Report 97/08b (Revised edition)

Guidelines for the Assessment of Soil Degradation in Central and Eastern Europe

G.W.J. van Lynden

Food and Agriculture Organization of the United Nations

International Soil Reference and Information Centre

Enquiries:
c/o Director,AGL
FAO
Viale delle Terme di Caracalla
00100 Rome, Italy
Fax: +39 06 570 56275
E-mail:land-and-water@fao.org

and

c/o Director, ISRIC
P.O. Box 353
6700 AJ Wageningen
The Netherlands
Telefax: +31-(0)317-471700
E-mail: soil@isric.nl

TABLE OF CONTENTS

ACKNOWLEDGEMENTS....................II

1 INTRODUCTION....................1
1.1 Background....................1
1.2 Degradation assessment....................1

2 CONCEPTS AND DEFINITIONS OF SOIL DEGRADATION....................3
2.1 General....................3
2.2 Types of soil degradation....................4
2.2.1 Pollution....................4
2.2.2 Other types of degradation....................6
2.3 Soil degradation extent....................9
2.4 Degree and impact of degradation....................9
2.4.1 Degree of pollution....................10
2.4.2 Impact of pollution....................12
2.4.3 Degree of other degradation types....................12
2.4.4 Impact of other degradation types....................12
2.5 Rate of soil degradation....................15
2.6 Causative factors....................15

3 DATABASE IMPLEMENTATION....................17
3.1 Base map....................17
3.2 Data entry....................17

REFERENCES....................19

LIST OF TABLES

1 Original standards adopted in the Netherlands for soil contaminants....................11

2 Impact of degradation: management level and productivity....................13

LIST OF APPENDICES

APPENDIX I Input of degradation codes into the database....................20

APPENDIX II SOVEUR matrix table....................21

ACKNOWLEDGEMENTS

These guidelines were prepared for the project GCP/RER/007/NET on Mapping of Soil and Terrain Vulnerability in Central and Eastern Europe (SOVEUR), which was signed between the Food and Agriculture Organization of the United Nations (FAO) and the Government of the Netherlands within the framework of the FAO/Netherlands Government Programme. In view of the specific nature of the services to be rendered, the Project activities were implemented under a Contractual Service Agreement with the International Soil Reference and Information Centre (ISRIC). It was carried out in close collaboration with specialists from soil survey institutes in Belarus, Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Moldova, Poland, Romania, the Russia Federation (West of the Urals), Slovak Republic and the Ukraine, who collated the various national data sets using uniform guidelines. The guidelines have been prepared on the basis of the Guidelines for General Assessment of the Status of Human-Induced Soil Degradation (Oldeman, 1988) and the Explanatory Note to the World map of the Status of Human-Induced Soil Degradation (GLASOD, Oldeman et al., 1991), as well as the adapted Guidelines used for the Assessment of the Status of Human-Induced Soil Degradation in South and Southeast Asia (van Lynden, 1995b). At ISRIC, Ms. J. Resink was responsible for GIS operations and printing of the maps and P. Tempel for the development of the data entry program.

1 INTRODUCTION

1.1 Background

A two year project on Mapping of Soil and Terrain Vulnerability in Central and Eastern Europe (SOVEUR) was signed between the Food and Agriculture Organization of the United Nations (FAO) and the Government of The Netherlands, within the framework of the FAO/Netherlands Government Cooperative Programme. The project is being implemented by FAO in cooperation with the International Soil Reference and Information Centre (ISRIC) under a Contractual Service Agreement which included Letters of Agreement with National Collaborators within the frame of their National Institutes representing their countries in the project (13 participatory countries). The project calls for the development of an environmental information system for the region in close collaboration with soil survey institutes in Belarus, Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Moldova, Poland, Romania, the Russian Federation, Slovak Republic and the Ukraine. Using this system and auxiliary information on climate, land use and the type of soil pollution, the status of human-induced soil degradation and the areas considered vulnerable to defined pollution scenarios will be identified and mapped (scale 1:2.5 million).

Target beneficiaries are ministries and planning bodies in the collaborating countries who can use the databases and derived maps for policy formulation at the regional and national level, for instance by identifying areas considered most at risk. The project also contributes to strengthening of the capabilities of national "environmental" organizations in Central and Eastern Europe.

The SOVEUR project activities include:

(1) Refinement of methodological guidelines for the compilation of a soils and terrain digital database for the 13 participating countries (Batjes and Van Engelen, 1997).
(2) Refinement of methodological guidelines for assessment of the status of land degradation, with special focus on soil pollution status (this report)
(3) Development of methodological guidelines for assessment of the vulnerability of soils to selected categories of pollutants (Batjes, 1997).
(4) Application of the methodological guidelines, by country, in order to create georeferenced databases on:
    - soil and terrain units;
    - soil degradation and pollution status;

    which will subsequently be used, in combination with auxiliary data sources, to:
    - assess relative soil vulnerability;
    - determine areas considered at risk from re-mobilization of specific contaminants.

1.2 Degradation assessment

As a part of the SOVEUR project, the assessment of soil degradation in Central and Eastern Europe at a scale of 1:2.5 M aims to produce a geographical overview of the current status of soil degradation in this region, with emphasis on soil pollution. In a revision of the European part of the Global Assessment of Human-Induced Soil Degradation (van Lynden, 1995a), pollution in Europe was estimated to cover a total of 18.8M ha, or 72% of all chemical deterioration in Europe. This was mainly referring to pollution by atmospheric deposition without distinguishing between the various types of pollution, their sources, pathways and different impacts. The criteria applied were qualitative and open to subjective judgment. The required background data for the studied period (about 1960-1985) were not always readily available, especially in the former East Bloc countries.

At the scale of the current assessment, it still is difficult to provide quantitative criteria, in particular for soil pollution in view of the enormous variety not only in pollution types and impacts, but also in the criteria in so far as they exist. In the current guidelines the criteria for the assessment of pollution follow as much as possible the standards used previously for the other types of degradation, but separate classes and descriptions have been defined for the degree and the impact of pollution.

Like the previous assessments of soil degradation at a global (GLASOD, 1:10M) and regional (ASSOD, 1:5M) scale, the Assessment of Soil Degradation in Central and Eastern Europe will serve as a means to increase awareness on soil degradation in general and on the status of pollution in particular. In view of the scale and the anticipated available data, this inventory is, like GLASOD, based on experts' estimates. As such it will give an overall impression of the status of degradation in the region and identify priority areas ("hot spots"). Together with the soil and terrain data to be collected and the soil vulnerability assessment, the information on the status of soil degradation will facilitate the identification of specific areas at risk from soil pollution. For these areas more detailed studies will be required to determine the course of action.

The assessment will be based on the SOTER map, to be compiled following the Guidelines for the compilation of a 1:2.500.000 SOTER database (Batjes and van Engelen, 1997). For each polygon (unique delineated unit) of this map, degradation data should be provided.

1.3 Lay-out of these guidelines

In the following chapter some concepts of soil degradation will be treated. An explanation of the definitions of degradation types, separated into pollution and other types, is given in chapter 2.1. Chapter 2.2 briefly describes the concept of degradation extent. In chapter 2.4 the terms degree and impact of degradation are clarified, again separately for pollution (2.4.1 and 2.4.2) and for other types (2.4.3 and 2.4.4). Chapter 2.5 and 2.6 describe the rate of degradation and the causative factors, respectively.

Chapter 3 addresses the implementation of the assessment, suggesting a stepwise approach.

Appendix I provides some technical instructions related to the data entry program, while Appendix II contains an example of a SOVEUR matrix table as well as an empty table for actual use.

2 CONCEPTS AND DEFINITIONS OF SOIL DEGRADATION

2.1 General

Soil degradation, as defined for the GLASOD map, is "a process that describes human-induced phenomena which lower the current and/or future capacity of the soil to support human life" (Oldeman et al., 1991). This definition of soil degradation is rather broad and requires some further refinement. In a general sense, soil degradation could be described as the deterioration of soil quality, or in other words: the partial or entire loss of one or more functions of the soil (Blum, 1988). Quality should be assessed in terms of 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 (Council of Europe, 1990):

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 contaminants.
- *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 and 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.

A distinction should be made between soil degradation *status*, *rate* and *risk*. Soil degradation *status* reflects the **current** situation while the *rate* indicates the relative decrease or increase of degradation over the last 5 to 10 years (leading to the current status). The rate of degradation, as indicated on the status map, may give an indication of the danger of **further** deterioration, but it does not include areas that are now apparently stable but that may be at risk from degradation if, for instance, there is a change in land use. The degradation *risk,* defined in the broadest sense depends on soil and terrain properties which make a soil inherently prone to degradation, for example as a result of a change in external conditions (climate, land use). Within the SOVEUR context, *soil vulnerability* is defined in a somewhat narrower sense with respect to pollution (Batjes, 1997).

The emphasis in the GLASOD assessment was on soil degradation related to (food) productivity. The degree of degradation was mainly estimated on the basis of the intensity of the process (in particular for water and wind erosion, nutrient decline and salinization). In the Assessment of the Current Status of Human-Induced Soil Degradation for S. and SE. Asia (ASSOD), degradation was evaluated on the basis of its impact on productivity. This is rather straightforward for degradation types like erosion, compaction or fertility decline, but becomes more complicated with pollution where the main impact often is on other aspects than productivity, e.g. effects on human health. For the SOVEUR project, the status of degradation will be evaluated both in terms of the type and intensity of the process (degree) as well as the impact of degradation on various soil functions (in qualitative terms, as, for example, impact on productivity cannot be compared with impact on human health).

2.2 Types of soil degradation

The type of soil degradation refers to the nature of the degradation process (displacement of soil material by water and wind; in-situ deterioration by physical, chemical and biological processes). Types of soil degradation are represented by a code, the first capital letter indicating the major degradation type, the second lowercase letter referring to the subtype. A third lower case letter can be used for further specification. Most of the codes are the same as the ones used on the GLASOD map, but some extra ones have been added, whereas for others the definition has been changed slightly. In the context of the SOVEUR project, pollution has been treated as a separate degradation type and the assessment criteria for pollution have been modified accordingly. In this chapter the different (sub)types of pollution will be discussed first, followed by a review of other types of degradation such as water- and wind erosion, other forms of chemical deterioration and physical deterioration and non- degraded land.

2.2.1 Pollution

Soil pollution may result from a wide range of human activities and can emanate either from local (point) sources or from diffuse sources. Pollution may affect the soil via different "pathways", namely through the air, over land or by water. The total “accumulated load” of a contaminant may thus emanate from various sources and different pathways.

For the SOVEUR degradation assessment, five main types of soil pollution (Cp) as identified in the Dobris report on Europe’s Environment (Stanners and Bourdeau, 1995) are distinguished:

- Soil acidification (**Cpa**)
- Soil pollution by heavy metals (**Cph**)
- Soil pollution by pesticides and other organic contaminants (**Cpp**)
- Eutrophication by nitrates and phosphorus (**Cpn**)
- Soil pollution by radionuclides (**Cpr**)

Since these are major groupings, and subtypes differ significantly in their impact and behaviour, it is necessary to indicate specific compounds involved, in particular for Cph and Cpp.

Cpa: Soil Acidification

Atmospheric deposition by industrial and traffic emissions of sulphur dioxide (SO_2) and nitrogen (hydr)oxides (NH_x , NO_x) may be many times higher than under natural conditions levels (Ulrich, 1987). When deposited in excessive quantities, these substances are major contributors to soil acidification and thus usually referred to as "acid rain". The exchangeable base cations (Ca^{2+}, Mg^{2+}, K^+, Na^{2+}) in the soil are mobilized under influence of the acidic inputs and leached out to the ground water. This connotes a loss of some important plant nutrients. As the soil buffer capacity is depleted, the pH will start to drop and with increasing acidity, aluminium (and other metal) ions in the soil are mobilized. These can be toxic to most plants and have harmful effects on aquatic environments.

Soil acidification is further caused by acidifying fertilizers, removal of base cations through over-exploitation (soil mining), planting of acidifying vegetation (e.g. fir), or drainage of wetland soils containing pyrite, as well as by natural processes.

The following characteristics may affect the acidification of (forest) soils (Posch and Kauppi, 1991*)*:

- increased deposition of acid or potentially acidifying compounds
- decreased deposition of acid-neutralizing compounds; increased primary productivity
- increased rates 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 base 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).

Cph: Soil pollution by heavy metals

Soil pollution with heavy metals, e.g. cadmium, lead, chromium or copper, may emanate from various sources, such as industry, agriculture, incineration of waste and burning of fossil fuels, and road traffic (Stanners and Bourdeau, 1995). Atmospheric transport may contribute considerably (in natural areas almost entirely, except where geochemical background levels are already high) to the heavy metal load in the soil. Most heavy metals tend to accumulate in soils of higher pH, where they are less mobile. Consequently, lowering the pH may trigger a mobilization of the accumulated heavy metals, a phenomenon referred to as “chemical time bomb” (Stigliani, 1991; Batjes and Bridges, 1991; Batjes, 1997).

Cpp: Soil pollution by pesticides and other organic contaminants

The use of biocides (pesticides, herbicides, fungicides) and other agrochemicals in Europe is the highest worldwide (RIVM, 1992). After their application various processes modify the properties of these substances, such as degradation, sorption, plant uptake and transport (RIVM, 1992). Biocides and other organic contaminants (PCB’s, PAH’s, oils, tars, dioxins) may have a direct negative impact on soil flora and fauna and reduce the organic matter contents of the soil (especially in the case of herbicides). Crop yields can be severely affected by residual herbicides. Deleterious effects on animal and human health may occur through the pollution of ground and surface water. In particular the slowly degradable (persistent) substances or, conversely, those which are very mobile, are likely to give problems.

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 rapidly (Ulrich, 1987). As the surface layer is also the first to be removed by erosion, it means that the transported sediment and the transporting water can be enriched in pollutants.

Cpn: Eutrophication by nitrates and phosphates

A special type of "pollution" is the occurrence of excessive nutrient loads through overapplication of phosphorus and nitrogen, which may lead to eutrophication of ground and surface waters. Therefore, it is not a soil pollution problem *sensu stricto*. Both elements are essential for plant growth, but can become damaging when applied in quantities that exceed plant requirements. The excess may be leached from the soil, eroded or simply washed off the land into the ground water, waterways and coastal systems. The major source of nitrates is agriculture, through application of manure and fertilizers. In addition to direct application of nitrates (and phosphates), atmospheric deposition emanating from decomposing manure-slurry or from intensive animal husbandry in sheds may contribute significantly to the total accumulated load (Stanners and Bourdeau, 1995). Phosphorus is generally strongly fixed to clay particles and therefore mainly causes problems on poor sandy soils with a low adsorption capacity and high permeability, or in areas where ground water tables are high, creating anaerobic conditions in which the phosphate fixing capacity of the soil is lowest. Moreover, in such areas the leached phosphate reaches the ground water much faster than where the water table is deeper. Beside agriculture, sewage water is a major source of increased phosphate concentrations.

Cpr: Soil pollution by radionuclides

Radioactive elements occur naturally in the soil, but since World War II anthropogenic additions from fall-out of nuclear bombs testing and /or spillage from nuclear power plants or waste dumps have begun to become increasingly important (van Lynden, 1995a). Since the Chernobyl accident in 1986, concern about radioactive pollution has increased. The most significant radionuclides are caesium (Cs^{137}) and strontium (Sn^{90}), which have long half-lives and are strongly bound in the upper soil layers. These layers are the most prone to radioactive pollution, as most soil flora and fauna is found in these layers.

2.2.2 Other types of degradation

Other types of degradation not only pose environmental threats by themselves, but may also trigger sudden delayed occurrences of pollution or chemical time bombs. Moreover, they often do not occur in isolation, but may influence each other.
In the following paragraphs, brief descriptions and definitions are given for water erosion, wind erosion, chemical deterioration (other than pollution), physical deterioration and land without apparent degradation.

Water erosion

Wt *Definition:* loss of topsoil by sheet erosion/surface wash
Description: a decrease in depth of the topsoil (A horizon) due to more or less uniform removal of soil material by runoff water

Possible causes: inappropriate land management especially in agriculture (insufficient soil cover, unobstructed flow of runoff water, weak soil structure), leading to excessive surface runoff and sediment transport

Wd *Definition:* "terrain deformation" by gully and/or rill erosion or mass movements
Description: an irregular displacement of soil material (by linear erosion or mass movements) causing clearly visible scars in the terrain
Possible causes: inappropriate land management in agriculture, forestry or construction activities, allowing excessive amounts of runoff water to concentrate and flow unobstructed

Wo *Definition:* off-site effects of water erosion in upstream areas
Description: Three subtypes may be distinguished:
- Wos: sedimentation of reservoirs and waterways
- Wof: flooding
- Wop: pollution of water bodies with eroded sediments

Possible causes: see Wt and Wd

Wind erosion

Et *Definition:* loss of topsoil by wind action
Description: a decrease in depth of the topsoil (A horizon) due to more or less uniform removal of soil material by wind action
Possible causes: insufficient protection by vegetation (or otherwise) of the soil against the wind, insufficient soil moisture, destruction of soil structure

Ed *Definition:* "terrain deformation"
Description: an irregular displacement of soil material by wind action, causing deflation hollows, hummocks and dunes
Possible causes: as with Et

Eo *Definition:* off-site effects of wind erosion
Description: covering of the terrain with wind borne sand particles from distant sources ("overblowing")
Possible causes: see Et and Ed

Chemical deterioration (other than pollution)

Cn *Definition:* Fertility decline and reduced organic matter content
Description: a net decrease of available nutrients and organic matter in the soil
Possible causes: a negative balance between output (through harvesting, burning, leaching, etc.) and input (through manure/fertilizers, returned crop residues, flooding) of nutrients and organic matter

Cs *Definition:* salinization/alkalinization
Description: a net increase of the salt content of the (top)soil leading to a productivity decline. Two subtypes may be distinguished:
- Csi: inland salinization
- Css: intrusion of seawater (which may occur under all climate conditions)
- Csa: alkalinization

Possible causes: improper irrigation methods and/or evaporation of saline ground water (Csi), ground water extraction (Css), industry (Csa).

Physical deterioration

Pd *Definition:* aridification
Description: decrease of soil moisture
Possible causes: lowering of ground water tables for agricultural purposes or drinking water extraction; decreased soil cover and organic matter content; climate change.

Pc *Definition:* compaction
Description: deterioration of soil structure by trampling or the weight and/or frequent use of machinery
Possible causes: repeated use of heavy machinery, having a cumulative effect. Heavy grazing and overstocking may lead to compaction as well. Factors which influence compaction are ground pressure (by axle/wheel loads of the machinery used); frequency of the passage of heavy machinery; soil texture; climate; soil moisture.

Pk *Definition:* sealing and crusting
Description: clogging of pores with fine soil material and development of a thin impervious layer at the soil surface obstructing the infiltration of rainwater
Possible causes: poor soil cover, allowing a maximum "splash" effect of raindrops; destruction of soil structure and low organic matter.

Ps *Definition:* lowering of the soil surface
Description: subsidence of organic soils, settling of soil
Possible causes: oxidation of peat and settling of soils in general due to lowering of the water table (see also Pd); solution of gypsum in the sub-soil or lowering of soil surface due to extraction of gas/water

Pu *Definition:* Urban/industrial land conversion
Description: soil (land) being taken out of production for non-bio-productive activities, but *not* the possible "secondary" degrading effects of these activities.
Possible causes: urbanization and industrial activities; infrastructure; mining; quarrying, etc.

Pw *Definition:* waterlogging
Description: effects of human induced hydromorphism
Possible causes: rising water table (e.g. due to construction of reservoirs/irrigation) and/or increased flooding caused by higher peakflows.

Land without apparent degradation

Sn Stable under natural conditions; i.e. (near) absence of human influence on soil stability, and largely undisturbed vegetation. NB: some of these areas may be vulnerable to even small changes in conditions that may disturb the natural equilibrium.

Sh Stable under human influence; this influence may be passive, i.e. no special measures had or have to be taken to maintain stability, or active: measures have been taken to prevent or reverse degradation.

X “Wasteland”: land without appreciable vegetation and with (near) absence of human influence on soil stability, e.g. deserts, high mountain zones. Although geomorphological and pedological processes may be active, these can not be considered to “degrade” the soil, since they cause no real deterioration of soil properties (e.g. no fertile topsoil to be washed away).

2.3 Soil degradation extent

At the working scale of 1:2.5M, it is not possible to map separate areas of soil degradation within a given polygon. In the present guidelines, the extent of soil degradation refers to the percentage of the area within a polygon affected by a given type of degradation or by an association of several types. Often several types of degradation will overlap and in some cases even interact. Where such associations occur, the extent of the composite area must be indicated as a percentage of the entire polygon. For example: in a given polygon Wt alone covers 30%, Cn alone covers 20%, whereas an additional 15% is covered by the association Wt/Cn (hence total Wt is 45% and total Cn is 35%, but this needs not be indicated in the matrix table/database). *NB: in case of 100% overlap of two(or more) types, the extent of the individual types is 0%, but all other attribute data should be given as applicable (see example of SOVEUR matrix table, p. 21).*

Each polygon which does not show a 100% extent for degradation must by definition contain some stable and/or wasteland. Clearly, overlaps do not occur here. The total percentage of all single degradation types plus associations plus stable/wasteland should thus be 100%! Hence in the above example: Wt: 30%, Cn: 20%, Wt/Cn 15%, and Sn (or Sh, W, as appropriate) for the remaining 35%.

Especially in the case of pollution, localized problems may exist (waste dumps, spillage). This may be indicated in the matrix table/database with the letter "*l*" instead of a percentage, while the location can be specified by giving coordinates under Remarks.

2.4 Degree and impact of degradation

Degree is defined here as the intensity of the soil degradation process, e.g. in the case of erosion: the amount of soil washed or blown away. Relative changes of the soil properties are good indicators of soil degradation: the percentage of the total topsoil lost, the percentage of total nutrients and organic matter lost, the relative decrease in soil moisture holding capacity, changes in buffering capacity, etc. However, although such data may exist for experimental plots and pilot areas, precise and actual information is often lacking at a regional scale. The criteria for the assessment of pollution differ from the criteria for other degradation types and will be treated in a separate paragraph (2.4.1).

Impact refers to the effects of soil degradation on the various soil functions. Changes in soil and terrain properties (e.g. loss of topsoil, development of rills and gullies, exposure of hardpans in the case of erosion) may reflect the occurrence and intensity of soil degradation but not necessarily the seriousness of its impact. Removal of a 5 cm layer of soil may have a greater impact on a poor shallow soil than on a deep fertile soil. The impact is depending on the function/use of the soil: a heavily compacted soil is unsuitable for agriculture, but may be an appropriate basis for road construction. Again, criteria to assess the impact of pollution will be treated separately (2.4.2).

2.4.1 Degree of pollution

One problem in assessing the “degree” of pollution is the wide variety of criteria used in different countries for various pollutants. There is no single standard for all types of pollution, nor for specific subtypes of pollution (van Lynden, 1995a; Visser, 1993), because different soils and biota react in different ways to similar pollutants. When assessing degradation or deterioration, a reference base is required. A natural or undisturbed situation is for most countries not a realistic reference base for the current assessment, as only the developments in the past 25 years are considered. The level of pollution is often compared with natural or so-called background levels, which may differ greatly from one place to another. Many concepts refer to the perceived level of urgency for remedial action and are thus influenced by national policies and priorities. Moreover, the required data for these concepts lack in many cases (Stanners and Bourdeau, 1995), or, where they are available, may have been acquired through different measurement methods.

In this study, criteria for the evaluation of the degree of pollution have been derived from the original generic standard values that were established in the Netherlands to determine the course of action in case of suspected soil pollution, the ABC list (Table 1). The lower A-value represents soils which are in a multi-functional and unpolluted state. 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 need to be taken. If the investigations reveal that the C - or *intervention* - value is exceeded, the soil in question requires clean-up measures, depending on site-specific circumstances (Moen and Brugman, 1987). *The ABC values will be used in the current guidelines only in an indicative way*, hence ***not*** related to any kind of recommended action.

For nitrates, where the harmful effects are highly depending on the sensitivity of the soil to leaching of these elements to the ground water, additional criteria have been derived from the EU target value for ground water (25 mg NO_3/L) and the drinking water standard (50 mg NO_3/L) respectively. Generally, phosphate pollution is more a local problem (Stanners and Bourdeau, 1995) for which no generic criteria are used. Radioactive contamination is highly dependant on type of soil, plant uptake and intended use of products. An indication of the impact will therefore suffice in this context.

Summarizing, three degree classes will be used:

L Light: concentration of pollutant(s) between A and B-value
M Moderate: concentration of pollutants between B and C-value
S Strong: concentration of pollutants above C-value

For any pollutant not included in the list, estimates of the degree of pollution should be made.

Table 1 Original standards adopted in the Netherlands for soil contaminants (Moen and Brugman, 1987)

Substance	Concentration in soil (mg/kg dry weight)		
	A-value	B-value	C-value
Metals			
Cr	100	250	800
Co	20	50	300
Ni	50	100	500
Cu	50	100	500
Zn	200	500	3000
As	20	30	50
Mo	10	40	200
Cd	1	5	20
Sn	20	50	300
Ba	200	400	2000
Hg	0.5	2	10
Pb	50	150	600
Inorganic pollutants			
NH (as N)	-	-	-
F (total)	200	400	2000
CN (total free)	1	10	100
CN (total complete)	5	50	500
S (total)	2	20	200
Br (total)	20	50	300
PO (as P)	-	-	-
Aromatic compounds			
Benzene	0.01	0.5	5
Ethylbenzene	0.05	5	50
Toluene	0.05	3	30
Xylene	0.05	5	50
Phenols	0.02	1	10
Aromatics (total)	0.1	7	70
Polycyclic aromatic compounds (PACs)			
Naphthalene	0.1	5	50
Anthracene	0.1	10	100
Phenanthrene	0.1	10	100
Fluoranthene	0.1	10	100
Pyrene	0.1	10	100
Benzo(a)pyrene	0.05	1	10
Total PACs	1	20	200
Chlorinated organic compounds			
Aliphatic chlor.comp. (indiv.)	0.1	5	50
Aliphatic chlor.comp. (total)	0.1	7	70
Cholobenzenes (indiv.)	0.05	1	10
Cholobenzenes (total)	0.05	2	20
Chlorophenols (indiv.)	0.01	0.5	5
Chlorophenols (total)	0.01	1	10
Chlorinated PCA (total)	0.05	1	10
PCB (total)	0.05	1	10
EOCI (total)	0.1	8	80
Pesticides			
Organic chlorinated (indiv.)	0.1	0.5	5
Organic chlorinated (total)	0.1	1	10
Pesticides (total)	0.1	2	20
Other pollutants			
Tetrahydrofuran	0.1	4	40
Pyridine	0.1	2	20
Tetrahydrothiophene	0.1	5	50
Cyclohexanone	0.1	6	60
Styrene	0.1	5	50
Fuel	20	100	800
Mineral oil	100	1000	5000
Nitrates	25 mg/L	35 mg/L	50 mg/L (leaching in topsoil)

2.4.2 Impact of pollution

Although degree and impact of pollution are more interrelated - and often less visible - than for the other types of degradation under review, the *types* of impact of soil pollution vary more than for the other types. Pollution may (directly or indirectly) affect plant growth and hence crop yields, animal and human health, inanimate objects (foundations, pipelines, etc.) and may threaten entire ecosystems. Therefore separate classes are distinguished for the impact of pollution, based on a) the main target of impact and b) the magnitude of impact.

a) Target classes

- **H**: direct impact on human health
- **F**: direct impact on animal health
- **P**: direct impact on plant growth and productivity
- **E**: direct impact on entire ecosystem/biodiversity
- **O**: other direct impacts (specify under “Remarks”)
- **I**: indirect impacts, e.g. through pollution of ground- and surface water

b) Magnitude

- **0** No apparent impact (“contamination” rather than pollution)
- **1** Low impact: effects of pollution can be easily countered
- **2** Moderate impact: important effects of pollution, but restoration is possible
- **3** Strong impact: damage is serious and difficult to restore
- **4** Extreme impact: intense and irreversible damage

A single pollution type may have several impact targets and magnitudes, e.g. H2, P3, but these should only be indicated if applicable to the entire affected area.

2.4.3 Degree of other degradation types

For the assessment of the degree of other types of degradation (water and wind erosion, other chemical and physical deterioration) qualitative indicators are used, referring to the intensity of the degradation process.

- **L** Light: some indications of degradation are present, but the process is still in an initial phase. It can be easily stopped and damage repaired with minor efforts.
- **M** Moderate: degradation is apparent, but control and full remediation to its current function is still possible with considerable efforts.
- **S** Strong: evident signs of degradation. Changes in soil properties are significant and very difficult to restore within reasonable limits.
- **E** Extreme: degradation beyond restoration. The soil has lost one (or more) of its functions during the past 25 years.

2.4.4 Impact of other degradation types

Whereas the degree of degradation mainly refers to the degradation *process*, the impact of degradation can be manifold, depending on the current function (or use) of the soil. In many cases the impact of degradation types - other than pollution - will be on its biotic functions, or more specifically on its productivity. Models which describe relationships between soil degradation and decrease in productivity are still scarce and often not suited for extrapolation to large areas. A significant complication in indicating productivity losses caused by soil degradation is the variety of reasons that may contribute to yield decline. Falling productivity may be caused by a wide range of factors like erosion, fertility decline, improper management, drought or waterlogging, quality of inputs (seeds, fertilizer), pests and plagues, often in combination with each other. However, if one considers a medium to long term period (e.g. 25 years), large aberrations resulting from fluctuations in the weather pattern or pests should be levelled out.

The effects of soil degradation can be partially hidden by various management measures such as soil conservation, use of improved varieties, fertilizers and pesticides. Part of these inputs is used to compensate for the productivity loss caused by soil degradation, for instance application of fertilizers to compensate for lost nutrients. In other words, yields could have been much higher in the absence of soil degradation (and/or costs could have been reduced). Therefore productivity changes should be seen in relation to the amount of inputs or level of management. The latter may include: use of fertilizers, biocides, improved varieties, mechanization, various soil conservation measures, and other important changes in the farming system. Three levels of management are distinguished (no qualitative judgment!):

A-High: fully mechanized and/or modernized, high inputs
B-Medium: partly mechanized and medium inputs
C-Low: low level of mechanization and inputs, more “traditional” systems

The magnitude can be estimated by considering the share of the total farm expenses. Table 2 is a simplified framework for assessing the degradation impacts on productivity.

Table 2: Impact of degradation: management level and productivity (after van Lynden, 1995b)

	Level of Management		
Productivity level	*A) High*	*B) Medium*	*C) Low*
1) Large increase	Negligible	Negligible	Negligible
2) Small increase	Slight	Negligible	Negligible
3) No change	Moderate	Slight	Negligible
4) Small decrease	Strong	Moderate	Slight
5) Large decrease	Extreme	Strong	Moderate
6) Unproductive	Extreme	Extreme	Strong to Extreme

Changes in productivity are to be expressed in relative terms, i.e. the *current average productivity compared to the average productivity in the non-degraded situation (or non-improved, where applicable),* and in relation to inputs. For instance, if previously an average yield of 2 tonnes of wheat per hectare was attained while at present only 1.5 tonnes is realized in spite of high(er) inputs - and all other factors being equal -, this would be an indication of strong soil degradation. Sometimes the impact may be ranked as negligible, even when degradation occurs, because of the capacity of the soil to resist a certain amount of degradation, or its so-called “buffer capacity” (see above).

A) *High management level* *Impact of degradation*

A1 Large productivity increase .... Negligible
(improvements fully benefit yields and are not required for compensation of degradation impacts)
A2 Small productivity increase .... Slight
(improvements partly benefit yields and are partly required for compensation of degradation impacts)
A3 No productivity increase .... Moderate
(major improvements necessary to fully compensate degradation effects)
A4 Small productivity decrease .... Strong
(degradation impacts can only partly be compensated by major improvements)
A5 Large productivity decrease .... Extreme
(degradation impacts cannot even be compensated by major improvements)
A6 Unproductive .... Extreme

B) *Medium management level* *Impact of degradation*

B1 Large productivity increase .... Negligible
(improvements have large impact on yields and are not required for compensation of degradation impacts)
B2 Small productivity increase .... Negligible
(improvements have moderate impact on yields and are hardly required for compensation of degradation impacts)
B3 No productivity increase .... Slight
(minor improvements do not directly benefit yields but suffice for compensation of degradation impacts)
B4 Small productivity decrease .... Moderate
(degradation impacts insufficiently compensated by improvements)
B5 Large productivity decrease .... Strong
(degradation impacts only slightly compensated by improvements)
B6 Unproductive .... Extreme

C) *Low management level* *Impact of degradation*
(e.g. "traditional" systems existing for more than 25 years)

C1 Large productivity increase .... Negligible[1]
C2 Small productivity increase .... Negligible[1]
C3 No productivity increase .... Negligible
(equilibrium between natural and man-induced factors, "sustainable" situation)
C4 Small productivity decrease .... Slight
(equilibrium has been slightly disturbed by external factors)
C5 Large productivity decrease .... Moderate
(equilibrium has been considerably disturbed by external factors)
C6 Very large productivity decrease to unproductive .... Strong to Extreme
(equilibrium has been highly disturbed by external factors)

1 These categories are not common for this management level, as no major improvements are supposed to have occurred in the system over the last 25 years or so and productivity is not likely to increase rapidly.

2.5 Rate of soil degradation

The recent past rate of degradation relates to the rapidity of degradation over the past 5 to 10 years, or in other words, the *trend* of degradation. A severely degraded area may be quite stable at present (i.e. low rate, hence no trend towards further degradation) whereas other areas that are now only slightly degraded, may show a high rate, hence a trend towards rapid further deterioration. From a purely physical point of view, the latter area would have a higher conservation priority than the former. Areas where the situation is improving (through soil conservation measures, for instance) can also be identified.

Three classes with a trend towards further deterioration (i.e. from a lower to a higher degree) and three with a trend towards decreasing degradation (i.e. from a higher to a lower degree, either as a result of human influence or by natural stabilization) have been defined, plus one class to indicate no changes in the degree of degradation.

- 3: rapidly increasing degradation (very negative trend)
-2: moderately increasing degradation
-1: slowly increasing degradation
0: no change in degradation
1: slowly decreasing degradation
2: moderately decreasing degradation
3: rapidly decreasing degradation (very positive trend)

A comparison of the actual situation with that of the preceding decade may suffice, but often it is preferable to examine the average development over the last 5 to 10 years to level out irregularities.

Whereas the degree of degradation in fact only indicates the current, **static** situation (measured by decreased or increased productivity compared to some 10 to 15 years ago) the *rate* indicates the **dynamic** situation of soil degradation, namely the **change in degree** over time.

2.6 Causative factors

Various types of human activities may lead to soil degradation. Although some degradation processes may also occur naturally, this inventory focuses mainly on those degradation types that are the result of the human disturbance of either a natural or anthropogenic state of equilibrium. The following classification of causative factors is slightly modified from the GLASOD study.

a: *Agricultural causes*: defined as the improper management of cultivated arable 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 or bad maintenance of erosion control measures, improper use of heavy machinery, etc. Degradation types commonly linked to this causative factor are erosion (water or wind), compaction, loss of nutrients, salinisation, pollution (by pesticides or fertilizers).

f: *Deforestation or removal of natural vegetation*: defined as the near complete removal of natural vegetation (usually primary or secondary forest) from large stretches of land, for example by converting forest into agricultural land (frequently leading to causative factor “a”!), large scale commercial forestry, road construction, urban development, etc. Deforestation often causes erosion and loss of nutrients.

e: *Over-exploitation of vegetation for domestic use:* contrary to "deforestation or removal of natural vegetation", this causative factor does not necessarily involve the (near) complete removal of the "natural" vegetation, but rather a degeneration of the remaining vegetation, thus offering insufficient protection against erosion. It includes activities as excessive gathering of fuel wood, fodder, (local) timber, etc.

o: *Overgrazing*: besides actual overgrazing of the vegetation by livestock, other phenomena of excessive livestock amounts are also considered here, such as trampling. The effect of overgrazing usually is soil compaction and/or a decrease of plant cover, both of which may in turn give rise to water or wind erosion.

i *Industrial activities*: includes all human activities of a (bio)industrial nature: industries, power generation, infrastructure and urbanization, waste handling, traffic, etc. It is most often linked to pollution of different kinds (either point source or diffuse) and loss of productive function.

n *Natural causes:* while in previous studies like GLASOD and ASSOD *only* human-induced degradation was taken into consideration, it has been judged worthwhile to include natural types of degradation in the current assessment, since this may be of importance for the assessment of vulnerability. However, so-called “problem soils” (e.g. Solonetz, Solonchaks), which have unfavourable characteristics by nature (or since more than 25 years) are *not* included. The emphasis will remain on soil degradation caused by human activities, as it remains the most appropriate domain for possible remediative action.

3 DATABASE IMPLEMENTATION

3.1 Base map

The mapping units for which the degradation information has to be provided are to be delineated according to the SOTER methodology (Batjes and van Engelen, 1997). A 1:2.5 M physiographic map of Central and Eastern Europe has been drafted by ISRIC (for the western section) and IIASA (for the former Soviet Union) as a basis for developing this SOTER map, using the same methodology.

The Karta Mira topographic map at a scale of 1:2.5 M was used as a base map, while additional topographic maps of various scales and variable quality were used to obtain additional information. The physiographic criteria, as described in the Guidelines for the Compilation of a 1:2.500.000 SOTER database (Batjes and van Engelen, 1997), could not always be applied in a precise manner. This is particularly true for the relief intensity criteria, which are difficult to assess when using small scale maps (1:250.000 and less).

Physiographic units were delineated on a hand drawn map and their respective codes were entered into a database. The map was then digitised and linked to the physiographic database through a GIS (ILWIS and ARC-INFO).

3.2 Data entry

To facilitate implementation of the degradation assessment the following is enclosed:

1) one physiographic map (showing major landforms and a code in each polygon referring to major landform, hypsometry and slope class) and a black-and-white map, showing only the polygon boundaries, with the corresponding polygon label numbers. The scale of the black-and-white map may be larger than the scale of the coloured print to facilitate corrections. The physiographic map is the basis for compiling the SOTER database (see Guidelines for the compilation of a 1:2.500.000 SOTER database (Batjes and van Engelen, 1997)).
3) A printed (empty) matrix table, to manually enter degradation data for each polygon (using the guidelines in chapter 2), *after* completion of the SOTER database and map. See example on page 21. Please make additional copies of the table as required.
4) A diskette with a compressed (ZIP-)file containing a data-entry program (SOVEUR.EXE) to link degradation information to the polygons of the SOTER map.

The maps, tables and data-entry program permit the input of soil degradation data into the database. In Chapter 2, a detailed description is given of degradation parameters to be entered in the database. This information should be given for each *polygon* (not SOTER unit!) on the base map. The data can be entered manually on the matrix tables prior to input into the computerized database using the SOVEUR.EXE data entry program (see Step 1-8 below). Please send the matrix tables to ISRIC with all information clearly written or printed, especially if you cannot use the computer program for some reason.

The following steps are suggested (Step 1 refers to the compilation of a SOTER map):

Step 1 Check the supplied **physiographic map** for errors and/or omissions and correct where necessary. Refine this map on the basis of lithology and soils, to identify SOTER units, following the Guidelines for the compilation of a 1:2.500.000 SOTER database (Batjes and van Engelen, 1997)).

Step 2 Determine for each polygon (unique delineated units) of the SOTER map for your country the **type(s) of soil degradation** and/or stable types occurring within that area. Where two or more degradation types overlap spatially within the same polygon, this should be indicated as an association (see example of SOVEUR matrix table on page 21). Definitions of soil degradation types are given in Chapter 2.2.

Step 3 Estimate the **relative extent** of each degradation type, association and/or stable type for every polygon, rounded to the nearest 5%. ***NB**: the sum of all degradation types, associations and stable/wasteland must be 100% for every polygon.* See Chapter 2.3 for further explanation.

Step 4 Indicate for each degradation type the **degree and impact of degradation.** Please read Chapter 2.4 carefully for explanation and for options given. Degree an impact need not be given for associations as long as they correspond with the data for the individual components.

Step 5 Estimate the **rate** of each soil degradation process over the past 5 to 10 years, as explained in Chapter 2.5. For associations, the rate needs not to be entered as long as it corresponds with the data for the individual components.

Step 6 Indicate the major **causes** for each degradation type (see Chapter 2.6). No causative factor has to be given for associations as long as they correspond with the data for the individual components.

Step 7 Enter the attributes of soil degradation into the database by using the SOVEUR data entry program, following the instructions on the screen (see Appendix I). If you want to use the SOVEUR program, but you encounter problems running it, please contact ISRIC as soon as possible. Meanwhile, data can be entered manually on the black-and-white prints and in the matrix tables. Do not forget to copy your data back to the diskette!

Step 8 Prepare a brief report, accompanying your database and/or matrix tables, to be sent to ISRIC.

REFERENCES

Batjes, N.H. and E.M. Bridges, 1991. Mapping of Soil and Terrain Vulnerability to Specified Chemical Compounds in Europe at a Scale of 1:5 M. Proceedings of an International Workshop held at Wageningen, the Netherlands. ISRIC, Wageningen.

Batjes, N.H., 1997. A methodological framework for assessment and mapping of the vulnerability of soil to diffuse pollution at a continental level (Version 1.0). Report 97/07, ISRIC, Wageningen

Batjes, N.H. and V.W.P. van Engelen, 1997. Guidelines for the compilation of a 1:2,500,00 SOTER database (SOVEUR project). Report 97/06, ISRIC, Wageningen

Blum, W.E.H., 1988. Problems of soil conservation - Nature and Environment N° 40, Council of Europe, Strasbourg.

Council of Europe, 1990. European Conservation Strategy. Recommendation for the 6th European Ministerial Conference on the Environment. Council of Europe, Strasbourg.

Moen J.E.T. and W.J.K. Brugman, 1987: Soil Protection Programmes and Strategies: examples from the Netherlands. In: H. Barth and D. L'Hermite (eds.): Scientific basis for Soil Protection in the European Community, p. 429-446 -Elsevier Applied Science, London, N.Y.

Oldeman, L.R. (ed.), 1988. Guidelines for General Assessment of the Status of Human-Induced Soil Degradation. Working Paper and Preprint 88/4, ISRIC, Wageningen.

Oldeman, L.R., R.T.A. Hakkeling and W.G. Sombroek, 1991. World Map of the Status of Human-induced Soil Degradation: An Explanatory Note, *second revised edition*. ISRIC/UNEP, Wageningen

Posch, M. and L. Kauppi, 1991. Potential for Acidification of Forest Soils in Europe. In: F.M. Brouwer, A.J. Thomas and M.J. Chadwick (eds.): Land Use Changes in Europe, Processes of Change, Environmental Transformations and Future Patterns, p. 325-350 - Kluwer Academic Publishers, Dordrecht.

RIVM, 1992. The Environment in Europe; a Global Perspective. RIVM, Bilthoven.

Stanners, D. and P. Bourdeau (ed.), 1995. Europe's Environment; The Dobris Assessment. European Environment Agency, Copenhagen.

Stigliani, W.M. (ed.), 1991. Chemical Time Bombs: Definitions, Concepts and Examples. IIASA, Laxenburg.

Ulrich, B., 1987. Impact on soils related to industrial activities - Part IV: Effects of Air Pollutants on the soil. In: H. Barth and D. L'Hermite (eds.): Scientific basis for Soil Protection in the European Community, p. 299-311 -Elsevier Applied Science, London, N.Y.

Van Lynden, G.W.J., 1995a. European soil resources. Nature and Environment N°. 71. Council of Europe, Strasbourg.

Van Lynden, G.W.J., 1995b. Guidelines for the Assessment of the Status of Human-induced Soil Degradation in South and Southeast Asia. ISRIC Working Paper and Preprint 95/2.

Visser, W.J.F., 1993. Contaminated land in various industrialized countries. Review of approaches Technical Soil Protection Committee, The Hague.

APPENDIX I Input of degradation codes into the database

You are requested to enter the required degradation code(s) in your degradation database *for each polygon* on the SOTER map, as explained above.

The matrix table can be used for manual data entry (make as many copies as required) prior to, or instead of, computerized data input, as in example on page 21.

To install the database entry program on a directory on your hard disk C: (assuming this is the name of a hard disk on your computer and accessible, otherwise use manual unzipping), put the SOVEUR diskette in the floppy drive and type:

A:INSTALL <ENTER>

This will automatically install the SOVEUR data entry program and database files in the directory C:\SOVEUR. To start the program, type

CD\SOVEUR <ENTER> (if you are not in the C:\SOVEUR directory already)

followed by:

SOVEUR <ENTER>[1]

Select the SOVEUR file (database) for your country with **<F2>**. This database contains labels (poly_ID's) corresponding to the polygons (not SOTER units!) of the SOTER map of your country. Enter the respective item codes as indicated in Chapter 2. For most items, you can press **<F2>** to browse through a list of permitted codes and select the appropriate one. In the memo fields, which you can enter by pressing **<F9>**, you may give additional information on type (etc.) of degradation respectively. After you have filled in a code for each item, advance to a new poly-ID or, if you want to enter a second (or third, etc.) degradation code for the same polygon, press **<F5>**. New polygon ID's cannot be added here!

WHEN ALL DATA HAVE BEEN ENTERED, DO NOT FORGET TO COPY THEM BACK TO THE DISKETTE!

The databases are dBaseIV files. It is strongly recommended however, to use the SOVEUR.EXE data entry program (which will run even without dBase) for adding and editing records, since this will reduce possible errors and guide you through the database.

Please do not change the structure of the database! You cannot use codes different from those mentioned in these guidelines (the program will not accept these).

[1] It is possible that the following message appears: "System is not configured for current code-page. Quit/Continue". Choose "Continue" and the program will start normally

APPENDIX II **SOVEUR MATRIX TABLE**

EXAMPLE (Fictitious)

Poly-ID	Degr.type	Pollution only: specific substance	Extent	Degree	Impact	Cause	Rate	Remarks
378-PL	*1 Wt*		*30%*	*M*	*B3*	*a*	*1*	*Some improvement due to conservation measures*
	2 Cpp	*PCB*	*25%*	*L*	*I2*	*a*	*-2*	*Effects on ground- and surface water*
	3		*15%*					*NB: Enhanced downstream effect of Cpp due to erosion*
	4 Sn		*30%*					
379-PL	*1 Cpa*	NO_x, SO_2	*40%*	*S*	*E2*	*i*	*-2*	*Mainly atmospheric deposition*
	2 Pc		*30%*	*M*	*A3*	*a*	*-1*	*Frequent use of heavy machinery*
	3 Wo		*30%*	*L*	*A2*	*i,f*	*-2*	*Construction activities*
380-PL	*1 Wt*		*40%*	*M*	*A3*	*a*	*1*	*Conservation measures having positive effect*
	2 Cn		*30%*	*M*	*B2*	*a*	*-1*	
	3 Wt/Cn		*20%*	*E*	*B3*	*a*	*-1*	*Degree and Impact higher than for individual types!*
	4 Cph	*Cd, Pb*	*l*	*S*	*H2,P3_*	*i*	*-2*	*local : 50°30'20"N 20°00'15"E*
	5 Sh		*10%*					*Successful conservation and rehabilitation measures*
381-PL	*1 X*		*100%*					*Mountain areas with bare rock*

SOVEUR MATRIX TABLE

make additional copies as required

Poly-ID	Degr.type	Pollution only: specific substance	Extent	Degree	Impact	Cause	Rate	Remarks