Intern. J. Environmental Studies
1978, Vol. 12, pp. 189–197

LOSS OF PRODUCTIVE SOIL

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(Received November 4, 1977)

INTRODUCTION

Soil is an important component of the biosphere, and is an absolutely essential component for agricultural production. It is axiomatic that the agricultural self-sufficiency of any country is dependent on availability of good soil and its continuing proper management. Unfortunately this simple fact is often overlooked, resulting in serious socio-economic consequences. Productive soil is being continually lost in both developed and developing countries for a variety of reasons, and the general global trend seems to be continuing increase in the total loss.

The population[1] of the world is increasing at a rapid rate, and the projections by the United Nations and other organizations clearly indicate that global population is unlikely to stabilize well before the middle of the twenty-first century. The medium variant population projection of the United Nations, and the approximate time when population of different regions are expected to stabilize is shown in Figure 1.

Currently in a world of some 4 billion people, we cannot even satisfy the basic human needs of every individual. Presently millions of people do not have shelter, adequate nutrition, basic health care, access to potable water, or have elementary education and gainful employment. Barring unforeseen catastrophe, it now seems inevitable that at least another 2 billion beings may be added to the global population by the year 2000. If mankind is not in a position to satisfy the basic human needs of 4 billion people today, the task to satisfy such needs for a total of 6 billion people by the year 2000 slightly more than two decades from today, is going to be a major challenge by whatsoever criteria considered. The Food and Agriculture Organization of the United Nations (FAO) has estimated that some 484 million people suffer from malnutrition at present. Other estimates differ from that of FAO, ranging from a total of 1 billion people to the accusation that FAO overestimates the number of people suffering malnutrition due to political and institutional reasons. Whatever the present number of people suffering malnutrition may be, every one will agree that the figure is serious and unacceptable. Such a concern is only for protein-calorie malnutrition—it does not consider other forms of nutritional imbalances. In terms of overall nutrition, the global scenario is likely to be much worse. Thus, it is essential that more food should be available to a significant portion of mankind, both in terms of quantity and quality, to obliterate the present imbalances.

SOIL LOSS

The future global situation, and the human prospect, does not look very encouraging at present. It does not mean, however, that all is lost and doomsday is inevitable, and the only real option left for mankind is to "eat, drink and be merry," at least for those of us in both the developed and developing countries, who can afford that luxury! On the contrary, it can be shown that given adequate resources and good will on the part of all the countries, combined with strong determination and political commitment to solve the problems, they can be solved. There are enough resources in the world to correct the imbalances, but whether there is enough political determination and institutional infrastructure to carry out desirable policies at present is another question.

Soil is an essential component for food production, and every school boy knows this elementary fact. Thus, if the global food situation has to be improved, it means better management of our soil resources, without which much hoped for socio-

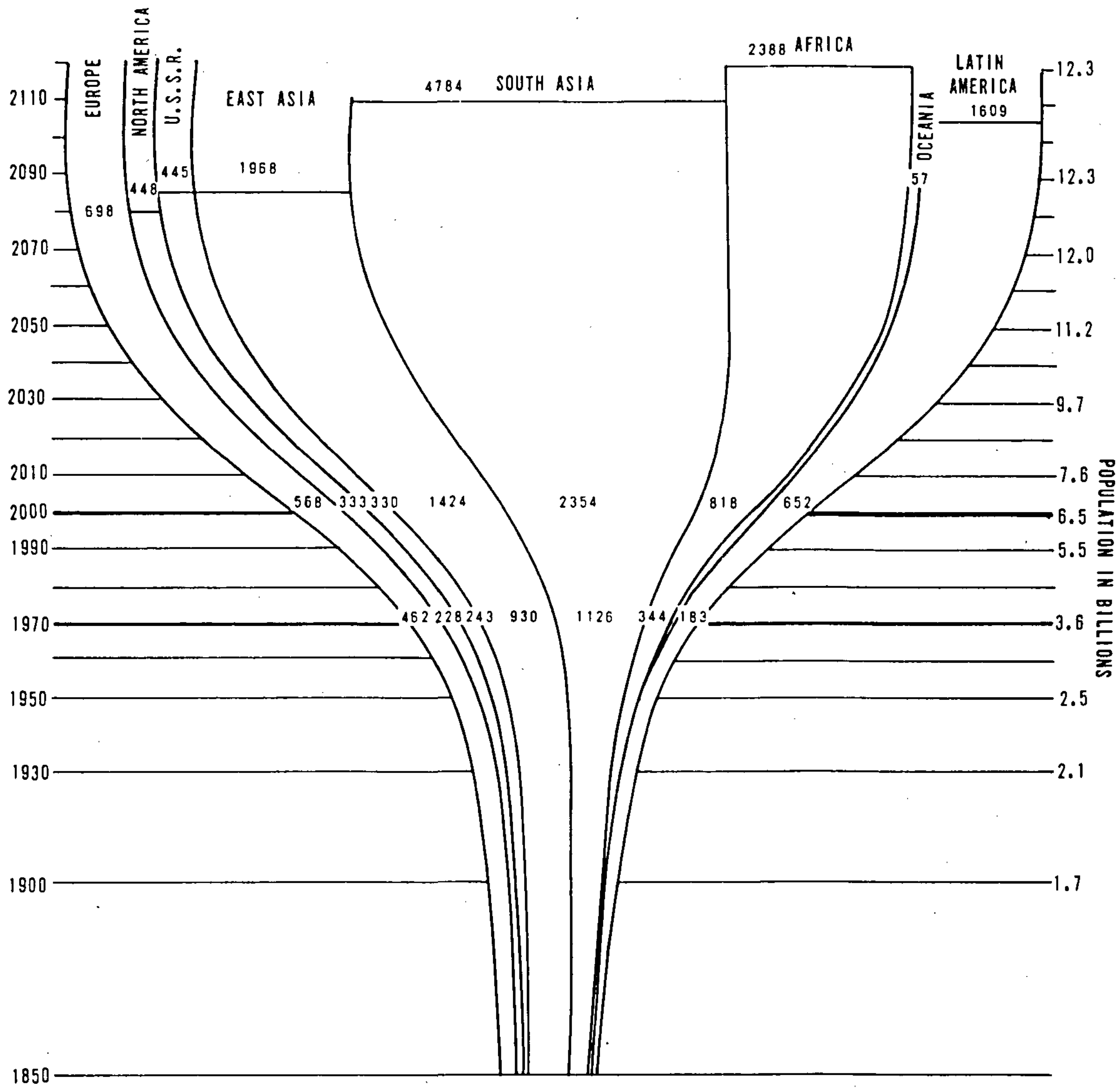


FIGURE 1 The diagram shows eight major world areas along with their populations and indicates the year when the population in each case will cease growing: around 2120 for Africa with 2338 million and 2070 for Europe with 698 million.

economic development of the developing countries under the framework of the New International Economic Order (NIEO) will never take place. Agricultural self-reliance—to the extent it is possible for each country, depending on its available physical characteristics—is the basic prerequisite to socio-economic development. As many countries have painfully learnt during the last two to three decades, emphasis on industrial development at the cost of the agricultural improvement is likely to be counterproductive and certainly is not the road to development. Thus, it is to the self-interest of each country that basic resources necessary for agricultural production—soil, water, energy and seeds—be carefully managed. Development of rational management policies is important for all the resources mentioned, but it is especially important for soil. Water is a renewable resource that can be replenished by rainfall or can be transported over long distances by gravity and/or pumping systems at certain economic cost. Energy and seeds can be made available to one area from other regions. Such options, however, are not available for soil. Transportation of soil on a massive scale for basic food production is neither an economic nor a practical proposition. It may, however, be possible for luxury crops or for greenhouse production. Hence, one can logically argue that management of productive soil requires special attention.

MAGNITUDE OF THE PROBLEM

Loss of productive soil is one of the most pressing and difficult problems facing the future of mankind. The problem is not new, but increase in population and attendant requirements to increase food production have given it an urgency that it lacked before. A historic example is North Africa, which was the fertile granary of the Roman Empire, but is currently a desert or semi-desert which has to import much of its food for basic survival. According to Kovda,[2] the total area of destroyed and degraded soil that was biologically productive at one time is estimated at 2 billion hectares, a figure that is 33 percent higher than the entire arable area cultivated for agricultural purposes at present, estimated at 1.5 billion hectares. The dust bowl experience of the 1930s in the United States was followed by similar examples in the Soviet Union and South Africa. Nearly 80 percent of land in Malagasy Republic is affected by severe erosion. To this must be added world-wide changes in soil property induced by 5000 million tons of minerals, 32,000 million m^3 of industrial waste water, 250 million tons of dust, 70 million tons of toxic gaseous substances, and grazing and excrements of some 3000 million head of cattle per year. All these contaminants naturally affect soil fertility.[2] Loss of productive soil should be viewed both in terms of quantity and quality. Quantitatively soil could be lost physically from the agricultural or other land by erosion due to water or wind. In other words, soil is transported from where it is required to another place where it is not necessary, and often contributing to environmental problems. Qualitatively soil can be considered to be lost when its fertility declines due to bad management practices. In between is urbanization, where soil is simply taken out of the agricultural production system. While urbanization is physically reversible, it is mostly irreversible due to economic reasons.
There are many reasons for soil loss. These could be the following:[3]

- Erosion by water and wind;
- Impoverishment of the soil, resulting in a disastrous change in its properties unaccompanied by any effort, or at best by inadequate efforts, on the part of man to maintain its level of fertility;
- Silting of soils with drifts carried by water or wind from the places of erosion activity, resulting in a loss of productive lands;
- Waterlogging and flooding, resulting in a hazardous change in the water régime;
- Salinization and alkalinization of soils, resulting from both natural and man-induced processes, including primary and secondary salinization and alkalinizations;
- Chemical pollution and accumulation of toxic elements and compounds;
- Soil loss due to widespread mining operations;
- Soil loss due to building, transport, communications;
- Soil loss and degradation due to waste disposal, both domestic and industrial;
- Soil degradation due to unbalanced and uncontrolled use of fertilizers, herbicides, pesticides and detergents;
- Soil acidification as a man-induced or natural process connected with sulphur accumulation;
- Irreversible hazardous change of the physical features of the soil because of its imporper utilization in relation to its natural potentialities.

FAO has classified different forms of soil degradation into three categories, depending on their seriousness, as shown in Table I.[3]

Soil may be considered as a renewable resource, but time necessary for its formation is much too long to compensate for the losses currently taking place for a variety of mismanagement practices. Once soil has been destroyed by natural phenomena or due to human actions, it may take as long as 7000 years to reform and to provide an adequate depth of topsoil to sustain the agricultural activities of man. Present estimates indicate that under natural conditions, soil may form at a rate of one cm every 125 to 400 years. The formation process accelerates considerably under

TABLE I
Forms of soil degradation

Category	Form of degradation
I	Building, transport and communications Erosion and silting of soils with drifts Salinization and alkalinization Organic wastes Infectious diseases and wastes
II	Solid waste and sewage Inorganic industrial waste products Mine refuse Radioactivity Heavy metals
III	Excessive fertilizers Pesticides and herbicides Detergents

normal agricultural practices, when it takes approximately 40 years to form one cm of soil. Even under the most ideal soil management conditions, soil may form at a rate of one cm in about 12 years. Soil formation is thus a lengthy process and thus it is to man's best interest to preserve it as best as possible. Under normal agricultural conditions approximately 3.75 tons of topsoil is formed per hectare per year. In contrast, current average annual loss of topsoil in the United States from agricultural land is estimated to be 30 tons per hectare. In other words, agricultural topsoil is being lost in the United States 8 times faster than soil formation.[4]

The mangitude of the loss of productive soil can be best illustrated by considering a specific country, and then analysing losses due to different causes. The country selected in this case is the United States, primarily because good data on soil loss are available. The situation in other countries is somewhat similar, but the magnitude may vary depending on local conditions.

During the last 200 years, at least 30 percent of the topsoil on the U.S. agricultural land has been lost. The Department of Agriculture estimated in 1935 that nearly 100 million acres of land had been ruined by soil erosion for agricultural purposes, and 50 to 100 percent of topsoil had been lost in another 100 million acres. Thus, by 1935, some 200 million acres of land were either ruined or seriously affected due to soil erosion. The U.S. Soil Conservation Service estimates that more than 3.2 billion metric tons of soil is lost each year through erosion from approximately two-thirds of the U.S. land which is privately owned.[5] The Service further estimates that soil loss from cropland adequately treated against erosion averages less than 11 metric tons/ha/year, from pastureland less than 4.5 metric tons/ha/year, from rangeland about 33 metric tons/ha/year and from forest land about 1.1 metric tons/ha/year.[5]

The dominant form of soil loss in the United States is due to runoff which carries away fine sediments. Nearly 4 billion tons of sediments are carried every year to the streams in the 48 contiguous states, 3 billion tons of which come from agricultural lands. One-quarter of the water-borne sediments eventually end up in the oceans, and the rest remain in lakes, reservoirs and watercrosses, creating environmental problems. The economic cost of such siltation to the country is quite significant. Some 450 million cubic yards of sediment are dredged every year from water bodies at a cost of about $250 million. Sediments also continually reduce the economic life of man-made lakes which costs the nation a further $50 million per year.[6] These, plus other damages, are estimated at approximately $500 million every year. The total cost obviously is much higher, since the damages estimated do not include the cost of agricultural products that might have been raised had the soil degradation not taken place. Such damages run to about two percent of the total economic value of agricultural products raised every year.

Wind erosion is not as severe as water erosion, but it is still quite significant. Wind erosion is responsible for 850 million tons of soil loss per year in the Western United States alone. A very conservative estimate of wind erosion is 1 billion tons every year. Thus, nearly 5 billion tons of soil is lost per year due to combined effects of water and wind. This is equivalent to about 7 inches of soil loss from about 5 million acres of land surface.

In addition to erosion, the United States loses more than 2.5 million acres of arable land every year to urbanization, highways and other special uses. Thus, between 1945 and 1970, the country lost 45 million acres of land, equivalent to the size of the state of Nebraska.

So far some 40 million acres of land have been lost to urbanization, nearly half of which used to be cropland, and another 32 million acres have been lost to roads and highways. In addition, strip mining directly disturbs 153,000 acres of land every year, and affects at least three to five times the exploited area due to acid drainage and accelerated erosion.[6]

Studies carried out in Kenya during the period 1948 to 1965, show great variations in erosion and sedimentation in different parts of the country. Highest rates of soil erosion occurred in an area of very steep slopes on the eastern sides of Mount Kenya, where land is cultivated on the steep valley slopes of the upper part of the basin, and cultivation and grazing being the dominant form of land use along the gentler but drier hillslopes of the lower parts. Thus, the annual rate of soil loss in the catchment area of the Tana River varied from 1550 tonnes/sq. km, between Kindaruma and Grandfalls (agriculture/grazing), to about 320 tonnes/sq. km above Kamburu Dam (agriculture/forestry).[7] In contrast, soil erosion in undisturbed forest, in areas of steep slopes, is extremely low. For example, in the Sagana Drainage Basin, the annual rate of soil loss is approximately 4 tonnes per sq. km. Soil loss tends to increase under agricultural conditions and is much greater in pastoral semi-arid parts of the country.

Currently 46 percent of the total degradation of the earth's surface due to different hazards can be directly related to water. These hazards can be roughly estimated as follows: water erosion, 22 percent; waterlogging and flood damage, 8 percent; salinity and alkalinity, 5 percent, and frost, 11 percent.[8]

Loss of agricultural land to urbanization is a common but serious problem in all developed and developing countries. Table II shows the annual loss of cultivated land, not including pastures and meadows, to other uses in Japan during the period 1968 to 1973.[9]

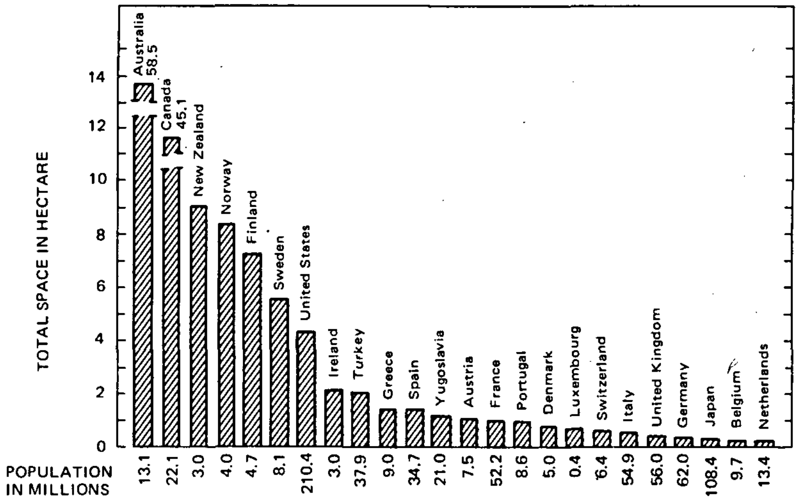
The situation is not much different in a developing country like Egypt, which has continued to lose some of its better agricultural land to urban development. The magnitude of the problem can be best realized by considering the fact that total irrigated land has virtually remained the same in Egypt during the last two decades, inspite of the thousands of hectares of new irrigated land developed due to the building of the Aswan Dam. In other words, Egypt has continued to lose good arable land to urbanization as fast as she has brought new land under irrigation, at tremendous investment costs. Closer analysis of these facts indicates that the situation is far worse than normally realized. Overall better quality agricultural land has been lost to urbanization than those brought under cultivation. Moreover, the agricultural land lost was closer to centres of population, and thus the energy cost of transportation of products to the market and the necessity of developing sophisticated storage systems was minimum. Since the new land is not so conveniently located, more energy has to be expended to transport, store and distribute the products, thus imposing additional costs to the economy.

In a world where the land available per inhabitant is already at a premium, and is being constantly reduced due to increases in population, man can ill-afford to lose good soil due to short-sighted management practices. Figure 2 shows both total space available and cultivated land area per inhabitant for 1973 for 24 selected countries. Such statistics will continue to be progressively reduced for most countries of the world, at least for the rest of the present century.

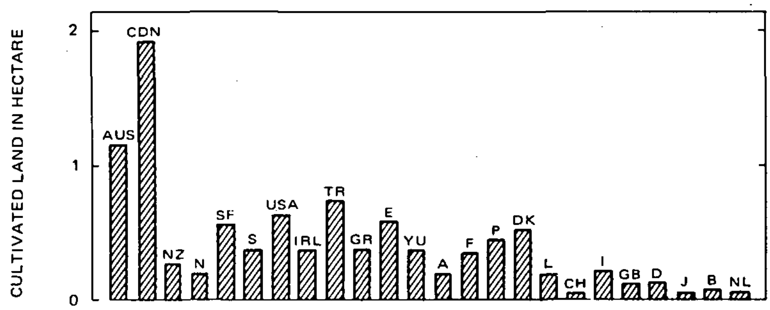
There are other reasons that could contribute to soil loss. Waterlogging, salinization, and alkalinization have been discussed in the previous section, and soil degradation due to improper technology transfer is described in the next section. Overgrazing can create serious problems. For example, in the Patagonia region of Latin America (78 million hectares in Argentina and 24 million hectares in Chile), a vast semi-desert area, sheep were introduced at the beginning of this century. The sheep thrived, and by 1912, their number was

TABLE II
Loss of cultivated land in hectares in Japan

Year	Housing and urban services	Industry and mines	Communication systems	Forests, parks, etc.	Total
1968	23,888	4,502	7,297	5,133	40,820
1969	31,876	7,595	7,067	6,806	53,343
1970	32,228	8,739	7,720	8,447	51,134
1971	29,543	6,958	8,068	15,898	60,468
1972	31,585	6,743	8,780	16,652	63,760
1973	35,941	9,197	9,012	12,625	66,765
1974	23,096	5,385	7,197	9,140	44,818



TOTAL SPACE AVAILABLE PER INHABITANT IN 1973



CULTIVATED LAND AREA PER INHABITANT
(The order of countries is the same as in above graph)

well over 25 million. Sheep are highly selective in their grazing habits, and they started to eat up the best pastures. It gradually reduced the fodder production, which in turn, reduced the sheep population to below 20 million during the last decade. Overgrazing also led to a serious problem of wind erosion, which was further accentuated by the strong wind characteristics of the region.[9,10] Similar problems due to overgrazing have been observed amongst other places in the Sahelian countries and Rajasthan in India. Overgrazing is one of the main reasons for the deterioration of the plant cover and desertification in Iraq and Syria. Although the natural rangelands in the north of Iraq are able to support 250,000 head of sheep in actual fact they contain around one million head. Similarily, the arid and semi-arid natural rangeland zones in Syria contain three times the amount of livestock that they can support.[11]

In many developing countries, an expanding population requires more food, and has increased pressure to expand the cultivated area. This pressure, coupled with political expediency and lack of expertise, has resulted in more and more utilization of marginal land, for which either technology is not available for farming on a sustained basis, or, if available, has been disregarded for socio-economic reasons. Thus, the expansion of agriculture on steep hillsides has led to serious erosion in Indonesia and Kenya; increasing pressure of slash-and-burn agriculture is destroying tropical forests in the Philippines; deforestation in the Himalayas is contributing to the increase in the frequency and severity of flooding in India, Bangladesh and Pakistan; deforestation to build Transamazonica is accelerating soil erosion in Brazil, and overgrazing and deforestation is contributing to the southward march of the Sahara. These are prime examples of developments that contribute short-term benefits but have long-term costs in terms of soil deterioration, which would eventually negate the increased food production.

Finally, it is important to discuss cost aspects of soil deterioration. According to U.N. estimates the degradation of range land, non-irrigated farmland, the areas destroyed by waterlogging and salinization has held their worldwide annual production of food and animal produce $16 billion below their potential. Current estimates of soil erosion data from the United States indicate that more than 50 million tons of plant nutrients are lost each year, and the cost of replacing the nitrogen, phosphorous and one-fourth of the potassium ranges from $6.8 to $7.75 billion. Water and wind erosion further contribute to two percent of annual loss in crop productivity. Currently, soil loss costs most farmers $50 per acre—a figure higher than losses from weeds estimated at $40 per acre. Such costs should be compared with the conservation treatment of irrigated land estimated at $3.10 per acre per year. In the short-term, the net farm income will undoubtedly be higher if no soil loss measures are undertaken. Thus, a simulation model of a typical Iowa farm indicates that the maximum net farm revenue obtainable was $4278 when average annual soil loss was restricted to six tons per acre, but it increased to $4573 when soil loss per acre was increased to 22 tons. The fallacy of such short-term income maximization is that in the long run, the farmer may have no income at all!

Since it is estimated that between 50,000 and 70,000 sq. km of useful land are going out of production every year,[12] soil management and conservation must be a priority for mankind. Accordingly, the United Nations Conference on Desertification, held in Nairobi in 1977, adopted a Plan of Action that states the principles that guide proper land use and outlines the measures that conform to good practice.

Soil degradation is also caused by improper technology transfer processes. The agricultural history of the present century is replete with examples in which straight transfer of technology from developed to developing countries, or from one region to another, has created additional problems. Thus, methods of irrigation that may be successful in humid regions where drainage is efficient are not suitable for arid environment, having less efficient drainage characteristics. Inadequate drainage contributes to the acceleration of the rise of the water table. Similarly attempts to use temperate zone technology to develop agricultural potential of tropics and the semi-tropics have not always been successful, and have often contributed to soil degradation. A few select examples are the deep-plowing of the rice paddies in Java by the Dutch, corresponding operations by the British in Burma, failure of the ground-nut scheme in Tanzania and broiler production in Gambia.[9]

SOCIAL AND ECONOMIC IMPLICATIONS

Social and economic implications of soil degradation are many, and only the important aspects will be discussed herein.

Quality and management of soil of any country has ramifications that extend to virtually every sphere of economic activity, irrespective of that country's stage of development. The main economic impacts can be traced by availability of food and employment. In this respect, countries could be very broadly classified into three categories—those that are net exporters of food, basically in equilibrium and that are net importers of food. Majority of the countries are now in the third category.

For the first category of countries, United States, Canada and Australia, food export plays a dominant part in their export trade, and thus balance of payment problems. Even in these countries, as demonstrated earlier, soil degradation is a serious problem. Thus, as mentioned earlier, in the United States, more than 2.5 million acres of arable cropland are being lost every year to urban development and other special uses. This loss is partially offset since another 1.25 million acres of land is converted to cropland every year by new irrigation development and drainage improvement, resulting in an annual net loss of 1.25 million acres. The different forms of soil degradation have had little economic impacts so far on the United States. This is because the reserves of agricultural land are considerable, and crop yields have increased at a much faster rate than the land losses if the trend continues for the rest of this century, there is no room for complacency. Once soil degradation takes place, it is an expensive and time-consuming process to rectify the situation. Thus, it is simpler and more economical to take appropriate soil conservation measures to reduce soil losses.

Current studies in the United States indicate that reduction in topsoil reduces crop yields. Such reductions in corn yields is shown in Table III.[6]

TABLE III
Relation between corn yield and topsoil depth

	Corn yield (bushels/acre)		
Topsoil depth (inches)	Range	Average	Decrease in yield from 12″ topsoil depth
0–2	25–56	36.2	38.1
2–4	28–69	47.0	27.3
4–6	39–83	56.3	18.0
6–8	49–97	64.7	9.6
8–10	50–102	69.0	5.3
10–12	50–125	74.3	

Generally speaking, during the past decades land lost by the agricultural sector of most countries did not result in the overall reduction of production, but has rather led to a lack in growth. In the future, however, the situation might well change. While there is no doubt that productivity per hectare can still be further increased, it should be realized that much of the increased production was made possible by continually increasing energy input. Such developments no doubt made economic sense in the past era of cheap energy, but they may not do so at present, when energy prices are high. In addition further increase may be expected in the future, at least for the rest of this century. Furthermore environmental constraints could well restrict the alternatives availability to the farmers to intensify production. Hence, it makes far more sense to preserve soil by implementing good management practices than to let soil deteriorate and then undertake expensive measures to boost yield.

The situation with regard to soil loss in countries that are basically in equilibrium or net importers of food are not much different than above. However, the urgency of taking measures to prevent soil loss is much greater in such countries. Also, the classification of countries into net exporters or importers or in equilibrium is often a matter of time. Thus, a country like Mexico, which was a net exporter of food before the Second World War, became an equilibrium country soon after and now is a net importer of food. Such transition takes place for many reasons, two of which are population increase and soil deterioration, which more than offset any gains due to increase in yield. The global average of cultivated area available, per person, in 1970, amounted to 0.37 hectares, ranging from a high of one hectare in Australia and New Zealand to a low of 0.23 hectares in India. With an increasing global population, mankind cannot afford to continue to lose productive soil, and thus decrease amount of land available to sustain each individual.

For developing countries that are net importers of food, soil loss is a basic problem that should receive priority attention. As mentioned earlier agricultural self-reliance is a prerequisite to their socio-economic development, and they cannot continue to spend their meagre foreign currency reserves on continuing food imports. In addition, agriculture is a way of life for nearly 70 percent of the people in Africa and Asia. Thus, if the lot of average farmer has to be improved, soil management and other forms of agricultural development should receive emphasis in national planning. Furthermore, unemployment and under-employment are continuing to be critical problems in developing countries. According to the International Labour Organization, one billion new jobs must be created in the developing countries by the year 2000, only 22 years from today. Such an objective will never be achieved unless agricultural sector is made more productive, and thus providing some of the investment capital necessary for further development.

Finally, it is important to discuss the benefit-cost aspects of soil deterioration. Current estimates of soil erosion data from the United States indicate that more than 50 million tons of plant nutrients are lost each year, and the cost of replacing the nitrogen, phosphorous and one-fourth of the potassium ranges from \$6.8 to \$7.75 billion. Water and wind erosion further contribute to two percent of annual loss in crop productivity. Currently, soil loss costs most farmers \$50 per acre—a figure higher than losses from weeds estimated at \$40 per acre. Such costs should be compared with the conservation treatment of irrigated land estimated at \$3.10 per acre per year. In the short-term, the net farm income will undoubtedly be higher if no soil loss measures are undertaken. Thus, a simulation model of a typical Iowa farm indicates that the maximum net farm revenue obtainable was $4278 when average annual soil loss was restricted to six tons per acre, but it increased to $4573 when soil loss per acre was increased to 22 tons.[6] The fallacy of such short-term income maximization is that in the long run, the farmer may have no income at all!

CONCLUSION

An attempt has been made in this paper to indicate the nature of the problem of soil loss, the magnitude of the problem and its socio-economic implications to both developed and developing countries. The higher the crop yields desired and the better the agricultural techniques used, the more complete and profound knowledge of soils is required, and the better must be the supervision exercised over the condition of, and changes in, soil resources. Thus, soil management and conservation must be a priority subject for mankind.

ACKNOWLEDGEMENT

The initial version of this paper was prepared for the first meeting of the Steering Committee of the International Federation of Institutes of Asvanced Studies (IFIAS), for the project "Save our Soils," of which one of the authors is a member. Permission of IFIAS to publish this paper is gratefully acknowledged.

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