



Global Extent of Soil Degradation

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1 Introduction

Past and present human intervention in the utilization and manipulation of environmental resources are having unexpected consequences. The earth's soils are being washed away, rendered sterile or contaminated with toxic materials at a rate that cannot be sustained. As stated by Brundtland *et al.* (1987): "There is a growing realization in national and multilateral institutions that not only many forms of economic development erode the environmental resources upon which they are based, but that at the same time environmental degradation can undermine economic development".

Although soil degradation is recognized as a serious and widespread problem, its geographical distribution and total areas affected is only very roughly known. Dregne (1986) states 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. This feeling was also expressed by the United Nations Environment Programme (UNEP). This organisation indicated the need to produce, on a basis of incomplete knowledge, a scientifically credible global assessment of soil degradation in the shortest possible time. "Politically it is important to have an assessment of good quality now instead of having an assessment of very good quality in 15 or 20 years" (ISSS, 1987).

UNEP's project 'Global Assessment of Soil Degradation (GLASOD)' was implemented and coordinated by the International Soil Reference and Information Centre, ISRIC, the Netherlands. Three years later the World Map of the Status of Human-Induced Soil Degradation was published (Oldeman *et al.* 1990). The map sheets themselves do not provide quantitative information on the global extent of soil degradation, mainly because the scale of the (Mercator) projection of the topographic base map is increasingly distorted at higher latitudes. Therefore, the map units were digitized with a Geographic Information System, capable of converting the Mercator projection into an 'equal area' projection. It is now possible to make an estimate of the regional and global extent of the various soil degradation processes and their seriousness.

2 Methodologies for the assessment of global soil degradation

The preparation of a World Map of Soil Degradation within a three years period could only be accomplished in a cooperative effort with a large group of soil and environmental scientists worldwide, who were asked to give their expert opinion on the types, degree, areal coverage and human-induced causes of soil degradation in their regions. A team of 21 regional correlators was provided with a simplified topographic base map. In order to ensure uniformity of interpretation they were asked to use general guidelines for the

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assessment of the present status of human-induced soil degradation (ISRIC, 1988). These guidelines gave definitions of the various types of soil degradation, of the degree to which the soil was degraded, and of the various human-induced interventions that had caused the soil to deteriorate to its present situation.

The methodology called for a stepwise approach. The first step involved the delineation of mapping units on the topographic base map based on physiographic characteristics. These units should show a maximum homogeneity of topography, soils, climate, vegetation and land use.

The second step involved an evaluation of the various types of soil degradation that may occur in the mapping unit. For each recognized type of soil degradation an indication was given of the degree of soil degradation, the relative extent of the area within the mapping unit being affected, the recent past rate of the degradation process and the causative factor(s). Additionally, information was provided on the relative extent of the wasteland portion and the stable terrain portion of the mapped unit.

The third step was the compilation of the regional information into a global map and the development of a legend for the global GLASOD map. Each map unit in its final version would contain not more than two types of soil degradation. Although in total 12 different types of soil degradation are included in the legend, only four major groups of soil degradation were represented on the map by different colours. The severity of the major type of soil degradation was indicated on the map by a different shading of the colour. The severity index is a combination of the estimated degree of the soil degradation process and the relative extent of the area affected. Although it is recognized that this compilation resulted in a simplification of the provided information, the final GLASOD map itself provides sufficiently detailed information for the user group for which it was intended: policy-makers and decision-makers. The major objective of the map is to strengthen their awareness of the dangers resulting from inappropriate land and soil management. However, each map unit is provided with a symbol giving more detailed description of the two dominant types of soil degradation.

3 Characteristics of the GLASOD map

3.1 SOIL DEGRADATION TYPES

The information on soil degradation processes does not relate to the relative fragility of the ecosystem. It describes situations where the balance between the natural resistance of the soils (and its vegetative cover) and the climatic aggressivity has been disturbed by human intervention. Soil degradation is defined as a process which lowers the current and/or future capacity of the soils to produce goods or services.

Two categories of soil degradation processes are recognized. The first group relates to displacement of soil material. The two major soil degradation types in this category are soil erosion by water forces or by wind forces. The second group deals with soil deterioration in-situ. This can either be a chemical or physical soil degradation process.

3.1.1 *Water erosion (W)*

The displacement of soil material by water can have several negative consequences. The removal of part of the usually fertile topsoil reduces the productive capacity of the soil, while in extreme cases the rooting depth can become restricted for agricultural crops. Although measurements of crop yield reductions caused by soil erosion are difficult, mainly because over time farmers may substitute increasing amounts of fertilizers to compensate for the loss of the natural fertility of the soil, studies in the U.S.A. have established relationships between soil erosion and reduced crop yield (Batie, 1983). In fragile soils with a low structure stability run-off water may lead to rapid incision of gullies, eating away valuable soils and making the terrain eventually unsuitable for farming. The GLASOD approach distinguishes two forms of water erosion:

1. Loss of Topsoil (Wt). This form of water erosion is generally known as surface wash or sheet erosion. It occurs almost everywhere, under a great variety of climatic and soil conditions and land uses. Loss of topsoil is often preceded by compaction and/or crusting resulting in a decrease of the infiltration capacity of the soil.
2. Terrain deformation (Wd). Although the total area affected by rills and gullies is far less compared to loss of topsoil (see 4.1.1) its effects are more spectacular and more easy to observe in the field. Control of active gullies is difficult and restoration is almost impossible.

3.1.2 *Wind erosion (E)*

The displacement of soil material by wind is nearly always caused by a decrease of the vegetative cover of the soil, either due to overgrazing or to the removal of vegetation for domestic use or agricultural purposes. It is a wide-spread phenomenon in arid and semi-arid climates. In general, coarse textured soils are more vulnerable to wind erosion than fine-textured soils. Three types of wind erosion are recognized by GLASOD:

1. Loss of topsoil by wind erosion (Et), defined as a uniform displacement of the topsoil.
2. Terrain deformation (Ed), defined as an uneven displacement of soil material, leading to deflation hollows and dunes. Although mapped separately, this type of wind erosion may be considered as an extreme form of loss of topsoil.
3. Overblowing (Eo) is defined as the coverage of the land surface by wind-carried particles. In contrast to off-site effects of water erosion, this off-site effect of wind erosion occurs on relative large areas and is mappable. Overblowing may seriously influence the infrastructure (road, rail roads), buildings and waterways, and may cause damage to crops.

3.1.3 *Chemical degradation (C)*

Chemical degradation of the soil does not refer to cyclic fluctuations of the soil chemical conditions of relatively stable agricultural systems, in which the soil is actively managed to maintain its productivity, nor to gradual changes in the chemical composition as a result of soil forming processes. The following chemical degradation processes are distinguished:

1. Loss of nutrients and/or organic matter (Cn). Loss of nutrients is a common phenomenon in countries with low-input agriculture. It occurs if agriculture is practiced on poor or moderately fertile soils, without sufficient application of manure

or chemical fertilizers. The rapid loss of organic matter of the topsoil after clearing of the natural vegetation is also included.

2. Salinization (Cs) is defined as a change in the salinity status of the soil. It can be caused by improper management of irrigation schemes, mainly in the arid and semi-arid regions covering small areas. Salinization may also occur if seawater or fossil saline groundwater intrudes in coastal regions or in closed basins with aquifers of different salt content when there is an excessive use of groundwater. Finally, salinization takes place where human activities lead to an increased evapotranspiration in soils on salt-containing parent material or with saline groundwaters.
3. Acidification (Ca) may occur in coastal regions upon drainage/oxidation of pyrite-containing soils. Acidification is also caused by over application of acidifying fertilizers. In both cases the agricultural potential of the land is reduced.
4. Pollution (Cp). Many types of pollution can be recognized, such as industrial or waste accumulation, excessive use of pesticides, acidification by airborne pollutants, excessive manuring, oil spills, etc. This form of soil degradation is generally restricted to heavily industrialized nations with high population densities, although the effect of acidification by airborne pollutants may lead to deposits at considerable distance from its source.

3.1.4 *Physical degradation (P)*

Within the category of physical degradation, three different types are identified:

1. Compaction, crusting and sealing (Pc). While compaction of the soil is usually caused by the use of heavy machinery, sealing and crusting of the topsoil occurs if the soil cover is not sufficiently protected from the impact of raindrops. In particular, soils low in organic matter with poorly sorted sand fractions and appreciable amounts of silt are vulnerable.
2. Waterlogging (Pw). Human intervention in natural drainage systems may lead to flooding by river water and submergence by rainwater. It should be noted that the construction of paddy fields is not included in this category as it is considered an improvement of the terrain for wetland rice cultivation.
3. Subsidence of organic soils (Ps). This phenomenon is caused by drainage and/or oxidation of organic soils. It is only identified on the map if the agricultural potential is negatively affected.

3.1.5 *Miscellaneous terrain types*

Human-induced soil degradation is widespread throughout the world, but large areas are not affected by human intervention because the land is either unsuitable for agricultural activities (climatic, topographic and soil constraints) or poorly accessible. On the GLASOD map, two categories of land are recognized without human-induced soil degradation.

3.1.5.1 *Stable terrain (S)*

The stable terrain is subdivided in three categories depending on the type of human intervention or its absence:

1. Stable terrain under natural conditions (SN). Absence of any kind of human-intervention because the type of land, the climatic conditions or the accessibility is not suitable for living or for agricultural activities. Large portions in northern Canada, northern Europe and the former U.S.S.R. are included, but also large parts of the Himalaya and Andes mountains, as well as certain portions of the rainforests in South America and Africa.
2. Stable terrain with a permanent agricultural land use (SA). If agricultural land is well managed, no soil degradation will occur and productivity levels will not decrease.
3. Terrain stabilized by human intervention (SH). With the growing awareness of the dangers of soil degradation, efforts to conserve this precious natural resource are growing. Examples of conservation practices are reforestation, terracing, gully control, improved water management.

3.1.5.2 Wastelands

Historic or recent natural processes have rendered these terrain into unused wastelands. There is no appreciable vegetative cover or agricultural potential. The GLASOD map recognizes in this group active dunes (D), deserts (A), salt flats (Z), rock outcrops (R), arid mountain regions (M), and ice caps (I).

It should be noted that these miscellaneous terrain types are identified on the GLASOD map, only if the mapping unit does not include any form of human-induced soil degradation. This implies that even if a mapping unit has an infrequent occurrence of a certain type of soil degradation, the whole mapping unit is coloured according to that type of soil degradation, although the vast majority of the land in that mapping unit may be stable.

3.2 THE DEGREE OF SOIL DEGRADATION

Soil degradation processes by definition result in a loss in soil productivity, although the ways in which this happens differ greatly with the various soil degradation processes. In the GLASOD approach, the degree to which the soil is presently degraded is 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.

The degree of soil degradation should also be related to a time scale. The GLASOD approach provides information only on human-induced soil degradation that occurred after the second World War.

The following four degrees of soil degradation were specified:

1. Light. The terrain has a somewhat reduced agricultural suitability, but is suitable in local farming systems. Restoration to full productivity is possible by modifications of the management. Original biotic functions are largely intact.
2. Moderate. The terrain has a greatly reduced productivity, but is still suitable for use in local farming systems. Major improvements are required to restore the terrain to

- full productivity, which are beyond the means of local farmers in developing countries. Original biotic functions are partially destroyed.
3. Strong. The terrain has virtually lost its productive capacity and is not suitable for use in local farming systems. Major investments and/or engineering works are required to rehabilitate the terrain, which are often beyond the means of national governments in developing countries. Original biotic functions are largely destroyed.
 4. Extreme. The terrain is unreclaimable and beyond restoration. It has become human-induced wasteland. Original biotic functions are fully destroyed.

These general definitions are qualitative and judgements made by the experts in the field are subjective, although the guidelines provided some quantitative tools to support these estimates.

3.3 THE RELATIVE EXTENT OF SOIL DEGRADATION

At the chosen scale of the GLASOD map it is obviously not possible to indicate individual events of soil degradation. Expert estimates were however provided to indicate the relative frequency of occurrence of each soil degradation event within each mapping unit.

3.4 CAUSATIVE FACTORS

The concept of human-induced soil degradation implies by definition a social problem. No person will intentionally destroy this precious natural resource. But increasing pressure on the land, the increased desire for better living conditions, and higher standards of living, the search for land to survive etc. etc., have resulted in some kind of physical human intervention that has caused the soil to degrade. The GLASOD approach distinguishes the following types of causative factors:

1. Deforestation or removal of the natural vegetation (f). Clearing of the land for agricultural purposes, large scale commercial forestry, road construction, urbanisation.
2. Overgrazing (g). Actual overgrazing of the vegetation may not only lead to vegetation degradation, but can cause soil compaction, wind and water erosion.
3. Agricultural activities (a). This includes a wide variety of agricultural practices, such as insufficient or excessive use of fertilizers, use of poor quality irrigation water, improperly timed use of heavy machinery, absence of anti-erosion measures on land susceptible to water and wind erosion, etc.
4. Overexploitation of the vegetation for domestic use (e), e.g. for fuel needs, fencing, etc. There is not a complete removal of the vegetation but the remaining vegetation does not provide sufficient protection against soil erosion or sealing and crusting of the topsoil.
5. Bio-industrial and industrial activities (i). These causative factors are directly related to the soil degradation type 'soil pollution'.

4 Global extent of soil degradation

The global extent of soil degradation is calculated in two steps. First the surface area for each individual GLASOD map unit is calculated. For each map unit, the relative extent of the two dominant soil degradation types, its degree and causative factor are known. This allows for an estimation of the area affected by each degradation type per GLASOD unit. The portion of the GLASOD unit not affected by soil degradation is either stable or non-used wasteland or other land used for non-agricultural purposes.

The GLASOD map covers the earth surface between 72 degrees North and 57 degrees South. Summation of the surface area of all GLASOD units leads to a total land area of 13013 M ha (million hectares), which compares favourably with FAO's estimate of 13069 M ha (FAO, 1990).

The GLASOD map and accompanying statistics do not allow assessment of soil degradation on a country by country basis. However, statistics are provided for the 7 continental regions. Human-induced soil degradation worldwide has affected 1966 M ha or 15% of the total land area.

A more realistic estimate would be to express the percentage of human-induced soil degradation in relation to the inhabited land area. This area is estimated as the total land area minus the sum of non-used wastelands and stable terrain under natural conditions (see 3.1.5). Human-induced soil degradation has affected 24% of the inhabited land area. The values for individual continents range from 12% in North America, 18% in South America, 19% in Oceania, 26% in Europe (including the European part of the former U.S.S.R.), 27% in Africa and Central America, and 31% in Asia.

4.1 GLOBAL EXTENT OF SOIL DEGRADATION TYPES

4.1.1 Water Erosion

Water erosion is by far the most important type of soil degradation affecting about 1100 M ha worldwide (56% of the total area affected by human-induced soil degradation). The most widespread form of water erosion is the loss of the topsoil (on 920 M ha), while terrain deformation (rills and gullies) occurs on 175 M ha. Water erosion occurs on all continents and under all climatic conditions, although somewhat more in humid climates. Almost 80% of the terrain affected by water erosion has a light to moderate degree of degradation. This implies that around 225 M ha is to such an extent degraded by water erosion that they are no longer suitable for agricultural land use. Table 1 illustrates the global and continental extent of human-induced water erosion. The most important causative factor is deforestation (43%), while overgrazing (29%) and agricultural mismanagement (24%) are also important human interventions (see Table 7).

Table 1. Global and continental extent of Water Erosion in M ha

	Light	Moderate	Strong + Extreme	Total	Percentage of degraded soils	Dryland zone ¹	Humid zone ¹
Africa	58	67	102	227	46 %	122	105
Asia	124	242	73	441	59 %	165	276
S. America	46	65	12	123	51 %	35	88
C. America	1	22	23	46	74 %	38	68 ²
N. America	14	46	-	60	63 %		
Europe	21	81	12	114	52 %	48	66
Oceania	79	3	+	83	81 %	70	13
WORLD	343	526	223	1094	56 %	478	615

¹ Dryland zone is defined as the climatic region with an annual precipitation/evapotranspiration ratio of 0.65 or less (UNEP, 1992a). The humid zone has a ratio of more than 0.65.

² North + Central America

4.1.2 Wind Erosion

Wind erosion is a widespread phenomenon in arid and semi-arid zones, usually on coarse textured soils with a limited vegetative cover. The global extent of soils, affected by wind erosion is around 550 M ha (28% of the total terrain affected by soil degradation). Similar to water erosion, the loss of topsoil by wind forces is by far the most important type of wind erosion (on 455 M ha), while terrain deformation (82 M ha) and overblowing (12 M ha) are relatively speaking less important in extent, although these types of wind erosion may have very serious effects on human activities. The degree of wind erosion is mainly light or moderate. Table 2 indicates the continental distribution of wind erosion affected terrain. Wind erosion is mainly caused by overgrazing (60%), followed by agricultural mismanagement (16%) and exploitation of the vegetative cover for domestic use (16%). Deforestation (8%) is the fourth causative factor leading to wind erosion (see Table 7).

Table 2. Global and continental extent of Wind Erosion in M ha

	Light	Moderate	Strong	Total	Percentage of degraded soils	Dryland zone ¹	Humid zone ¹
Africa	88	89	9	186	38	186	1
Asia	132	75	15	222	30	206	16
S. America	26	16	-	42	17	28	14
C. America	+	4	1	5	7	38 ²	1 ²
N. America	3	31	1	35	36		
Europe	3	38	1	42	19	39	3
Oceania	16	-	+	16	16	16	+
WORLD	269	254	26	548	28	513	36

¹ Dryland zone is defined as the climatic region with an annual precipitation/evapotranspiration ration of 0.65 or less (UNEP, 1992a). The humid zone has a ratio of more than 0.65.

² North + Central America

4.1.3 Chemical Soil Degradation

Types of human-induced chemical soil degradation are very different in nature. A total of almost 240 M ha is affected by chemical degradation worldwide, which is about 12% of the total area affected by human-induced soil degradation (see Table 3). In South America, almost 30% of the degraded soils is related to chemical soil degradation, nearly all as a result of loss of nutrients and/or loss of organic matter. In North America and Oceania, chemical soil deterioration is of minor importance in comparison to other forms of human-induced soil degradation. In Africa, Asia, Central America and Europe, about 12% of the degraded soils are chemically affected. Loss of nutrients is the major type in Africa and South America, while salinization is the most important form of chemical degradation in Asia. Pollution is the dominant type of human-induced soil degradation in Europe. Acidification plays a role on 6 M ha, of which 4 M ha is located in Asia.

Chemical soil degradation is mainly caused by agricultural mismanagement (56%) and deforestation (28%). Industrial and bio-industrial activities are the main agents for pollution of the soils (9%) (see Table 7).

Table 3. Continental and global extent of chemical soil degradation in M ha

	Loss of nutrients	Salinization	Pollution	Acidification	Total	Percentage of degraded soils	Dryland zone ¹	Humid zone ¹
Africa	45	15	+	1	62	12%	33	29
Asia	15	53	2	4	74	10%	54	20
S. America	68	2	-	-	70	29%	17	53
C. America	4	2	+	-	7	11%	2 ²	5 ²
N. America	-	+	+	+	+	+		
Europe	3	4	19	+	26	12%	4	22
Oceania	+	1	-	-	1	1%	1	+
WORLD	136	77	21	6	240	12%	111	130

¹ Dryland zone is defined as the climatic region with an annual precipitation/evapotranspiration ratio of 0.65 or less (UNEP, 1992a). The humid zone has a ratio of more than 0.65.

² North + Central America

4.1.4 Physical soil degradation

This type of human-induced soil degradation is identified on 'only' 83 M ha or around 4% of the total area worldwide affected by soil degradation (see Table 4). The major forms of physical soil degradation are compaction, sealing and crusting (68 M ha). Nearly 33 M ha is located in Europe, where the main causative factor relates to the use of heavy machinery. Sealing and crusting, mainly a result of cattle trampling and an insufficient cover of the topsoil by natural vegetation or crops is found in Africa (18 M ha) and Asia (10 M ha). Waterlogging, mainly caused by human intervention in natural drainage systems is the major form of physical soil degradation in Central America, but is also identified in South America, accounting worldwide for some 10 M ha. Subsidence of organic soils is mainly found in the coastal swamps of Southeast Asia, but also affects the soil productivity in some parts of the European section of the former U.S.S.R. Its total area worldwide is around 5 M ha. Agricultural mismanagement (80%) and overgrazing (16%) are the two major causative factors of human-induced physical soil degradation (see Table 7).

Table 4. Continental and global extent of physical soil degradation in M ha.

	Compaction, Sealing and Crusting	Water-logging	Subsidence of Organic Soils	Total	Percentage of degraded soils	Dryland zone ¹	Humid zone ¹
Africa	18	1	-	19	4 %	14	5
Asia	10	+	2	12	2 %	10	2
S. America	4	4	-	8	3 %	+	8
C. America	+	5	-	5	8 %	1 ²	5 ²
N. America	1	-	-	1	1 %		
Europe	33	1	2	36	17 %	9	27
Oceania	2	-	-	2	2 %	1	1
WORLD	68	11	4	83	4 %	35	48

¹ Dryland zone is defined as the climatic region with an annual precipitation/evapotranspiration ratio of 0.65 or less (UNEP, 1992a). The humid zone has a ratio of more than 0.65.

² North + Central America

4.2 GLOBAL EXTENT OF THE SEVERITY OF SOIL DEGRADATION

The degree to which the soil is degraded is related in a qualitative manner to the decreased productivity of the soil and the possibility of restoring the soil to its original productivity, and in those cases where the terrain is covered by natural vegetation, to the degree of destruction of its original biotic functions. Estimates are based on expert opinion from a worldwide group of soil scientists and agronomists. The differences between the various degrees of soil degradation are relative and cannot be directly translated into production losses or costs for rehabilitation.

The assessment of yield reductions as a result of soil erosion is difficult, because 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 change tillage practices, use different kinds of machinery, grow improved varieties of plants. Despite these complicating factors, 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 increase the productivity of the soil, the average rate of change in total productivity increases has declined from 2.2 percent annually during the 1950-1965 period to 1.8 percent annually during 1965-1979 in the U.S.A.

As illustrated in Table 5, over 300 M ha is strongly degraded on a world scale. For this area—about the size of India—restoration to original productivity can only be achieved through major investments and engineering works. The terrain has virtually lost its productive capacity. More than 40% of this strongly degraded terrain is in Africa and 36% is located in Asia. Water erosion alone accounts for 224 M ha strongly degraded terrain, followed by chemical deterioration of the soil (43 M ha), mainly as a result of loss of nutrients and salinization.

Table 5. Global extent of the degree of soil degradation for the major types of soil degradation

	Light	Moderate	Strong + extreme	Total
Water	343	527	224	1094
Wind	269	254	26	549
Chemical degradation	93	103	43	239
Loss of nutrients	52	63	20	135
Salinization	35	20	21	76
Pollution	4	17	1	22
Acidification	2	3	1	6
Physical degradation	44	27	12	83
Total	749	911	305	1965

A much larger portion of the earth surface –more than 900 M ha– has a moderate degree of human-induced soil degradation. By definition this terrain is still suitable for use in local farming systems but has a serious decline in productivity. However it can be restored to its original productive capacity. This category needs the full attention of national decision makers. If no efforts are undertaken to rehabilitate this moderately degraded land, one may fear that a major portion of this land will further deteriorate to the point where may become unreclaimable. Water erosion is again the main type of soil degradation, occurring on more than 500 M ha, followed by wind erosion on some 250 M ha. Loss of nutrients and/or rapid loss of organic matter in the topsoil occupies an area of over 60 M ha. About one third of this moderately degraded terrain is found in Asia, about 20% is located in Africa, and 12% in South America. Deforestation is the major cause of soil degradation in this moderately degraded portion of the earth surface (38%), followed by agricultural mismanagement (28%) and overgrazing (25%).

A significant portion of the earth surface –750 M ha– is now slightly degraded, characterized by somewhat decreased productivity, but farmers can restore the terrain to its full productivity by some modification of their management. Water and wind erosion are also the major types of soil degradation in this slightly degraded terrain, respectively 343 M ha and 269 M ha. This slight degree of soil degradation occupies 295 M ha in Asia, 174 M ha in Africa and 105 M ha in South America. In Oceania, more than 95% of the degraded soils are slightly degraded.

4.3 SOIL DEGRADATION AND CAUSATIVE FACTORS

The GLASOD map recognizes five different types of human intervention that has caused the soil to degrade to its present status: deforestation, overgrazing, agricultural practices, overexploitation of the vegetative cover and bio-industrial and industrial activities. Table 6 illustrates the global and continental extent of each causative factor, while Table 7 shows how each causative factor is related to the type of soil degradation.

Table 6. Causative factors of human-induced soil degradation in M ha

	Deforestation	Overexploitation	Overgrazing	Agricultural activities	(Bio)industrial activities
Africa	67	63	243	121	+
Asia	298	46	197	204	1
S. America	100	12	68	64	-
C. America	14	11	9	28	+
N. America	4	-	29	63	+
Europe	84	1	50	64	21
Oceania	12	-	83	8	+
WORLD	579	133	679	552	23

More than 50% of the degraded soils caused by deforestation are found in Asia, and it is the dominant causative factor of soil degradation in South America. In Africa, the major causative factor of soil degradation is overgrazing. Agricultural mismanagement is an important causative factor in Asia and Africa, and is the most important cause of soil degradation in North America. In Oceania, overgrazing is the dominant cause of soil degradation. While (bio)industrial activities are a relatively minor problem of soil degradation worldwide compared to other causative factors, it is important to note that out of 23 M ha worldwide, 21 M ha are located in Europe.

Deforestation, overgrazing and agricultural activities are all main causes of water erosion, mainly as a result of exposing the soil to the aggressive forces of rainfall or as a result of cultivating on steep slopes without proper anti-erosion measures. Overgrazing is the major cause of wind erosion by exposing the fragile soil to the aggressive force of wind. Agricultural activities such as improper water management in irrigation schemes, insufficient application of fertilizers are major causes of chemical degradation. Also deforestation, leading to a rapid decline of organic matter in the topsoil is an important cause of chemical degradation. Obviously (bio)industrial activities are the causative factor of soil pollution. Physical degradation is mainly caused by agricultural activities (heavy machinery) and to a certain extent by overgrazing (trampling by cattle).

Table 7. Type of soil degradation and causative factors worldwide in M ha

Type of soil degradation	Causative factor				
	Deforestation of natural vegetation	Overexploitation	Overgrazing	Agricultural activities	(Bio)industrial activities
Water erosion	471	36	320	266	-
Wind erosion	44	85	332	87	-
Chemical degradation	62	10	14	133	23
Physical degradation	1	+	14	66	-
WORLD	579	133	679	552	23

4.4 SOIL DEGRADATION AND LAND USE

Although the statistical information derived from the GLASOD map does not give direct information about the relationship between land use and human-induced soil degradation, the types of human intervention that have caused the soil to degrade to its present status are all related to extensive land use activities (except the (bio)industrial activities). Therefore the human-induced soil degradation figures may be linked to agricultural land use (permanent agricultural crops or arable land), to grazing land (permanent pastures) or to forest and woodland.

The statistics reported in FAO's production yearbook series give information on five categories of land (FAO, 1990):

- Arable land refers to land under temporary crops, temporary meadows, land under market and kitchen gardens and land temporary fallow. Soil degradation as a result of mismanagement of agricultural practices directly relates to this land.
- Land under permanent crops refers to land cultivated with crops that occupy the land for long periods. It excludes land under trees grown for wood or timber. Also in this portion of the land agricultural activities may lead to soil degradation.
- Permanent pasture refers to land used permanently for herbaceous forage crops, either cultivated or growing wild. Overgrazing of these areas may lead to soil degradation.
- Forest and woodland refers to land under natural or planted stands of trees, whether productive or not, and includes land from which forests have been cleared. Deforestation and overexploitation of the vegetative cover are the main human-induced factors that cause soil degradation in this category.
- Other land includes unused but potentially productive land, wasteland, urban land, barren land, parks, etc. Since this land includes unused land, it is not affected by human-induced soil degradation.

4.4.1 *Soil degradation on agricultural land*

The total agricultural land includes land under permanent crops and arable land. According to FAO this area occupies 1475 M ha. The total area affected by human-induced soil degradation as a result of agricultural mismanagement of the land occupies around 560 M ha., including an estimated 10 M ha of agricultural land in Europe which is affected by (bio)industrial activities. The implication is that, worldwide 38% of the agricultural land is affected by human-soil degradation. It is also known that of this 560 M ha, about 285 M ha is moderately degraded. This implies that around 20% of the agricultural land worldwide is moderately degraded (around 6% is strongly degraded). Table 8 illustrates the percentage agricultural land affected by human-induced soil degradation for each continent. In Central America almost 75% of the agricultural land suffers from soil degradation, while 65% of the agricultural land in Africa is affected.

Table 8. Global and continental extent in M ha for agricultural land, permanent pasture, forest and woodland, and the portion of these areas affected by human-induced soil degradation

	Agricultural land			Permanent pasture			Forest and woodland		
	Total ¹	Degraded	%	Total ¹	Degraded	%	Total ¹	Degraded	%
Africa	187	121	65	793	243	31	683	130	19
Asia	536	206	38	978	197	20	1273	344	27
S. America	142	64	45	478	68	14	896	112	13
C. America	38	28	74	94	10	11	66	25	38
N. America	236	63	26	274	29	11	621	4	1
Europe	287	72	25	156	54	35	353	92	26
Oceania	49	8	16	439	84	19	156	12	8
WORLD	1475	562	38	3212	685	21	4048	719	18

¹ Source: FAO, 1990

4.4.2 Soil degradation on pasture land

The total area under permanent pasture worldwide accounts for 3212 M ha according to FAO (1990). Although a major portion of the rangeland area is affected by vegetation degradation, the GLASOD data refer only to human-induced soil degradation. Overgrazing is the obvious causative factor leading to soil degradation, although it may be assumed that in Europe around 20% of the area affected by human-induced (bio)industrial activities (4 M ha) also has affected the pasture land. This implies that worldwide, around 685 M ha of permanent pasture land is affected by human-induced soil degradation or around 21%, of which almost 40% (271 M ha) is moderately degraded. Table 8 illustrates the percentage of the permanent pasture land degraded for each continent. A relative large proportion of the permanent pasture land affected is in Europe (36%) and Africa (31%), while on the other continents between 10% and 20% is degraded. It should be noted that Dregne *et al.* (1991) estimated that 73% of the dryland rangelands worldwide are desertified, which implies soil and vegetation degradation in the dryland zone.

4.4.3 Soil degradation on forest and woodland

Deforestation and overexploitation of the natural vegetative cover for domestic use are the major causative factors for human-induced soil degradation in forest and woodland. FAO (1990) estimates the total area worldwide on forest and woodland in 1989 to be around 4049 M ha. The total area affected by soil degradation in the forest and woodland is around 719 M ha. This implies that around 18% of the forest and woodland is affected by human-induced soil degradation, of which almost 50% (348 M ha) is moderately degraded. Table 8 illustrates the percentage of forest and woodland for each continent, which is affected by soil degradation. Soil degradation in the forest and

woodlands of Central America is relatively large (36%), but it has affected around 25% of the forest and woodlands in Asia and Europe. Soil degradation caused by deforestation and overexploitation of the vegetative cover in South America is observed on 'only' 13% of the forest and woodland.

5 Concluding remarks

An overview is given of the global extent of the deterioration of the soils as a result of human intervention. Although soil degradation was and is recognized as a serious and widespread problem, its geographical distribution, total areas affected and the severity of the problem was only very roughly known. In 1974, Biswas and Biswas (1974) estimated that already some 10% of the world's arable land was despoiled by human activities. The GLASOD figures indicate that almost 40% of the agricultural land has been affected by human-induced soil degradation, and that more than 6% is degraded to such a degree that restoration to its original productivity is only possible through major capital investments. Rehabilitation to the original productivity is possible on the lightly and moderately affected soils. However, GLASOD does not provide the essential elements to determine the state of soil resilience. It may however help to indicate where soil rehabilitation is possible. In setting priorities for rehabilitation in differently affected degraded areas, convincing arguments may exist for intervention in strongly degraded areas if human populations have to be supported for humanitarian reasons. However, for sustainable economic and agricultural development, stabilizing inputs would have to be primarily in moderately degraded areas (UNEP, 1992b).

Rehabilitation of degraded land can only be done effectively if the characteristics of the land are well defined and quantified. There is a pressing need for a system which can store detailed information on natural resources of all kinds in such a way that this information can be accessed and combined in order to analyze each combination of land, water, vegetation and population which exists within a country or a region from the point of view of potential use, in relation to food requirements, socio-economic factors, environmental impact or conservation. The International Society of Soil Science, in a joint effort with ISRIC, UNEP and FAO, has developed an international concept for a World Soils and Terrain Digital Database – SOTER. Once created, SOTER would provide the necessary ingredients for a wide variety of soil and land development related issues. As pointed out by Higgins (pers. comm., 1990): 'Only through development and application of such techniques can we catalyze the required breakthrough in land resource use, which is essential to halt and reverse current soil degradation in developing countries'.

GLASOD had as its main objective to increase the awareness of policy-makers and decision-makers of the dangers resulting from inappropriate land and soil management. A computerized land resource information system has now become a prerequisite for policy formulation, development planning at all levels, efficient use of both internal and external resources, and for the implementation of a programme for soil resilience and sustainable land use.

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