately obvious if farmers are to abandon established practices that may be damaging the land. Farmers in Kenya, for example, have enthusiastically adopted a new terracing idea that substantially increases yields of maize and beans, while simultaneously controlling run-off and soil erosion.

  Cooperation can be further encouraged by helping land users set up their own associations, linked to district-level organizations; providing technical advice and training; and publicizing the dangers of soil loss using every possible medium and stressing the advantages

Lesotho: land users learn to help themselves

Photo: women workers in Lesotho build a low stone wall to check erosion.

Lesotho is a small, land-locked country with only about 400 000 ha of cultivable land that rises from 1500 to 3480 m. The land has long been subject to heavy erosion from violent rainstorms and the human-induced effects of overgrazing and fuelwood cutting. According to one estimate, the average soil depth has been reduced from 38.5 cm to about 28.5 cm—a loss of more than 25 percent. There are 20 000–30 000 gullies in the lowlands, some of them 20 m deep and 100 m wide.

Past soil conservation measures, such as contour banks, buffer strips and small dams, have not been enough to reverse the trend; land tenure difficulties and lack of farmer participation have been mainly to blame.

A 1987 government project supported by FAO with funding from The Netherlands, Support to Soil and Water Conservation in Southern Lesotho (SOWACO), has been combatting soil erosion problems in the severely degraded Mohale's Hoek district. Following the guidelines of FAO's International Scheme for the Conservation and Rehabilitation of African Lands, the project has shifted from classic erosion control towards combining conservation with increased production and land-user participation.

Having first convinced the farmers and villagers of the need for and benefits of soil conservation, the SOWACO approach makes them—through local community organizations—responsible for development programmes. Villagers are given incentives, such as fertilizers, tree seedlings and better seeds, for completing soil conservation measures that also increase production. Village meetings and field trips allow the locals to express their own concerns about resource management.

Follow-up visits from project extension officers, as well as village-awareness campaigns, gain the villagers' trust and help them understand the project objectives.

Conservation practices and improved land-use and cropping techniques are introduced through elected village conservation committee members (VCCs) and local technicians. VCCs are also an important link between the local farmers and their village development councils (VDCs).

Although frequent training sessions are needed to help VCCs develop their resources, improve production and reduce erosion, it is hoped that the villagers will gradually form coherent units that can overcome their own problems. This would reduce the requirement for extension staff, while providing strong examples of sustainable agriculture to surrounding villages.

of doing something about it. Reforestation programmes in countries such as Kenya, Cape Verde and the Philippines have been successful at least partly because their presidents personally supported the cause, planting trees at demonstrations and advocating conservation.

- *Developing national institutions*
  Each country needs to develop policies and strategies tailored to its own situation. National government institutions must be strong enough to provide the back-up needed by land users to plan and implement their own local programmes.

  Most countries need a high-level advisory commission to develop, monitor and coordinate government departments, NGOs and regional associations. It is also important to establish one clearly defined government ministry, department or unit with overall responsibility and authority for conservation. Existing, often fragmented, legislation should be reviewed for applicability and then consolidated with new laws to create an effective and integrated package.

  Training and research in conservation techniques are also essential for successful future programmes at a national, district and local level.

II. Regional

Regional and subregional programmes are the best way of handling most aspects of training and research that would otherwise be beyond the resources of most developing countries.

Several well-established regional organizations in Africa, such as the Inter-state Committee for Drought Control in the Sahel (CILSS) and the Southern African Development Coordination Committee (SADCC), have allowed nations to benefit from the experience of others by pooling valuable (and costly) research among countries facing similar problems. Far more research is still needed in all aspects of land degradation and soil conservation.

Training is also more effective at regional and subregional levels because it is immediately relevant to the area. Most advanced conservation training is obtained in Europe or North America, which is expensive, limited and largely irrelevant for most of the countries concerned. On-the-spot courses, such as the M Sc degree in soil and water conservation offered by the University of Nairobi, need to be copied and expanded.

III. International

The most important function of international coordination is assuring long-term technical assistance and financing. Close cooperation between organizations such as FAO, the World Bank and the International Fund for Agricultural Development (IFAD) is needed to achieve this.

National governments have an important role to play in committing themselves to long-term soil conservation policies and programmes before meeting potential donors, NGOs and technical assistance agencies to discuss the plans and arrange funding.

This type of coordination is usually successful because both governments and assistance agencies are aware of the requirements from the start. Technical assistance and funding organizations are more inclined to help if they have some input and control over how their contributions will be used.

Conclusions

Soil erosion now affects the lives of many million people and is hampering the development plans of scores of countries. Controlling erosion is a high priority in many areas of the world. Fortunately, both the problem and its solution are now understood, and the means are available to overcome erosion in ways that will both ‘protect and produce’.

In the last analysis, soil conservation must not be regarded as an independent entity, to be pursued regardless of all other factors. Worldwide, there is a startling correlation between poverty and soil erosion. While poverty is often a cause of soil erosion, the poor are not to blame: their problems are too pressing to allow them to take a longer-term view.

It follows that rural development can often lead to improved soil conservation. In many projects, it is essential to try to raise the living standards of the rural population before expecting them to practise soil conservation.

But soil is a country’s most precious resource. If the soil is not well cared for, a country can never develop a sound agricultural base. And without that, national development plans rarely succeed. Soil conservation effectively increases today’s agricultural yields while insuring the well-being of future generations.

For technical advice on soil conservation problems and programmes, write to:

Land and Water Development Division

Agriculture Department

Food and Agriculture Organization

Via delle Terme di Caracalla

00100 Rome

Italy

This publication is also available in French and Spanish.

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‘If the soil on which all agriculture and all human life depends is wasted away then the battle to free mankind from want cannot be won.’

Lord John Boyd Orr, first Director-General of FAO, 1948