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Soil Degradation:

A Threat to Food Security?

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International Soil Reference and Information Centre

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1 INTRODUCTION

The soil is a very complex medium which displays a great diversity in physical appearance, in chemical processes, and in the flora and fauna present (bio-diversity).

The role of the soil is of vital importance to mankind and the maintenance of a healthy natural environment. The soil is a natural resource, which is not renewable in the short term and very expensive either to reclaim or to improve once it is eroded by water or wind, physically degraded or chemically depleted. It is our common duty to maintain this precious resource for the future, while at the same time to obtain the best benefit from its use now (Stoops and Cheverry, 1992).

One of the most intensively debated issues in projections on directions that agricultural policies should take over the next 25 years is the extent of land degradation and its effect on food production. While many argue that land degradation is a potential threat to global food production ("Arguments about the severity of global land and soil degradation, and the crises which humans are facing as a result of the shrinking productive natural resource base are convincing", Hurni, 1996) there are others who indicate that land degradation is over-estimated and relatively unimportant to global food production (Crosson, 1994).

There is a wealth of scientific literature, workshop proceedings and policy statements (e.g. Serageldin, 1995; Pinstrup-Andersen, 1995; Saouma, 1994) that link rapidly increasing world population, stagnant aggregate cereal output and the extent of soil degradation worldwide. These are central themes on the international and national agendas of policy-makers, decision makers and agricultural research organizations.

The International Food Policy Research Institute (IFPRI) initiated in 1994 an initiative for "A 2020 Vision for Food, Agriculture and the Environment". This initiative aimed to develop a shared vision and a consensus for action on how to meet future world food needs while reducing poverty and protecting the environment. It grew out of a concern that the international community is setting priorities for addressing these problems based on incomplete information (IFPRI, 1995).

Each year global population increases by some 80 million people. The world population is estimated to rise to a total of 8.2 billion people by the year 2020. Cereal deficits in developing countries are projected to increase from 78 million metric tons in 1988 to 244 million tons in 2020 even under the most optimistic scenario, that food production will continue to grow at the same pace as it has since 1988 to the present, and that current levels of investment in agriculture by governments will be maintained (IFPRI, 1994).

In the past the demand for more food by increasing population was partly satisfied by opening up new land for agriculture and partly by intensified management of the land to obtain higher yields per unit land. Although world cereal production almost doubled between 1966 and 1990, the growth in aggregate cereal output started to decline after 1982, mainly as a result of a decline in quality and performance of irrigation systems, an inefficient use of fertilizers, a negative nutrient balance in most non-irrigated drylands in developing countries, increased losses from pests and diseases, and a deterioration of commodity prices, leading to reduced incentives to invest.

In much of Africa and also in most non-irrigated drylands in Asia and Latin America the "mining" of soil nutrients, often induced by poor socio-economic conditions, are pushing average yields into decline (Paarlberg, 1994). In response, farmers are trying to produce more food by extending their traditional low-input practices into forest land, or onto drier and more fragile pasture lands, or by shortening fallow-periods. As a consequence, fertile topsoil is washed away by the erosive forces of water, or blown away by wind. This so-called first generation of environmental problems leads not only to a negative nutrient balance, but also causes habitat destruction and loss of bio-diversity. Alternatively, it may also lead to positive off-site effects in e.g. valleys.

In OECD countries agricultural policies were guided by advances in sciences and technologies, focusing almost exclusively on production and financial efficiency (Dumanski and Smyth, 1993). As a result fewer farmers are producing more food on less land. However, excessive use of fertilizers and pesticides, and inadequate nutrient and animal waste containment have resulted in pollution of soil and water resources. This second generation of environmental problems not only caused a health hazard for increasing human and animal populations, but also lead to loss of bio-diversity and contamination of surface waters, including coastal waters and lakes.

In some of the economically more advanced developing countries, poorly managed yet high-input farming practices have also caused this so-called second generation of environmental problems. Excessive use of water in irrigated areas in the semi-arid and arid regions have led to waterlogging and secondary salinisation. Acidification by atmospheric deposition of sulphide from coal mining industries is another form of land degradation, which may trigger a whole range of pollution processes.

2 THE STATUS OF SOIL DEGRADATION

2.1 The GLASOD Project

Although soil degradation is generally recognized as a serious and wide-spread problem, its geographical distribution and total areas affected was only roughly known. Dregne (1986) stated that sweeping statements on the fact that soil erosion is undermining the future prosperity of mankind do not help planners who need to know where the problem is serious and where it is not.

Recognizing the need to obtain a better overview of the geographical distribution and the seriousness of human-induced soil degradation, the United Nations Environment Programme (UNEP) commissioned the International Soil Reference and Information Centre (ISRIC), in

1988 to coordinate a worldwide programme in cooperation with a large number of soil scientists throughout the world to produce, on the basis of incomplete existing knowledge, a scientifically credible global assessment of the status of human-induced soil degradation within the shortest possible time frame. This global study (GLASOD) was published as a world map at an average scale of 1:10 million and was complemented with statistics on the global and continental extent of the various types of soil degradation — water and wind erosion, chemical degradation and physical degradation — their degree and causative factors. GLASOD aroused world-wide interest and the results (Oldeman *et al.*, 1991, 1994 a,b) have been widely cited in many policy papers (Scherr and Yadav, 1996; FAO, 1993, 1996) and reviewed in several scientific journals (Thomas, 1993; Young, 1993). Annex 1 illustrates some results of the GLASOD study.

While there is wide-spread evidence that soil losses resulting from erosion are far in excess of the natural rate of soil formation, the impact of such losses on crop yields or production has not been well-established in physical or economic terms, although there have been many attempts to do so (FAO, 1993).

Hurni (1996) states that science faces the challenge of assessing the impact of soil erosion by water and wind. To what extent is soil productivity affected? Economic estimates only focusing on production can be misleading because the underlying problem of soil degradation, its long-term irreversible consequences on soil productivity and the urgent need for action are under-estimated.

Crosson (1996) calculated the on-farm economic costs of soil erosion on a global level. Using data derived from GLASOD on lightly, moderately, and strongly degraded land in crops and permanent pastures and assuming percentage losses of productivity for each degradation category (5%, 18%, 50% respectively) he arrived at an average productivity loss on the total area of land in crops and permanent pastures of 4.8 percent. Even if higher loss percentages (15%, 35%, 75%) are used, the average world-wide productivity loss would not be higher than 8.9%. Using Crosson's approach, we separated cropland from permanent pastures and calculated these losses per continent. For Africa productivity losses on cropland would be 25% and for Central America even as high as 36.8% (see Table 1).

Table 1. Average percentage cumulative loss of productivity during post-second world war period as a result of human-induced soil degradation, worldwide and per continent

	Crop land	Pasture land	Crops and Pastures	(Crops and Pastures)
Percentage loss per degradation category (light, moderate, strong)	15, 35, 75	5, 18, 50	5, 18, 50	15, 35, 75
World	12.7	3.8	4.8	8.9
Africa	25.0	6.6	8.1	14.2
Asia	12.8	3.6	4.7	8.9
S. America	13.9	2.2	4.1	6.7
C. America	36.8	3.3	8.7	14.5
N. America	8.8	1.8	3.0	5.8
Europe	7.9	5.6	4.6	9.0
Oceania	3.2	1.1	1.2	3.2

Crosson (1997) concludes that nothing we could feasibly do to deal with degradation is going to contribute much to meeting future global demands for food! However, one may assume that if we do not deal with the causes of soil degradation, the areas now slightly degraded may become moderately degraded, areas now moderately degraded may become strongly degraded, while areas now strongly degraded may go out of production leading to higher, yield loss percentages.

There is an urgent need to better characterize the status of human-induced soil degradation and to prepare more detailed regional assessments, based on country-based inventories. The World Resources Institute, which assembled many of the GLASOD results in its World Resources Report 1992-1993 (WRI, 1992), indicated the critical need for further study to more accurately portray soil degradation problems at the national and local level.

2.2 The ASSOD Project

At FAO's 21st Regional Conference for Asia and the Pacific (New Delhi, 1992) it was recommended that FAO should find means to strengthen the collection and analysis on land degradation data in the Asian Pacific region. FAO's Asian Network of Problem Soils convened an expert consultation in 1993 (RAPA, 1994). This consultation, composed of 15 member countries in the region, recommended to prepare an Assessment of the Status of Human-induced Soil Degradation in South and Southeast Asia (ASSOD) at a scale of 1:5 million, based on refined and modified GLASOD methodology and using as a working template a physiographic map and database to be constructed along the lines of the internationally endorsed Soils and Terrain Digital Database (SOTER) approach (see also Section 4). UNEP commissioned the responsibility to coordinate and implement this study to ISRIC. The study was carried out in close cooperation with national resources institutions in the region (Van Lynden and Oldeman, 1997).

In Section 3 we will discuss the methodology followed in the Asian soil degradation study to relate in a qualitative approach the impact of human-induced soil degradation to the crop productivity, taking into account different management levels.

The qualitative approach used, does not however give an indication on the future risks of soil degradation under certain management scenarios. In order to establish such a risk assessment using existing modelling techniques, it is essential to know the geographically referenced attributes of soil and terrain, of climatic parameters and information on land use. This information can be stored in a GIS-linked database. In Section 3 we will briefly discuss procedures to assess the impact of water erosion risk on food productivity using the internationally endorsed SOTER methodology (Section 4).

3 THE STATUS OF SOIL DEGRADATION AND ITS IMPACT ON FOOD PRODUCTIVITY

Soil degradation was defined in GLASOD and ASSOD as a process that describes human-induced phenomena which lower the current and/or future capacity of the soil to support human life (Oldeman, 1988). These studies did not intend to indicate and delineate the instantaneous present and future rate of degradation processes and the potential hazards that may occur under human influence. They describe and delineate situations where the balance between climate aggressivity and the potential resistance of the land has been broken by human interventions.

In the GLASOD approach the degree to which the soil is degraded to its present status was related in a qualitative manner to the agricultural suitability of the soil, to its declined productivity, to its possibilities for restoration to full productivity and in relation to its original biotic functions. A light degree for example indicated that the soil had a somewhat reduced agricultural suitability, but was considered suitable in local farming systems. Restoration to full productivity was considered possible by slight adjustment of its land management. A moderate degree of degradation status was defined as a status of the soil with a greatly reduced productivity, but still suitable for use in local farming system. Major improvements were required to restore the soil to its original productive potential. A strong degree of degradation reflected a status of the soil, which had virtually lost its productive capacity. Major investments would be needed to rehabilitate the soil, often beyond the means of national governments in most developing countries. An extreme degree of soil degradation indicated that the soil was unreclaimable.

The GLASOD study (Oldeman *et al.*, 1991) revealed that 38% (or 749 million hectares) of the area affected by human-induced soil degradation was lightly degraded, 46% (or 910 million hectares) was moderately degraded, 15% (296 million hectares) was strongly degraded, while 9.3 million hectares (less than 1%) was extremely degraded on a world-wide basis.

Although the definitions used in the GLASOD approach were appropriate for the scale it was intended for, the severity of the soil degradation problem was not related to the management level. Crosson (1994) pointed out that according to GLASOD most of the mapping units in 6 states of the U.S.A. are moderately degraded, implying that the land suffered a greatly reduced agricultural productivity. However, in that region yields of the principle crops have been rising steadily over the last 40 years. Because of this apparent inconsistency with reality and being "unable to investigate whether there may be similar anomalies in other regions of the world between actual yield experience and severity of soil degradation", he concluded that real land degradation problems lie in the strongly or extremely degraded area.

Although Crosson's conclusions from the U.S.A. may be correct, he fails to recognize that the high level of management in the U.S.A. is not generally practised in many of the developing countries. The GLASOD map indicates that worldwide about 45% of the degraded land is moderately degraded. If degradation of this non-renewable resource continues unabated for the next 25 years or so, these moderately-degraded lands may become strongly degraded. The map therefore can strengthen the awareness of global policy-makers on the dangers of inappropriate land and soil management, which was the prime objective. It should however be recognized that GLASOD is indeed based on informed opinion and not on quantitative measures.

In the Assessment of the Status of Human-induced Soil Degradation in South and Southeast Asia (ASSOD), more emphasis was placed on the apparent impact of soil degradation on food productivity. Changes in soil and terrain properties such as loss of topsoil, development of rills and gullies, loss of nutrients, may reflect the occurrence and intensity of the process of soil degradation, but not necessarily the seriousness of its impact on food productivity. The removal of a 5 cm layer of topsoil may have a severe impact on a shallow soil with a thin topsoil, but may not directly affect the productivity on a deep fertile soil. It would therefore be much better to use as criterium for soil degradation impact the relative changes of soil characteristics: the percentage of the total topsoil lost, the percentage of total nutrients and organic matter lost; the relative decrease in soil moisture holding capacity, the relative increase of the salinity of the soil, etc. It is obvious that this type of information only exists in experimental plots and micro-catchment study areas, while precise information for a region is lacking.

A significant complication in assessing productivity losses as a result of soil degradation processes is the variety of reasons that may lead to yield decline. Yield decline may be caused by a wide range of factors, such as erosion, fertility decline, improper management, drought or waterlogging, quality and quantity of inputs (like seeds, fertilizers), pests and diseases, and adverse weather conditions. It is therefore important to consider a medium or long-time period □ 10 to 15 years □ to level out aberrations resulting from fluctuations in weather patterns or pest and disease occurrences.

The assessment of yield reductions as a result of soil degradation is also complicated by the fact that over time farmers may apply increasing amounts of fertilizers both to substitute nutrients lost by topsoil erosion and to further enhance the natural fertility of the soil. They may improve tillage practices to improve the soil structure when compacted by heavy machinery, and grow improved varieties. Despite these ameliorating management practices, studies in the U.S.A. have shown a relationship between soil erosion and reduced yields on many soils (Batie, 1983). Despite technological innovations to improve the productivity of the soil the average rate of change in total productivity increases has declined from 2.2% annually during the 1950-1965 period to 1.8% annually during the 1965-1979 period in the U.S.A. Since soil degradation can be more or less hidden by the effects of various management practices, productivity changes should be assessed in relation to the amounts of inputs or level of management.

In ASSOD, the impact of human-induced soil degradation on productivity is therefore assessed in relation to the level of management. Five classes of soil degradation impact were defined (negligible, light, moderate, strong and extreme). The changes in productivity, ranging from a large increase, small increase, no increase, small decrease, large decrease, unproductive, are expressed in relative terms: the current average productivity compared to the average productivity in the non-degraded situation, or the inferred change in productivity over the last 10-15 years.

In summary, one can say that the degree of degradation reflects the intensity of the degradation process itself, whereas the impact considers the effect of that process. In areas with deep fertile soils the degree of soil erosion may be quite high, but the impact may only be light or even negligible. Note that negligible is thus not necessarily synonymous with "stable" land, which implies no degradation process. Table 2 shows how the impact of soil degradation on productivity is related to the changes in productivity and the management level.

Table 2. Impact of human-induced soil degradation on changes in food productivity in relation to management level

Level of productivity change	Level of management		
	High	Medium	Low
Large increase	negligible	not applicable	not applicable
Small increase	light	negligible	not applicable
No increase	moderate	light	negligible
Small decrease	strong	moderate	light
Large decrease	extreme	strong	moderate
Unproductive	extreme	extreme	strong/extreme

If one indicates a small increase in productivity under a high level of management we may conclude that management improvements partly benefitted yields and were partly needed to compensate the impact of degradation. Therefore the impact is light. If we find a small decrease in productivity under a high level of management, we may conclude that the management measures could not or only partly compensate the impact of soil degradation. Therefore the impact is strong. If a small decrease in productivity occurs under a medium level of management, we can say that the degradation impact was insufficiently compensated by improvement measures. The impact is moderate.

This methodology to assess the impact of soil degradation on food productivity in relation to management level was used in the ASSOD study. It should be noted that information on management level is subjective, and relates only to those areas where soil degradation has occurred. It appears that 38% of the land affected by human-induced soil degradation had a high level of management, 35% a medium level and 27% a low level. Table 3 indicates the percentage of areas within each management category in relation to the level of productivity changes.

Table 3. Areas affected by soil degradation in relation to changes in food productivity under different management levels for South and Southeast Asia

Level of productivity change	Level of management		
	High	Medium	Low
Large increase	18%	--	--
Small increase	46%	23%	--
No increase	22%	40%	12%
Small decrease	11%	22%	48%
Large decrease	3%	15%	28%
Unproductive	--	--	12%
Total (= 100%)	372 Mha	338 Mha	248 Mha

Source: Van Lynden and Oldeman (1997)

The total area, affected by human-induced soil degradation in South and Southeast Asia is equivalent to 46% of the total land area. From this affected area 18% showed a negligible impact on food productivity, 45% had a light impact, 13% a moderate impact, 13% a strong impact, while an extreme impact was observed on 1% of the affected land. Although this assessment is still qualitative and based on informed opinion, the results indicate that human-induced soil degradation is a serious problem and has a clear impact of food productivity. More details can be found in the technical report (Van Lynden and Oldeman, 1997) (see also Section 2.2).

4 IMPACT OF WATER EROSION RISK ON FOOD PRODUCTIVITY: THE SOTER APPROACH

In Section 3 we have shown that soil degradation affects food productivity and is therefore a threat to food security. The GLASOD and ASSOD studies however only reflect the present status of human-induced soil degradation and its impact on food productivity related to productivity changes observed in the recent past. These studies also revealed that the process of water erosion is dominant on all continents (see also Appendix 1).

As indicated earlier under ASSOD, the impact of soil degradation on the functional properties of land and its productive capacity may differ between land units and/or soils. If the seriousness, and thus the need for soil conservation measures or for alternative land uses is to be made explicit, the initial productivity of a certain land use system must be known as well as the effect of soil degradation on this productive capacity (Driessen, 1986).

In order to assess future risks of soil degradation more precise and quantitative information is needed on the various soil and terrain attributes, on climatic variables, on present land use and vegetation cover. The International Society of Soil Science, FAO, UNEP and ISRIC have developed an internationally endorsed methodology for the systematic storage of detailed information on natural resources in such a way that this geographically referenced database ▯ the Soils and Terrain Digital Database (SOTER) ▯ can be assessed and combined in order to analyze each combination of land, water and land use within a country or region from the point of view of potential use, in relation to food requirements, environmental impact or conservation (Van Engelen and Wen, 1995). National SOTER databases have now been developed for a number of countries in Latin America, Africa, Europe and West Asia.

In the context of their Global Environmental Outlook (GEO) project, UNEP expressed the need for a quantitative assessment of the impact of soil erosion on food production. We will briefly indicate how the SOTER database and complementary data files on climate can be used to assess the impact of water erosion (in this case, loss of topsoil) on the productive capacity of the soil. More details can be found in the ISRIC study by Mantel and Van Engelen (1997). They used a so-called mixed qualitative/quantitative land evaluation approach. For the qualitative land evaluation an ALES-based model was used ▯ SOTAL, developed by Mantel (1995). The risk of water erosion ▯ SWEAP, developed by Van den Berg and Tempel (1995) ▯ and the assessment of potential productivity ▯ WOFOST, developed by Van Diepen *et al.* (1989) ▯ were simulated using quantitative models. We will briefly describe the various steps involved in the assessment of the impact of water erosion risk on food productivity as used in a case study of Uruguay.

A qualitative model for physical land evaluation developed in ALES (Automated Land Evaluation System) (Rossiter, 1990) was linked to the SOTER database for Uruguay to assess the suitability for mechanized, low input wheat in Uruguay. The sufficiency of the land quality "availability of water" was determined separately with a water balance model. This resulted in a land suitability map for wheat. The non-suitable SOTER mapping units were excluded in further quantitative calculations.

In a simultaneous exercise the erosion risk under mechanized, low input wheat was calculated using the SOTER Water Erosion Assessment Programme (SWEAP). In SWEAP two erosion risk models are defined in the model sub-system. In this study the Universal Soil Loss Equation (Wischmeyer and Smith, 1978) modified to handle SOTER data, was selected. Considering the scale of study (1:1 million) and the fact that the parametric model is not calibrated for the range of conditions as represented by the climatic and SOTER databases, it is not justifiable to present the results on an absolute scale as soil loss in tons per hectare. The results are therefore presented in qualitative terms (erosion hazards units). This allows for a comparison between the various areas within a country.

A crop simulation model — WOFOST — was used to calculate the potential yield of wheat under the present agro-ecological conditions of soil and climate. The potential yield (or constraint-free yield) reflects the 'bio-physical production ceiling' determined by the crop's genetic potential under ambient radiation and temperature regime. The water-limited yield calculations reflect the influence of limited or excessive water supply. The water supply to the plant is determined by the water buffering capacity of the soil, and only indirectly by the forcing variable: rainfall. Changes in crop yield as a function of water availability due to altered hydraulic characteristics as a consequence of erosion are (in this study) a consequence of texture shifts and change in rootable depth. The QUEFTS (Quantitative Evaluation of the Fertility of Tropical Soils) methodology was used to calculate nutrient-limited yield as a function of the availability of macro-nutrients (Smaling and Jansen, 1993).

The soil erosion risk as calculated for the mapping units in Uruguay were then used as a basis for a simulated soil loss over a period of 20 years. In this study no account is taken of the possibility that soil deposition occurs in some units. This simplification is justified when the objective is to study the impact of erosion on crop productivity under different agro-ecological settings. In this manner topsoil losses ranging from 0 to 50 cm over a 20-year period were established for the dominant soils in the mapping units and new WOFOST input files were created to calculate water-limited and nutrient-limited yields.

Comparison of the water-limited yield now and after 20 years erosion show the modelled impact of erosion on crop yields. Not only does this give a possibility to calculate the yield decline as a result of water erosion at national level, more importantly perhaps it gives a spatial impression where soil erosion shows the highest impact. This information can be useful for national land use planning agencies.

The results of this study can be complemented with some statistical trends. The qualitative land suitability evaluation indicates that 53% of Uruguay is not considered suitable for mechanized low-input wheat. Further quantitative assessments were therefore based on the remaining 47% of the country (12% highly suitable; 32% moderately suitable; 3% marginally suitable).

Erosion risk under mechanized low input wheat cultivation was low on one percent of the remaining area, medium on 15%, high on 57% and very high on 26%. In this study six yield classes were defined. For each yield class the areas were calculated under constraint-free conditions, nutrient-limited yields before and after erosion and water-limited yields before and after 20 years erosion. Table 4 shows the results.

Table 4. Trends in wheat yield under constraint free, nutrient limited (before and after erosion) and water-limited (before and after erosion) conditions expressed as a percentage of the total suitable area for mechanized low-input wheat (Uruguay)

Conditions	Yield classes (in ton/ha)					
	0-0.5	0.5-1.0	1.0-2.0	2.0-3.0	3.0-4.0	4.0-5.0
Constraint-free			30	31	31	9
Nutrient-limited	1	1	34	34	21	8
Nutrient-limited after erosion	4	-	34	43	9	8
Water-limited	7	20	43	16	13	2
Water-limited after erosion	28	27	42	1	1	1

It can be concluded that the nutrient-limited yield potential is not significantly different from the constraint-free yield, and that the nutrient-limited yield on the generally fertile and organic matter rich soils is little affected by topsoil erosion. The water-limited yield on the other hand is significantly different from the constraint-free yield and the water-limited yield is strongly affected by topsoil erosion. If we set the total wheat production under constraint-free conditions at 100 percent, then the nutrient-limited yield is reduced to 93% before erosion and to 86% after 20 years of erosion. The water-limited yield before erosion is 65% of the constraint-free yield before erosion and is reduced to only 16% after 20 years erosion.

5 CONCLUSIONS

Soil degradation is occurring over vast areas. As a consequence of increased population pressure and the scarcity of unreclaimed land, physically and socio-economically suitable for cultivation, there will be increasing pressure on all sectors of society to utilize the existing cultivated areas as efficiently as possible and on a sustainable basis. While it may be true that it is economically not interesting to reclaim already strongly degraded land, it appears essential that all available mechanisms be set in motion to prevent further degradation of the land and to protect the land which is not yet affected by soil degradation.

The Science Academies Summit (Madras, July 1996) developed an agenda for future action to be adopted by world leaders at the World Food Summit in Rome in November 1996 (IFPRI, 1996). They urged world leaders to revert the global trend of disinvestment in agricultural research and development, convinced that such short-sighted policy can only have tragic results. "Meeting the challenge of increasing food availability now and in the future demands equal focus on production systems and on the larger issues of access to food". They stress among other that a national natural resources conservation and enhancement strategy will be fundamental to a national food security system. "High priority must go to combating desertification and deforestation and to restoring degraded land".

In the preceding sections we have indicated how rapidly our natural resource base has been degraded in the last decades. We have attempted to illustrate how soil degradation affects food security and what might happen if soil degradation processes continue uninterrupted. It is our duty to communicate our concerns on soil degradation and its impact on food production to all stakeholders; international and national policy-makers; international and national agricultural research organizations; non-government organizations (NGOs); agricultural extension services; and last but not least, the farmers who cultivate the soils. There is a great demand for well-documented soil information to better understand and quantify the impact of soil conditions and human-induced alterations of these soil conditions on biomass production. A comprehensive project proposal for the development of an Asian Land Resources Information System has been developed in close cooperation with IBSRAM and national agricultural research systems in the Asian countries.

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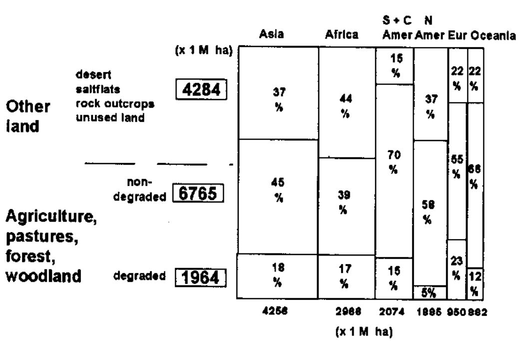
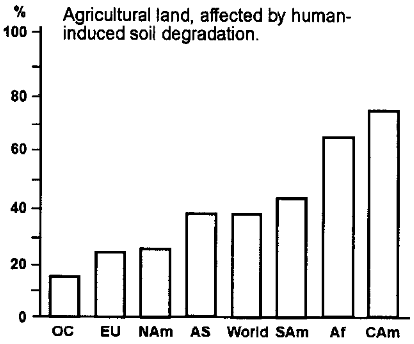
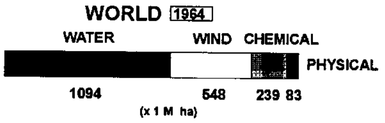
APPENDIX 1 Global Extent of the Status of Human-induced Soil Degradation

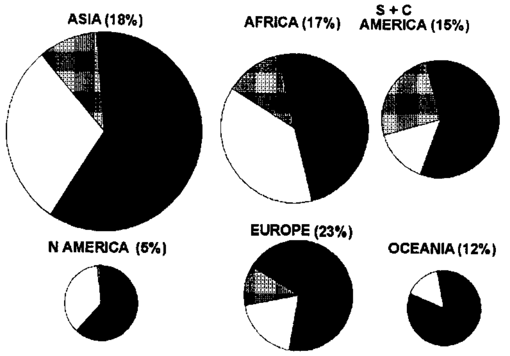
WORLD SOIL DEGRADATION





TYPE OF DEGRADATION: AFFECTED AREA





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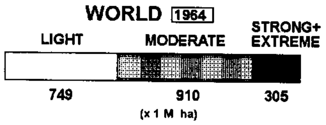
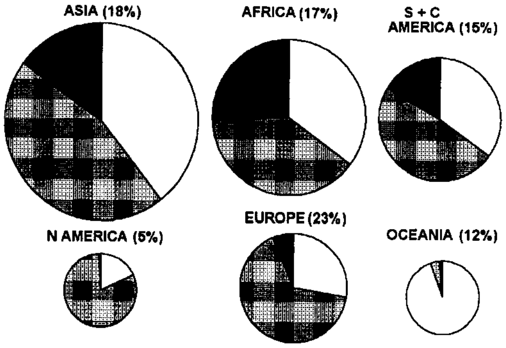
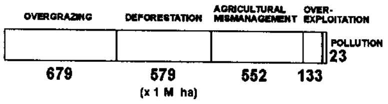




HUMAN INTERVENTIONS



	OVERGRAZING	DEFORESTATION	AGRICULTURAL MISMANAGEMENT	OVER-EXPLOITATION	POLLUTION
AFRICA	243	67	121	63	+
ASIA	198	298	204	46	1
S. AMERICA	68	100	64	12	-
C. AMERICA	9	14	28	11	+
N. AMERICA	29	4	63	-	+
EUROPE	48	84	64	1	21
OCEANIA	83	12	8	-	-

(All data from GLASOD, 1991)