THE EUROPEAN SOIL RESOURCE

Current status of soil degradation
causes, impacts and need for action

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EXECUTIVE SUMMARY

In this report the current situation in Europe with regard to human-induced soil degradation and soil protection is examined. The Global Assessment of the Current Status of Human-induced Soil Degradation (GLASOD), prepared by ISRIC in cooperation with UNEP in 1990, is taken as a basis for this review.

In the **Introduction**, a review of past and present trends and developments in soil conservation and soil protection, as well as a brief explanation of the methodology and sources used are given.

In **Chapter I**, the most frequently used terms and some important principles are explained. Then the current situation with regard to soil degradation in Europe is assessed Thematic maps derived from the GLASOD map are inserted as illustration to the text. The processes, causes and effects of the various degradation types are examined. A summary is presented of existing databases and monitoring systems related to soil problems in Europe. Finally a range of measures taken (or to be taken) to prevent or repair damage from human-induced soil degradation are presented. This involves both technical, legal and "economic" measures.

Chapter II evaluates the existing criteria and threshold values used in European soil protection policies. The complexity of fixing values is addressed with specific reference to three types of soil degradation, namely pollution, erosion and salinization. A brief overview per country is given.

The major conclusions are summarized herewith:

a) Soil degradation is a serious problem in Europe, both in terms of severity and irreversibility; in particular erosion by water and to a lesser extent by wind, pollution, compaction and perhaps urbanisation.

b) Research is mostly focused at soil erosion and at soil pollution. Monitoring programmes also exist either as part of an overall environmental programme or as a single theme. There is no integrated research or monitoring programme into soil degradation at a European level.

c) Technical measures are mostly taken on a short term basis and are aimed at repairing damage rather than at prevention. Also, a sectoral rather than an integrated approach prevails.

d) Legislation on soil protection and economic measures are common, but in many different forms. Some laws are preventive, others rehabilitative. Some countries put more emphasis on law enforcement and taxes, others on codes of practice and incentive measures, but combinations of both are quite common.

e) Criteria and standard values are relatively common with respect to soil pollution, but less so or even non-existent for other types of soil degradation. Neither values nor terminology are standardized between countries

In Chapter III recommendations for a pan-European approach to the problem of soil degradation and soil protection are given. These can be summarized as follows:

a) A detailed assessment of all aspects of current soil degradation in Europe should be made, including trends shown by recent changes. Objective values should be obtained as to how critical the situation is, since its perception may vary from country to country.

b) A detailed assessment should be made of soil vulnerability to all aspects of soil degradation in Europe, and the most sensitive areas to soil degradation should be identified.

c) An extensive review of existing measures, techniques, legislation and economic measures to counter soil degradation should take place.

These three projects should be carried out more or less simultaneously and in relation to each other. The fulfilment of these objectives involves an immense task, but some initiatives that partly cover one or more of the three modules have already been proposed or are now in state of development.

These efforts could be combined and coordinated with other similar projects to achieve the aforementioned goals.

Chapter IV outlines the requirements for the development of a European soil protection database. A Soil Protection Database would provide essential elements for the formulation of appropriate national soils policies on the basis of sound scientific information. For several countries assessments have been made at a national scale. If the information were gathered in an agreed form and combined into a European database, more detailed and more quantitative information on human-induced soil degradation on a pan-European basis would become available. This would allow the development of international policies to combat the problems.

Other measures that can be taken at a European level concern matters like the coordination of monitoring and research and to some extent also of legislation and economic measures.

INTRODUCTION

1 GENERAL BACKGROUND, HISTORICAL OVERVIEW, JUSTIFICATION

Unlike many other environmental problems, soil degradation is not a recent phenomenon. Throughout history, human beings have influenced and changed the environment worldwide, including the soil. These changes were sometimes deliberate and beneficial, as in the case of the Dutch "eerdgronden" and northwestern European "plaggen", where favourable soil conditions were created through repeated additions of organic matter over a prolonged period. In other cases, changes were not intended and were damaging to the soil, for example by using agricultural practices which caused or enhanced soil erosion. This degradation was so severe that the decline of whole civilizations such as in Mesopotamia, or the Roman Empire has been, at least partly, attributed to declining soil productivity *(71,84)*. At several places in the Mediterranean region, the soil has disappeared completely. The removal of forest and overgrazing has resulted in soil erosion leaving only bare rock. Early civilizations were almost entirely based on agriculture, and they depended upon healthy and productive soils for their existence. In Europe, agriculture and forestry remains far the most widespread landuse, though economically its relative importance has changed.

However, if soil degradation is an old phenomenon, so is soil conservation. In Latin America, the Inca people were very much aware of the hazards of soil erosion, as is still shown by their stone terraces on the slopes of the Andes. Other examples of spectacular traditional soil conservation are the bench terraces in Nepal or the rice terraces of Luzon in the Philippines. Even the much criticized traditional system of shifting cultivation system which is still practised in many parts of the world, can be considered as a kind of soil conservation, because the soil is given a chance to regain its natural fertility after a few years of cultivation. In Europe measures have been taken to prevent soil degradation, in particular soil erosion. Examples are the "Bocage" landscape in France and the "graften" in S. Limburg, the Netherlands. Although these measures were not always taken simply to prevent erosion, the small fields effectively restricted erosion. An example of conservation of fertility is the development of the "three field" system in medieval Europe in which a fallow was taken every third year. The addition of organic manure, and the folding of sheep on root crops, was a practice developed in England in order to maintain the fertility of the soil. Only within the last few decades have additions of organic wastes become a problem as their composition has changed and their volume increased.

Soil degradation is a more serious and also a more complex problem than it used to be. It has been estimated that in Europe, 72000 km^2 (25%) of all agricultural land, 54000 km^2 (35%) of all pasture land and 26000 km^2 (92%) of all forest and woodland is affected by some kind of soil degradation *(66)*. Awareness of this developing problem has been growing rapidly over the last decade. Whereas in historical times soil erosion through water and wind was the major culprit, and still is a quite important in some localities, other forms of physical and chemical degradation have recently emerged. Several factors have contributed to this.

Increasing population has exerted pressure on the soil by requiring ever more land for buildings and other infra-structural works and space for recreation. This has often been the level, well drained land most suitable for crops. There has been also a growing demand for more and better quality food. The ensuing *intensification of agriculture* has led to increased and sometimes excessive applications of mineral fertilizers, manure and pesticides. The use of more powerful, heavy machinery has led to compaction, loss of structure, and so indirectly to erosion. Larger field sizes have also increased the erosion risk. It has been pointed out *(63)* that *de*population of rural areas may also result in soil degradation, for instance through lack of maintenance of soil conservation structures.

The *industrial revolution* brought about not only the production of consumer goods but also an increased production, directly or indirectly, of wastes and refuse materials. In many cases these materials were, and sometimes still are, spread on the soil, or concentrated in refuse dumps. The potentially serious consequences of these practices have been perceived only recently. Until one or two decades ago in many countries, perhaps still in some others, dumping of municipal refuse and waste materials or residues from factories took place without any form of control. After these sites were filled and covered with "new soil", houses, playgrounds, and sports fields were built on top of them. In many cases no positive preventive anti-pollution measures were taken to contain the toxic wastes. One or two decades later a growing number of sites are being discovered, where soil, groundwater and the atmosphere have been severely polluted by chemical substances. Either dispersed or concentrated forms of pollution, may not be noticed for several years, either because of the slow rate of reactions or because effects suddenly become apparent due to the "Chemical Time Bomb" effect *(80)*. This concept implies a sudden release of hazardous substances, which until certain changes in the environment took place were "safely" stored in the soil.

Although "soil degradation" would appear fairly site-specific, which is true for the actual *processes* taking place in and on the soil itself, the *causes* and *impacts* are often of a trans-boundary character. Polluting compounds from industrial and other sources may be transported over long distances before they are deposited on the soil and actually cause degradation. On the other hand, erosion may have impacts away from the site where the actual erosion takes place, for instance through pollution and siltation of rivers and coastal waters by the transported sediments. Many aspects of soil protection therefore necessitate an international rather than a national or local approach. Nevertheless, with regard to the sensitivity of ecosystems to acidic depositions, a concept has been suggested *(24)* of tailoring protection measures to site specific conditions. Some sites are less sensitive to degradation than others and therefore need less protection. This may enable better use of limited resources in a European approach, which of necessity cannot consider all local parameters and differences.

Another aspect of soil degradation is the wide variety of the types of degradation and the links between them. Links between the different types, for instance between erosion and pollution, are often not very obvious and consequently different degradation problems may be treated separately when a combined approach would be more economical. This document gives a global overview of the European situation with regard to the different types of soil degradation and the measures that have been taken or that need to be taken to control them. It does not, and cannot pretend to be exhaustive, but it highlights the major difficulties which are associated with soil conservation/protection in Europe and gives some recommendations to curb these problems.

2 *METHODOLOGY, SOURCES*

The map of the Global Assessment of the Status on Human-Induced Soil Degradation (GLASOD) has largely served as a basic reference document for the present report. The different types of soil degradation presented in this map, together with a few other types regarded as relevant in the European context have been considered. The relevant causative factors were studied in relation to the processes and their impacts on the environment and on society.

In order to collect as much relevant information as possible in the time available a circular letter containing a brief questionnaire was sent to the members of the Group of Soil Conservation Experts of the Council of Europe. This questionnaire was also sent to some 50 scientists all over Europe that had previously been involved in the preparation of the GLASOD map or other ISRIC activities. The response was variable and so detailed comparisons between individual countries should not therefore be made. Nevertheless, the conclusions and recommendations based on this information and other literature *(see annex III)* are considered relevant and valid at a European level.

CHAPTER I - CURRENT STATUS OF HUMAN INDUCED SOIL DEGRADATION IN EUROPE AND PRACTICAL COUNTERMEASURES

1 DEFINITIONS AND PRINCIPLES

In order to avoid confusion, some of the terms used frequently in the following chapters are defined in the next section.

1.1 Soil

Soil is a complex medium which displays a great diversity in physical appearance, in chemical processes, and in the flora and fauna present. Soil is necessary for the growth of commercial crops of food and fibre and it is an essential component of terrestrial ecosystems. Consequently, the role of the soil is of vital importance to mankind and the maintenance of a healthy natural environment. It is an indispensable resource for life on earth and it must be conserved for future generations.

Definitions of the term "soil" are abundant in literature. For the purpose of this study the concept of soil as adopted by the Council of Ministers in 1990 *(26)* is used:

> "Soil is an integral part of the Earth's ecosystems and is situated at the interface between the earth's surface and the bedrock. It is subdivided into successive horizontal layers with specific physical, chemical and biological characteristics and has different functions. From the standpoint of history of soil use, and from an ecological and environmental point of view, the concept of soil also embraces porous sedimentary rocks and other permeable materials together with the water which these contain and the reserves of underground water."

When treating problems of conservation and pollution it is often necessary to take a wider view of soil than that of the pedologist. In many cases the concept of *land* (which include above-ground activities and factors) rather than soil in the strict sense is considered. The definition given above meets this consideration.

1.2 Soil Conservation

The term "soil conservation" is most frequently used in the context of measures and techniques to protect the soil against the effects of only one specific type of degradation, namely (accelerated) soil erosion. In many countries "soil conservation" in this context also includes the concept of water conservation. Erosion often follows deforestation, overgrazing, construction of roads, buildings, or inadvisable agricultural practices.

In the context of this book it is important to note that soil conservation covers many types of soil degradation, not only erosion by water and wind, but various types of chemical and mechanical degradation as well. Consequently, soil conservation will be interpreted here in a broad sense, i.e. the protection and rehabilitation of soils affected by various types of human induced degradation. The specific types of soil degradation in Europe will be discussed later in this chapter, together with their spatial distribution and underlying causes.

1.3 Definition of Soil Degradation: Soil quality, soil functions

Soil degradation is directly related to soil quality. However, soil quality, and soil degradation, are subjective terms, related to the actual or intended use of the soil by man. For example, a soil with low quality (or *suitability*) for agriculture may be quite suitable for construction activities. Therefore it is useful to determine the different potential *functions* of the soil. Three functions can be distinguished that are mainly ecological, and three functions that are more related to human activities *(26)*:

Ecological functions:

* *Biomass production* (nutrient, air and water supply, root support for plants), providing food, (renewable) energy, raw materials and natural features (e.g. forests provide an important habitat for many species).
* *Filtering, buffering, storage and transforming functions.* For instance buffering and storage of (rain)water, filtering, buffering and retention of pollutants.
* *Biological habitat and gene reserve*: fauna and flora in the soil are not always as apparent and spectacular as life on top of it but they are certainly rich and also indispensable for the "surface" species.

Human activity related functions:

* *Physical medium*: the soil functions as a spatial base for technical and industrial structures and socio-economic activities: buildings, roads and railways, sports fields, recreation areas, waste dumps and deposits, etc.
* *Source of raw materials*: e.g. water, gravel, sand, minerals.
* *Geogenic and cultural heritage*: soils form part of the landscape and thus hold important geological and geomorphological information. They also preserve historical information in the form of palaeontological and archaeological materials.

With respect to the storage and filtering capacity of the soil, the soil may perform in four different ways, depending on both the soil properties and the characteristics of the input substance: *(79,86)*.

as an **inert matrix:** the soil functions as a "neutral" transport medium between the surface and (for example) the groundwater without further effects on the soil itself;
as a **sink:** the materials are retained and accumulate in the soil (e.g. water; heavy metals, persistent pesticides, nitrogen in non-nitrogen saturated soils, hydrocarbons, radioactive isotopes);
as a **source:** the soil releases certain substances, often triggered by the input of other material(s) (e.g. Base cation or Aluminium release equivalent to acid input, Cationic acids idem, stabile Nitrogen & Sulphur gaseous compounds released into the air, eg. NO_2). Emission of "greenhouse gases" (NH_4, CO_2) from the soil contributes to global warming *(17)*.
as a **transforming medium:** organic and inorganic substances may be broken down or transformed in the soil so as to "neutralize" certain hazardous materials but this may generate other harmful substances.

The filtering or buffer function of the soil is determined by the presence of basic cations sodium (Na), calcium (Ca), potassium (K), and magnesium (Mg) derived from weathering of clay minerals in the parent material. This buffer capacity is the ability of the soil to neutralize to a certain level external inputs such as the acidifying pollutants which displace the basic cations from the soil. When the input of these substances is faster than the formation of new cations from weathering, the buffer capacity will be exhausted and pollutants will begin to leak into the ground water. Environmental changes may reduce suddenly the capacity of the soil to store pollutants - the chemical time bomb effect. The soil thus first acts as a **sink** in which the pollutants are accumulated with only indirect effects (leaching of nutrients) until the buffer capacity is depleted and then the soil will turn into a **source** *(79)*. Micro-organisms are responsible for decomposition of certain substances, such as sulphate and nitrate *(24)*.

Soil degradation results from the competition between the aforementioned soil functions, but the excessive misuse of a single soil function may also be to the detriment of the others *(13)*. In some countries, e.g. the Netherlands, the view is therefore taken that soil quality, and degree of degradation, should be assessed from the view of the multi-functionality of the soil, i.e. its potential to support as wide a variety of uses as it would be able to support in its undisturbed state, in order to "keep all options open for future generations" *(61)*. For the purpose of the Global Assessment of the Current Status of Human Induced Soil Degradation (GLASOD), human-induced soil degradation has been defined as: *"a process that describes human-induced phenomena which lower the current and/or future capacity of the soil to support human life" (66)*.

1.4 Soil degradation: processes, soil sensitivity, impacts

1.4.1 Soil degradation processes

The contents of this document will focus on soil degradation resulting from human activities. A significant number of processes occur under natural conditions as well, but in these cases lead to a relatively slow deterioration of soil properties, as part of natural soil formation processes. A clear example of this is erosion by water, a phenomenon occurring in principle in all areas with relief. Other processes that occur naturally are wind erosion, acidification, salinization, subsidence and waterlogging, and sedimentation. Pollution is inherently a type of chemical deterioration that is most closely tied to human activities and other forms of pollution are rare. If the degradation processes take place at a pace which does not exceed the rate of soil formation or regeneration, no serious problems will occur, or they may even have positive consequences. Countries like the Netherlands owe their existence mainly to sediment deposition resulting from erosion of soils in the upstream areas. When erosion runs out of control through human mismanagement the results can be disastrous. Unless adequate forest cover is maintained on the watersheds and soil conservation is practised in agricultural areas, this could occur in Europe as well.

The following major types of soil degradation processes can be distinguished:

* displacement of soil material (erosion) from the soil profile and sedimentation elsewhere
* in-situ deterioration by chemical, physical and/or biological processes (no physical displacement of material from the soil profile involved)
* a special type of degradation is to exclude the soil from its natural functions by covering it with asphalt, concrete and buildings. This type of soil degradation is associated with construction, urbanisation and related activities.

The degradation processes that are either caused or enhanced by man will be discussed in more detail below (§ 2.3 - §2.10).

1.4.2 Soil sensitivity/vulnerability; "renewability" of soils, reversibility of degradation processus

The damage inflicted on a soil by degradation depends first of all on the type of degradation processes involved and secondly on the "sensitivity" or "vulnerability" of the soil to the action of a specific process. This relates to the response of the soil to certain changes in its environment, such as the influx of pollutants. "Sensitivity" may be defined as the rapidity with which the soil succumbs to the tendency for the soil to deteriorate under the influence of "anthropogenic activities" *(37)*. The factors that determine the sensitivity of the soil are given below for the respective types of degradation (§ 2.3 - §2.10.). "Vulnerability" was defined as the "capability for the soil system to be harmed in one or more of its ecological functions" *(11)*.

Soil can be considered as a partly renewable resource. "Renewable", because under the influence of climate, flora and fauna, soil is slowly but constantly being produced by weathering of underlying rock or sediments together with biological activity in the soil. "Partly", because the process of soil formation is very slow and variable.

An important aspect is the strength of the degradation process: can a damaged soil regenerate, and if so, in what length of time? With respect to the sensitivity of entire ecosystems an arbitrary limit of at least 50 years has been suggested for the concept of "long term harmful effects" *(24)*. At present rates of erosion, considerable areas in the Mediterranean and the Alpine areas, which are currently not considered at risk may reach a stage of "ultimate physical degradation", beyond a point of no-return, within 50-75 years *(62)*. Some smaller areas have already reached this stage The reversibility of soil degradation is site specific as it is dependent on soil properties, the type and severity of degradation and the tendency of the degradation to increase or decrease. This reflects the importance of past, current, and expected rates of degradation. The following impacts of soil degradation may be considered to be irreversible *(13)*: *soil loss* through sealing, stripping, mining and erosion, *soil contamination* by heavy metals from atmospheric deposition, waste disposal and agricultural inputs and by radioactive compounds with long half-life periods, and *when through acidification* an advanced stage of decay of soil constituents is reached. Reversible damage includes: contamination by *some organic compounds* from air emissions and agricultural sources, and *soil compaction*, though examples of irreversible damage through deterioration of soil structure have been cited *(7)*. Furthermore, damage caused by *salinization*, or the effect of *depletion of nutrients and organic matter* is, technically at least, repairable.

1.4.3 *Impacts, interaction and combined effects of degradation processes*

Degradation processes may have different impacts *(105)*:

Loss of volume caused by erosion, compaction, induration, flooding;
Deterioration of structure induced by erosion, mechanical breakdown, salinization, flooding, loss of organic matter, raindrop impact, ;
Loss of organic matter and biological activity as a result of erosion, exhaustive soil management, excessive drainage;
Loss of chemical equilibrium through chemical degradation caused by leaching, acidification, salinization, carbonation, pollution, unbalanced fertilization, erosion, deposition;
Loss of soil fertility brought about by erosion, leaching, fixation, volatilization, exhaustive soil management.
Off-site effects such as excessive sedimentation/burying and flooding of downstream areas.

This review indicates the relative prominence of erosion amongst the processes of soil degradation, as well as the important relationships between the various types of degradation.

In nature, soil degradation processes do not necessarily operate in strictly separate compartments from each other and interactions may occur with one type of degradation leading to another. For example, compaction may cause biological degradation, erosion can lead to pollution. Furthermore, the combined effects of several degradation processes or different causative factors may lead to an accumulated impact. A case in point is the combined effect of eutrophication of water bodies and soil by nitrogen and phosphorus from various sources such as manure, mineral fertilizers, atmospheric deposition and also from erosion and leaching in upstream areas. Plant nutrients are taken from the soil during harvesting, but losses also occur through leaching and erosion. At the same time, the erodibility of the soil is increased by a lower organic matter content.

A special type of interaction and/or combined effects is the so-called "Chemical Time Bomb" (see above) indicating the delayed triggering of a process (release of pollutants) under the influence of another degradation process (changes in the soil environment caused by erosion, waterlogging etc.) or substance (influx of other pollutants).

In the study of soil degradation and in the search for remedies, the possibility of interaction should be kept in mind. Of course, other processes may also interact with soil degradation, climate change is an important example. Changes in precipitation, for instance, will influence soil moisture and the water table and together with changes in temperature this may affect biological activity in the soil. Modified rainfall patterns will have influence on the occurrence and severity of erosion *(21)*.

2 *THE CURRENT STATUS OF HUMAN-INDUCED SOIL DEGRADATION IN A EUROPEAN CONTEXT*

2.1 Degradation maps

The processes and factors influencing soil degradation will vary greatly in extent and intensity with the different degradation types. The heterogeneity of soils also provides a range of sensitivity or vulnerability to the respective degradation processes. The resulting geographical variability of the degradation types is shown on the maps 1- 4, derived from the World Map on the Status of Human-Induced Soil Degradation, GLASOD (see annex I and *(66))*. This map is taken as the basis for the following assessment of soil degradation in Europe. Although being the best currently available information, the maps shown here merely serve as illustration and should not be used for detailed evaluation of soil degradation at a national or regional scale. A soil degradation assessment for Europe at a larger scale and based on objective and quantitative data would hence be highly relevant

The maps clearly show that degradation by water erosion is occurring in most parts of Europe (53% of the total degraded surface area), the exception being flat lands and "Stable" areas. For large regions of Europe wind erosion appears to be much less of a hazard than water erosion. However, wind erosion occurs in 19 % of the total area affected. Human-induced chemical deterioration, is heterogeneous, random and widespread (26000 km^2 or 12 % of total area). Pollution, in its various forms and intensity (see Annex I for the definition of "pollution" in this context) is undoubtedly the most common subtype of chemical deterioration (72% of total chemical degradation, or 8.5% of the total area affected by degradation). Physical deterioration is significant, in particular compaction (90% of all physical deterioration), poses problems in at least 15% of all degraded soils in Europe.

Not all degradation types discussed in this document are shown in the separate degradation maps, as they could not be derived from the original GLASOD map.

2.2 Causative factor maps

A distinction is made between "inherent" and "causative" degradation factors, the former being the soil properties and environmental factors which directly control the sensitivity of the soil to a certain degradation process, whereas the latter concerns the underlying cause of degradation (type of land use, agricultural practices).

The inherent factors are strongly linked to the geographical distribution of the soils and are also closely related to the different degradation types. The causative factors on the other hand can be displayed independently of the degradation types, as in the maps 5-7.
Although no direct relationship with the respective degradation types could be shown on the maps, some fairly reliable assumptions can be made. Agriculture and overgrazing, together with deforestation are assumed to be the prime cause of soil erosion *(64)*. Agriculture on arable lands also has major effects on physical and chemical deterioration (compaction, waterlogging, contamination with pesticides and mineral fertilizers, and through over-application of manure, etc.) *(10)*. Overgrazing (23 % of the total degraded area, or 50 m. ha) appears rather closely associated with wind erosion, as in the case of Iceland *(38)* and Southeast Russia *(54)*. The main impact of industrial activities, transport, urbanisation and other related activities is pollution *(10)*. The spatial importance of these causative factors may be underestimated from the map of "Industrial Activities", because of the significance of industrial and urban point pollution, as well as the removal of soils from a biological role by construction, surface sealing and land dereliction none of which can be displayed at this scale.

It is clearly shown that in terms of the area affected, deforestation and agriculture are the most important causative factors of soil degradation in Europe. They affect 38 % (84 m. ha) and 29 % (64 m. ha) respectively of the total degraded area. Furthermore, a distinct regional difference can be noted between agriculture- and deforestation-induced degradation respectively, the former occurring chiefly in W. and N. Europe, the latter being more restricted to Eastern Europe and mountainous areas in S. Europe. One partial explanation for this is the practical lack of large forests in W. Europe. A similar map for the situation a few centuries ago would have looked quite different!

The occurrence of industry-induced degradation (9.5% of the total degraded area or 21 m. ha) merits some explanation. It is obvious that the major urban areas and the heavily industrialized regions of W. and C. Europe may produce various types of "local" pollution. The large extent of industry-induced degradation in Scandinavia, however, must be attributed to long range transboundary air pollution from the industrial regions, rather than to local sources.

The maps are derived from the GLASOD map and consequently problems of scale and correlation with specific types of degradation, as mentioned above, should be taken into consideration. Nevertheless the maps present a useful general image with regard to the relative importance of the respective types of human impacts.

For the sake of clarity, the respective types of soil degradation will be treated individually in the following paragraphs, together with the factors, causes and impacts that determine their inherent sensitivity.

2.3 Water erosion

Erosion involves the **displacement of material** and its deposition elsewhere. This also includes some cases of mass movements, which are influenced by the presence of water. Erosion is a process which in natural conditions with a good vegetation cover causes minimal damage to soils. Catastrophic erosion can be initiated or enhanced by human activities, especially on bare cultivated soils; this is called "accelerated" or "anthropogenic" erosion. The process of accelerated erosion may be 10 to 50 times greater than the "natural" rate. In general, accelerated erosion exceeds the natural rate of soil formation, resulting in a net soil loss. This has both on-site consequences and off-site effects (see below).

The effects of river and coastal erosion are not considered here and therefore the term water erosion refers solely to *rain induced erosion*.

Soil particles are detached by the impact of raindrops on the soil or by running water. When the surface soil becomes saturated with water after lengthy or intense rainfall or the rate of infiltration is inhibited by sealing or crusting of the soil surface, the excess water flows down the slope across the soil surface as overland flow and is able to transport the detached soil particles. When this happens more or less evenly over the land surface, it is called sheet erosion. If surface runoff concentrates in small rills or larger gullies, the scouring action of the flowing water may cause deep channels to develop and the land surface becomes dissected so deeply that the damage may not be easily rectified by normal agricultural implements. Ultimately, the sediment may be transported to the sea.

The *sensitivity* of the soil to water erosion is determined in various degrees by the interaction between:

- soil properties such as texture, structure, organic matter, infiltration rate and moisture content, surface roughness, etc.
- topography (slope length, inclination, form and orientation),
- climate (rain- or snowfall: quantity, distribution and intensity; temperature, evaporation, frequency, drought periods),
- vegetation (type, cover percentage, root-system),
- management practices (none, intensive, conservation practices, etc.).

Fine sandy and silty soils have the highest "erodibility" but alone this does not account for the large areas affected by water erosion (see map 1). This shows that other factors, in particular topography and management practices, are equally if not more important.

Crusting of the topsoil under the impact of raindrops is a process that causes a thin impervious coating to form at the soil surface, closing the pores. This decreases the infiltration rate of water into the soil and so increases surface run-off. Crusting is influenced by a lack of vegetative cover, soil texture, organic matter and aggregate stability.

The on-site *effects* of water erosion usually consist of a decrease in soil depth, hence less rooting depth for the plants, a selective removal of fine soil material and removal of plant nutrients, and in more severe cases the uprooting of plants and/or trees and dissection of the terrain by rills and gullies. Water erosion may cause serious loss of fertile topsoil at a rate of up to several mm/ha/yr. The proportions of nutrients, organic matter and clay/silt particles in the transported sediment is generally higher than in the material from which the sediment was derived and the remaining soil material becomes less fertile. Erosion also disturbs the hydrological equilibrium between runoff and infiltration. Subsoil materials have a lower infiltration rate, and so the capacity of the soil to buffer high amounts of rainfall is reduced and peak discharges will increase. The lower water holding capacity of the soil leads to a decrease in crop yields which may be quite significant, though in the current European conditions not always clearly visible due to other, yield increasing, agricultural practices *(63)*. Severe soil erosion may be considered to be an irreversible degradation process as the rate of degradation is significantly higher than the rate of renewal. The possibility of regeneration depends on several factors, such as the extent of the damage, the type and amount of soil remaining, parent material, vegetation, climate, and of course the rate of soil formation, which is determined by the background environmental factors.

Harmful off-site effects of water erosion may consist of land and crops down the slope being covered with a layer of sediment, deposition of eroded material in river beds causing flooding, lakes, reservoirs, and irrigation channels or on roads, railways, etc., pollution of streams (and sometimes coastal waters) by sediment and chemical substances (fertilizer and pesticides). Often the seriousness of this type of damage is recognized more readily than the on-site erosional effects.

A special type of erosion is mass movement. This takes place under the influence of gravity as soil and subsoil move down the slope. This can happen very slowly (soil creep), very fast (avalanches) or at intermediate speeds (slumps, slides). Mass movements cannot be considered as a typical form of water erosion, but they are associated with loss of stability caused by overloading slopes, and so are usually associated with heavy rain or rapid snow melt. Avalanches, rockfall, and soil creep are natural occurrences, not always clearly associated with human activities.

Mass movements often create new landforms, often in spectacular events. This may cause difficulties for farmers and foresters with crop losses, and can cause damage to buildings and infrastructure such as roads, railways, and overhead cables. Mass movements are determined dominantly by physical factors such as slope, soil texture, deeper soil layers or parent material, infiltration rate and moisture content, rather than by human intervention, but the effect of specific land use should not be disregarded *(67)*.

A comparison of the respective maps indicates the importance, in terms of geographical distribution, of water erosion. This type of degradation may occur practically anywhere with sufficient relief if the soil is insufficiently protected by dense vegetation (or synthetic) cover. This is frequently the case under agriculture. The most dominant subtype of water erosion is the damaging loss of topsoil which is often not conspicuous. As explained previously, the physical factors, of climate, topography and soil properties are important in the process of soil erosion. This partly explains the difference between the severe water erosion problem on Iceland, and the virtual absence of erosion in Scandinavia where the climate is less harsh and the soils are less erodible *(38)*. A similar comparison can be made between the northern Mediterranean coasts from Spain to the Adriatic and NW Europe (Netherlands, N. Germany, Denmark), the first region being subject to long dry periods followed by aggressive rainfall on generally steep slopes with fragile soils, as opposed to the well-distributed rainfall on gentle slopes in NW Europe. Here some fragile and eroded soils do occur but erosion is more restricted in its extent. Management aspects play a significant role, either by significantly increasing or decreasing the erosion hazard. In any case, the role and interactions of the different factors that determine the severity of erosion are complex and the interpretations given should be carefully considered. As yet there appears to be no systematic pan-European analysis of the distribution of water erosion and the significance of its various determining factors.

In parts of the Mediterranean region, erosion has reached a stage of irreversibility and in some places soil erosion has practically stopped through lack of soil! With a very slow rate of soil formation, any soil loss of more than 1 t/ha/yr can be considered as irreversible within a time span of 50-100 years. Losses of 20 to 40 t/ha in individual storms that may happen once every two or three years are measured regularly in Europe with losses of more than 100 t/ha in extreme events *(64)*. It may take some time before the effects become noteworthy, especially in the case of more fertile and deep soils or on heavily fertilized soils, but this is all the more dangerous, because once the effects become obvious, relatively little can be done about it.

Agriculture usually has a considerably influence on several of the soil erosion factors, such as soil structure, organic matter content, vegetation, management practices. It therefore plays a major role in the occurrence of both water and wind erosion. Whereas good soil and crop management may reduce the risk and effects of erosion, improper farming practices such as ploughing up and down slopes, poor crop management, untimely farming operations, compaction by heavy machinery, etc. will accomplish the contrary. In some regions, existing conservation structures have even been eliminated for the purpose of mechanization and increasing or decreasing the size of farms. Preventive or protective measures will be discussed later (§ 4).

Overgrazing and untimely grazing has an impact on soils because as the vegetation is destroyed, soil structure breaks down by trampling and the micro-topography may be changed by frequent use of certain tracks causing concentration of run-off water. Another important cause of man-made erosion is *deforestation*. The soil is deprived of supply of organic matter or a root system to help retain the soil.

Construction activities for buildings, roads, etc., are usually a highly underestimated cause of erosion. The soil is often tightly compacted (creating high run-off rates) and/or intensely disturbed and left unprotected for a prolonged period. Tourism in mountain areas also may have a negative impact, especially skiing facilities and paths/trails. The local nature of these causative factors means that they do not feature on the GLASOD maps.

2.4 Wind erosion

Soil particles may be detached and transported by wind. The process is somewhat comparable with that of water erosion, i.e. detachment, transport and deposition of soil particles but in this case the agent is the wind. Here too, removal of topsoil, deformation of terrain, and (off-site) deposition of the soil particles (overblowing, burying) can occur.

Sensitivity to wind erosion is determined to a large extent by similar factors to those discussed for water erosion, especially the presence of a vegetation cover, structure, soil texture, topography, management practices, organic matter content, soil moisture and in this case, wind dynamics *(70)*.

Loss of topsoil is the predominant impact of wind erosion in Europe. The selective removal of material is even more obvious than for water erosion, as only fine particles (clay, organic matter with their adsorbed nutrients) will be transported, leaving an impoverished, coarse textured soil. The off-site effects are air pollution with dust particles, covering of fertile soils and in more extreme cases complete burial and dune formation. Terrain deformation in the form of windblown depressions may occur at small scales as well. Damage through wind erosion is practically irreversible.

The more distinct regional distribution of wind erosion suggests that physical factors, in particular climate, are relatively more critical than human influences than is the case for water erosion. The fairly moist conditions prevailing in Western Europe and storm events often associated with rain (oceanic depressions) diminish the chances of wind erosion. That this is not a general rule, however, is demonstrated by the incidence of severe wind erosion in Iceland and (less severe) in parts of NW. Europe (N. Germany, the Netherlands, E. England). Extensive conservation measures such as wind breaks, have considerably reduced the hazard. The widespread and serious wind erosion in the southeastern part of Europe (S. Russian plain) can be partly explained by the dry continental climate and sensitive soils in combination with inappropriate farming practices *(54)*. Excessive drainage is one prominent cause for conditions that favour wind erosion.

Human activities again play their part in causing wind erosion. *Overgrazing* appears to be a significant causative factor, in part because the areas most sensitive to wind erosion (semi-/arid regions with sandy soils) are less suitable for other types of land use.

2.5 Chemical deterioration

The chemical properties of the soil can be affected in various ways:

2.5.1 Contamination and Pollution

It is important to distinguish between the mere presence of a "contaminating" substance in the soil and its role as a "pollutant" as a consequence of location, concentration and adverse biological or toxic effects. A case in point is the presence in the soil of nitrate or phosphates, which are essential nutrients to plants but only become "pollutants" in excessive quantities.

Soil pollution may occur from a wide range of human activities and can be either from local (point) sources or widely dispersed from diffuse sources. Pollution or contamination may affect the soil via different "pathways", namely airborne, terrestrial or by water. For instance the total heavy metal threat to a soil may emanate from various sources and follow different pathways such as atmospheric deposition or application of sewage sludge.

The same is valid for the pathways *from* a contaminated soil to the environment and human beings. Here the health or environmental hazard may be transmitted from different sources including those not directly related to the soil (e.g. air or water pollution). The contaminants in the soil may follow different pathways or "exposure routes" to human beings and in some cases combine with contaminants from other sources. Possible exposure routes for soil contaminants include *(34,72,98)*:

* direct contact and/or ingestion of the soil (especially by children)
* consumption of contaminated plant and animal products
* consumption of contaminated drinking water
* inhalation of volatile compounds or windblown particles

Various forms of soil pollution can be distinguished, according to either the source of pollution (e.g. point source vs. diffuse), the substance involved (e.g. acidifying compounds/heavy metals/organic substances/pesticides), pathways (see below) and/or impacts (acidification/eutrophication etc.). The GLASOD map, for cartographic reasons, does not distinguish between these various types and mainly concentrates on pollution by atmospheric deposition (e.g. "acid rain"). This does not mean that the other types of soil pollution are not important.

Airborne pollution, usually referred to as "acid rain", involves the deposition on the soil of industrial and traffic emissions of sulphur dioxide (SO_2) and nitrogen (hydr)oxides (NH_x NO_x), which may be many times natural emission levels *(86)*. These substances, when deposited in excessive quantities, are major contributors to soil acidification as the exchangeable base cations (calcium, magnesium, potassium, sodium) in the soil are mobilized under influence of the acidic inputs and leached out to the groundwater. This at the same time includes a loss of some important plant nutrients. When the soil buffer capacity is depleted, the pH will start to drop, reflecting the increasing acidity. With increasing acidity, aluminium ions in the soil are mobilized, which are toxic to most plants and have harmful effects on aquatic environments.

Airborne deposition also contributes significantly to contamination and pollution with heavy metals (see below).

Pollution from direct land application is more diverse than airborne pollution and results from waste disposal, spillage, excessive organic manuring etc., or from contact with pollutants in ground- or surface water. The soil is polluted with substances that are directly toxic for plant- and animal life or that negatively affect certain soil functions or properties. The possibility of interaction of pollutants should not be neglected. Some pollutants may trigger releases of other hazardous substances already present in the soil (e.g. due to earlier deposition), turning a sink into a source. This may happen a considerable time after the input of the original hazardous substance has started or even long after the end of the inputs, especially in the case of persistent chemicals. The metaphor "Chemical Time Bomb" is being used for such processes *(48,79,80)*. Release of chemicals stored in the soil may also be "triggered" by other human induced changes in the soil environment, like pH, temperature, moisture content or water-level, and exceeding of the "critical load", amounts in excess of which are considered to be dangerous.

Heavy metals (either from direct dumping or atmospheric deposition) tend to accumulate in soils of higher pH because they are less mobile than in acid soils. Consequently, lowering the pH will trigger a mobilization of the accumulated heavy metals. Some toxic metals will accumulate mainly in the surface layers due to their low mobility, but others may be leached lower in the soil profile. The humus layer of forest soils is an important sink for PAH (polycyclic aromatic hydrocarbons). A concentration of pollutants tends to take place in the topsoil where most soil organisms live and so the pollutants may enter the food chain *(86)*. As the surface layer is also the first to be removed by erosion, it means that the transported sediment and the transporting water is enriched in pollutants.

A special type of pollution is eutrophication of ground- and surface water by excessive nutrient loads. The over-application of phosphorus and nitrogen is a clear example. Both elements are essential for plant growth, but can become damaging when applied in excessive quantities that do not correspond with plant requirements. The excess may be leached from the soil, eroded or simply washed off the land into the groundwater, waterways and coastal systems.

Pollution has many different aspects with soil sensitivity varying widely from one type of pollution to another. Deposition rates for airborne pollution depend mainly on the concentration of the gaseous and particulate contaminants in the air. Other factors are the location, relative to the source and the prevailing winds, and the ecosystem's retention of the pollutants (filtering capacity). This is large in the case of evergreen forests, small for deciduous plantations and smallest in the case of agricultural crop and grassland *(86)*. The buffer capacity of the soil is an important parameter, being the ability of the soil to "neutralize" polluting in particular by acidic inputs. This buffer capacity is directly dependent on the parent material and the weathering rate, on the clay and organic matter content as well as lime ($CaCO_3$) content.

The concept of a "critical load" has been defined as "the highest load that will not cause chemical changes leading to long-term harmful effects in the most sensitive ecological systems" (24). A critical load is a maximum tolerable value rather than a target value. Forest soils are more sensitive to acidification than cultivated soils, because trees filter larger quantities of pollutants from the atmosphere than crops, and because agricultural land is subject to various agricultural treatments (e.g. liming) which diminish the effect of acid deposition. Moreover, forest soils in Europe often are already quite acid, most of the better soils being used for agriculture. The base-equivalent of total acid deposition since the beginning of this century is estimated at 2500-10000 kg $CaCo_3$/ha *(86)*.

The following characteristics may affect the acidification of (forest) soils *(69)*:

- increased deposition of acid or potentially acidifying compounds
- decreased deposition of acid-neutralizing compounds; increased primary productivity
- increased rate of nitrification or sulphur oxidation; changes in land use,
- reduced decomposition rate of litter and soil organic matter
- increased production and vertical transport in the soil of organic acids

- Removal of cations (increased biomass production, low biomass decomposition and harvesting as in intensified forestry in N. Europe may lower the buffer capacity of the soil and so cause acidification).

Pollution is the most widespread type of soil chemical degradation in Europe (18600 km^2 or 72% of the total degraded area). Long range, trans-boundary air pollutants contribute for an important part to this problem. Pollution is mainly concentrated around densely populated areas and major industrial centres (Western and Central Europe, Moscow Region, Po Valley), but is also a major degradation type in large parts of rural Scandinavia. The Scandinavian ecosystems are in particular sensitive to atmospheric deposition of acidic pollutants *(24)*, because of the low buffering capacity of the soils. The first evidence of soil (and surface water) acidification revealed itself as early as fifty years ago, much earlier than around the major emission centres in Central Europe *(80)*. Now the higher buffer capacities of Central and Western European soils appear to have become depleted as the result of decades of accumulated pollution. This process can not even be stopped by drastically reducing emissions only, as the effects only develop after a considerable delay. A majority of forest soils have had their cation exchange capacity depleted and now have a pH of <4 which severely restricts plant growth *(69)*. It may be questioned whether the situation is still reversible, even if drastic reductions of polluting inputs can be achieved and immediate (effect-oriented) measures such as liming are undertaken.

Although the major cause for acidification has been through atmospheric deposition of pollutants from *power generation*, emissions by *traffic* and spreading of *fertilizers* have also contributed. Agricultural and forestry practices such as liming and biomass accumulation or intensive harvesting also influence the acidification process, either positively or negatively. Agricultural *wastes and sewage sludge* may change soil properties such as pH, carbon content, buffer capacity, nutrient and pollutant content *(75)*.

A special type of acidification concerns drainage of pyrite containing wetland soils in coastal regions. This drainage will increase aeration in the soil leading to oxidation of the pyrite into sulphuric acid which reduces the pH to extremely low values. This type of acidification is not very widely distributed and is not represented on the degradation map(s) for Europe.

2.5.2 *Salinization*

Accumulation of salts in the soil may occur as a result of rock weathering and transport of salts by wind and water, and/or circumstances hindering the removal of salts from the soil system *(83)*. Improper irrigation/drainage, intrusion of salt water from the sea or from saline fossil sources, or evapotranspiration of saline soil moisture, may all cause salinization *(66)*. Salinization through capillary rise of (saline) groundwater is more confined to (semi)arid zones, whereas intrusion of sea water can occur in all climatic zones. The term "salinization" is used here in its broadest sense, i.e. covering the various aspects of salt accumulation in the soil.

Salinity is determined by *(83)*:
- Climate
- Hydrogeological factors
- Soil factors
- Agro-technical factors
- Irrigation practices

Salinization has a toxic effect on plants and soil biota through high osmotic pressures and an excessively high pH which adversely affects soil structure *(84)*.

Of the three chemical degradation types, *salinization* is most strongly tied to site-specific soil properties and climatic conditions and therefore its distribution is restricted to southeastern Europe where arid or semi-arid conditions prevail. The effects of seawater intrusion occur locally elsewhere in Europe but are not shown on the map because of the small scale.

Irrigated agriculture (with insufficient drainage to remove excess salts) is the main anthropogenic factor causing salinization in arid or semi-arid areas. It occurs either because irrigation raises the level of groundwater which may be saline, or because the irrigation water itself has a high salt content *(83)*. For coastal soils, intrusion of sea water resulting from a *rising sea level* or *excessive pumping* of overlying fresh groundwater poses a potential salinization threat.

2.6 Physical deterioration

The physical properties of the soil may be affected as follows:

2.6.1 Compaction

Compaction is by far the most prominent type of physical degradation in Europe (33000 km^2 or 90 % of the total surface area affected by physical degradation *(66)*). As compaction is mostly caused by frequent use of heavy machinery its occurrence is mainly restricted to areas with intensive and strongly mechanized agriculture or forestry activities. Large machines can only be used on relatively flat land and on large plots, so compaction is most frequently found in many parts of Europe on large farms.

Compaction is normally caused by the repeated use of heavy machinery, the frequent use of this machinery on the same piece of land having a cumulative effect. This occurs frequently in monocultures. Heavy grazing and overstocking may lead to compaction as well. A distinction should be made between plough layer compaction and subsoil compaction, because the former has a more direct influence on the efficiency of plant nutrient uptake. Examples from Sweden (7, 46) however, show that subsoil compaction may be more serious because it may be impossible to reverse its effects, especially in deeper soil layers (>40 cm). Factors that influence compaction are ground pressure (by axle/wheel loads of the machinery used), frequency of the passage of heavy machinery, soil texture, climate and soil moisture and the occurrence of counteractive factors.

Compaction negatively influences several important physical properties of the soil. that are of importance to plant growth. The effects may consist of poor drainage of the soil, impaired root growth, reduced filtering capacity, reduced bio-degradation of substances including pesticides. However, on some occasions moderate compaction can have positive effects. Compaction is countered by biological activity, cycles of wetting/drying and freezing/thawing, and tillage, but the effect of all of these decreases with depth. Sensitivity for the shallower layers depends largely on texture whereas the continued use of heavy machinery will also negatively affect the situation. High ground pressures on wet soils have particularly damaging effects.

2.6.2 Other types of physical deterioration

Waterlogging
Waterlogging as defined here (see also Annex I) may be induced by accidental or deliberate flooding, increased run-off from higher areas resulting from lower infiltration rates, or raised water table, for example as a result of irrigation. Waterlogging is related to the position of the ground-water table, and the occurrence of impermeable layers in the soil.

It should be noted that waterlogged soils occur in natural wetlands and these should be protected as important environmental features

Soil degradation due to human induced waterlogging however occurs mainly in Northern Russia and at a few scattered sites in the rest of Europe (foremost along the Black Sea coast and the lower Danube Valley).

Soil water deficiency
Water deficiency problems caused by *lowering* of the ground-water table, appear to be increasing in parts of Europe *(47)* and receive relatively little attention. Predicted climate changes, which

could lead to drier and hotter conditions in some parts of Europe (and wetter in other parts) may focus attention upon this problem. Water deficiency depends on the incidence of rainfall, the infiltration rate, moisture retention capacity of the soil, soil texture, structure and organic matter, and the depth below the soil surface of the water table.

Drier soil conditions may lead to lower organic matter contents of the soil, deterioration of soil structure, changes in the salt and water balances, and higher surface run-off, which increases the wind and water erosion risks *(47)*. Water deficiency is mainly the result of lowering of groundwater tables due to regulation and lowering of surface waters, extraction (for drinking water, irrigation), drainage, changes in land use. Often it is also related to other soil degradation problems that reduce water infiltration such as compaction, erosion, etc.

Shrinkage of organic soils
Lowering of the ground-water table may result in excessive drainage and/or oxidation of organic soils. The productivity of land where the former organic soils have been oxidised is lower and greater inputs of fertilizer are needed to maintain production levels. Where the structure of underlying mineral silts is also inferior, acid sulphate conditions may be revealed as in the Fenlands of England.

Shrinkage of organic soils takes place in a large region in Byelorussia/Ukraine and South of St. Petersburg where lowering of the groundwater table for agricultural purposes has occurred.

Regrading
Regrading for construction or agricultural purposes may cause considerable damage to the soil. Examples from vineyard and orchard plantations in southern European countries show deleterious effects of stripping of topsoil in the excavation zone and burying of topsoil in the accumulation zone, whereas at the same time the entire soil is heavily disturbed. This will influence various important soil properties and biological activity. It also increases the erosion hazard.

2.7 Biological deterioration

Loss of biological activity and *a decreasing number of species* may be caused by removal or burning of vegetation, or by application of fertilizers and/or biocides which disturb the balance of the natural ecosystem. Frequently, biological degradation is associated with physical and chemical soil degradation. For example, compaction leading to less aeration of the soil may result in a decrease in activity of earthworms, which in turn will lead to degradation of the soil structure.

Biological deterioration is influenced by soil properties like structure, moisture, soil temperature, aeration, nutrient status, organic matter, vegetation, crop and soil management. There is a strong interaction between biological activity and (some) soil properties such as soil structure, aeration, fertility and organic matter. Whereas these factors are significant for biological activity, they all can in turn may be improved by increased biological activity *(9)*

Biological degradation is not represented as such on the European part of the GLASOD map and its extent is hard to estimate exactly. In view of its strong links with other types of degradation it may be assumed that biological degradation is occurring whenever other types of soil degradation are significant, especially erosion, compaction, and pollution.

2.8 Irreversible use of soil and reduced multi-functionality

These are related to urbanisation and associated land uses: housing, industry, infrastructure, recreation, junkyards, etc. Some of these activities, such as covering the soil with asphalt or concrete preclude the affected soil from almost any biological activity. Construction of barrages and reservoirs has comparable consequences. Another form of "land consumption" is mining as in gravel pits, quarries, etc., where the topsoil is physically removed and may not be reinstated when the work is finished. Derelict land is a remainder of past industrial or mining activity, which has left the land without soil, or with soil that has been polluted.

Soil "loss" through urbanisation dominates in the more densely populated regions and major metropolitan and industrial agglomerations, especially in Western Europe, where the "built-up area", for example in Germany (ex-FRG) and the Netherlands may be as much as 15% of the total land surface *(89)*. Figures of *daily* soil losses due to this type of exploitation are in the order of 120 ha for Germany (ex-FRG), 35 ha for Austria and 10 ha for Switzerland *(13)*. Although theoretically the soil is not irreversibly lost for other uses, it will be difficult and sometimes impossible to restore practical multi-functionality of the land..

2.9 Radioactive contamination

Radioactive elements occur naturally in the soil. It is only in the last few decades that anthropogenic additions of radionuclides have begun to create problems of contamination of the soil. Radioactive contamination of the soil occurs when radioactive nuclides fall on the soil surface (by atmospheric fallout) or enter the soil (through leakages, or from radioactive waste deposits). This is especially hazardous where contamination threatens the food chain. Atmospheric testing of nuclear bombs has been stopped since the 1960's but fallout resulting from these tests still occurs due to the injection of radioactive elements high into the stratosphere *(102)*. Elevated and widespread radioactive contamination of soils has occurred only occasionally and accidentally, though accidents such as Chernobyl have demonstrated the far reaching consequences they may have. Locally, much more severely affected sites may exist. Treatment and storage of radioactive waste materials if not properly managed and monitored over a long period is also a potential hazard with implications for plant and animal life and public health.

The severity of radio-active contamination is determined by the type and degree of contamination (point source as with dump sites, or diffuse as with atmospheric fallout after an accident or atomic explosion) and by the radioactive nuclides involved. Fallout is closely linked with meteorological and weather conditions (precipitation, wind direction and -force) after an accident. The half-lives of the radioactive nuclides are a very important factor, in combination with the sensitivity of the soil to those nuclides. Heavy textured acid soils, for example, are most sensitive to the elements Strontium^{90} and Caesium^{137} which are strongly bound in the upper soil layers and have long half-lives. Potassium and calcium contents of the soil are important influences on plant uptake of these radionuclides *(102,105)*. Accumulation of radioactive soil contamination may result from sedimentation or reduction takes place due to erosion and leaching and of course decay of radioactive elements. The contamination is most significant when concentrated in the surface layer of the soil. Dispersion of the radioactive elements into deeper soil layers effectively reduces the hazard due to absorption by the containing soil mass *(102)*. Ploughing therefore has a reductive effect on radioactive contamination.

The major impact of radioactive contamination is the retention of long-lived radionuclides in the upper layer of the soil, from where they may enter the food chain with resulting deleterious effects to plant and animal and human health. Contamination from the leakage of waste deposits or during use and transport will not necessarily have effects over extensive areas but may be highly hazardous locally. Radioactive contamination from nuclear accidents and/or explosions will however have a high risk of widespread contamination due to transport of radioactive elements by wind and water.

Radioactive contamination was widespread over large parts of Europe after the Chernobyl accident in 1986. The Western part of the former USSR received considerable amounts of radioactive fallout, but in Austria and Germany and even as far away as Italy, Scandinavia and Great Britain significant fallout was registered. In most cases the direct contamination was shortlived (especially with respect to iodine-131) *(89)*. The accident nevertheless caused serious health problems in the C.I.S. and imposed constraints on agricultural and farming practices, harvesting and food movement in many countries of Europe in order to protect public health *(102)*. Through build-up in the food chain, effects are still noticeable in various places, even at long distances from Chernobyl. In particular caesium-137 may present problems for many years to come due to its long half-life. In Sweden it is reported that shortly after the accident, 63.000 reindeer had to be slaughtered and destroyed due to high caesium contamination. Even in 1992, six years after the accident, fish and game from the most contaminated areas were only suitable for human consumption in small amounts. Potential sources of more local contamination are deposits of radioactive waste materials if inadequately protected after disposal and/or not closely monitored. Some sites may well pose a most hazardous "Radioactive Time Bomb" threat, especially in the case of highly radioactive wastes. Mining and processing of some ores, such as Uranium may locally give rise to relatively slight increases in radioactivity in and on the soil *(57)*.

2.10 Damage caused by armed conflicts and military activities

The damage to soils in wartime is rather easily and understandably overlooked. However, once peace returns, this damage not only becomes more clearly visible, but it may prove to have impacts for a long period after the hostilities have ended. This is especially well shown in Vietnam, where large stretches of land have been affected by bombardments and by the use of the defoliant "Agent Orange". This has resulted in cases of severe pollution (in particular dioxin, related to the Agent Orange) and in erosion due to the destruction of vegetative cover and exposure of the soil often on steep slopes, to very erosive climatic conditions.

In other regions the effects of past or present warfare may be comparable, depending on the type of military actions performed (heavy bombardments, chemical weapons and the kind used, frequent passage of heavy military traffic, etc.). In areas that have been heavily bombed either from the air or by artillery, one may expect an increased contamination by heavy metals. The soil will also have been severely disturbed by the bomb impacts (craters). The occurrence in the soil of *un*exploded bombs, grenades and in particular mines could be considered a special type of "soil pollution", in the sense that it certainly poses great risks to those using the land. Cambodia is a particular case, but Europe is unfortunately rapidly creating its own examples.

Some impacts of nuclear bombs have been discussed briefly in § 2.9.

An indirect consequence of armed conflicts, and of poverty in general, is the increased (over)exploitation of vegetation for domestic use, in particular for fuel. In mountainous regions this will often lead to increased erosion.

In peacetime, military actions (i.e. exercises) will have impacts on the soil that are comparable in kind with those in wartime, but that can be better controlled and will be more restricted. Common impacts will be due to the passage of heavy military traffic such as trucks, tanks, armoured vehicles and large numbers of infantry, resulting in compaction and erosion, and some pollution due to artillery exercises.

The subsequent effects of storage of organic and inorganic chemicals may prove a problem where leakages and/or accidental spills occur, as is increasingly becoming evident in several Central and Eastern European countries.

3 DATABASES AND MONITORING RELATED TO SOIL PROBLEMS

There is a wide variety of field research, monitoring programmes, modelling and database developments in Europe related to soil degradation. Though the amount of research in soil science aimed at soil protection should not be underestimated, a majority of the programmes are part of wider environmental research programmes. Most frequently, these consider only one type of degradation, for example water erosion, or changes in pH due to acidification. In general, erosion seems to get most of the attention, especially in the Mediterranean region, with pollution/acidification in Scandinavia and several west and central European countries following close behind.

Official frameworks for comprehensive soil and/or environmental monitoring or data collection exist in a minority of the countries and sometimes monitoring is conducted on an "ad hoc" basis by research institutes or universities. Uniformity in methodology and coverage, albeit existing in some countries, is far from common even among national systems, and is an exception at a regional or supra-regional level.

There exist nevertheless a number of environmental monitoring systems and/or databases at a European level. These systems have some soil components, but usually their focus is upon a wider environmental basis and so soils, and soil degradation in particular, are not given the full attention they deserve. Examples of such monitoring systems are:

* A soil map of the European Communities at a scale of 1:1.000.000 was published in 1985. The map, which contains some 312 units, provides a basis for making very broad assessments of the suitability of soils of the Community for particular uses. It is a broad planning tool and not appropriate for use at more detailed levels. Recently (1993) a first version of a soil map at the same scale for Central and Eastern Europe has been published *(52)*

* From 1985 to 1990, the European Commission has developed the CORINE programme (Coordination of Information on the Environment). This programme consists among other things of an information system on the state of the environment in the European Community (the actual CORINE system), composed of a series of databases describing the environment in Europe as well as a series of databases with background information. At the land level, soil types, land quality, land cover and soil erosion risk are the most relevant elements in this context. Data on soils were obtained primarily by digitization of the 1:1 million soil map of the European Community.

* Atmospheric heavy metal deposition is monitored by moss analysis (Nordic Council of Ministries *(65)*). Samples of two species of mosses are measured for concentrations of heavy metals in nationwide networks at 5 year intervals. Samples are taken from Denmark, Finland, Norway and Sweden, to a lesser extent also from Greenland, Iceland, Svalbard and the northern part of western Germany

* UN-ECE Integrated Monitoring. These integrated projects are designed to monitor climatic, atmospheric, aquatic, terrestrial and biotic variables in the same catchment areas (including soil sampling, soil chemistry analysis and determination of the bulk density of the soil). Guidelines for this integrated monitoring have been formulated and the results are held in a central database in Finland

* The work on Critical Loads and Levels under the Convention on Long Range Transboundary Air Pollution (CLRTAP). This Convention was signed in 1979 by 32 European countries and its purpose is to reduce emissions of Sulphur and Nitrogen by 30% in 1993. A map has been prepared showing the relative sensitivity of ecosystems in Europe to acid deposition *(24)* and a country by country analysis of critical loads of sulphur and total acid depositions has been attempted.

* Within the framework of the Cooperative Project of Soil Erosion Mapping and Measurement in the Mediterranean Coastal Zones (Mediterranean Action Plan, UNEP), a pilot project was initiated (1989-1992) to elaborate a common methodology of erosion mapping, monitoring and measurement in Mediterranean coastal zones, leading to the preparation of an erosion map of the entire mediterranean coastal region *(87)*.

* The Winand Staring Centre in the Netherlands has developed a database for acidification of forest soils in Europe. The database consists of a number of entities reflecting the source of the data and methodology, the site characteristics and soil horizon descriptions, as far as relevant for forest soil acidification *(64,80)*.

- Various soil conservation monitoring systems in Europe were presented and discussed in the FAO/ECE Workshop on the "Harmonization of Soil Conservation Monitoring Systems in Europe" which was held in Budapest, 14 - 17 September 1993. The proceedings of this workshop will be published in early 1994.

At a global level, several monitoring systems and data bases have potential or actual interest for Europe, such as the FAO/UNESCO soil map and database, the Digital Soils and Terrain database (SOTER) developed at ISRIC, containing information on scales of 1:1.000.000 and larger, the proposed Soil Vulnerability Map for certain chemical compounds (SOVEUR), and the World soil database (WISE) currently being compiled at ISRIC for scales of 1:5.000.000 *(12).*

4 *CONTROLLING SOIL PROBLEMS*

4.1 Sectoral and Integrated Approaches, Effect Oriented and Source Oriented Approaches

The measures to prevent soil degradation and to reclaim the areas affected are as numerous and as various as the factors that cause the problem. In fact each type of degradation requires its own solution, and unfortunately, there is no panacea that cures all problems. Anti-erosion techniques for instance differ greatly from pollution control methods. This wide diversity explains the *sectoral approach* that is most commonly taken with regard to soil protection in Europe and elsewhere. The different types of degradation are most often analyzed and treated separately, whether this involves research, legislation or practical measures.

It has already been explained in § 1.4.3 that soil degradation processes often do not operate in an isolated manner, but may exhibit interactions or combine with each other. This implies a risk that some impacts of soil degradation will be overlooked or underestimated when attention is focused on a single factor or single cause. An example is the impact of over-applications of nitrogen from organic manure. This may volatilize or the excess that is not taken up by the plants is leached from the soil. However, organic manure is but part of the problem and reducing its application therefore only part of the solution. Other sources of nitrogen must be considered also, such as atmospheric deposition from industrial and traffic emissions, and applications of mineral fertilizers. When considering all factors and causes, a combined but small reduction of each may be better and more effective than a large reduction of any single one.

Another example is to consider water erosion in terms of "soil loss" and "runoff" rather than considering the more obvious results in situ. Water lost through runoff may lead to a serious reduction of *productivity* which means more to the farmer than the number of tonnes of soil lost. Moreover, if one takes productivity loss as the real damage of soil erosion, this may lead to quite a different approach to soil conservation than if the soil loss itself is regarded as the prime impact. Low productivity is only one possible effect of erosion, but at the same time it may be part of the cause: the vegetative cover being lower and biomass production less, so organic matter returned to the soil is less. The basic soil fertility is affected and the thresholds at which various toxicities become apparent are lower. Often measures introduced to increase soil productivity will also reduce erosion, but not always. Such measures are generally cheaper, easier to implement and more attractive to farmers, but not always effective in reducing soil erosion

These examples demonstrate that it is important to make a clear distinction between an effect oriented approach, aimed only at a reduction of the adverse *effects* of soil degradation, and a source oriented approach, aiming at eliminating the problem at the source. A further example is the acidification of soils by atmospheric deposition. Great efforts are being made to counteract the effects of this process, by extensive lime-applications. However, this is a highly expensive measure and only a temporary solution. The alternative, but only really effective solution is not easy to implement, expensive, and has no short term benefits for the soil. It implies important reductions *at source* of the emissions of all acidifying pollutants. Here too, it is important to calculate the optimal reductions feasible for each emission source. Source oriented measures usually have a more preventive character, whereas effect oriented solutions rather aim at repairing the damage already inflicted.

4.2 Rehabilitation (clean-up) programmes

Many soils are already in an advanced stage of degradation and the processes need to be reversed. In some extreme cases the damage is so serious that rehabilitation is impracticable or unfeasible. This is the case for some areas in the Mediterranean region, where most if not all soil has been lost through erosion *(87)*. In other circumstances rehabilitation may be technically feasible, but the benefits involved may not compensate for the costs and efforts involved. Sometimes there are no immediate benefits, but action is imperative in view of direct health hazards or unacceptable damage to the environment.

4.3 Criteria and standard values

Several threshold values and criteria exist as to whether a soil is degraded and whether it needs rehabilitation. Most of these relate to chemical or radioactive soil pollution. They differ from one country to another *(73,72)*. In Chapter II an overview is given of existing criteria and standard values for soil pollution and other types of degradation.

4.4 Technical measures for soil protection and rehabilitation

In this section, a brief description will be given of soil protection measures currently used for each degradation type.

4.4.1 Protection against water erosion

Probably the most widespread and oldest type of soil protection is aimed at controlling the effects of water erosion. These measures are most closely associated with the term "Soil Conservation" and literature on the subject of erosion control or soil conservation measures is abundant and only a brief summary of techniques can be given here.

Three types of soil conservation measures may be distinguished *(64)*: *structural*[1], *agronomic*, and related to *soil management*. As soil conservation measures most frequently are applied to farm land, it is important that the farmers are involved recognizing the need for the measures to be taken. Socio-economic aspects should also form an integral part of any soil conservation strategy. The following criteria are critical in the selection of soil conservation measures (for both water and wind erosion):

- They must have been shown by research and on-farm practice to be effective in reducing erosion below soil loss tolerance
- They must not prejudice viable farming systems. The direct cost of soil erosion to the farmer is generally small, but the additional expenses of the conservation practices may be considerable. The farmer will consequently only be motivated to practise soil conservation if he benefits in terms of protection against actual crop loss or in terms of productivity increase
- The main justification for soil erosion control in Europe is the prevention of off-site damage as the on-site productivity losses are often partly or wholly compensated by other agronomic measures in the short and medium term. This means that measures to prevent runoff and sediment leaving a field will be as important as measures to control soil loss within it.
- There may be additional advantages of several conservation measures, e.g. the use of winter cover crops to protect the soil will also reduce nitrate leaching.

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1 The term "structural" indicates here the use of a *physical structure* and not the character of the solution

A common *structural measure* is the reshaping of steep hill-slopes in sub-horizontal terraces by a cut and fill method. This is a very effective way to reduce gradients and to control runoff and sediment transport at "source", but its construction as well as maintenance is highly laborious and expensive. It does not give large direct or short term benefits on site and therefore can be recommended only in regions where it is already an accepted part of the farming system. In some cases terracing may increase the risk of mass movements where a soil overlying an impermeable layer becomes saturated with water until the point of instability is reached *(57)*. Lack of maintenance of existing terraces may also cause severe erosion, as is the cases in some mediterranean areas.

Other structural measures are generally effect-oriented, and aim at halting, diverting or interrupting already generated runoff and sediment transport. Examples are ditches and drains, contour banks, gully plugs, dams and reservoirs specifically to trap sediment, etc.

Most *agronomic* measures are more source-oriented, and aim to prevent excessive run-off and sediment transport. This can be achieved by keeping the ground covered by vegetation. Some examples are: cover crops to protect the soil outside the cropping season, crop rotations (successively planting of different crops), mixed cropping (simultaneously growing of different crops), strip cropping (alternating crops in strips along the contour), agroforestry (combining crops with trees in the same field), grass- or hedgerows (to filter and slow down runoff), mulching (to provide soil cover and increase organic matter at the same time), etc.

Finally, *soil management practices* relate to the way in which the land is worked. Conventional tillage may increase the soil erodibility by loosening the soil and destroying its structure. On the other hand conventional tillage may reduce runoff simply because of the increased surface roughness it produces. Minimum or zero tillage techniques may be advocated, combined with direct drilling of (spring) crops into the residues of the preceding (winter) cover crop. The use of herbicides for killing off the cover crop should be kept to a minimum and should be practised carefully in order to avoid risks of pollution.

Ploughing along the contour is indispensable in reducing erosion if properly performed but exclusively on gentle slopes. It is only feasible on elongated fields along the contour. If the contour is not correctly followed, the remedy may prove worse than the problem. If runoff concentrates in the lowest parts and breaks through a furrow it can have a more devastating effect *(64)*.

With respect to non-agriculturally induced water erosion, solutions should be preventive and source-oriented, aiming at minimum soil disturbance as well as at reduction and control of runoff. A good vegetative or synthetic cover is probably most cost-effective, depending on the actual use of the land. Hydroseeding has been recommended *(39)* as a means of rapidly establishing vegetative soil cover. The establishment of "protection forests" is a good practice in mountainous regions *(78)*.

Erosion is a practically irreversible process, as it is generally not economically feasible to return the topsoil to the land where it was lost. However many measures can be taken to give the soil a chance to regain its fertility and productivity. Most of these measures are also preventive and have been mentioned earlier. With regard to gully erosion, torrent and gully control measures aim at repairing damage as well as preventing it from occurring anew. The original situation however can never exactly be restored.

4.4.2 Protection against wind erosion

Several of the factors that determine the soil sensitivity to wind erosion, such as wind dynamics, soil cover and management practices can be manipulated to a greater or lesser extent. Preventive and rehabilitative measures focus on reducing wind speed by erecting shelterbelts or windbreaks and which have helped significantly in reducing wind erosion in many countries, e.g. Denmark, Northern Germany, the Netherlands, England and several mediterranean countries; also on establishing a good vegetative soil cover by crops, grass and/or mulch, and avoid or reduce detrimental farming practices such as intensive soil disturbance and destruction of soil aggregates by ploughing and harrowing. Dunes can be stabilised by planting trees or shrubs. Overgrazing should be avoided by keeping the number of animals within the carrying capacity of the land and/or by controlled grazing. When a quick restoration of vegetation is desired the aforementioned hydroseeding technique could be useful.

4.4.3 Protection against chemical deterioration

- *Pollution* may emanate from a great number of different sources and act in various ways, while interactions of different pollutants are possible. This makes a comprehensive and source oriented approach desirable. Individual effect-oriented measures may have a temporary result, but will not produce a long term improvement. The example of liming of acidified soil has already been mentioned in this respect. Perhaps more than any other soil degradation problems, soil pollution requires a transboundary and regional approach, as (in some cases) the consequences are more far reaching in space and time. Preventive measures that should be taken are: reduction and regulation of pollutant emissions from various sources, protective measures at waste deposits, regulated use of pesticides, manure and mineral fertilizer applications. However, general reductions of certain compounds are not always cost effective and these should be related to the sensitivity of the soil (or the environment in general) to that specific pollutant *(24)*.

  The emphasis in soil rehabilitation is generally on polluted soils. There is a wide variety of different types of soil pollution that each require a specific cleaning method, also depending on the soil properties. *(6,19,20)*

  Some contaminants can be **stabilized** by chemical treatment to decrease solubility of the contaminants or prevent them from being distributed by water or wind erosion. Other methods of stabilization are to inject the soil with a solidifying agent or fusing the soil into a glassy solid by passing a strong electric current through it.

  Alternatively, contaminated soil can be **isolated** from groundwater or surrounding unpolluted soil by placing horizontal or vertical barriers to prevent (further) spreading of the contaminants.

  Thermal techniques are yet in a pioneer stage and consist of heating contaminated soil to destroy pollutants. The required temperatures differ widely depending on the type of pollutant.

  Microbial action may be an efficient off-site treatment for some contaminants, in particular mine wastes, oil products and some other pollutants (aromatic hydrocarbons). As a rule, this is a relatively less expensive method.

  Chemical reactions are being used as well to transform contaminants in the soil into less harmful components. This may involve oxidation, reduction, ion-exchange or injection of appropriate chemicals. In some cases the resulting products from one site may be used as neutralizing agent on another site.

  Biological decontamination occurs with the help of specific plant species (so-called hyper-accumulators) that take up the most mobile (mainly inorganic) fraction of the pollutants. Disposal of the plants should obviously be handled carefully.

  Finally, removal of pollutants by **physical (or mechanical) methods** makes use of specific gravity, particle size, settling velocity, surface and magnetic properties.

  Special attention is required for pollution by gases in the soil, especially on landfills and previous industrial premises. The gas can be isolated, collected and/or burned if there is a demand for the generated heat, in the latter case turning a hazard into an asset.

- *Salinization* can be avoided or reduced by using good quality irrigation water and proper drainage, which will prevent salt accumulation. A too high groundwater table should be avoided in the case of saline groundwater *(91)*. Salinization in coastal areas through intrusion of sea water is prevented by avoiding excessive extraction of groundwater where this is overlying salt or brackish water. This is especially important in some mediterranean areas with a water deficit (evaporation exceeds precipitation) in summer, at a time that water demand is higher due to tourism. Recharging of fresh (ground)water aquifers with river water is a possibility to counter such problems.

  Saline soils can be rehabilitated by lowering of the water table (except for coastal areas!) together with irrigation with non-saline water, which will leach out the accumulated salts. Active amelioration is also possible through Na^+ --> Ca^{2+} ion exchange through applications of calcium containing amendments such as gypsum or mobilization of soil-calcium *(91)*.

4.4.4 *Protection against physical deterioration*

- As *compaction* is caused by heavy machinery, techniques to reduce high ground pressures will help to alleviate compaction. This can be achieved by increasing the number of axles and wheels under machines, increasing tyre width, and also by reducing tyre pressures. Of course, the use of smaller and lighter vehicles will help as well, but as these generally have less capacity, they may require more frequent passages and a longer time span to cover the same area, which may counter the preventive effect. Frequent passage of any machinery under wet conditions has to be avoided.

  The economic costs of soil compaction damage should be offset against benefits of large scale operations with heavy machinery, but restricted axle loads may have advantages (compare road traffic). Machinery is often too heavy because of multi-functionality; more specialized machines could be much lighter. Very large fields also cause either heavy loading of vehicles or frequent passage *(46)*. Conversely, small fields require proportionally more turning on headlands thus increasing the risk of compaction. Lighter machinery causes compaction mainly in the plough layer, whereas heavy machinery tends to cause subsoil compaction as well.

  Subsoil loosening is an effect-oriented, but expensive, measure which can give temporary relief, but which may also be counterproductive, if no simultaneous measures are taken to reduce the loads on the soil by the machinery used. In general, the advantages of the use of large and heavy machines should be balanced against the negative impacts related to compaction.

- Human induced *waterlogging* and *soil water deficiency* caused by local factors or shrinkage of organic soils can be prevented by maintaining the water table at an appropriate level. In the first case this implies proper drainage and avoiding excessive influx of water, in the latter case the implication is no, or properly controlled drainage so that no excessive lowering of the water table occurs and oxidation of organic material remains minimal. To prevent shrinkage altogether, highly productive agricultural soils would have to be returned to their natural waterlogged conditions.

  If soil water deficiency is the result of a lowered groundwater table, the process can be reversed in most cases and the soils rehabilitated to their former condition. Where the problems are caused by climate change they will require more far-reaching and comprehensive (partly source-, partly effect-oriented) measures at regional and global scale. Soils thus affected can only be rehabilitated at high costs and great efforts, such as regional irrigation schemes.

4.4.5 Protection against biological degradation

Good soil structure, permeability, aeration, moisture content, nutrient status and proper soil management are among the factors that will enhance biological activity in the soil. As a rule, tillage, crop rotation and fertilization not only have positive effects on plant growth, but on microbial activities as well, which in turn affects nutrient uptake by plants, transformation of organic matter, mineralization and nitrification *(9)*. On the other hand tillage and other operations may cause compaction which is unfavourable to soil biota.

Rehabilitation of biological activity can be achieved by restoring adequate aeration, a balanced soil moisture regime, the presence of sufficient organic matter, and by ensuring the absence of deleterious human activities, such as excessive use of biocides, severe compaction or erosion. In principle, biological degradation is a reversible process and if the soil is left undisturbed for sufficient time, biological activity will sooner or later reach "normal" levels.

4.4.6 Protection against irreversible soil use and reduced multi-functionality

Sealing of soil often cannot be avoided in case of construction, roads, etc. Consideration should be given in the planning phase to an optimum use of the soil surface, whereas construction on soils with high potential for other uses should be kept to a minimum. In the case of some recreational uses of the soil, more options are available, as the soil may still perform some of its other functions. Ski-runs for instance should preferably be located at sites that are less susceptible to compaction and/or mass movements (especially avalanches), and proper attention ought to be given to a rapid recovery of the vegetation after the skiing season is over.

The need to "rehabilitate" soil that has been isolated from outside influences and/or has been subject to other impacts associated with urbanization and infrastructure or mining, in general only arises when the soil is to be used for other purposes. Derelict land is often associated with pollution problems which will require measures as outlined in § 4.4.3.

4.4.7 Protection against radioactive contamination

Radioactive contamination is hazardous and difficult to deal with once it has occurred, thus the major emphasis should be on prevention of contamination. However, once contamination does occur, remediation measures are necessary. These are discussed below.

In cases of radioactive contamination, measures may include costly excavation and/or isolation of the contaminated material. Radiation from fallout lying on the soil surface presents a direct danger to those working the soil as disturbance can cause dust with a greater concentration of radionuclides which may be inhaled. Only in particularly severe cases of pollution, for example around Chernobyl, has it been worthwhile to completely remove the surface soil. There are problems of disposal, however.

Different restoration measures can be taken depending on the severity of contamination. At a low level of contamination ploughing may be sufficient, but at higher levels removal by mechanical means or by controlled erosion may be appropriate.

A major part of radioactive fallout will be intercepted by vegetation and will only reach the soil when the leaves fall off. Removal and safe disposal of such foliar-intercepted fallout can therefore greatly reduce the level of soil contamination although dangers remain with the collection and again there are problems of disposal of the contaminated plant material. Burning the contaminated vegetation can re-release the radionuclides into the atmosphere and must be avoided.

In all cases *time* is an important factor in that, without further measures taken, (most) radionuclides will lose their significance through natural decay and through transport to deeper soil layers. Measures to facilitate this transport will thus help to reduce soil contamination *(102)* but may affect groundwater. Incorporation of a contaminated surface layer into the body of the soil would mix the radionuclides to plough depth in a "dilute and disperse" solution to the immediate problem. Irrigation and the natural processes of leaching will also remove radioactive contamination from the surface and distribute it down the soil profile. In both cases, radionuclides may remain available for plant uptake, so the problem is only partly solved. As radionuclides are cationic, it has been proposed to limit plant uptake of strontium by liming; similarly, plant uptake of caesium can be limited by addition of phosphate and potash fertilizers or organic matter *(102)*.

The use of solvents containing ion-exchange resins has been proposed to flush radioactive contaminants out of the soil and thus reducing the plant uptake. This solution is probably only possible on a small scale.

4.5 Legal and economic measures

Beside the technical measures to stop or reduce soil degradation, which are generally taken at a local level, most countries in Europe have some kind of *legislation*, regulations, or codes of practice that are related to prevention or rehabilitation of soil degradation. As with monitoring of soil degradation, these vary greatly from country to country and most often they are not focused at soil degradation alone, but at wider aspects of environmental management or, oppositely, at single aspects of soil degradation. A distinction should be made between legislative measures (laws, rules and regulations, codes of practice, legal standards) and economic measures (subsidies, incentives, taxes or fines).

An overall national legislation that covers the various aspects of soil degradation and its control exists in few European countries as yet (e.g. the Netherlands), but is under preparation in some others (e.g. Germany). In most existing cases reference to "soil" is made in legislation and regulation concerning agriculture (manure, pesticides, mineral fertilizers), industrial and other pollution, waste disposal, nature, physical planning, mining and quarrying operations, water and air. As these measures are not aiming at protection of the soil itself, they may or may not be effective in that respect *(26)*.

In a number of countries (for example: Switzerland, Italy, Austria, Liechtenstein, Norway, Cyprus and in two "Länder" in Germany) laws do exist that focus specifically on soils or on causes of soil degradation (such as overgrazing). This, however, does not always imply that appropriate conservation rules are also proposed. Statutory protection of soils against erosion is probably the oldest type of legislation (e.g. Act for Resolution on Sand Erosion and Reclamation of 1895 in Iceland). Legal measures to control soil pollution date from a few decades back in most countries, whereas legislation relating to other types of soil degradation is far less common, which is especially remarkable in the case of compaction in view of its widespread occurrence as well as its economic impact.

Many countries have guidelines or standards related to target or threshold values of certain potentially hazardous substances, but the values differ from country to country (see Chapter II and *73,74*). At EC level too, several directives exist with regard to maximum admissible values, for example for nitrate, heavy metals, air pollutants and several chemical substances.

When dealing with any soil protection legislation, the variability of intrinsic soil functions as well as their different sensitivity to various types of soil degradation should be kept in mind in order to set realistic targets. When considering a soil's suitability for agriculture the same standard for fertility cannot be applied to two soils that differ greatly in cation exchange capacity and organic matter content, for example.

In a comprehensive overview for the Council of Europe *(26)*, five different types of legal treatments of soil protection are distinguished (that are not mutually exclusive):

1) Drafting of specific legislation to cover all soil functions, which is most innovative but also least common (e.g. Netherlands, Liechtenstein)
2) Specific legislation concerning only certain soil functions (e.g. Cyprus, Iceland, Malta and Spain with respect to erosion control and to some extent Austria and Italy as well)
3) Specific soil regulations within general environment legislation (e.g. Switzerland, related to "soil fertility"; Portugal related to soil as "a natural resource"; Denmark, Greece, Norway, Sweden, Turkey, UK, as part of Physical Planning Acts and/or others)
4) Integrating soil protection considerations into various sectoral environmental legislation (e.g. Germany, Denmark, Greece, Norway, France, UK, Belgium, Luxembourg, Slovenia)
5) Preference for negotiated agreements or for incentives (e.g. UK, France, Switzerland, Spain: codes of practice, incentives, subsidies; Austria, Netherlands: taxes)

For further details the reader is referred to Council of Europe *(26)* and to UN-ECE *(89)* p. 346 for an extensive overview of legal measures to reduce the impact of farming.

Economic measures may consist of incentives or subsidies to take soil protection measures or of levying taxes (for example on over-production of organic manure) and imposing fines in case of negligence (e.g. erosion due to lack of proper conservation measures).

Funding for soil protection comes from a wide range of sources in the individual countries. In many countries activities related to soil protection and in particular its financial consequences are a responsibility either for national, regional or local authorities. This may involve direct funding of measures or payment of subsidies and incentives as an indirect measure. Financial provisions are sometimes ad-hoc, sometimes at a more structural basis. In a few countries funds are partly or entirely recovered from the "polluters" - in these cases it mostly concerns pollution rather than other types of degradation.

Chapter II - CURRENT DEFINITIONS AND STANDARDS FOR THRESHOLD VALUES FOR SOILS

1 *INTRODUCTION*

1.1 The need for developing threshold standards for soils.

As soil is being recognized as an integral part of the environment, the role of soil protection within environmental policies has increased in importance. Until recently soil degradation problems were thought to be insignificant and approached in an ad-hoc manner, i.e. each problem was treated individually when it occurred. More and more countries now realize that a national policy is necessary to deal with the variety and complexity of problems associated with soil degradation. The relationship between the soil and important spheres of human interest such as public health, food and drinking water supply and other environmental issues is becoming increasingly apparent. Some of these relationships are reciprocal, with agriculture serving as a clear example: a "poor" soil will result in a relatively low productivity even under proper management, but conversely inappropriate agricultural practices can cause a good soil to deteriorate through erosion, pollution, compaction, salinization etc.

Awareness is growing also that a more comprehensive soil protection policy requires certain quantitative standards and criteria to determine when the soil is degraded and subsequently what course of action should be followed. This is particularly the case where soil pollution occurs. However criteria are far from being uniformly established among European countries *(77,99)*. This results partly from different priorities adopted by individual countries in matters of environmental and soil degradation, and partly from the complexity of the problem itself.

1.2 Complexity and problems of developing threshold standards

The first problem to be encountered in setting standards for soil quality is the lack of clear and consistent definitions and terminology. Some terms related to soils and soil protection have recently been defined in a (draft) document of the International Standards Organization (ISO), but many definitions have yet to be agreed upon.

1.2.1 Technical complexity

The soil may perform many and various functions (see Chapter I). Furthermore, the relative recent awareness of soil degradation problems means that concepts and criteria are still being evaluated. The perception of the role of the soil varies rather widely between scientists and between countries. These factors have implications for the criteria that are being used or still need to be identified to determine *soil quality*. In simple words: what constitutes a *good soil* and what is a *bad soil*? Soil quality can be interpreted as the ability of the soil to fulfil all or some of its functions.

In the literature about soil degradation and soil protection, figures are frequently available, such as soil loss by erosion in tonnes per hectare per year or concentration percentages of substances in the soil, but these figures do not relate directly to soil quality. The (quantitative) impact on various soil functions of a soil loss of, say, 20 t/ha/y for a given soil, or of a pesticide load of 10 kg/ha is unknown. Several factors make a quantitative assessments of soil quality difficult to achieve; these are the relationships between respectively soil quality and soil functions, interactions and pathways, soil types, types of degradation.

- Soil quality in relation to soil functions

As has been stated in Chapter 1, § 1.3, "soil quality is related to the actual or intended use by people". This should be interpreted as broadly as possible, including deliberate *non*-use of a certain soil for whatever reason. In other words, soil quality is directly related to land use. For instance (the quality of) a soil used for agriculture is generally more sensitive to the effects of sheet erosion than a soil having a bearing function.

Some soil functions are mutually exclusive. Urban soils have lost their function as a major food and biomass producer (with the exception of gardens and parks). Similarly, a soil can have a good quality to perform its function as a physical medium (foundation), but a poor quality as a biomass producer.

In its broadest definition soil quality can be described in terms of the combination of soil properties that will enable a soil to maintain all of its natural functions. Some countries (e.g. the Netherlands, Switzerland, Hungary) have adopted this concept of "multi-functionality". It implies that a soil is considered degraded as soon as a single function is permanently endangered, but, as shown above, it does not mean that under current use all its natural functions necessarily must be maintained.

In the Dutch approach a soil is considered multi-functional when *(61,99)*:

- it poses no harm to humans or animals
- it can function in natural cycles without restriction
- it does not contaminate other parts of the environment

Although probably being the safest and optimum approach, the multi-functionality concept is not always feasible in the short or medium term. In several cases a practical solution is chosen and the situation may be left unchanged if no risks exist for continuance of the present use. Some urban soils for instance that are polluted and pose a direct hazard to human health would be unfit for agricultural use. It would not be feasible however, to restore all these soils to their original, multi-functional state.

Maintenance of the multi-functionality of soil however must remain the primary goal of soil protection policies. For the clean-up or restoration of soils after they have been degraded exceptions may have to be made in view of the environmental and economic consequences of clean-up and of its technical feasibility. In the Netherlands criteria have been developed for making realistic decisions about clean-up objectives within the framework of a general policy aimed at restoration of multi-functionality *(99,100)*. A number of other countries have adopted a practical compromise which ensures adequate soil quality for the *actual* (or immediate future) land use (UK, for example). This approach comes close to the concept of "suitability" in which an evaluation of the properties for a specific land use occurs *(36)*. Remediation measures generally will be less extensive and not as costly as with a "multi-functional" solution. On the other hand, the suitability or "subjective" quality, may suddenly alter when the intended land use is changed and hence extra measures may need to be considered.

The above concepts refer mainly to soil pollution but could also be applied to other types of soil degradation.

- Soil quality in relation to soil types[2]

Soil quality should be defined and characterised in terms of the limitations imposed by soil properties within which a given ecosystem or ecosystem function can be maintained over the medium to long term e.g. more than 50 years or two forest rotations *(49)*. Soil quality, therefore, is a derivative of soil properties, such as pH, organic matter, texture, structure, permeability, porosity, etc., and hence intimately related to soil type. For a limited quality assessment, related to a specific use of the soil, not all soil parameters will be required in all cases.

Soil quality can be expressed quantitatively through measurement of the relevant soil properties that determine the suitability of that soil for certain uses (e.g. for a specific crop) or the inherent

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[2] NB: the word "soil type" is not used here in the same sense as in soil classifications, but to distinguish between soils with different properties that are relevant for the assessment of soil quality and soil degradation.

"vulnerability" of the soil to certain external influences (e.g. to soil erosion or to a particular pollutant).

- Soil quality in relation to type of soil degradation

The diversity of types of soil degradation and processes that may threaten soil quality has been extensively discussed in the previous chapter. It has been emphasized that the impact of degradation processes on soils (which implies the impact on their quality) differs greatly from one type of degradation to another, as well as from one soil type to another.

The large heterogeneity of soils in Europe, including the high variability that may occur even within a small area, as well as the interlinked processes and functions, make it impossible to establish universal fixed criteria that determine in a quantitative manner the effect of a certain type of soil degradation on soil quality. With regard to soil pollution it has been proposed that sliding scales be used that may take the various factors controlling the effect of certain substances on soil quality into consideration *(44)*.

It is clear that criteria of a "good" or "bad" soil, hence criteria for soil protection, will vary with the different concepts of soil quality.

- Process interactions and pathways

As mentioned in Chapter I § 4.3, soil degradation processes may interact to have an enhanced, combined impact. Therefore when assessing the threats to soil quality such interactions need to be considered as well as their possibly different *pathways* to the soil. Whereas the soil quality may not be put at risk by a certain application of sewage sludge alone, the total acidification load, i.e. including the inputs from atmospheric deposition, may well exceed acceptable safety limits. A single maximum standard for application of a sewage sludge does not take such cumulative effects into account and will consequently not suffice for a proper evaluation of threats.

These exposure routes must be combined with other potential pathways to obtain a fair judgment of the risks at hand.

Direct contact and ingestion of polluted soil in particular threatens children in the age of 2-6 years. This explains why several countries have specific criteria for children's playgrounds.

The hazard of consumption of plant products that grow on contaminated soil is determined by the uptake of polluting substances by the plants. In this respect heavy metals are of specific interest because of their persistence and their tendency to accumulate in the topsoil. Although some heavy metals will cause toxicity to plants before having implications for animal and human health, others can accumulate in the plant tissue well beyond that point and hence pose a health hazard *(14)*. It needs to be emphasized that several heavy metals are important micronutrients, but in enhanced concentrations are toxic for plants. Although the term "trace elements" might be more correct, they are commonly referred to as "heavy metals" and will be so in this text.

The uptake by plants of heavy metals and other substances from the soil is a complicated process on which there is continuing research. There is no simple correlation between heavy metal concentration in the soil and plant uptake. This again demonstrates the weakness of criteria that only focus on absolute concentrations in the soil.

The scale of potential exposure must always be considered: possible exposure to pollutants in the soil by ingestion, inhalation or consumption of vegetables from the garden takes place at the scale of house and garden (+ 50 m^2). Therefore soil sampling schemes need to reflect this scale for proper exposure assessment *(97,98)*.

1.2.2 Non technical constraints and considerations

Other factors that may hamper the development of standard values, are non-technical.

- Political and public awareness

Basically, soil quality, defined in the broadest sense, refers to all relevant biological, chemical and physical attributes of the soil. However, in establishing standard values and criteria for soil quality, protection policies and clean-up purposes soil pollution (in particular by heavy metals) is the type of soil degradation on which most attention is focused in Europe *(49)*. This results from the political and public awareness of the problem and the (apparent) direct relationship between pollution and health. Living on a polluted soil arouses more apprehension than an eroded soil would do.

- Recent awareness of the problem

Another factor is that soil degradation has only recently emerged as a problem and that the scale and extent of soil pollution in particular has automatically caused it to receive much more media attention than other types of soil degradation. In several countries polluted sites are still regularly being discovered. These factors have stimulated research with the result that far more relationships between chemical soil properties and soil quality have been established (e.g. for heavy metals) than for physical/biological properties *(45)*.

- Relationship with other types of environmental degradation

Standard values and criteria have been introduced for air and water pollution by many countries. Thus standards for clean drinking water or air are common but fewer countries have standards for clean soils. This is probably because the relationship between air- or water pollution and health is more obvious and direct than between soil pollution and health. In several cases, norms for soil pollution have been directly derived from air or water pollution standards. Ongoing research reveals that although valid, many relationships are quite complicated and care has to be taken in "transferring" values from one field of environmental protection to another.

Given the strong bias of soil protection in Europe towards soil pollution control, most of the following paragraphs refer to soil pollution rather than other types of soil degradation unless it is explicitly stated.

Although several countries have legislation, or codes of practice, concerning other types of soil degradation such as erosion, compaction or salinization, these are qualitative rather than quantitative. Quantitative criteria appear not to exist in this respect. No values for permissible levels of soil erosion or salinization have been implemented in legislation as yet. Research into this matter is proceeding, for instance on soil loss tolerance levels and on the effects of soil erosion on soil productivity, but this has not yet resulted in practical recommendations.

- Scientific values vs. policy criteria

Criteria and standard values for soil protection policies and implementation need to be based on scientific research, but this does not mean that the exact values stemming from such research are always being used in practice. Scientific research and modelling provides many relationships and values (e.g. "critical loads"), but in daily practice political decisions on whether and how to use these have to be reached through compromise and negotiations with the various interested groups.

Furthermore, a significant part of the research is science-oriented rather than being aimed at practical applications. There is an urgent need for better and more integrated cooperation between research, policy and target groups *(32,29)*. Sometimes scientific values that are based on laboratory experiments are just too much out of line with the socio-economic and political "real-life" situation.

Strict application of such values might be impossible in practice. The example of contaminated urban soils has been mentioned earlier. In other cases the political sensitivity and risk potential of the problem have urged authorities to impose standards with relatively limited scientific justification, such as the original ABC values in the Netherlands (see below).

After further research some of these proved to be either too strict or too lax. It has been stated however that it is preferable to take measures with only limited scientific basis rather than to wait for 100% proof by which time it may be too late *(15,31,45)*. The best way to assure that standards of the right type are obtained by scientific methods is to provide provisional standards of the right type as a scientific hypothesis, which might be tested and adjusted on the basis of scientific evidence *(96)*.

- Different approaches

Soil protection can be approached from a *generic, fixed criteria* point of view or from a *risk assessment* point of view. The former method, which consists of the use of fixed levels for admissible concentrations of substances in the soil such as heavy metals or complex organic chemicals, is more rigid but is more readily applicable in a wider context and at a smaller (i.e. national, regional) scale. Criteria applied for related fields of environmental protection, such as for drinking water or groundwater monitoring, are more straightforward than in soils where relationships between concentrations of substances and health or environmental hazards are less obvious.

Risk assessment methods enable a better consideration of site-specific circumstances such as soil properties and other environmental factors, as well as socio-economic inputs. They also may entail an evaluation of accumulated hazards from diverse pathways to the soil. However not all risk assessments necessarily consider every possible pathway. This would in fact even increase possible uncertainties and hence it is more likely and desirable that for the generation of acceptable soil contamination concentrations exposure assessment will be restricted to selected, simplified scenarios, such as ingestion by children playing outdoors *(8)*.

Although the risk assessment method is best suited for an optimum solution at individual sites, in practice a soil protection policy at the national or supra-national level cannot be built on site-specific criteria only. Therefore a combination of generic and site-specific criteria or guidelines is the most appropriate when establishing national - or European - policies. Such an approach has not yet been adopted in many European countries. At the strategy and planning stage, emphasis would be on generic elements, whereas site-specific aspects deserve more attention in the implementation phase. However, the importance of local conditions must always be recognized.

2 *EXISTING THRESHOLD STANDARDS FOR SPECIFIC TYPES OF SOIL DEGRADATION*

2.1 Reason for selecting these specific degradation types

In this chapter a review will be given of existing national threshold values or other criteria that currently are being implemented in Europe. First, criteria and threshold values will be discussed in more general terms and in relation to three different types of soil degradation: soil pollution (by heavy metals in particular), soil erosion and salinization. The last paragraph reviews the situation in a number of European countries for which relevant information was made available.

In respect of the selected types of soil degradation, soil pollution was an obvious choice in view of the large amount of research which has taken place on criteria and standards; soil erosion was considered relevant because of its widespread occurrence, and salinization was considered because of its local but very specific problems.

It must be emphasized that even for these selected fields, this inventory does not pretend to be fully comprehensive. It concentrates on the practical application of criteria and values for policy or implementation purposes, i.e. those fixed in some kind of legislation or practical guidelines at the national or European level.

2.2 Threshold values and criteria for soil contamination

2.2.1 *Terminology*

The terminology used in soil protection matters is sometimes rather confusing. In a number of countries *"threshold"* or *"trigger"* values are being used as standards to determine the necessity and urgency for action. Although the meaning of these terms differs somewhat from one country to another, generally they refer to the need for action to be undertaken when specific values are exceeded. A good example are the values that exist in the Netherlands and in some other countries.

A *target value* gives the (maximum) concentration for a given substance which causes no or negligible risks for human beings, plants, animals, ecosystems and other parts of the environment. Up to this level the soil can be regarded as unpolluted, at least with respect to the substance in question *(29)*. In practice an exception is made for natural background levels exceeding this value or for function properties that are more sensitive *(30)*. The Dutch *reference* (A-)values that were established in 1987 were a first attempt to quantify the concept of target values. Contamination exceeding the A-level is a first indication for further investigation.

An *intervention value* refers to the situation where the maximum permissible risk level has been reached. A figure in excess of this level indicates ("triggers") the need for immediate action. The Dutch C-values (see below) quantify the levels at which intervention should occur for different substances.

A *limit value* reflects the environmental quality of soils on a polluted site that should be reached by specific remedial measures within a certain planned restoration period. It can be formulated where part of the environment does not meet the quality required by the target values. A limit value is an intermediate level between target values and intervention values *(29)*. The Dutch "B-value" is an intermediate value that indicates a level of pollution above which the need for eventual remediation measures should be investigated more in detail.

2.2.2 *Example: the Netherlands*

A leading role in the development of soil protection policies has been played by the Netherlands, in particular related to soil pollution and setting soil quality criteria. This can be explained by the high demands made on the land and soils due to a high population density, a high level of industrialization, a very intensive agriculture, a dense infrastructural network (roads, railways, rivers and canals) and the geographic situation in a delta area where several rivers deposit their sediments and accompanying pollutants *(99)*. Furthermore, the main source of drinking water in the Netherlands is groundwater which is directly endangered by pollution because of the high water table present in most parts of the country.

In the Netherlands three generic standard values were established under the Interim Soil Clean-up Act (1983) to determine the course of action in case of suspected soil pollution. A preliminary investigation must reveal whether a site is polluted or not. For this analysis historic information such as maps, past activities and site-specific data e.g. soil type, groundwater data, special objects in the soil, are gathered. This information determines the methodology of further investigation and is combined with specific soil information. The results are compared with the standard values, the so-called ABC list. The lower "A"value represents soils that are in a multi-functional and unpolluted state. This value may be considered a *target* value for total clean-up. Target values for metals in the Netherlands are set at a level of twice the average background contamination in Dutch nature reserves *(85)*. Target values for organic contaminants are related to the so-called "No Observed

Effect Concentrations" (NOEC). Contaminants in the soil at concentrations below the NOEC cause no adverse effects on growth, reproduction and survival of a species. The maximum permissible concentration (MPC) at the ecosystem level is reached if the NOEC of 5% of the species in an ecosystem is exceeded. Target values are derived from MPC levels by dividing MPC by 100 to account for the combined toxicity of the substance with that of other toxic substances in the environment. At present a discussion is taking place whether this factor of 100 should be changed which would only affect the target values for organic contaminants. Soils with contaminant levels below the A-value are considered clean. Soils with values between the A- and B-values are not "clean" in the absolute sense but do not require further action. If the B-value is exceeded, more research is necessary and some remediation measures may already need to be taken. If the investigations reveal that the upper C - or *intervention* - value is also exceeded, the soil in question requires clean-up measures, depending on site-specific circumstances. Possible solutions will be examined in the clean-up investigation, as well as the financial aspects and other technical and environmental aspects *(99,34,72)*.

The original A-values in the Interim Soil Clean-Up Act were the same for all soil types and were not based on toxicological data, but more or less on the average background concentrations in Dutch topsoils. These background levels however do not necessarily reflect the natural situation or a "desirable soil quality" as it can be assumed that all European topsoils have been affected by atmospheric deposition of pollutants *(44)*. Recently indications have been found that heavy metal levels in organs of wildlife in the Dutch National Park "de Hoge Veluwe" were too high for human consumption.

In 1987 the A-values were revised to become "reference values" dependent on soil type and eco-toxicological effects, based on expert judgment. In 1991 "target values" were established, derived by more explicit procedures, involving eco-toxicological risk evaluation *(98)*.

New intervention (C-)values were also proposed in 1991, based on quantifiable toxicological risks (to individual human beings) and eco-toxicological data (risks to ecosystem populations) as well as considering the spatial scale of exposure.

The B-value will be replaced by a value equal to (A+C)/2, which splits the "uncertainty zone" between A ("good soil") and C ("bad soil") levels in two parts, the lower requiring no further action, the upper part indicating the need for more detailed investigation *(99)*.

Limit values are not implemented in Dutch soil protection policy. In water and air pollution control limit values serve as a temporary target to be reached by reduction emissions and discharges. For the soil such a pollution control model will not work. In most cases a reduction of emissions to the soil may diminish the accumulation of substances in the soil, but concentrations of contaminants in the soil can persist over very long periods of time. *(99,100)*

In Annex II an overview is presented of reference, target and C-values for soil and groundwater as used in the Netherlands as well as similar values in a few other countries.

Federal and regional authorities in some other European countries also use locally adapted lists for guide values in soil protection similar to the Dutch list *(1,2,3,5)*

2.3 Threshold values and criteria for soil erosion

Approaches to soil conservation are mostly qualitative rather than quantitative. Some limits exist such as slope limits for certain conservation practices, but these are in the form of a voluntary code rather than being mandatory.

The concept of *soil loss tolerance*, in combination with predictive models for erosion hazard, may to some extent facilitate quantitative risk assessments for erosion impacts. To define the soil loss

tolerance we must not only consider the soil-productivity relationship but also the environmental implications and the off-site effects of soil erosion.
In that regard, soil loss tolerance may be defined as "the maximum rate of erosion (for a particular soil, but not reflecting different land uses) that permits a high level of productivity to be sustained, also considering respect for the environment and off-site implications of sediment yields".

The hazard of soil erosion by rainfall is estimated by the application of different predictive tools, depending on the type of approach. At the field scale several models are available, the most common being the Revised Universal Soil Loss Equation (RUSLE). This may be applied directly or as a sub-routine in other models, such as the Erosion Productivity Impact Calculator (EPIC), to estimate the effect of soil erosion on productivity and on removal of chemical substances.

At watershed level other provisional models are available for the assessment of sediment yield, enabling the planner to predict the off-site effects of soil erosion.

In view of the wealth of research into erosion problems it is somewhat surprising to see that an enlarged concept of soil loss tolerance, possibly differentiated for the specific soil functions, has not found its way into practical implementations and legislation. The gap between scientists and politicians/decision makers *(31)* apparently has not been adequately bridged with respect to soil erosion. There is a clear need for development of a relatively simple set of values to be used by politicians and decision makers in judging the urgency for protection of soils from further degradation by erosion, as is now becoming the case for soil pollution.

2.4 Threshold values and criteria for salinization

The situation, as described for erosion, is perhaps even more true for problems of salinization. Formulas have been established to calculate the effect of salt in irrigation waters on soil salinity *(18)*. Crop yields are generally not affected by salinity below a specific threshold level expressed in terms of electric conductivity. This threshold level reflects the salt tolerance of a specific crop. It depends on the type of salt, the crop and its maturity, but knowledge on mechanisms influencing plant salt tolerance is still limited.

Another tool which can be used to deal with salt problems is the salt balance. This is the balance between incoming and outgoing salts in the soil solution. As long as this is zero, there is no net salt accumulation. The salt balance reveals the effects of amelioration, of agrotechnical measures on changes in the degree of salinity and alkalinity of the soil and the effect of irrigation on the soluble salt contents *(82)*.

Because man-induced salinization problems are very often associated with irrigation in combination with insufficient drainage, some recommendations exist with regard to the quality of irrigation water. The most important factors determining the maximum admissible salt content of irrigation water are soil texture (higher salt contents permitted for soils with low clay content), degree and chemistry of soil salinity, drainage conditions, salt tolerance of the plants grown and intensity of plant production methods, frequency and quantity of irrigation *(82)*. In the former USSR a simple irrigation water grouping system was applied based on total salt concentration, with more detailed classifications being applied locally. A detailed irrigation water quality classification system has proven its use in Hungary.

One other, often neglected, "golden rule" is that (in semi-/arid zones) the groundwater table should not be allowed to rise above a level at which capillary rise to the soil surface will take place. Such a value can be relatively easily calculated for each soil.

3 OVERVIEW OF SOIL PROTECTION CRITERIA, STANDARD VALUES OR GUIDELINES IN EUROPE[3]

The following information on soil criteria, standard values and guidelines at the national level was supplied directly by the institutes or departments represented in the Group of Specialists on soil conservation of the Council of Europe. More detailed information can be obtained from the institutes listed in Chapter V.

AUSTRIA

No national approach, but legislation on chemical soil and groundwater contamination by the provincial governments ("Länder").

In seven of the nine provinces the assessment of soil degradation on a grid base of 4 km^2 (2x2km) is concluded, with comprehensive evaluation of chemical and biological, partly also physical impacts. In two provinces this assessment is under way.

Harmonization of provincial legislation by federal committees exists in actual problem areas such as sewage sludge application in agriculture, use of fertilizers and plant protection products, and remediation of polluted sites.

CZECH REPUBLIC

Legislation related to soil protection only concerns agricultural land ownership in cases of change of land use such as urbanisation, infrastructure, etc (Law No. 334/1992). Soil conservation aspects are part of other related laws, in particular law No 144/1992 on the protection of nature and landscapes, No 244/1992 on environmental impact assessment, No 17/1991 on the environment. In executive documents under development limits are set for dangerous substances in different soils. These limits refer to EC directives and to the "Dutch list". They will come into force in 1993-94. A "base monitoring project" for soils, financed by the state, is being implemented. The data base being developed contains technical measures and methods compatible to systems implemented elsewhere in europe.

Lack of effective and comprehensive control on soil protection is manifest, activities being to sectoral, partial and isolated. Separated policies for agricultural and forest land ownership remains a reality contributing to doubts about this project.

CYPRUS

General soil conservation policy: not aimed at specific land use. Emphasis on *erosion protection*: importance of topsoil. Protection against *heavy metals*: fertilizers to be registered and approved by Fertilizer Control Board. Standards set (maximum values) for heavy metal content of sewage sludge and already present in the soil.

DENMARK

Soil protection is considered an integral part of environmental protection. Criteria for clean-up of contaminated groundwater and upper soil layers down to application depth (defined as depending on intended use) under Act on Waste Deposits. Criteria are general, fixed and sufficient to secure most sensitive use of the land. Values are comparable to Dutch A-values.

For polluted sites, a priority listing is made for reclamation after evaluation of actual risk with regard to groundwater and land use. Guidelines for soil quality and groundwater criteria issued by Danish Environmental Protection Agency include 10 substances at present.

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3 A detailed review of several national and international approaches with regard to pollution problems is given in *(100)*

The Environmental Protection Act (1991) relates to soil, air and water pollution. Some Statutory Orders relate to soil, e.g. on application of sludge, sewage and compost for agricultural purposes, on storage and spreading of livestock manure, silage etc.

The Waste Deposit Act (1990) regulates waste and the Act of Chemical Substances and Products (1993) regulates chemicals, e.g. a Statutory Order (1993) on pesticides, and regulations on heavy metals.

The Protection of Nature Act provides general protection of habitat types, dune conservation and prevention of sand drift. Beside nature conservation and management in general, it further provides protection lines, e.g. on beaches, lakes and streams, forests and protection for plant and animal species.

The Forest Act (1989) regulates multiple use of forests.

Several Acts regulate land use and farming, e.g. the Planning Act (1991) on spatial planning, the Raw Materials Act and the Farming Act.

ESTONIA

No specific soil protection legislation in force, it being considered an integral part of environmental protection. Both the Nature Protection Law (passed in 1990) and the mineral Resources Act (under consideration at present) include general soil protection chapters, not fixing standards or numeric criteria.

FINLAND

Soil "conservation" considered as integral part of environmental protection. Emphasis on prevention, with systematical cleanup of contaminated sites. Soil "conservation" programme being developed with threshold values for *pollution* and clean-up/recovery regulations. Here also importance of (landuse/physical) planning.

FRANCE

No national approach, but control by local authorities. Use of *qualitative* risk assessments. Development of soil pollution standards is now under consideration *(99)*.

GERMANY

No national approach, but control by provincial governments ("Länder").
First draft of federal soil protection legislation presented in 1992: special emphasis on determination of figures and assessment of soil quality. "Orientation levels" (cf. Dutch ABC list), based on average clay-content, pH and OM. Action levels based on bio-available soil concentration for worst case exposure scenario *(8)*.

Concept for Soil Protection:
- minimization of pollution
- appropriate land use + supportive research plan

Federal quality and cleanup criteria

General approach: three soil standards: risk value ("harmful change of the soil"), trigger value (examination) and precautionary value (minimum). Main focus on risk defense rather than aiming at multi-functionality.

General criteria and standards being prepared at federal level. Sewage Sludge Ordinance within Waste Disposal Act: limit values for 7 heavy metals on agricultural and horticultural land (depending on pH and texture).

Some more specific guidelines for "Recording and evaluation of anorganic harmful substances" at federal level (Baden-Württemberg). Trigger values for examination.

Recently the so-called "Eikmann-Kloke list" has been proposed, a three level system of trigger concentrations of substances for eight types of soil/land use *(99)*. Some of the "Länder" have taken this as a point of orientation when establishing their own soil standard lists.

GREECE

Standards or numeric criteria used are in compliance with EC directives (in particular for heavy metals). USDA or EPA standards are also used where applicable. Erosion risk is presented in a map at a scale of 1:1.000.000, giving four classes, following EC - CORINE standards. For salinity, study reports are based on FAO standards.

HUNGARY

Immediate land use based on actual risk assessment, future land use to be based on more or less fixed criteria.

Criteria and standard values are under elaboration for inclusion in a soil protection act by a team of national experts. A system with limit values for *soil fertility* evaluation already exists. Criteria for soil protection against salinization and limit values for the quality of irrigation water have been determined.

Maps have been prepared that classify soil susceptibility to physical degradation *(94)* and acidification *(91)* as well as small- and large scale maps for the control of water and wind erosion.

ICELAND

The most important legislation on soil protection is the act on soil conservation. Its main objectives are to halt ongoing destruction of vegetation cover and soil erosion, to reclaim eroded and damaged areas, to control all grazing areas and prevent excessive utilization and to improve the condition of vegetation and soils that have been degraded.

Furthermore, soil in general is considered as an integrated part of nature and is as such protected by the act on nature conservation.

Provisions pertaining to pollution control measures are contained in the hygiene and public health act, the toxic and hazardous chemical substances act and in the pollution control regulations. These acts do not, however, contain specific criteria or values for the assessment of soil pollution.

ITALY

Soil protection is not based on fixed criteria but on a qualitative actual risks and problems based approach (e.g. recommendations for reduced tillage or re-introduction of crop rotations). No official standards or numeric criteria. Where applicable following EC guidelines (in particular for heavy metals from sewage sludge). Project with Min. of Agriculture to set up a "Pedological Observatory for the study of Soil Quality".

Law prescribes regional reclamation programmes. Technical guidelines for formulation of regional reclamation programmes. Identification, inventory, assessment, mapping & filing + ad hoc field studies --> priority areas.

LIECHTENSTEIN

Raster based survey net with determination of physical parameters, nutrients and heavy metals every 10 years, more detailed every 5 years on subsample plots: organic pollutants, biological parameters and soil fauna. Furthermore ad-hoc investigations (pollution). Generic threshold values (guidelines) for *heavy metals* under preparation.

MALTA

No fixed standards or numeric criteria. Some EC standards were recommended for adoption in recent FAO-report on "Malta Agricultural Policy and the EC membership: Challenges and Opportunities".

Permanent sealing of soil is absolutely prohibited by the Soil preservation Act. The Development Planning Act 1992 (structure Plan 1990) designates rural conservation areas and restricts any development in these areas. The Water ordinance specifies water contamination zones, where disposal of waste materials and contaminants is prohibited and in which no new livestock farms are permitted. The formulation of a Pesticide Control Act is almost completed.

NETHERLANDS

Soil Protection Act forms integrating network for soil policy. Important role for provinces. Specific protection level for so-called soil protection areas and groundwater protection areas.

Basic Strategies:

- *Point sources:* ICM approach. Emissions are prevented by appropriate isolation techniques. Isolation is controlled and the surroundings of the contained source are monitored. Examples: waste dumps, industrial process plans, storage of hazardous materials. For point sources that cannot be isolated, such as building materials, standards for leaching are developed.

- *Diffuse sources:* Balance approach. Input of substances to the soil must be balanced by output from the soil by drainage, volatilization, decomposition and uptake by crops. The resulting concentration in soil and groundwater must be equal to or less than reference values. Output from the soil should not lead to air or surface water pollution. examples: Dutch sewage sludge and compost regulation.

- *Soil Clean-up:* General goal of clean-up is restoration of soil multi-functionality. target values for clean soil must be reached unless the clean-up:

  * will cause environmental problems, or
  * is impossible for technical reasons, or
  * is too expensive

  Criteria for environmental impact of clean-up, technical constraints and cost effectiveness are now being developed to facilitate this decision making. If restoration of multi-functionality is not possible for one of the aforementioned reasons, the site is isolated, controlled and monitored (ICM approach). ICM solutions may involve partial excavations and may be related to current or intended use of the soil but often involve severe restrictions on land use.

NORWAY

No national approach. Limited experience to date. Generic criteria ("Dutch list") available for general guidance but ad hoc approach considering site-specific elements such as: intended use, technical feasibility, cost and secondary contamination during cleanup *(77,99)*.

Several acts directly or indirectly regulate changes in land use or in land ownership and spatial planning (such as The Act of Planning and Construction, Act of change in Land Ownership, Act of Right of Way, Act of Water Rights and the Act of Farm Inheritance)

The pollution Control Act of 1981 relates to air, water and soil pollution and contains some specifically soil related directives, e.g. on the use of sewage sludge, on storage and spreading of manure, on the use of silage fluid, on special wastes and a directive on land levelling.

In the Nature Conservation Act of 1970 (amended in 1985) soil is protected against environmental impacts, but not including the effects of long range trans-boundary air pollution.

Economic incentives to stimulate more timely farming practices (tillage in spring rather than autumn) started from 1991 onwards.

RUMANIA

There is no specific soil protection legislation. Soil protection is partly covered by the Environmental Protection Act (1973) and partly by some acts and rules under the responsibility of the Ministry of Agriculture and Food and Ministry of Waters, Forests and Environmental Protection. On the basis of some special acts on erosion control, irrigation and drainage, large areas of agricultural and forests land were reclaimed and reforested.

Maps have been prepared at small and large scales showing different soil constraints and soil susceptibility to various risks such as erosion, structure deterioration, acidification, pollution with heavy metals.

Criteria and standards concerning soil protection are generally at a preliminary stage. Preliminary Agricultural Soil protection Standards were issued in 1977. the use of DDT and HCH in agriculture has been banned since 1985.

The first national environmental quality monitoring system with special consideration to air, water and soil was set up in 1975. Since then, the state authorities are annually provided with a special report on the quality of the soil, including data on various aspects of soil degradation. recommendations are given concerning prevention and control of soil pollution and sustainable use of soils.

In 1992, a new integral country-wide soil quality monitoring system was established which includes forest soils and which is harmonized with other European systems. It contains several criteria for soils.

Currently, a new draft of an Act on environmental protection is submitted to the Parliament for approval. In this Act, soil conservation is considered an integral part of environmental protection. The Act contains specific soil related guidelines.

RUSSIA

The following basic laws for soil protection were passed in 1992:
"Environment protection", "Regulation on State control of land management and conservation", "Regulation of order of conservation of degraded agricultural lands polluted by toxic wastes and nuclides".

Criteria and standards were prepared and they are under discussion now.
Four categories of soil quality are distinguished:

- Biological
- Chemical (relating to the natural chemical soil properties, e.g. depletion of nutrients);
- Physical
- Cleanliness (related to pollution)

Beside the natural factors, special standards have been proposed that differentiate between the different natural and economical regions. Together with the criteria for degradation, these geographic standards are intended for fixing the sum(s) to be paid by those liable for restoration in case of soil degradation. Criteria for pollution are based on health hazard assessment, not on eco-toxicological impacts.

SLOVAKIA

Protection of the Environment is an important point of the Constitution of the Slovak Republic. The present soil protection legislation is focused mainly on soil functions, like biomass production and protection of soil fertility. A system of limit values for soil fertility evaluation (soil nutrient status) and of limit values for water quality is in use.

Currently used threshold values for heavy metals in soils will be replaced by criteria similar to the "ABC list" of the Netherlands. A general soil monitoring system, as part of environmental monitoring, has been developed and is currently in use.

A soil vulnerability map for acidification and soil contamination maps have been prepared. A geochemical atlas for soils is currently under preparation. A database of soil properties is also available.

SLOVENIA

Soil protection legislation is partly covered by the new Environmental Protection ACT (June 1993) through ecological balance and preservation of productive soil, use of harmless and non persistent and non-accumulating substances. The National Environmental Programme contains goals, guidelines and a strategy for environmental protection and the use of natural resources for a period no less than 10 years. The Act includes also environmental vulnerability studies, environmental impact assessment and environmental monitoring where observation and supervision of immission in the soil is especially evident.

The decree on the identification of pollution of agricultural and forest land (Official Gazette of Republic of Slovenia, No. 6/90) sets out basic guidelines for environmentally sound land use and criterions for some agrochemicals (triazine), organic fertilizers (pig slurry) and waste material applications (sewage sludge), as well as some measures in accident situations.

SWEDEN

Soil protection criteria are controlled mainly by the national environmental protection legislation. Other legislation like the Forestry Act and the Act of Soil Cultivation give general criteria with consideration of sustainable use of the soils.

Groundwater must pass the criteria for drinking water. Drinking water may not contain any residues of pesticides or insecticides. Target values for nitrate are labelled on groundwater.

A new monitoring programme on both national and regional level has partly started in 1993. It covers (i.a.) natural ecosystems, agricultural and forest land and it includes different criteria for soils.

Environmental objectives concerning forest soils are given such as critical loads for Sulphur and Nitrogen. Other objectives stipulate a reduction of the present loads of heavy metals and some persistent organic pollutants by 50-70%. Drainage of forest land has recently been tightened up through new rules in the Nature Conservation Ordinance. Restricted distribution of forest fertilizers is recommended.

Strong reduction by 1995 of pollution by pesticides, heavy metals, and some persistent organic compounds, is aimed at. Cadmium concentrations for Phosphorus fertilizers has been regulated.

Target loads have been set for use of sludge or wood ashes on agricultural or forest land

SWITZERLAND

Maintaining soil fertility is the basic concern in environmental protection legislation. Preventive measures such as emission control (prevention at source) to guarantee soil fertility. Cantonal authorities have powers to implement more stringent measures at emission control if federal legislation in certain cases does not suffice to guarantee long term soil fertility. Monitoring soil quality with regard to heavy metals and fluorine contamination occurs at appropriate time intervals at federal and cantonal levels.

Legislation :

- Federal law of 1983 for environmental protection also covering protection of soils against chemical contamination. Revision of 1993 also covers:
  * Biological and physical quality criteria for long term protection of soil fertility
  * Decontamination of locally heavily polluted soils
- Federal Ordinance of 1986 related to pollutants in the soil (guide values adjusted to most vulnerable mineral soils; to allow assessment of impairment of long-term fertility of all mineral soils due to contaminants); need for revision at a later date.

Loss of soil due to land use is covered by the Federal law on spatial planning of 1979 (quantitative criteria).

TURKEY:

Soil protection and restoration is undertaken by public institutions. The Ministry of Agriculture and Rural Matters plays an important role in the implementation of agricultural politics and management of cultivated lands. Until recently, cultivated land in Turkey was protected against any change in land use, but the legislation has been modified in 1989 in view of growing population pressures. The fact that taxes, prices and subsidies have not been harmonized has further contributed to the non-agricultural utilization of arable land. Inappropriate location of certain activities has also led to soil and water pollution
Soil protection is not based on fixed criteria but on a qualitative assessment of risks and actual problems. However, the legal structure and in some cases detailed regulations, permits essential integrated measures against soil pollution to be taken.

A law for the evaluation of environmental activities exists since 1993 in order to inhibit further degradation of natural resources due to industrialisation and excessive soil use. Other legislation (1992-1993) against soil and water pollution applies EC standards.

UNITED KINGDOM:

No specific soil protection legislation. Various aspects covered in wide range of measures, directly or indirectly related to soils. *Overall land quality* plays important role in planning: the most productive soils are protected from "development". Attention is paid to soil quality during redevelopment of former industrial areas: Soils are restored according to present or immediate future use and not necessarily to multi-functionality). Best Practicable Environmental Option - approach.

Soil contamination is controlled by emission - and waste disposal restrictions (hence at the source). There are no specific control/sanctions on spreading of manure but pollution must be avoided. Legal thresholds do exist for spreading of sewage sludge on agricultural land, targeted at multi-functionality. The Department has published guidance on maximum permissible concentrations of potentially toxic elements in soil after application of sewage sludge (Code of Practice for Agricultural Use of Sewage Sludge HMSO 1989). However a certain degree of contamination will be permitted. Authorities have to licence or be informed about other types of waste deposition on agricultural land, but no specific criteria exist in law. A comparison has been made between known acidic deposition and estimated critical loads to assist in determining future atmospheric pollution control policies.

Advice on the assessment of contamination of land is provided in guidance published by the DoE on behalf of the Interdepartmental Committee on the Redevelopment of Contaminated Land (ICRCL). There are guideline (trigger) values for certain contaminants in the soil related to site end use.

Trigger values (threshold/action) have been developed as guidance to mitigate effects of previous degradation *by limiting or changing future land use* or providing management advice *(50)*. Below threshold value soil is considered safe for intended use, between threshold and "action" value remedial action may be needed, above "action" value soil considered too contaminated for intended use: remedial action necessary or change of intended land use. Again *planning* legislation important for enforcing guidelines in correspondence with site characteristics/requirements.

To minimise *pollution* by agriculture voluntary Codes of Good Agricultural Practices for Protection of Water, Air and Soil have been published. Aspects of these codes are covered by statutory control. A statutory code exists for pesticides. Advice on best practical means to protect soils is given in the Soil Code. *Compaction* problems are less serious than 20 years ago, but still require attention on susceptible soils.

EEC

A number of regulations and directives which are more or less directly related to soil protection have been established at EC level:

- Directive fixing limit values for concentration of heavy metals in sewage sludge
- Directive limiting content of copper in pig feed
- Directive fixing limits for pesticides
- CORINE Soil Erosion Risk assessment for Southern Europe based on USLE
- Directives on water protection

The criteria usually consist of generic, fixed values, which is logical in view of the (European) scale of application.

FAO

An *erosion risk* factor evaluation (rather simplistic) is used in the Framework for Land Evaluation *(36)*; more sophisticated approach using USLE

4 CONCLUSIONS

Currently relatively few countries in Europe employ quantitative criteria or standard values to assess and control soil degradation. The variety of criteria and standard values that are applied is considerable and the terminology used is far from uniform. The focus of specific criteria for different substances may vary between countries, but notably, the values themselves often differ as well.

Approaches and concepts for establishing and applying these criteria and values also vary widely from one country to another and even within individual countries. This is probably a subject to be considered for further harmonization among European countries.

Whereas quite explicit values are fixed in several countries for some types of degradation, in particular for soil pollution by heavy metals, other degradation types have not been evaluated in a quantitative manner by means of such criteria. This is largely true for erosion and to some extent for salinization, which is only a regional problem within Europe.

It has been mentioned previously that soil protection requires an integrated approach. Achieving this integration still seems rather in the future with regard to criteria and standard values for soil degradation and soil protection. It seems sensible therefore to work towards the establishment of certain standards for all relevant types of soil degradation, based on a uniform general methodology. In order to avoid the rather confusing situation that exists in soil pollution assessment and control, an appropriate degree of coordination at the European level would be necessary to obtain some level of uniformity between countries in the development of criteria and their terminology. It would also be helpful to have general agreement on a standard data set required for the assessment of soil degradation and for the development and use of criteria and standard values (see also Chapter IV).

There is ample evidence, however, that proper criteria/standard values need to be flexible to accommodate a range of site-specific characteristics, such as soil properties, type of degradation/type of polluting substance, socio-economic issues, additional environmental factors.

CHAPTER III - PROPOSED METHODOLOGICAL APPROACH FOR FUTURE ACTION

1 EVALUATION and CORRELATION OF THE AVAILABLE INFORMATION

Summarizing, the available information provides the following picture:

a) Soil degradation is a serious problem in Europe. Erosion by water and (to a lesser extent) by wind, pollution, compaction and perhaps urbanisation appear to be the main issues, both in terms of their severity and (ir)reversibility. As with many environmental problems, there is competition between the economic and ecological functions of the soil, or sometimes between the different ecological functions (eg. excessive agricultural use vs. filter, buffer and transformation system).

b) Much research is being undertaken, especially related to soil erosion and several types of pollution (acidic atmospheric deposition, heavy metals and organic compounds from municipal and agricultural wastes). Monitoring programmes, both at national and regional/European levels, also exist on the same issues, either as part of an overall environmental programme or as a single theme. There appears to be no monitoring programme or integrated research into soil degradation at a European level

c) Technical measures are often being taken on a short term basis and aimed at repairing damage rather than at elimination or reduction of the causes. Also, a sectoral rather than an integrated approach prevails. Measures taken to tackle one type of soil degradation often do not consider combined effects or interaction with other degradational processes.

d) Legislation on soil protection is common, most often as part of a wider environmental programmes, but some regulations are focused on just one aspect, such as the effect of spreading sewage sludge or farm manure. Some laws are preventive, others rehabilitative, such as the "polluter pays" principle. Some countries put more emphasis on law enforcement and taxes, others on codes of practice and incentive measures, but combinations of both are quite common.

e) Criteria and standard values are relatively common with respect to soil pollution, but less so or even non-existent for other types of soil degradation. Both values and terminology are far from standardized between countries

The overriding impression is that much information is available on practically all aspects of soil erosion and its control, though slightly less on its detailed geographical distribution. Although the GLASOD map gives a useful world view of soil erosion, and soil degradation in general, the small scale makes it unsuitable for a detailed European assessment. The World Overview of Soil Conservation Activities and Techniques (WOCAT), currently conceived by the World Association of Soil and Water Conservation (WASWC) will be a valuable contribution to our knowledge, but will have similar limitations of scale.

Information is available on various aspects of soil pollution. Research on this subject generally is relatively recent having been undertaken during the last two decades and cause- and effect relationships are not too clear. Hence measures to monitor soil pollution will mostly be of preliminary nature and must allow for refinements in a later stage, based on additional scientific information. The importance of socio-economic factors and the acceptability of measures by the target groups must not be overlooked. Legal and economic pollution control measures are quite common, most often under the umbrella of a wider environmental legislation, but confined to one or a few aspects of pollution.

Far less literature relating to other types of soil degradation exists. This is understandable in that they are less extensive in Europe. A significant exception being soil compaction, about which relatively more information was encountered than for the other degradation types. This is a serious degradation process that sometimes causes irreversible damage especially in terms of the biomass production function of the soil. It may also lead to other at least partly irreversible degradation processes, such as erosion. It would seem that compaction does not attract all the attention it deserves.

2 *PROPOSAL FOR A METHODOLOGICAL APPROACH FOR FUTURE ACTION TO IDENTIFY, MONITOR AND SOLVE SOIL DEGRADATION PROBLEMS*

In order to make an effective approach to soil degradation at the European level, it should be noted that the following recommendations should not be seen in a separate context but in simultaneous development with national scale activities. Furthermore, existing projects and programmes would be used to the maximum possible extent in the implementation of pan-European activities:

a) A detailed assessment of the various aspects of current soil degradation in Europe, including trends shown by recent past rates. Objective values as to determine how critical the situation is should be established, since its perception may vary from country to country.

b) A detailed assessment of soil vulnerability to all aspects of soil degradation in Europe, and identification of the most sensitive areas to soil degradation

c) Preparation of an extensive review of existing measures, techniques, legislation and economic measures to counter soil degradation

A combination of a) and b) gives the actual degradation situation related to the potential hazard. This is important when choices have to be made between areas regarding the urgency of intervention. A currently already severely degraded area may have a lower priority for intervention than a slightly degraded area that has highly sensitive soils to that type of degradation, as the former may require large rehabilitation efforts to bring about only modest results whereas the latter may be protected from serious degradation by simpler and cheaper preventive action. However, heavily polluted sites may threaten surrounding areas through migration of pollutants and in such cases must be given priority for clean-up. The review of existing measures (c) will facilitate the choice of relevant intervention(s) for the selected critical areas.

2.1 Comprehensive assessment of the Current Status of Human Induced Soil Degradation in Europe

The thematic maps derived from the GLASOD survey *(66)* illustrate the value of a comprehensive overview and cartographic representation of the current status of soil degradation in Europe. The shortcomings of maps at this small scale are outlined in annex I, whereas other types of degradation, as discussed in Chapter I, §§2.3-2.10 need to be considered as well.

A proposal has recently been made to compile a map of the Status of Human-Induced Soil Degradation in Europe ("EURASOD") at a publication scale of 1:3 million, with an appropriate database. The assessment would be largely based on the GLASOD methodology. Furthermore, a more specific assessment for carrying out soil pollution oriented studies in Europe (EUSOPOL) was also proposed, including some detailed studies at larger scales (1:1 m.) in priority areas. Implementation of these proposals would be a significant contribution to a pan-European approach of soil degradation.

It is important that these assessments are more heavily based on quantitative and objective data than the current GLASOD map. This is especially the case for so-called "stable" areas, the definition of which varies greatly between different countries.

It should be possible, and indeed desirable, to expand the assessment to cover both land degradation and soil degradation. The close links between soil, vegetation and water resources would then be shown more clearly. This would facilitate an integrated approach to soil degradation as previously proposed.

2.2 Assessment of Soil Vulnerability to all types of human induced soil degradation in Europe

An international workshop was held in Wageningen in November 1991 in which procedures and methodology were outlined for a project to assess and map the vulnerability of soils to specified chemical compounds in Europe at a scale of 1:5 m and based on computerized soil and terrain data (SOVEUR) *(11)*. Although this would entail only a part of the soil degradation problem, the methodology could be adapted and used in a broader approach. The difficulty of establishing criteria and standards for the different types of degradation however should not be underestimated. Parameters and corresponding soil and terrain characteristics will need to be identified for each degradation process, thus permitting an assessment to be based on existing soil data.

2.3 European Overview of Soil Protection Activities and Techniques

The World Association of Soil and Water Conservation is currently in the process of developing a World Overview of (soil) Conservation Activities and Techniques (WOCAT) *(104)*. The objectives are:

- to compile information about existing conservation techniques, activities and approaches, in particular to record specific details on technological and ecological parameters for each technique and approach.
- to report on the extent and efficiency of each technique and activity in relation to the areas involved and their problems.
- to present the most promising techniques pictorially and cartographically on a global map at an approximate scale of 1: 15 m.
- to produce a compendium of techniques and activities in the form of a handbook, with an expert system designed to be used by field experts and technicians
- to compile a GIS database and a software expert system about soil erosion and conservation techniques and activities on a global scale

To be applicable in the European situation, an appropriate scale would have to be chosen for the overview. Furthermore, whereas WOCAT will concentrate on erosion control only, the proposed overview would cover all types of soil degradation. But the WOCAT methodology may be useful for such a survey together with a considerable amount of data on erosion which is already available or is in the process of being collected and processed.

Other appropriate bodies specialized in other types of soil degradation should be consulted as well, such as international institutions and specialized national laboratories and institutions

2.4 Possibilities and problems with regard to a pan-European approach

As shown in Chapter I, soil degradation may have an impact at local, national and regional scales, depending on the type, the degree and the extent of degradation. This implies that soil protection needs to be considered at these three levels as well. At the field level these considerations will chiefly relate to the implementation of measures and site specific research, whereas at national and regional levels, emphasis will be on legislation, policies and strategies, as well as on monitoring and research. Special fields of interest at the European level would pertain to the coordination of activities, especially with respect to monitoring and research, and to supra-national policies and strategies, for instance conventions aimed at the reduction of certain pressures on the soil, such as the existing Convention on Long Range Transboundary Air Pollution.

Problems related to this approach will be the sheer size of the subject matter and heterogeneity of data and applied criteria. Often, the only common factor will be the soil, but it is important enough to merit an integrated treatment. A further practical problem will be the current sectoral approach in research, monitoring, legislation and implementation. Soil acidification by atmospheric deposition for instance is treated as an entirely different "discipline" to soil compaction or soil erosion. If this administrative problem could be overcome in research and development, an integrated legislative approach would be facilitated. International collaboration and information exchange between institutes and research agencies concerned with different aspects of soil degradation should merit priority.

2.4.1 *Standardized comprehensive European soils and terrain database (SOTER)*

An important task comprises the further development of uniform criteria for measurement of soil degradation and soil sensitivity/vulnerability for the whole of Europe. A standardized methodology for data collection and analysis is indispensable for such an undertaking. The World Soils and Terrain Digital Database *(35)*, developed by ISRIC in cooperation with and endorsed by FAO and UNEP, is a suitable instrument for the collection of compatible and uniform quantitative and descriptive data on which the assessments of current status of soil degradation and of soil vulnerability in Europe could be based (see *88*). The combined assessment will then lead to the identification of areas with a high degree of urgency of intervention for soil protection. A choice of measures to be taken could be derived from the overview of measures and techniques based on experiences elsewhere under similar conditions.

For land use planning and for the planning and implementation of protective and rehabilitation measures, other types of data, for example climate, water resources, land use and socio-economic data, will be required as well as a reliable and comprehensive soils and terrain database. Provision for some of these parameters is already made in the SOTER structure.

2.4.2 *Regular updates of "EURASOD" to monitor trends*

Whereas the vulnerability of a soil will not change spontaneously in a significant manner, the status of soil degradation may change considerably over a relatively short period. For this reason it is important to assess the status of soil degradation by regular monitoring, which could be done by updating "EURASOD" data. Special attention should be focused on those regions with a high vulnerability for a particular type of soil degradation, as this is where changes are most likely to occur. The update intervals can be made dependent on the individual degradation types as one degradation process (e.g. pollution) may induce significant changes much more rapidly than another (e.g. compaction, subsidence).

3 *PRINCIPLES AND STRATEGIES*

The principles laid down in the European Conservation Strategy *(26, 28)* and the recommendations on soil protection should also form the basis of any soil protection strategy. The following principles in particular should be highlighted or added.

The emphasis in soil protection "should move from remedial and reactive strategies to preventive and pro-active strategies. Past damage needs to be repaired but in future we should seek to prevent such damage".

Soil protection requires an integrated approach. Sectoral approaches, i.e. focusing on more specific types or aspects of soil degradation are useful, but should be integrated at policy and decision making levels. Not only should each distinct soil problem be treated within the larger context of soil degradation, but links with other environmental factors must be kept in mind as well. This could mean that some aspects of soil degradation (e.g. atmospheric deposition of pollutants) would be treated more efficiently as part of another problem e.g. air pollution, rather than as a typical soil problem. Therefore, soil protection ought not only to be an integral part of environmental policies, but part of other related policies as well, such as for agriculture, forestry, industry, town and countryside planning, etc.

Policies and strategies directed at soil protection should be flexible, as the soil is part of a dynamic environmental system. They should take into account the changes in the soil in response to external disturbances.

The urgency for action has been emphasized *(13)* even if the degradation processes at work are not yet fully understood or scientifically explained ("plausibility principle"). It is indisputable for some irreversible processes and it can be assumed for others that there is no time to loose before action is taken in order to repair or prevent further damage. The Chemical Time Bomb concept clearly illustrates this point. At the same time, care must be taken that because of possible interactions, the remedies are not worse than the disease.

At a European level of action, it was suggested *(26)* that the European Soil Charter of 1972 could be reviewed and modernised to accommodate present knowledge about soil degradation and to reinforce its principles and specify their legal scope so that they can serve as a base for national legislatures. These suggestions were considered by the Council of Ministers but were not estimated appropriate at the time. However, the European Conservation Strategy *(28)*, which has developed from that meeting, includes the recommendation to reinforce national legal provisions and, if necessary, to draw up a European legal instrument on soil protection. Alternatively, new recommendations could be drawn up for a specific Council of Europe work Programme which could lead to a new international legal instrument.

CHAPTER IV - DEVELOPMENT OF A EUROPEAN SOIL PROTECTION DATABASE

1 *INTRODUCTION*

To enable the results of research into soil protection to have a wider applicability throughout Europe, a better standardization of terms and methodologies is required. Though it may not be useful in view of varying site specific conditions, to fix very detailed criteria at too high a central (e.g. pan-European, EC-) level, it will be valuable to have compatible methodologies for the assessment of soil quality and for the establishment of criteria. It is essential that methodologies used in the measurement of the different parameters and in establishing relationships between soil properties, soil functions and the processes of soil degradation are at least comparable. Guidelines could then be prepared for an inventory of soil degradation and soil vulnerability, for example at a European level. Such guidelines would ensure uniform application of methodologies *(11)* and would have to be based on comparable and compatible data.

2 *DATA REQUIREMENTS FOR THE RESPECTIVE STAGES OF SOIL PROTECTION*

It is clear from the previous chapters that for planning and carrying out proper soil protection policies to prevent soil degradation as well as to restore degraded soils where applicable, an elementary understanding of the underlying factors and processes is indispensable. A core of adequate and well established background information constitutes the basis of this understanding. In this chapter, the requirements for a database that contains such information will be discussed. To identify data requirements for the formulation of soil protection policy, a stepwise approach can be followed. Obviously, the data sets can not be strictly separated from each other and in practice overlaps will be quite common.

2.1 Soil quality assessment

For a general soil protection approach at national or higher level, the present "quality" of the soils must be established. As described in chapter II, the perception of soil quality is dependent on the functions that the soil performs, on soil properties and on other environmental factors. It has also been stated previously that no fixed universal criteria can be applied to soil quality, hence no simple data set will suffice for a quality assessment. This is already true for one type of soil degradation, i.e. soil pollution, but it applies to other degradation types as well. This implies that quality criteria and hence data requirements for the assessment of several types of soil degradation and soil vulnerability will show a large variety and complexity.

In some cases the condition of the soil may have been improved through amelioration practices, which have enhanced certain soil functions. In other situations the soil condition may have deteriorated due to natural or human-induced processes. Soil quality in its most simple form thus can be defined as the condition of a soil compared to that of a *"reference soil"* in a multi-functional state. It should be realised that such a reference soil may have natural restrictions with regard to multi-functionality.

A reference soil should be available for each soil type to be examined. A qualitative and quantitative description and normal ranges within each of the properties should be available. This will facilitate the identification of anomalies in a given soil compared to its reference counterpart. For all major soil types in Europe soil properties have been defined in various soil classifications at both national and regional (e.g. FAO, EC) scale.

However, some properties that are needed to determine soil quality are not regularly included in soil survey and mapping exercises. An example is concentration of heavy metals or some persistent organic compounds. Contrarily, some other properties that are part of standard soil classifications may be less important for the definition of such a "reference soil".

This means that for the definition of a reference soil, a selection should be made of those soil properties in existing soil classifications that are considered relevant in view of possible changes in soil quality, complemented by other relevant soil properties *not* included in regular soil classifications.

The results of the soil quality assessment should, where possible, be compared with earlier inventories to detect any developing trends.

If no anomalies are detected the soil can be considered representative, however without reference to the *suitability* of the soil for a given use.

The soil properties also determine the *vulnerability* (see Chapter I, §1.4.2; and *(11)*) of that soil to a given type of degradation, although the relevant properties may vary with the type of degradation. Soil vulnerability is an critical element in risk assessment for soil degradation.

Up to this point, a full description of the relevant *soil properties* and those of the reference soil will be the major requirement. To make an assessment of soil vulnerability, however, the type of land use is another important parameter. To facilitate comparison of data, this description should be as objective and quantitative as possible.

2.2 Identification and monitoring of soil degradation factors and processes

If the soil has anomalies, it should be checked to see if these have a natural cause or whether they are induced by human activities. In other words: the soil must be checked for any *signs of human induced degradation*. Most of these signs can be derived directly from the soil properties, especially in comparison with previous measurements when available in order to distinguish them from natural causes. The time frame of such comparisons should be uniform, i.e. it makes no sense to compare situations in one area within a time interval of say, five years, and taking an interval of fifteen years in another area. To detect any negative trends at a relatively early stage, such monitoring should be repeated at regular intervals.

Decrease in the thickness of topsoil will indicate occurrence of sheet erosion, increased levels of heavy metals or xenobiotic substances will be evidence of pollution, an abnormally low pH shows acidification, increased bulk density could be caused by compaction, etc.

If it appears that a soil is affected by, or vulnerable to, a particular type of soil degradation, the *factors involved in the degradation process* need to be identified and described. These include specific *soil and terrain properties* as well as *"external" natural parameters* such as climate and topography. *Human influences* that cause a degradation process to occur such as mismanagement of the land, deforestation, industrial and bio-industrial activities, as well as possible pathways also need to be examined. A combination of several factors or several pathways should always be considered a possibility.

2.3 Impact assessment

The demands imposed by a given function (biomass production, filtering, storage and buffering, etc.) determine which soil properties are relevant for that function. Soil degradation will have a negative effect on some or all of the soil functions. The *impacts* of soil degradation can be assessed for a given current or immediate future use, or for *all* natural *functions* for that soil type (multi-functionality).

On the other hand soil functions may have negative impacts on soil quality. Every use of the soil will exert a certain stress (or in pollution terms: load) on that soil, which may lead to some degree of degradation, depending on the vulnerability of the soil to that specific stress. The impact is determined by the combination of the soil vulnerability with the "load" exerted by a certain land use or soil function. The evaluation will evidently determine the urgency and type of action to be taken.

The *impact* of the type of soil degradation on for instance crop productivity, on health, or infrastructure, should be evaluated as well as the eventual negative consequences of a certain use of the soil for soil quality. In other words, the degree to which the soil functions are affected or threatened should be assessed.

2.4 Final decision making, implementation and control

The impact- or risk assessment will lead to the identification of the need for action e.g. by means of the "trigger values" used in pollution control. In the case of active soil degradation, policies should be aimed at restoring soil quality to a "good" or acceptable level. In case of vulnerability to a certain type of degradation the focus will be more on prevention, but a combination of both aims is quite common. If action is to be taken, a choice must be made from the options available, after consideration of the site specific conditions.

The final decision for taking a particular remedial or preventive action will depend on *site-specific circumstances*, of which *soil properties* are quite important, beside *other natural and human-induced factors*. *Political and socio-economic factors* will generally be of similar, if not decisive importance, for example by setting *threshold or target values* for concentrations of substances in the soil.

For subsequent *control*, any changes in soil properties should be measured with reference to the situation after remediation which does not necessarily reflect the reference soil characteristics. Control must take place at regular intervals in order to detect any trends. At a European scale such intervals would be in the order of five years but for vulnerable areas and at more detailed levels, a higher frequency is required.

2.5 Conclusion: required data sets

Summarizing the previous paragraphs, the following information is required for proper soil protection formulation:

- *Soil parameters*: physical, chemical and biological characteristics of the soil environment in the broad sense, i.e. including groundwater, parent material and topography. Natural or background values must be known. Data for the soil under investigation and the reference soil should be in uniform format and comparable.

- *External degradation parameters*: the characteristics of the degradation types in question, for instance in case of pollution: the properties of the substances involved, their source, mobility, bio-degradability, toxicity, etc.

Depending on the available information cause/effect relationships may then be established for a defined soil and a given type of degradation. Possibly new models can be developed or existing models tested and validated. While some soil properties are more significant for resisting one type of soil degradation, other characteristics will be more relevant for an other degradation type. For example: as has been stated in Chapter I, erosion is to a large extent influenced by texture, structure and organic matter, slope and rainfall characteristics. On the other hand, in the case of soil pollution, the pH and cation exchange properties of the soil are much more significant *(49)*.

Relationships exist between soil properties on the one hand and soil functions on the other. The quality of a given soil for a definite land use can thus be determined when the relevant requirements for that land use are known. From this it follows that a third category of information is required:

- *Soil function parameters*: demands on soil quality will vary with different soil functions: for example nutrient and organic matter content and water availability for agriculture (biomass production function), or pH, texture, organic matter content, infiltration and percolation rate for the filter- and buffer function. Therefore, present and intended future land use is an important parameter in this category.

A "multi-functionality" approach will obviously impose the highest demands. It must be realised that optimal soil properties for one type of land use can be detrimental for another soil function; take for instance the positive influence of increased available nitrogen levels on agricultural or forest production versus the adverse effects on biodiversity *(49)*.

Land suitability assessment, as has been developed over the last 20 years or so *(36)*, takes into account the properties that are required for a given use. In this way, land properties (or "qualities") are distinguished and clearly related to productivity of crops, other plant growth, domestic animal productivity, forest productivity or management and inputs. Although many of the properties overlap between the various land uses, their importance in each case may differ.

Finally, a fourth category of parameters is important in the decision making process with regard to soil protection. Unlike all the parameters mentioned previously, these are "subjective" parameters, directly determined by man. Their value depends on the human perception of soil quality and suitability. As has been discussed in Chapter II, these parameters are derived from or dependent on other parameters. *Derived parameters*, determine the quality of a soil and the urgency of remedial or preventive action (criteria; threshold values, see Chapter II).

3 REQUIREMENTS FOR A EUROPEAN DATABASE FOR SOIL PROTECTION

3.1 Objectives of a European soil protection database

A Soil Protection Database should provide essential elements for the formulation of appropriate national soils policies on the basis of sound scientific information. For several countries assessments have been made at a national scale. If the information were gathered in an agreed form and combined into a European database, more detailed and more quantitative information on human-induced soil degradation on a pan-European basis would become available. This would allow the development of international policies to combat the problems.

It must be realised however that the database itself will not provide an evaluation of soil degradation nor will it suffice for the complicated assessment of soil vulnerability. The information from the database will merely serve as an indispensable tool in the establishment of models for analysis and validation of cause-effect relationships. For some areas of soil protection such models and relationships have been developed such as the critical loads concept for acidification, the Universal Soil Loss Equation, and cause-effect relationships/models for heavy metal pollution. As stated in Chapter II, relatively few such models have found their way into practical (e.g. legislative) applications.

To permit easy access, combination, analysis and further handling of the data enumerated above, the information needs to be stored in a readily accessible format in a computerized database. The following section will elaborate on the specifications for such a database.

3.2 Characteristics of a European soil protection database

It follows from the foregoing that a suitable computerized database for the evaluation of current soil related problems and threats should have the following characteristics:

a) Data input, storage, editing, analysis and retrieval should be possible in a suitable and smooth manner, i.e. using a common and internationally endorsed database management system thereby ensuring compatibility and facilitating data exchange with other systems.

b) It should contain a wide range of soil properties (see § 2) to enable a broad use of the database, i.e. considering the diversity of soil degradation and soil protection issues.

c) Both profile characteristics and spatial distribution patterns are important. The latter will facilitate links to and from GIS and remote sensing to be made which increases the applicability and enables integration in larger environmental models.

d) Data on other environmental parameters should be included, such as climate, topography, vegetation, geology, land use and hydrology. Alternatively, compatibility with other environmental databases should be assured.

e) The database should be applicable at varying scales in order to be valuable for both general policy development and more specific problems in case studies.

f) Allowance should further be made for political priorities and socio-economic parameters. This also implies the possible incorporation of set values such as threshold/trigger levels and other criteria.

With regard to the required parameters, it must be noted that in many European countries detailed soil surveys and inventories of other environmental data are available. The resulting information has been recorded on maps and stored mostly in computerized databases. Detailed "reference" descriptions exist for all common European soils. Consequently a European soil protection database would have the advantage that it could be built rapidly from the large amount of readily available information.

Among the existing systems that would be suitable for development into a European Soil Protection Database, the CEC CORINE (Coordination of Information on the Environment) project should be mentioned. This project created an Information System on the State of the Environment in Europe, including a soils database. This database contained information derived directly from the 1:1 m. soil map of the European Communities and has served for various applications, including a soil erosion risk assessment and a land quality evaluation for the Mediterranean area *(22, 23)*. A start has been made to expand the soils database from a digitized map legend into a soil profile and analytical database based on existing profile descriptions *(58)*. Furthermore the preparation of a soil map at a scale of 1:1 m. for Central and Eastern European countries (but excluding the former USSR) has also recently started *(52)*.

The World Soils and Terrain Digital Database (SOTER) is a somewhat different system, possessing the characteristics described in the previous paragraphs *(35)*. SOTER can accommodate soils and terrain data at various scales. It can easily be adapted to larger or smaller scales and is currently being used for several applications at scales varying from 1:5 m. to 1:250.000. Unlike many conventional soils databases, SOTER is especially suitable for practical applications, in particular land degradation assessment and modelling. A big advantage of SOTER is the direct access to original data in the database and its adaptability to different scales.

Practical applications for SOTER are already being realized outside Europe so far, but a proposal has been prepared for assessment of soil pollution in Central and Eastern Europe (EUSOPOL) while a proposal for Hungary has recently been approved (HUNSOTER) *(51)*.

A Pan European multi-purpose soil database may be ambitious, but it is an essential goal for the years to come. A successful start could be made by homogenization of methodologies and the use of one general soils database system at a European scale.

ANNEX I EXPLANATORY NOTE to the MAPS

As an illustration of this document seven small scale maps have been inserted that are derived from the data for the 1:10 m. world map of the Global Assessment of the Status of Human-induced Soil Degradation (GLASOD) which was published in 1990 by the International Soil Reference and Information Centre (ISRIC) in Wageningen at a request of the United Nations Environmental Programme (UNEP). The GLASOD map can be considered as a first step towards a global assessment of the geographical distribution of soil degradation *(66)*.

The scale of the maps imposes restrictions upon what can be shown. The original GLASOD map gives a generalized overview at a **global** scale which is here reduced to a European scale. Many degradation phenomena have a spatial extent which is insufficient to be represented on a map covering the whole world or even Europe alone. Nevertheless they should not be ignored during policy consideration. Examples include point source-pollution from waste deposits or former factory sites.

Degree of soil degradation

The degree to which the soil is presently degraded was estimated in relation to changes in agricultural suitability, in relation to reduced productivity and in some cases in relation to its biotic functions. Four levels are recognized:

1. **light:** The terrain has somewhat reduced agricultural suitability, but is suitable for use in local farming systems. Restoration to full productivity is possible by modifications of the management system. Original biotic functions are still largely intact.
2. **moderate:** The terrain has greatly reduced agricultural productivity but is still suitable for use in local farming systems. Major improvements are required to restore productivity. Original biotic functions are partially destroyed.
3. **strong:** The terrain is non reclaimable at farm level. Major engineering works are required for terrain restoration. Original biotic functions are largely destroyed.
4. **extreme:** The terrain is unreclaimable and beyond restoration. Original biotic functions are fully destroyed.

Relative extent of the degradation type

Physiography, i.e. major terrain characteristics, was taken as the basis for delineating mapping units in view of the close links between terrain and soil properties and consequently soil degradation. Where physiography is fairly homogeneous over an extensive area, a mapping unit can be quite large. This may give a somewhat distorted picture of the occurrence of soil degradation within that unit because the whole mapping unit is displayed in the colour of the degradation type in question. Therefore it is important to realize that, whereas all mapping units in Europe except for a few "Stable" regions display some type of degradation, this does not imply that indeed all European soils are degraded. The map only shows the average status of soil degradation within each mapping unit. At the chosen scale it is not possible to separate areas of soil degradation individually on the map. It is however possible to estimate the relative extent of each type of soil degradation within the mapped unit. Five categories are recognized:

1. **infrequent:** up to 5% of the unit is affected
2. **common:** 6 to 10% of the unit is affected
3. **frequent:** 11 to 25% of the unit is affected
4. **very frequent:** 26 to 50% of the unit is affected
5. **dominant:** over 50% of the unit is affected.

The severity of soil degradation

The status of degradation is calculated as a combination of its degree (seriousness) and its relative extent (percentage of the mapping unit truly affected) in a mapped unit, resulting in four "severity" classes (see fig. 1). On the map, each severity class is represented by different colour shades: light shades refer to low degradation severity, dark shades to very high severity.

This approach implies that a strong degree of degradation occurring infrequently may be given the same severity class as a light degree of degradation occurring frequently. A detailed comparative assessment of the economic and ecological damage between the different degradation types can therefore not be made on the basis of this information.

It should be realized that the shading of colours on the map is an interpretation of the situation based on the information supplied by the correlators. Other interpretations are possible and may result in different shadings.

Explanation of the Legend of the GLASOD Map

The colours on the map indicate the degradation type; the shading of the colour indicates the severity of the degradation taking place in a mapped unit.

Soil degradation types

A total of 12 types is recognized.

Water Erosion

Loss of topsoil

Loss of topsoil through water erosion is the most common type of soil degradation. It is generally known as surface wash or sheet erosion. On very steep slopes, natural loss of topsoil may occur frequently. This 'geologic erosion' is not indicated on the degradation map, unless it is accelerated by human intervention.

Terrain deformation/mass movement

The most common phenomena of this degradation type are rill and gully formation. Rapid incision of gullies, eating away valuable soil is well known and dramatic in many countries. Other phenomena of this degradation type are riverbank destruction and mass movement (land slides).

Wind Erosion

Loss of topsoil

This degradation type is defined as the uniform displacement of topsoil by wind action. It is a widespread phenomenon in arid and semi-arid climates, but it also occurs under more humid conditions. In arid or semi-arid climates natural wind erosion is often difficult to distinguish from human-induced wind erosion, but natural wind erosion is often aggravated by human activities.

Chemical Deterioration

Pollution

Many types of pollution can be recognized, such as industrial or urban waste accumulation, the excessive use of pesticides, acidification and heavy metal deposition by airborne pollutants, excessive manuring, oil spills, etc. Degree and distribution of these individual types vary strongly.

Although the differences in types of pollution are important, according to the substance(s) involved, source(s), pathways and impacts, no clear distinction was made in the GLASOD map for cartographic reasons. The major type shown on the maps as "pollution" concerns atmospheric deposition of acidifying compounds and/or heavy metals. Most of the other pollution types are, notwithstanding their importance, too localized too be properly represented on the maps.

NB: Two types of acidification occur also locally in Europe due to other causes. The first may occur in coastal regions, when upon drainage of pyrite-containing soils, pyrite will oxidize to, sulphuric acid, which strongly reduces the agricultural potential of the soils because of extremely low pH values. The second type of acidification is caused by over-application of acidifying fertilizer, which may also lead to strong acidification and reduced agricultural potential.

Salinization

Human-induced salinization can be the result of three causes. Firstly, under arid or semi-arid conditions, a high salt content in irrigation water or improper drainage of irrigated fields can lead to a rapid salinization of the soils. Secondly, salinization will occur in coastal regions with an excessive use of groundwater when seawater intrudes the groundwater reserves. A third type of salinization occurs where human activities lead to an increase in evapo(transpi)ration of soil moisture in soils on salt-containing parent material or with saline groundwater.

<u>Physical Deterioration</u>

Compaction, sealing and crusting

Compaction, sealing and crusting occur under nearly all climatic and soil physical conditions. Compaction is usually caused by the use of heavy machinery on soils with a low structure stability. Sealing and crusting of the topsoil occurs in particular if the soil cover does not provide sufficient protection to the impact of raindrops.

Waterlogging

Waterlogging includes flooding by river water and submergence by rain water caused by human intervention in natural drainage systems. Eventual positive effects of waterlogging (e.g. on natural wetlands) are not considered here.

Shrinkage of organic soils

Shrinkage of organic soils, as caused by drainage and/or oxidation, is only recognized on the maps if the agricultural potential of the land is negatively affected. In many cases however, drainage of organic soils will lead to an increase in agricultural potential, and is not mentioned on the map.

Mapped units without human-induced soil degradation

<u>Stable terrain</u>

Stable terrain under natural conditions

Areas which are stable under natural conditions show little or no agricultural practices, and usually show very little other human activities. This absence of human activities is in general due to the fact that the type of land concerned is not suitable for agriculture practices.

Stable terrain with permanent agriculture.

If agricultural land is well managed, no soil degradation of any kind will occur and productivity levels will not decrease.

Terrain stabilized by human intervention

Conservation practices have positive effects on the soil and may eliminate soil degradation altogether. Examples of conservation practices are reforestation, terracing, gully control, water management, etc.

Causative Factors

For each mapped unit with some form of degradation, one or two causative factors were given:

<u>Agricultural activities, including overgrazing</u>

This causative factor is defined as improper management of agricultural land. It includes a wide variety of practices, such as insufficient or excessive use of fertilizers, shortening of the fallow period in shifting cultivation, use of poor quality irrigation water, absence of anti-erosion measures, improperly timed use of heavy machinery, etc. Overgrazing can be defined as mismanagement of natural rangelands. Besides the actual overgrazing of the vegetation by livestock, this causative factor also includes other effects of livestock, such as trampling. Overgrazing usually leads to a decrease of the soil cover, which increases the water and wind erosion hazard. Trampling may cause compaction of the soil.

Deforestation and removal of the natural vegetation

This causative factor is defined as removal of the natural vegetation (usually forest) of stretches of land for agricultural purposes (cropping or cattle raising), large scale commercial forestry, road construction, urban development, etc.

(Bio)industrial activities

This causative factor is defined as those activities in the industrial and bio-industrial sector that lead to soil degradation, in this case usually pollution.

The causative factors are shown in maps 5-7. These maps only display the spatial extent of the various human activities that lead to any kind of soil degradation in Europe. Unfortunately it was not possible to establish a direct relationship between the causative factors and the degradation types. UNEP/GRID prepared tables that linked types and causes of soil degradation on a global scale, which indicated for each combination of types and causes the most probable links.

An overview of the extent of soil degradation in Europe is given in the following table as well as the total areas affected by the different causative factors. It should be kept in mind that the "extent" of degradation, i.e. the area percentage truly affected within each mapping unit, may vary from 0-5 % (class 1) to as much as 50-100% (class 5), so the figures shown are a best approximation only.

Human-induced Soil Degradation for Europe[1], expressed in million hectares

Type	Light	Moderate	Strong	Extreme	Total
Loss of Topsoil	18.9	64.7	9.2	-	92.8
Terrain Deformation	2.5	16.3	0.6	2.4	21.8
WATER	21.4	81.0	9.8	2.4	114.5 (52.3%)
Loss of Topsoil	3.2	38.2	-	0.7	42.2
WIND	3.2	38.2	-	0.7	42.2 (19.3%)
Loss of nutrients/O.M.	2.9	0.3	-	-	3.2
Salinization	1.0	2.3	0.5	-	3.8
Pollution	4.1	14.3	0.1	-	18.8
CHEMICAL	8.1	17.1	0.6	-	25.8 (11.8%)
Compaction	24.8	7.8	0.4	-	33.0
Waterlogging	0.5	0.3	-	-	0.8
Subsidence organic soils	2.6	-	-	-	2.6
PHYSICAL	27.9	8.1	0.4	-	36.4 (16.6%)
TOTAL	60.6 (27.7%)	144.4 (66.0%)	10.7 (4.9%)	3.1 (1.4%)	218.9 (100%)

	deforestation	overgrazing	agricultural mismanagement	bio(industrial) activities
Europe	84	50	64	21

[1] Europe includes the European part of the former U.S.S.R.

NB: Due to the scale of the map and the limited degree of detail of the data, the information should not be used at scales larger than about 1:5.000.000 and is not apt for assessments at the national level in Europe.

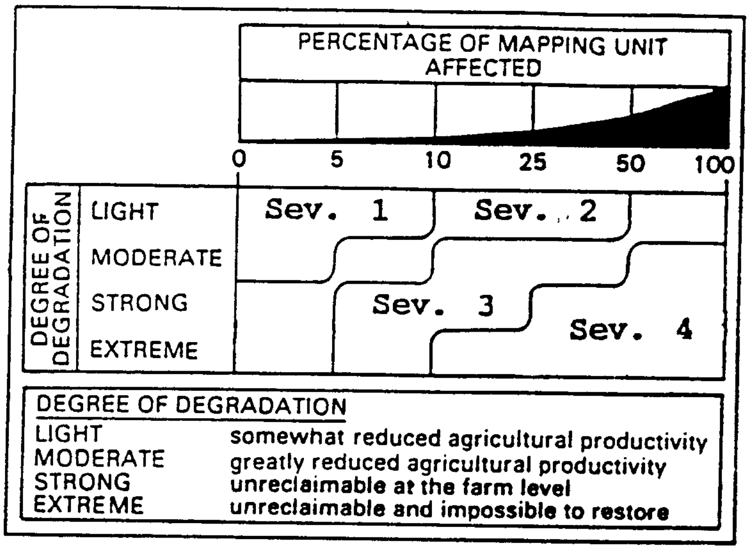

Figure 1: Severity classes

SWITZERLAND

Table 5 Guide values for maximum allowable pollution contents in Switzerland. From: Ordinance on Soil Pollutants, 1986.

Pollutants	Amounts of pollutants contained in air-dry mineral soil (gramme per tonne)	
	Total content (HNO3-extract)	Soluble content (NaNO3-extract)
Lead (Pb)	50	1.0
Cadmium (Cd)	0.8	0.03
Chromium (Cr)	75	-
Cobalt (Co)	25	-
Fluorine (F)	400	25 1)
Copper (Cu)	50	0.7
Molybdenum (Mo)	5	-
Nickel (Ni)	50	0.2
Mercury (Hg)	0.8	-
Thallium (Tl)	1	-
Zinc (Zn)	200	0.5

1) water soluble amount

The guide levels apply to the amount of pollutant contained in a mixed sample taken from the upper 20 cm of mineral soil investigated, which has been dried up to constant weight in circulating air at 40°C. In the case of soils dug from deeper than 20 cm, the result of the investigations must be adjusted as follows:

$$\text{Definitive amount} = \frac{\text{measured content} \times \text{depth at which dug in cm}}{20\ \text{cm}}$$

In order to determine the total content of heavy metals, 2 molar nitrous acid (HNO3) is used as solvent. The weight ratio of soil sample to solvent is 1 to 10.

In order to determine the soluble content of heavy metals, 0.1 molar sodium nitrate (NaNO3) is used as solvent. The weight ratio of soil sample to solvent is 1 to 2.5.

Table 6 Limit values for compost and sewage sludge in Switzerland. From: Revision (September 1992) of the Ordinance on Environmentally Hazardous Substances.

Substance	Limit value (mg/kg dry matter)	
	compost [1]	sewage sludge [2]
Cadmium	1	5
Cobalt	--	60
Chromium	100	500
Copper	100	600
Lead	120	500
Mercury	1	5
Molybdene	--	20
Nickel	30	80
Zinc	400	2000

[1] 2.5 t dry matter/ha + 3 years

[2] 5 t dry matter/ha + 3 years

Table 7 Orientation values for heavy metals in relation to the reuse of slightly contaminated soil in two land use categories (in mg/kg dry matter). From: Communication no. 4 to the Order on Soil Pollutants, Nov. 1993

Substance	Category I		Category II	
	T1)	S2)	T	S
Cadmium	0.8	0.03	2	0.05
Chromium	75	0.04	200	0.06
Copper	50	0.7	100	1.4
Lead	50	1.0	300	1.5
Mercury	0.8	--	1.2	--
Nickel	50	0.2	100	0.4
Zinc	200	0.5	350	1.0

1) total content; 2) soluble content

Table 7b. Orientation values for some organic substances in relation to the reuse of slightly contaminated soil in two land use categories (in mg/kg dry matter) From: Communication nr. 4 to the Order on Soil Pollutants, Nov. 1993

Substance	Category I	Category II
PAH	1	5
PCB	0.05	0.25
benzene	0.7	7
ethylbenzene	0.7	7
toluene	0.7	7
xylene	0.7	7
Mineral oils	50	300

X

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ANNEX II EXAMPLES OF SOME THRESHOLD VALUES AND CRITERIA

From: *(100): Visser, W.J.F. 1993: Contaminated land in various industrialized countries; Review of approaches Technical Soil Protection Committee, The Hague.*

THE NETHERLANDS

Table 1 Latest proposals for C-values (intervention values) for soil (mg/kg) and groundwater (mg/m^3); A-values (target values), and current C-values are included for reference.

SUBSTANCES	SOIL			GROUNDWATER		
	New C-values	A-values	Current C-values	New C-values	A-values	Current C-values
I. METALS						
chromium	380	100	800	30	1	200
cobalt	240	20	300	100	20	200
nickel	210	35	500	75	15	200
copper	190	36	500	75	15	200
zinc	720	140	3000	800	65	800
arsenic	55	29	50	60	10	100
molybdenum	200	10	200	300	5	100
cadmium	12	0.8	20	6	0.4	10
barium	625	200	2000	625	50	500
mercury	10	0.3	10	0.3	0.05	2
lead	530	85	600	75	15	200
II. INORGANIC COMPOUNDS						
cyanides (free)	20	1	100	1500	5	100
cyanides (complex. pH<5)	650	5		1500	10	200
cyanides (complex. pH≥5)	50	5	500	1500	10	200
thiocyanates	20	-		1500	-	
III. AROMATIC COMPOUNDS						
benzene	1	0.05	5	30	0.2	5
ethylbenzene	50	0.05	50	150	-	60
phenol	40	0.05	10	2000	-	50
cresol	5	-	-	200	-	-
toluene	130	0.05	30	1000	0.2	50
xylene	25	0.05	50	70	-	60
catechol	20	-	-	1250	-	-
resorcinol	10	-	-	600	-	-
hydrochinon	10	-	-	800	-	-
IV. POLYCYCLIC AROMATIC HYDROCARBONS						
PAH (sum of 10)	*40*	*1*	-	-	-	-
naphtalene	-	0.015	50	70	0.1	30
anthracene	-	0.05	100	5	0.02	10
phenantrene	-	0.045	100	5	0.02	10
fluoranthene	-	0.015	100	1	0.005	5
benzo(a)anthracene	-	0.02	50	0.5	0.002	2
chrysene	-	0.02	50	0.05	0.002	2
benzo(a)pyrene	-	0.02	10	0.05	0.001	1
benzo(ghi)perylene	-	0.02	100	0.05	0.0002	5
benzo(k)fluoranthene	-	0.025	50	0.05	0.001	2
indeno(1,2,3cd)pyrene	-	0.025	50	0.05	0.0004	2
V. CHLORINATED HYDROCARBONS						
1,2-dichloroethane	4	-	50	400	(d)	50
dichloromethane	20	-	50	1000	(d)	50
tetrachloromethane	1	0.001	50	10	(d)	50
tetrachloroethene	4	0.01	50	40	(d)	50
trichloromethane	10	0.001	50	400	(d)	50
trichloroethene	60	0.001	50	500	(d)	50
vinylchloride	0.1	-	-	0.7	-	-

Table 1 Continuation

SUBSTANCE	SOIL			GROUNDWATER		
	New C-values	A-values	Current C-values	New C-values	A-values	Current C-values
Chlorobenzenes (sum)	*30*	-	*20*	-	-	*5*
monochlorobenzene	-	(d)	10	180	0.01	2
dichlorobenzene	-	0.01	10	50	0.01	2
trichlorobenzene	-	0.01	10	10	0.01	2
tetrachlorobenzene	-	0.01	10	2.5	0.01	2
pentachlorobenzene	-	0.025	10	1	0.01	2
hexachlorobenzene	-	0.025	10	0.5	0.01	2
Chlorophenols (sum)	*10*	-	*10*	-	-	2
monochlorophenol	-	0.0025	5	100	0.25	1.5
dichlorophenol	-	0.003	5	30	0.08	1.5
trichlorophenol	-	0.001	5	10	0.025	1.5
tetrachlorophenol	-	0.001	5	10	0.025	1.5
pentachlorophenol	5	0.002	5	3	0.01	1.5
chloronaphtalene	10	-	-	6	-	-
sum of 7 PCB's	*1*	*0.02*	*10*	*0.01*	*(d)*	*1*
PCB 28	-	0.001	-	-	-	-
PCB 52	-	0.001	-	-	-	-
PCB 101	-	0.004	-	-	-	-
PCB 118	-	0.004	-	-	-	-
PCB 138	-	0.004	-	-	-	-
PCB 153	-	0.004	-	-	-	-
PCB 180	-	0.004	-	-	-	-
VI. PESTICIDES						
DDT/DDD/DDE	4	-	-	*0.01*	-	-
DDT	-	0.1	5-10**	-	(d)	1-2**
DDD	-	0.1	5-10**	-	(d)	1-2**
DDE	-	0.1	5-10**	-	(d)	1-2**
Sum (of 3 drin's)	4	-	-	*0.1*	-	-
aldrin	-	0.0025	5-10**	-	(d)	1-2**
dieldrin	-	0.0005	5-10**	-	0.00002	1-2**
endrin	-	0.001	5-10**	-	(d)	1-2**
HCH-compounds	2	-	–	*1*	-	-
a-HCH	-	0.0025	5-10**	-	(d)	1-2**
b-HCH	-	0.001	5-10**	-	(d)	1-2**
g-HCH	-	0.00005	5-10**	-	0.0002	1-2**
carbaryl	5	-	5-10**	0.1	-	1-2**
carbofuran	2	-	5-10**	0.1	-	1-2**
maneb	35	-	5-10**	0.1	-	1-2**
atrazin	6	0.00005	5-10**	150	0.0075	1-2**
VII. OTHER COMPOUNDS						
cyclohexanone	270	-	60	15000	-	50
phtalates (sum)	*60*	*0.1*	-	*5*	*0.5*	-
mineral oil	5000	50	-	600	50	-
pyridine	1	0.1	20	3	0.5	30
styrene	100	0.1	50	300	0.5	60
tetrahydrofuran	0.4	-	40	1	-	60
tetrahydrothiofene	90	-	50	30	-	60

5-10**) Chlorinated = 5 mg/kg; non-chlorinated = 10 mg/kg
1-2**) Chlorinated = 1 μg/l; non-chlorinated = 2 μg/l
(d) detection limit

Table 2 Eikmann-Kloke system: orientation values for (harmful) substances in soil related to types of use and protection objectives (in mg/kg, PCDD/F=ng TE(BGA⁺)/kg, SV=soil value). From: Eikmann and Kloke, 1991.

No.	Types of use	Elements	As	Be	Cd	Cr	Cu	Hg	Ni	Pb	Se	Tl	Zn	BaP	PCB*	PCDD/F
0	multifunctional use possibilities	SV I	20	1	1	50	50	0,5	40	100	1	0,5	150	1	0,2	10
1	children's playgrounds	SV II	20	1	2	50	50	0,5	40	200	5	0,5	300	1	0,2	10
		SV III	50	5	10	250	250	10	200	1000	20	10	2000	5	1	100
2	domestic gardens and allotments	SV II	40	2	2	100	50	2	80	300	5	2	300	2	0,5	30
		SV III	80	5	5	350	200	20	200	1000	10	20	600	5	2,5	100
3	sports and playing fields	SV II	35	1	2	150	100	0,5	100	200	5	2	300	1	1	30
		SV III	90	2,5	5	350	300	10	250	1000	20	20	2000	3	5	100
4	park and recreational areas - non-covered and vegetation-poor	SV II	40	5	4	150	200	5	100	500	10	5	1000	3	3	50
		SV III	80	15	15	600	600	15	250	2000	50	30	3000	6	10	150
5	industrial areas - heavy and light - non-sealed	SV II	50	5	10	200	300	10	200	1000	15	10	1000	5	5	75
		SV III	150	20	20	800	1000	20	500	2000	70	30	3000	10	15	200
6	industrial areas - heavy and light - covered and overgrown	SV II	50	10	10	200	500	10	200	1000	15	10	1000			
		SV III	200	20	20	800	2000	50	500	2000	70	30	3000			
7	agriculturally used areas, orchard market gardens	SV II	40	10	2	200	50	10	100	500	5	2	300			
		SV III	50	20	5	500	200	50	200	1000	10	20	600			
8	non-agricultural eco-systems	SV II	40	10	5	200	50	10	100	1000	5	2	300			
		SV III	60	20	10	500	200	50	200	2000	10	20	600			

+ BGA = Federal Agency of Germany, * Total 6 Ballschmiter PCB-Congeners

Table 3 Eikmann-Kloke system: criteria for various types of soil use. From: Eikmann and Kloke, 1991.

No.	Criteria: Types of use	protection objectives	intake path	soil location	soil depth *
1	children's playground	young children accompanying person	oral	playground sand vegetation free surrounds	35 cm
2	domestic garden allotments	children adults	oral inhalation	garden beds vegetation poor areas	35 cm
3	sports and playing fields	sports persons teenagers	inhalation	tamped area vegetation free area	10 cm
4	park and recreational areas non-covered vegetation poor	adults children	inhalation oral	non-covered vegetation poor areas	10 cm
5	heavy and light industrial and storage areas, non-sealed	adults of employment age	inhalation water pathways	non-covered vegetation free areas	10 cm
6	heavy and light industrial and storage areas, sealed or overgrown	adults of employment age groundwater	(inhalation) water pathways	non-sealed and overgrown areas	depending on location to 35 cm
7	agriculturally used areas orchards and market gardens	plants, food chains - humans and animals	oral plant pathways	arable land market gardens orchards	top soil to 35 cm
				grass lands	10 cm
8	non-agricultural areas eco-systems	groundwater wild and forest plants	oral water and plant pathways	forest, woods barren land, untouched nature areas	upper soil depending on soil profile to 50 cm

* If a suspicion of groundwater contamination due to waste exists, the total drain zone has to be included in the investigations.

Table 4 Tentative "trigger concentrations" used in the United Kingdom. From: ICRCL, 1987.

Compound	Planned Uses	Trigger Concentrations Threshold	Action
Selected Inorganic Contaminants		(mg/kg air-dried soil)	
Arsenic	Domestic gardens, allotments	10	TBD2
	Parks, playing fields, open space	40	TBD
Cadmium	Domestic gardens, allotments	3	TBD
	Parks, playing fields, open space	15	TBD
Chromium (VI)	Domestic gardens, allotments	25	TBD
	Parks, playing fields, open space		
Chromium (Total)	Domestic gardens, allotments	600	TBD
	playing fields, open space	1000	TBD
Lead	Domestic gardens, allotments	500	TBD
	Parks, playing fields, open space	2000	TBD
Mercury	Domestic gardens, allotments	1	TBD
	Parks, playing fields, open space	20	TBD
Selenium	Domestic gardens, allotments	3	TBD
	Parks, playing fields, open space	6	TBD
Boron (soluble)	Any uses where plants are grown	3	TBD
Copper	Any uses where plants are grown	130	TBD
Nickel	Any uses where plants are grown	70	TBD
Zinc	Any uses where plants are grown	300	TBD
Contaminants Associated with Former Coal Carbonization Sites			
Poly-aromatics	Dom. gardens, allotments, play areas	50	500
	Landscapes, buildings, hardcovers	1000	10000
Phenols	Dom. gardens, allotments	5	200
	Landscapes, buildings, hardcovers	5	1000
Cyanide	Dom. gardens, allotments, landscapes	25	500
(free)	Buildings, hardcovers	100	500
(complex)	Dom. gardens, allotments	250	1000
	Landscapes	250	5000
	Buildings, hardcovers	250	None
Thiocyanate	All proposed uses	50	None
Sulfate	Dom. gardens, allotments, landscapes	2000	10000
	Buildings	2000	50000
	Hardcovers	2000	None
Sulfide	All proposed uses	250	1000
Sulfur	All proposed uses	5000	20000
Acidity	Dom. gardens, allotments, landscapes	pH 5	pH 3
	Buildings, Hard cover	None	None

1
All proposed values are tentative and/or preliminary requiring regular updating. All values are for concentrations determined on 'spot' samples. If all values are below the Threshold Concentrations, site may be regarded as uncontaminated for these contaminants and development may proceed. Above the thresholds, remedial action may be needed. Above the action concentration, remedial action will be required or the form of development changed.

2
TBD- 'to be developed'

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