Working Paper and Preprint

95/02

GUIDELINES FOR THE ASSESSMENT OF THE STATUS OF HUMAN-INDUCED SOIL DEGRADATION IN SOUTH AND SOUTHEAST ASIA

G.W.J. van Lynden (editor)

February 1995

INTERNATIONAL SOIL REFERENCE AND INFORMATION CENTRE

GUIDELINES for the ASSESSMENT of the STATUS of HUMAN-INDUCED SOIL DEGRADATION in SOUTH and SOUTHEAST ASIA

Edited by G.W.J. van Lynden
International Soil Reference and Information Centre
Wageningen, February 1995

ISRIC

International Soil Reference and Information Centre

ACKNOWLEDGEMENTS

These 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 GLASOD map (Oldeman et al., 1991). Useful recommendations for the revision of these guidelines were made at the Expert Consultation of the Asian Network on Problem Soils (Bangkok, 1993), and various additional comments were received afterwards from some members of this network. Draft versions of these revised guidelines were sent for comments to R. Gallacher and F. Nachtergaele at FAO (AGLS) in Rome, F.J. Dent at RAPA, Bangkok, H. Hurni and H.P. Liniger of the GDE, University of Berne, Prof. Gong ZiTong of the Academica Sinica, Nanjing, P. Brabant at ORSTOM, Bondy, France, R. Leemans and H. Köster at RIVM, Bilthoven, the Netherlands. 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 programme.

TABLE of CONTENTS

FOREWORD

Based on recommendations of the Third Meeting of the Asian Network on Problem Soils (Bangkok, 1993), the United Nations Environment Programme (UNEP) formulated a project named: Assessment of the Status of Human-Induced Soil Degradation in South and Southeast Asia (ASSOD; 1994). This project is implemented by the International Soil Reference and Information Centre (ISRIC), Wageningen, The Netherlands, and the Regional Office for Asia and the Pacific of the Food and Agriculture Organisation of the United Nations, in association with the relevant national institutions. The project has a duration of fifteen months.

As a first activity, ASSOD calls for the preparation of Guidelines for Soil Degradation Assessment in South and Southeast Asia. These guidelines will serve as an operational tool in the development of a geo-referenced database on the status of human-induced soil degradation in the region. The guidelines reflect the methodology developed for the Global Assessment of the Status of Human-Induced Soil Degradation (GLASOD; ISRIC, 1991), incorporating comments received from various members of the Asian Network on Problem Soils and others.

A major modification in comparison with the original GLASOD methodology (ISRIC, 1988) relates to the definition of the degree of soil degradation. In the GLASOD guidelines some semi-quantitative criteria were given for a the degree of a few degradation types, but not for others. Only rather general rules were established to relate soil degradation to agricultural suitability or to productivity decline.In the ASSOD guidelines more emphasis is placed on the impact of soil degradation on productivity while taking into account the level of inputs/management.

The objective of the GLASOD project was the preparation of a world map of the Status of Human-Induced Soil Degradation. Only after printing and publication of the map, a decision was made to digitize the mapping units and to develop a database of soil degradation attributes derived from the map. For ASSOD a reversed order will be adopted. The first step after the initial data collection is the development of a computerized database containing the available attributes on human-induced soil degradation for all digitized physiographic mapping units. The database will be linked to the (geo-referenced) mapping units by means of a Geographic Information System (GIS). In this way all valuable information can be stored and retrieved for various thematic outputs.

Although we realize that the task to complete this important project within a twelve month period is formidable and that the scale of 1:5 M will require many arbitrary decisions to be made by the national collaborators, we nevertheless trust that this study will lead to a better insight in the extent and severity of human-induced soil degradation and its impact on agricultural productivity in the region.

L.R. Oldeman
Director
International Soil Reference and Information Centre
Wageningen, The Netherlands

INTRODUCTION

The assessment of soil degradation in South and Southeast Asia (ASSOD) is a sequel to the survey of Global Assessment of the Status of Human-Induced Soil Degradation (GLASOD) that was completed in 1991 by UNEP/ISRIC in collaboration with FAO, Winand Staring Centre and ITC, based on contributions of a large number of experts worldwide (Oldeman et al. 1991). This assessment resulted in a world map at an average scale of 1:10 million showing the global distribution, and severity, of various types of soil degradation. The immediate objective of the original GLASOD project, as defined in the project document, was:

"Strengthening the awareness of decision makers and policy makers on the dangers resulting from inappropriate land and soil management to the global well being, and leading to a basis for the establishment of priorities for action programmes".

Following the publication of this map, frequent requests for more detailed information were received, to which it was often difficult to respond in view of the small scale and global character of the GLASOD inventory. Many inquiries and comments also referred to the *impact* of soil degradation and what is being done about it.

In 1993, at a meeting of the Asia Network on Problem Soils in Bangkok, a recommendation was made (Dent, 1993) for the preparation of a soil degradation assessment for South and Southeast Asia at a scale of 1:5 million, based on the GLASOD methodology (modified where deemed necessary). A new physiographic map for Asia that was compiled by ISRIC and FAO (van Lynden, 1994), was to be used as a basis for this assessment. Also, links would be made with the WOCAT project (World Overview of Conservation Approaches and Technologies) of the World Association of Soil and Water Conservation and the Group for Development and Environment, University of Berne. These, and other, recommendations were endorsed by FAO and UNEP, the latter organization providing external funding support for the project. In accordance with the recommendations, ISRIC is the coordinating institution for this project.

When completed, the ASSOD map, at a scale of 1:5 M, will provide information on soil degradation in South and Southeast Asia, while at the same time increasing awareness on soil degradation problems among policy- and decision makers and the general public in the region. Like the GLASOD map, it will describe *the current status* of human-induced soil degradation, with a general indication of the "*recent past rate*". However, ASSOD should be more than just a revised and magnified GLASOD map for Asia and therefore several changes in the approach were adopted. More emphasis is placed on trends of degradation (recent past rate) and on the impacts of degradation on productivity (see below), while some elements of conservation/rehabilitation are added as well.

Recently, a FAO/UNEP/UNDP intercountry project RAS/92/560 (Young, 1993) carried out a "Study of Land Degradation in South Asia: its severity, causes and effects upon the people". This study made an interesting evaluation of the economic impacts of soil degradation, based on existing GLASOD data, complemented with data from other sources. In the current document however, it is proposed to use the (economic) impacts of degradation as a *criterium* for the degree of degradation, rather than taking these impacts as a consequence of a certain degree of degradation, which has been determined by physical criteria. See Annex II for more details.

Definitions:

Soil degradation in the GLASOD definition is "a process that describes human-induced phenomena which lower the current and/or future capacity of the soil to support human life".

The above definition of soil degradation is very broad and requires some further refinement. Soil degradation has been defined in many ways (e.g. Barrow, 1991), most often referring to the (agro)-productive function of the soil. 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 (see Blum, 1988). For the purpose of this inventory, the emphasis will be on soil degradation processes that lead to a deterioration of the production function of the soil. This implies that in the present context "soil quality" should be interpreted in terms of soil fertility, soil depth, structure, infiltration rate and water retention capacity, erodability, eco-toxicity, etc. Factors that are more important for other soil functions (e.g. for construction purposes) will receive less attention. This means that "severely degraded" soils shown on the map may still be useful for instance for building houses or roads upon.

The **type** of soil degradation refers to the degradation process (displacement of soil material by water and wind; in-situ deterioration by physical, chemical and biological processes). See Annex I for concise descriptions of each degradation type.

The **degree** of soil degradation refers to the present state of degradation (slight, moderate, severe). It is difficult to give quantitative and objective criteria for assessing the degree to which soils have been affected by various degradation types. The GLASOD guidelines (Oldeman, 1988) gave some (semi-) quantified criteria for erosion by water or wind, salinization, nutrient decline, but not for others. In this assessment more emphasis is placed on the *impacts of degradation on productivity* (see Annex II) than on the mere intensity of the individual processes (erosion, pollution, etc.). This means that the degradation type is more seen as the cause of eventual productivity decreases, while degradation itself can be the result of various types of human intervention (the "causative factors" as used in GLASOD).

The **extent** of soil degradation refers to the percentage of a mapping unit affected by a given type of degradation. See Annex III for further details.

The recent past average **rate** of soil degradation refers to the apparent rapidity of the degradation process estimated and averaged over the past 5 to 10 years. ASSOD aims to put more accent on this than was the case in GLASOD, as it gives an indication of the **trend** of degradation, which is a very important factor for planning purposes. See Annex IV for more details.

The **causative factor** indicates the kind of human action that can be considered responsible for the occurrence of the degradation type involved. See Annex V for further specification.

A clear distinction should be made between soil degradation *status*, *rate* and *risk* (Sanders, 1994). Soil degradation *status* reflects the **current** situation while the *rate* (or *trend*) indicates the relative decrease or increase of degradation over the last 5 to 10 years (leading to the current status). Although the rate of degradation as indicated on the status map also gives an idea of the danger of **further** deterioration, it does not include areas that are now perfectly stable but that may be under risk of considerable degradation if, for instance, land use is changed. The degradation *risk* defined in this sense depends on several soil and terrain properties that make the soil inherently vulnerable to soil degradation, for example when external conditions (climate, land use) change. A separate risk (or soil *vulnerability*) assessment could depict those areas that need to be protected against degradation, caused by certain changes in land use or other external factors. The ASSOD project however does not entail such an assessment.

When considering "degradation" or "deterioration", the question is: compared with what? In many cases a "natural", undisturbed situation is not possible as a reference base. Since our soil degradation assessment does not include historic developments (say > 25 years) one must take the situation of some 25 years ago, or even less in some cases, as a reference. This is particularly valid for the ASSOD region, since most developments potentially or actually leading to serious human-induced soil degradation have occurred during this period (population explosion, changes in land use and farming techniques, Green Revolution, mechanization and intensification, etc.). However, in view of data availability and comparability, it is probably more realistic to look at the last one or two decades.

TOOLS

The main tool to generate the ASSOD map is a computerized database, linked to a GIS, which enables a flexible output, adjusted to specific user groups or uses. It is possible to create a "general" soil degradation map mainly for awareness strengthening purposes, while more details can be retrieved from the database on specific issues. It is interesting, for instance, to show not only the status of degradation, but also the occurrence and impact of conservation/rehabilitation activities (see WOCAT). It is relatively easy to incorporate a few of these items in the matrix tables and guidelines, although at this stage only in a simplified format.

The base map for ASSOD will be the draft physiographic map for Asia at 1:5 million (excluding the former Soviet Union and Mongolia) that was compiled by ISRIC and FAO on the basis of available topographic and thematic maps and using the SOTER methodology (van Engelen et al., 1992). As this map is only a draft version, corrections can still be made where deemed necessary before the degradation status of each unit is determined (see Annex VII and VIII).

Because the original GLASOD map was compiled "manually", as a conventional map, it suffered from several limitations. As the aim was the production of a map rather than data collection per se, the compilation of data was dependent upon cartographic restrictions. Thus, considerable generalizations had to be made, resulting in some loss of information (a maximum of two degradation types per map unit, cutback on the total number of different degradation types, scale reduction, no clear link between degradation types and causative factors). Much information given in the original matrix tables could not be depicted on the map.

With a digital map based on information stored in a database, these problems can be alleviated. In principle *all* relevant information can be stored and depicted in some way when desired (through the creation of separate thematic maps), e.g. all occurrences of wind erosion caused by overgrazing, or only those areas with an increasing rate of degradation.

The assessment of the status of soil degradation is largely a qualitative judgment. In view of the scale and the estimated available data, this inventory is, like GLASOD, one and based on experts' estimates. As such it will give an overall idea of the status of degradation in the region and identify priority areas ("hot spots"). For planning at national and sub-national levels (scales 1:1 million and larger), however, a more detailed and quantitative assessment is recommended. The SOTER methodology for storing, analyzing and retrieving soils and terrain information at various scales is an appropriate tool for such an approach, as is illustrated by experiences in Africa, Latin America and Europe.

METHODOLOGY

Together with these guidelines are enclosed:

1) a set of maps, consisting of three coloured thematic physiographic maps (respectively: major landform, hypsometry and slopeclass) and two black-and-white maps, one blank one (with an extra photocopy), showing only the polygon (map unit) boundaries, the other also showing the corresponding polygon label numbers. The scale of the black-and-white maps may be larger than the scale of the coloured prints to facilitate corrections. For several countries more than one set is printed, each set covering a different part of the country.
3) A printed table containing the polygon label numbers ("POLY_ID") of your maps and the corresponding physiographic code ("CODE"), plus an additional empty field for eventual corrections of that code ("CORRECTION"). The table may contain polygon numbers outside your countries territory: please just ignore these, since they will be dealt with by other countries.
4) A printed (empty) matrix table (Annex X of these guidelines), to manually enter degradation data for each mapping unit. Please make additional copies as required.

5) A diskette (3½", high density) with a compressed (ZIP-)file containing a data-entry programme (ASSOD.EXE) and the country database(s). This database contains the polygon label numbers (POLY_ID) corresponding to the polygons on the country map, and physiographic information for each polygon. This information needs to be checked, and degradation data to be added. For countries with more than one map set, each map set has a corresponding database. *You will need a IBM (compatible) 286, 386 or 486 computer with at least 6 MB available space on hard disk and a minimum of 2 MB RAM, DOS Version 3.3x or newer and a CGA, EGA or VGA monitor* to run the programme. If your computer does not meet these requirements, just enter the data manually on the tables. To avoid possible memory capacity problems it is recommended to boot your computer with as few memory resident programmes (TSR's) as possible.

The maps, tables and database will enable changes to be made in the physiographic map where necessary and facilitate the input of degradation data into the database.

The databases are DBaseIV files. It is strongly recommended however, to use the ASSOD.EXE data entry programme (which will run even without DBase) for adding and editing records, since this will eliminate possible errors and guide you through the database. The data entry programme and databases can be installed by typing *A:INST_ASS*. See Annex VIII and IX for more explanation.

Please do not change the structure of the database or add/delete polygon label numbers! You cannot use codes different from the codes mentioned in these guidelines (the programme will not accept these).

In the various annexes, a detailed description is given of degradation parameters to be entered in the database. This information should be given for each delineated mapping unit (polygon) of the enclosed physiographic map. You can enter the data manually on the black and white maps and into the attached tables first before entering them into the computerized database by using the ASSOD.EXE data entry programme (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 programme for some reason. We would also like to receive (as a "backup") a copy of the black-and-white map containing the degradation codes, and, where applicable, another black-and-white map containing modifications (in red pencil) to the physiographic map.

We suggest that you start the work as soon as possible and send us your first results before the end of April for (a part of) your country which will enable us to:

a) pinpoint specific problems
b) get an idea of the work that can be done in some two months time.

The following steps are suggested:

Step 1 — Check the supplied **physiographic map** for serious errors and/or omissions. If you are content with the map unit delineations and the physiographic codes (see Annex VII) for each unit, go to Step 2. If you want to make corrections in the delineations and/or codes, please follow the instructions in Annex VIII.

Step 2 — Determine for each delineated map unit (polygon) the **type(s) of soil degradation** occurring within that area. Definitions of soil degradation types are given in Annex I. *NB: Unless the entire mapping unit is affected by some type of degradation, you will also have to indicate for each unit either type Sn (stable under natural vegetation), Sh (stabilized by human intervention), or Sw (stable natural land without vegetation). See also remarks Step 4.*

Step 3 — Indicate for each soil degradation type occurring within a map unit, the **impact of degradation on productivity**. Please carefully read Annex II for explanation and for options given. If reliable data on this aspect are not available, please use your expert judgment and/or consult other experts such as agronomists.

Step 4 Give your best estimate of the **relative extent** of each degradation type or stable type within the mapping unit, to the nearest 5%. If you have defined more than one degradation (and/or stable) type per map unit, please indicate under Remarks (memo field in the data entry programme) whether the different types are overlapping within the map unit and to what extent (e.g. overlap 75 % or 100%). As mentioned under Step2, for each unit of which less then 100% of the area degraded, the extent of Stable land must also be given. See Annex III for more explanation.

Step 5 Give your best estimate for the **rate** of each soil degradation process over the past 5 to 10 years, as explained in Annex IV.

Step 6 Indicate, for each degradation type, the kind of human activities that have **caused** soil degradation (see Annex V). If more than one causative factor play a role for the same degradation type within the map unit, this may be indicated under Remarks (memo field in data entry programme).

Step 7 Indicate the type, and if possible, the relative extent of **conservation or rehabilitation measures** (as a percentage of the degraded part of the mapping unit). See Annex VI for more explanation.

Step 8 Enter the attributes of soil degradation into the database by using the ASSOD.EXE data entry programme, following the instructions on the screen. The various definitions or descriptions as given in the annexes can be consulted (in a concise format) during data entry with the ASSOD programme by pressing **<F2>** ("Picklist"). If you want to use the ASSOD.EXE programme (and your computer has the required capacities, see above) but you encounter problems to run 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 9 Prepare a brief report, accompanying your database and/or matrix tables, to be sent to ISRIC.

Please do not hesitate to contact us if you have any problems.

Types of soil degradation are represented in the database by a two-letter code, the first capital letter giving the major degradation type, the second lower case letter giving the subtype. In some cases a third *lower case* letter can be used for further specification (see examples below). Most of the following codes are the same as the ones used on the GLASOD map, but some extra ones have been added, and for others the definition has been changed slightly.

Wt *Definition:* loss of topsoil by sheet erosion/surface wash
Description: a decrease in depth of the topsoil layer (A horizon) due to more or less uniform removal of soil material by run-off water
Possible causes: inappropriate land management especially in agriculture, (insufficient soil cover, unobstructed flow of run-off water, weak soil structure) leading to excessive surface run-off 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 run-off water to concentrate and flow unobstructed

Wo *Definition:* off-site effects of water erosion in up-stream areas
Description: Three subtypes may be distinguished: sedimentation of reservoirs and waterways (Wos), flooding (Wof), and pollution of water bodies with eroded sediments (Wop)
Possible causes: see Wt and Wd

Et *Definition:* loss of topsoil by wind action
Description: a decrease in depth of the topsoil layer (A horizon) due to more or less uniform removal of soil material by the wind
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

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

Cp *Definition:* pollution
Description: a distinction is made between "contamination", indicating the mere presence of an alien substance in the soil without significant negative effects, and "pollution", signifying soil degradation as a consequence of location, concentration and adverse biological or toxic effects of a substance. In this context only the latter is relevant. Both local source pollution (waste dumps, spills, factory sites, etc. (Cpl)) and diffuse or airborne pollution (atmospheric deposition of acidifying compounds and/or heavy metals (Cpa)) are considered under this category.
Possible causes: bio-industrial sources, dumping, spillage[1]

Cs *Definition:* salinization/alkalinization
Description: a net increase of the salt content of the (top)soil leading to a productivity decline.
Possible causes: a distinction can be made between salinity problems due to intrusion of seawater (which may occur under all climate conditions: Css) and inland salinization, caused by improper irrigation methods and/or evaporation of saline groundwater (Csi).

[1] Although erosion of upstream areas may lead to pollution (with pesticides etc.), this is considered as an off-site effect of erosion rather than a type of pollution.

Ct *Definition:* Dystrification

Description: the lowering of soil pH through the process of mobilizing or increasing acidic compounds in the soil.

Possible causes: draining of soils containing pyrite which will produce very acid sulphate soils ("cat-clays" (Cta)). Excessive planting of acidifying vegetation (e.g. fir) may also drop the soil pH (Ctf). NB acidification by airborne components is considered as pollution!

Ce *Definition:* Eutrification

Description: An excess of certain soil nutrients, impairing plant growth

Possible causes: Imbalanced application of organic and chemical fertilizer resulting in excess Nitrogen, Phosphorus; "recalcaric" land due to overliming.

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 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.

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.

Pw *Definition:* waterlogging

Description: effects of human induced hydromorphism (i.e. excluding paddy fields)

Possible causes: rising water table (e.g. due to construction of reservoirs/ irrigation) and/or increased flooding caused by higher peakflows.

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 Pa); solution of gypsum in the sub-soil (human-induced?) or lowering of soil surface due to extraction of gas/water

Pu *Definition:* loss of productive function

Description: soil (land) being taken out of production for non-bio-productive activities, but *not* the eventual "secondary" degrading effects of these activities.

Possible causes: urbanization and industrial activities, infrastructure, mining, quarrying, etc.

Pa *Definition:* aridification

Description: decrease of average soil moisture content

Possible causes: lowering of groundwater tables for agricultural purposes or drinking water extraction, decreased soil cover and organic matter content

Dc *Definition:* complex degradation types

Description: the result of interaction(s) of different degradation processes (pollution or compaction causing biological degradation and/or erosion)

Possible causes: respective causes for separate degradation types

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 very vulnerable to even small changes in conditions which may disturb the natural equilibrium.

Sw Stable land without vegetation; i.e. (near) absence of human influence on soil stability, e.g. deserts, high mountain zones. Natural soil degradation processes may occur!

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.

Degree of Soil Degradation

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 impacts on (overall) productivity of the soil. Removal of a 5 cm layer of topsoil has a greater impact on a poor shallow soil than on a deep fertile soil. Therefore, it would be better to measure the degree of degradation by the *relative* changes of the soil properties: 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, while such data may exist for experimental plots and pilot study areas, precise and actual information will be lacking for most of the region. Models that indicate exact relationships between degradation of soil quality and productivity are still very rare and not suited for large scale extrapolation. Since ASSOD intends to reflect the *actual* situation in the field, the extrapolation of experimental data and/or the use of models will not be considered for this purpose anyway. Where it is possible to indicate the changes in soil properties that can be attributed to one or several degradation processes, this would be welcome additional information. For the current assessment, however, the degree of soil degradation will be expressed in terms of the **impacts of soil degradation on productivity.**

A significant complication in indicating productivity losses caused by soil degradation is the variety of factors that may contribute to yield declines. Falling productivity can seldom be attributed to a single degradation process such as erosion, but may be caused by a variety (and/or combination) of factors, like erosion, fertility decline, improper management, drought or waterlogging, quality of inputs (seeds, fertilizer), pests and plagues, etc. However, if one considers a medium to long term period (10-15 years), large aberrations resulting from fluctuations in the weather pattern or pests will be levelled out. **Expert experience and knowledge of the region involved will be required to eliminate from this assessment other factors that may have contributed to yield declines, such as prolonged bad crop management.**

Soil degradation also can be more or less *hidden* by the effects of various management measures such as soil conservation measures, improved varieties, fertilizers and pesticides. It should be realized that 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 should be seen in relation to the amount of inputs.

As a first, very simplified, approximation for assessing the degree of degradation (or rather the magnitude of the degradation impacts on productivity), a few major classes are proposed here to indicate changes in productivity, taking the presence or absence and magnitude of management inputs into consideration. These inputs may include: introduction of fertilizers, biocides, improved varieties, mechanization, various soil conservation measures, and other important changes in the farming system. An estimation of their magnitude (if detailed figures are not available) can be made by considering their share of the total farm expenses.

The changes in productivity are expressed in relative terms, i.e. the *current (average) productivity as a percentage of the average productivity in the non-degraded (or non-improved, where applicable) situation and in relation to inputs.* For instance, if previously an average yield of 2 tonnes of rice per hectare was gained while at present only 1.5 tonnes is realized, in spite of high inputs (and all other factors being equal), this would be an indication of strong soil degradation.

Similarly, in several countries or regions detailed data for an exact assessment as described above will be lacking, and experts will have to use their best judgment.

Level of production increase/decrease	Level of Input/Management improvements		
	A) Major	*B) Minor*	*C) Traditional*
1) Large increase	No significant impacts (stable)	No significant impacts (stable)	No significant impacts (stable)
2) Small increase	Light	No significant impacts (stable)	No significant impacts (stable)
3) No increase	Moderate	Light	No significant impacts (stable)
4) Small decrease	Strong	Moderate	Light
5) Large decrease	Extreme	Strong	Moderate
6) Unproductive	Extreme	Extreme	Strong to Extreme

The degradation impact is represented in the database by a *capital* character with a single digit code, as shown below.

A) With major inputs/management improvements

Impact of degradation

A1. Large productivity increase . . . . None (stable)
(improvements fully benefit yields and are not required for compensation of degradation impacts)
A2. Small productivity increase . . . . Light
(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
(highly unsustainable situation)

B) With minor inputs/management improvements

B1. Large productivity increase . . . . None (stable)
(improvements have large impact on yields and are not required for compensation of degradation impacts)
B2. Small productivity increase . . . . None (stable)
(improvements have moderate impact on yields and are hardly required for compensation of degradation impacts)
B3. No productivity increase . . . . Light
(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
(highly unsustainable situation)

C) Without management improvements ("traditional" systems existing for more than 25 years)

(**C1**. Large productivity increase . . . . None (stable))[2]
(**C2**. Small productivity increase . . . . None (stable))[3]
C3. No productivity increase . . . . None (stable)
(equilibrium between natural and man-induced factors, "sustainable" situation)
C4. Small productivity decrease . . . . Light
(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 . . . . Strong
(equilibrium has been highly disturbed by external factors, unsustainable situation)
C7. Unproductive . . . . Extreme
(highly unsustainable situation)

[2] These categories are not really applicable, 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 rise spontaneously. This implies that so-called "indigenous conservation techniques" that have been applied in recent times should be considered in one of the other two categories (I/II: major/minor improvements)

ANNEX III **EXTENT of Soil Degradation**

The extent of degradation is defined as the area percentage of the entire mapping unit which is affected by a certain type of degradation, rounded to the nearest 5%. For each physiographic base map unit, one or more specific degradation types is indicated. If more than one type of degradation is present, overlaps may exist between the different types. This should be indicated under Remarks in the matrix table (Annex X) and/or in the memo field in the data entry programme (see Annex IX). Furthermore, each map unit which does not show a 100% extent for degradation must by definition have some stable land. Clearly, overlaps do not occur here.

Often only a part of the entire physiographic unit is affected by the given degradation type, but the colour representing the degradation type covers the entire mapping unit, i.e. no subdivision of the units was made on the basis of degradation criteria. On the GLASOD map, the shade of the colour (light/dark) indicates the "severity" by combining the degree (seriousness) and extent (area percentage) of the given degradation type. This may create confusion, in particular for larger mapping units, where a large area may seem slightly affected (i.e. low degree, high extent) whereas in reality only a small area may be severely affected (high degree, low extent) or vice versa! As the physiographic base units for the ASSOD map have been refined in relation to the scale, this problem probably becomes less critical than for the GLASOD map (by decreasing the size of the units and thus enlarging the relative percentage of the unit covered by a specific degradation type). Another reduction of the problem could be achieved by displaying on separate thematic maps type plus degree, and type plus extent. This obviously does not work for a general overview map.

ANNEX IV **RATE of Soil Degradation**

The recent past rate of degradation indicates 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 some areas that are now only slightly degraded, may show a high rate, hence a trend towards rapid further deterioration. The latter area clearly has a higher conservation priority than the former. For this reason, the ASSOD map will put more emphasis on "hot spots", i.e. areas with a high degradation rate. At the same time, areas where the situation is improving (through soil conservation measures, for instance) will show on the map. To this end three classes with a trend towards further deterioration and three with a trend towards decreasing degradation (either as a result of human influence or by natural stabilization) are defined.

The database contains a one-digit code corresponding to the following classes:

- **3**: rapidly increasing degradation
- **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

A comparison of the actual situation with that of a decade earlier may suffice, but often it is preferable to examine the *average development* over the last 5 to 10 years to level out irregular developments. Reasons for indicating various rates should be explained in the accompanying report with as much detail as possible .

NB: 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.

Various types of human activities may lead to soil degradation. Some degradation processes may also occur naturally, such as erosion, but in this inventory (as with GLASOD) only those degradation types are considered that are the result of the human disturbance of either a natural or anthropogenic state of equilibrium. The GLASOD classification of causative factors is adopted[3]. In the database they are indicated with a single lower case character:

a: *Agricultural activities*: 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, untimely or too frequent use of heavy machinery, etc. Degradation types commonly linked to this causative factor are erosion (water or wind), compaction, loss of nutrients, salinization, pollution (by pesticides, fertilizers).

f: *Deforestation and 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, large scale commercial forestry, road construction, urban development, etc. Deforestation often leads to erosion and loss of nutrients.

e: *Over-exploitation of vegetation for domestic use:* contrary to "deforestation and 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 fuelwood, 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).

[3] It may be useful to specify the type of causative factor more precisely. Such sub-divisions of the causative factor may be indicated in the Degradation Remarks field in the matrix table (see Annex X) and/or the Degradation Memo field in the data entry programme (see Annex IX)

All areas shown as degraded, as well as "stable" areas, may have been influenced to a greater or lesser extent by rehabilitation or conservation activities. It is useful to know what these activities comprised and how much influence they have had upon the present situation. In this context the WOCAT project is worth mentioning (GDE, 1993). The aims of WOCAT are to assess the results of soil and water conservation activities on a global scale through the compilation of 1) a "Handbook on appropriate soil and water conservation technologies", referring to the actual measures being taken within a given bio-physical and socio-economical context, 2) a "Report on successful Approaches", referring to the larger framework in which measures are implemented, 3) a World Map of soil and water conservation activities and 4) a soil and water conservation Expert System, for planning and implementation of soil and water conservation measures at the field level and for training purposes.

WOCAT primarily focuses on activities to combat soil erosion, this being by far the most prominent type of soil degradation worldwide (and in Asia). Some elements pertaining to practices of plant management, cultivation system, land management and small construction works for correcting, preventing or reducing soil degradation have been incorporated in this assessment.

Conservation measures can be categorised in several ways. Often a combination of these categories will exist, in which case the most prominent one is ascertained. Within the context of ASSOD, the following four broad categories are distinguished (after Bergsma, 1994):

V *Definition:* Plant management (vegetative) practices:
Description: using the plant and cover influence. These practices against erosion may be very effective, relatively simple and cheap. Examples are: fertilisation, crop-rotations, increasing plant density, revegetation, stubble-mulching, agroforestry.

L *Definition:* Land-management practices:
Description: using the land lay-out and soil management. These practices are used in addition to plant management practices, they involve some movement of soil. They may reduce erosion effectively to very low levels. Examples: contour-tillage, contour-strip-cropping, minimum-tillage, land lay-out

S *Definition:* Structural practices:
Description: soil conservation through the construction of physical barriers to reduce or prevent excessive run-off and soil loss. Examples are: contour-terraces/banks, gully-filling, constructed flumes

O *Definition:* Other practices
Description: Soil protection or rehabilitation practices not focusing at erosion control, but for instance at pollution or salinization problems.

Often a combination of these categories will exist, in which case the code for each one can be indicated, in order of importance and separated by a comma (see example in Annex IX). In the remarks-field, further specification of the measures taken would be welcomed.

The rate of degradation is a measure for the effectiveness of the practices: a negative degradation rate indicates a human-induced improvement (NB: this may entail the mere termination or diminution of degrading activities).

Where feasible, the extent of the soil and water conservation activities should be given. Please note that the extent here only concerns the percentage of the degraded part of the entire physiographic unit.

E.g.: total mapping (physiographic) unit area = 3500 km^2, degradation extent = 25% = 875 km^2 of which **50%** ($\pm$ 440 km^2) is controlled by conservation measures.

At a request of FAO, a draft 1:5 M physiographic map of Asia (excluding the former Soviet Union and Mongolia) has recently been completed by ISRIC (van Lynden, 1994), using the SOTER methodology (van Engelen et al., 1992). This physiographic map provides basic mapping units to be used for the soil degradation assessment project for South and Southeast Asia (ASSOD) at the same scale.

Soils and terrain are two closely linked natural phenomena which together determine to a large extent the suitability of land for different uses. An integrated concept of land has been adopted in the SOTER methodology viewing "land as being made up of natural entities consisting of a combination of terrain and soil individuals". The draft physiographic map for Asia has been prepared following this concept and is largely based on the hierarchy of landforms in SOTER, with minor modifications, as already applied for similar projects in Latin America (Wen 1993) and Africa (Eschweiler, 1993) respectively.

Terrain units were delineated on a handdrawn map and their respective physiographic codes were entered into a database. The map was then digitized and linked to the database through a GIS (ILWIS and ARC-INFO). Thematic maps have been printed for the three major physiographic items, namely: Major Landform, Hypsometry and Slopeclass (see also Annex VIII).

Topographic maps of various scales and variable quality were used to obtain the required information, whereas for some areas (China in particular) satellite imagery served as a major source of information. It should be noted that the criteria described below could not always be applied in a precise manner. This is particularly true for the relief intensity criteria, which are difficult to assess as most of the maps used were at scales of 1:250.000 and smaller.

The landform classification is based on morphological criteria, in particular slope gradient, hypsometry and slopeclass. At the first hierarchic tier, **three major landforms** are distinguished on the basis of the "*characteristic slope*": level land, sloping land and steep land. This is the dominant (not average) slope gradient within a terrain unit.

A breakdown of these three main classes is achieved through classes of **relief intensity** and **hypsometry**. For level land the absolute height (a.s.l.) is considered, while for sloping and steep land the height above local base level is taken[4].

A further delimitation is achieved according to the **relative position of a terrain unit vis-a-vis the surrounding terrain**. This for example distinguishes plains (not enclosed by steeper land) from plateaus (on at least one side bounded by sloping and lower land) or depressions (surrounded by higher and steeper land on all sides). It must be noted, however, that scale plays an important role here. This for instance explains why some very large plateaus (Tibet, Deccan) or depressions/basins (Tarim, Tsaidam) are not necessarily classified as such, since at this scale they are too large too fall within a single second tier landform class. Conversely, other units are too small to be represented at the publication scale, or to be observed at the working scale.

Additional information on specific landforms such as karst, dunes, ridges, is also given (as a suffix in the physiographic code).

More detailed information on the SOTER methodology with special emphasis on small scale physiographic mapping is given in Eschweiler's (1993) and Wen's (1993) reports on the physiographic maps of Africa and Latin America respectively and in the SOTER manual (van Engelen et al., 1992).

[4] This requires some explanation, as mountains with highly divergent absolute heights above sea level will not necessarily belong to different hypsometric classes. A decrease in absolute height does not always result in a lower hypsometric class, as is demonstrated by the Southeastern reaches of the Himalayas running along the Salween and Mekong rivers, with an altitude decreasing from well over 6000 m a.s.l. in Southern Tibet to about 3500 m a.s.l. in Burma but always more than 3000 m above the local base level (Salween and Mekong R.), class 15. Similarly, 6000-7000 m high mountains in Tibet, rising only some 1000-1500 meters above the surrounding elevated plateau, belong to the same hypsometric class (13) as rather low mountains along the South Chinese coast. In contrast, the Himalayas rise over 7000 m above the Indian plains and thus belong to a high hypsometric class (15, 16).

PHYSIOGRAPHIC CLASSES

MAJOR LANDFORMS

Level land (< 8%, <100m/km local relief):
LA Valley floor, elongated landform with gentle length gradient
LD Depression, surrounded on at least three sides by higher and steeper land
LF Low gradient footslope, bordering steeper land
LP Plain
LT Plateau, surrounded on at least three sides by lower and steeper land.

Sloping land
SG Uniform slopes: 8-30%, >50m/slope unit
SH Hills: 8-30% >50m/slope unit
SL Mountainous highland: 8-30%, >600m/2km

Steep land
TM Mountains: >30%, >600m/2km local relief

Complex landforms:
CV Valleys, too narrow to map lateral slopes and valley bottom separately

Other
WA Water bodies

HYPSOMETRY
1 Level land, < 300 m above sea level
2 Level land, 300-600 m above sea level
3 Level land, 600-1500 m above sea level
4 Level land, 1500-3000 m above sea level
5 Level land, > 3000 m above sea level
10 Sloping land, < 200 m above local base level
11 Sloping land, 200-400 m above local base level
12 Sloping land, 400-800 m above local base level
12* Sloping land, > 800 m above local base level (give * in Remarks/Memo field)
13 Steep land, 600-1500 m above local base level
14 Steep land, 1500-3000 m above local base level
15 Steep land, 3000-5000 m above local base level
16 Steep land, > 5000 m above local base level

SLOPECLASS
w 0-2% Flat, wet
a 0-2% Flat
b 2-8% Undulating
c 8-15% Rolling
d 15-30% Moderately steep
e > 30% Steep

SUFFIX1, SUFFIX2 (additional landform information)
i Intermontane basin
r Ridges
k Karst
d Dunes
l Lava fields

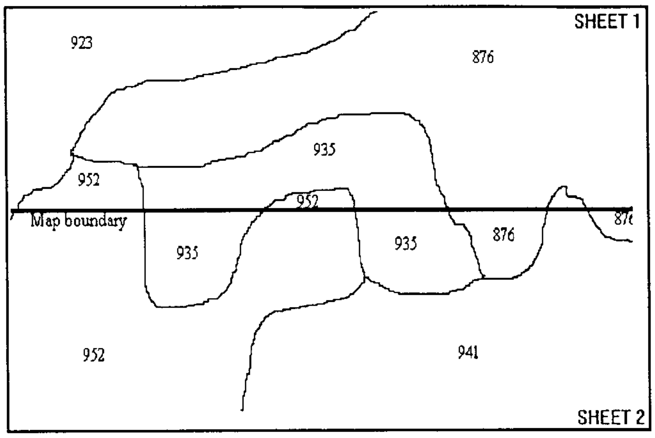

Figure 2

Where more than one set of map sheets was required to cover the whole country, some map units may have been bisected by the map sheet boundaries. Although polygon numbers are unique, i.e. each number corresponds to only one polygon on the original map for the entire region, you may thus find the same number more than once on your maps (see fig. 1) but only once in the database.

It may be difficult or impossible to read some of the polygon numbers. In that case, just write the correction on the black-and-white print with a red pencil.

The polygon label numbers are centred in the map units (polygons). This means that when a number could not be printed between the polygon boundaries, it belongs to the map unit in which the number is centred. The database and printed tables, like the maps, also contain polygon numbers outside your country borders. Ignore these, since they will be checked by other countries.

The physiographic code in the database and on the printed tables contains the information for the corresponding polygon and is composed as in the following example:

LP**1***a*/k/r

Corresponding to: MAJOR LANDFORM **Hypsometry** *Slope class* / First suffix / Second Suffix
(see above for codes for individual items)

This physiographic information should be checked and corrected where deemed necessary. Use a photocopy of the blank black-and-white print for corrections, as you will need a separate copy to indicate degradation codes.

When only the delineation of a map unit (polygon) needs to be corrected, draw the correct lines on the black-and-white print with a red pencil.

When an additional map unit is needed, draw the new unit on the black-and-white map with a red pencil and clearly write the physiographic code for the new map unit on the print. It is not necessary (or possible) to add the new polygon label numbers to the database (this will be done at ISRIC).

When the delineation of the map unit is correct, but the physiographic code needs to be modified, change the code for that polygon in the database and on the black-and-white map (in red pencil). In case you cannot use the computerized data entry programme, make a list of polygon label numbers for which changes have been made in the physiographic code.

To access the database, type:

A:INST_ASS <ENTER>

This will INStall the ASSOD programme and copy all relevant ASSOD files[5] on the diskette to a new directory C:\ASSOD (assuming there is at least 1.5 MB capacity left on your harddisk). *NB: DO NOT REPEAT THIS STEP AFTER YOU HAVE ENTERED DATA, BECAUSE THE DATABASE WILL BE OVERWRITTEN WITH THE ONE IN THE ASSOD.ZIP FILE on A: .*

[5] ASSOD.EXE, KEY.DBF, KEY.MDX, CONFIG.DB and your country database(s) [countryname].DBF and .DBT. All these files **must** be within the C:\ASSOD directory to run the programme!

Then type

ASSOD <ENTER> to start the data entry programme

Choose **<Physiography>** from the menu, to modify the physiographic codes and follow the instructions on the screen. Select the ASSOD file (database) that corresponds to your country map by pressing **<F2>**. In case you accidentally choose the wrong file (like KEY.DBF, which will also appear in the window on the screen) you will get a message "Not an ASSOD file. Press any key to continue" (and try again). After choosing your database file, edit the respective item codes as explained in Annex VII. For each item, you can press **<F2>** to browse through a list of permitted codes and select the appropriate one. In the memo field, which you can enter by pressing **<F9>**, you may give additional comments. After you have edited a code, *save the record with* ***<F6>*** before advancing to a new record.

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

ERRATA

If you change a Major Landform code into "WA" (water bodies), the programme will ask for values for Hypsometry and Slopeclass as well, even though this is not relevant. In that case, you may fill in any permitted value here, since these will later automatically be set to zero for this category.

You are kindly requested to enter the required degradation code in your degradation database *for each polygon* on your map, as explained below. For clarity reasons you may also indicate this code on the blank copies of the map. ***If you have indicated changes in the physiographic map on the black-and-white prints, do not use the same copy but a blank copy!*** Indicating several degradation types (with their impact, extent, etc.) per polygon is possible. The example below shows a possible degradation code:

The matrix table in Annex X is to be used for manual data entry (make as many copies as required) prior to, or instead of, computerized data input, as in following example.

Poly_id[6]	Type[7]	Extent[8]	Cause[9]	Impact[10]	Rate[11]	Degr.Remarks	Rehab./Cons. Measures[12]		Cons.Remarks
							CType1,2,3	CExtent	
435	Wt	25	f	A3	-1	Mainly in steeper areas	S,V	50	Terracing with mulching
435	Cn	40	a	B2	1	Especially loss of organic matter.			(No rehab. or cons. measures)
435	Sn	50				Overlap Wt/Cn = (25+40)-(100-50) = 15%			

NB: for stable areas, only type (Sn/Sh/Sw) and extent need to be indicated; for Sh the measures that have led to the stabilization should also be given.

To access the database (if you have not yet installed the programme, first follow the instructions given in Annex VIII), type:

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

followed by:

ASSOD <ENTER>

Now choose **<Degradation/Conservation>** from the menu, to add (or edit) degradation codes and follow the instructions on the screen. Select the ASSOD file (database) that corresponds to your country map by pressing **<F2>**. Enter the respective item codes as given in the previous Annexes. For each item, 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 or conservation, respectively. After you have filled in a code for each item, *save the record with* ***<F6>*** before advancing to a new record. If you want to enter a second (or third, etc.) degradation code for the same polygon, press **<F5>**.

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

6 The field POLY_ID indicates the label number of the mapping unit as defined for the physiographic map. Each map unit has its unique label number, *which may not be changed!* (see Annex VIII).

7 See Annex I

8 See Annex III

9 See Annex V

10 See Annex II

11 See Annex IV

12 See Annex VI
NB: since ASSOD, contrarily to WOCAT, addresses more types of degradation, other rehabilitation or protection measures aimed at non-erosive soil degradation may also be indicated

ASSOD MATRIX TABLE

(make copies as required)

Poly_id[13]	Type[14]	Extent[15]	Cause[16]	Impact[17]	Rate[18]	Degradation Remarks[19]	Rehabilitation/Conservation Measures[20]		
							CType1,2,3	CExtent	Cons.Remarks

13 The field POLY_ID indicates the label number of the mapping unit as defined for the physiographic map. Each map unit has its unique label number, *which may not be changed!* (see Annex VIII). More than one degradation type (with extent, rate, etc.) can be indicated for each polygon.

14 See Annex I

15 See Annex III

16 See Annex V

17 See Annex II

18 See Annex IV

19 Here for instance the degree of overlap can be indicated if more than one degradation type has been given. Further remarks on type, extent, rate, etc. can also be given.

20 See Annex VI
NB: since ASSOD, contrarily to WOCAT, addresses more types of degradation, other rehabilitation or protection measures aimed at non-erosive soil degradation may also be indicated

REFERENCES

Barrow, C.J, 1991. Land Degradation; Development and Breakdown of Terrestrial Ecosystems. Cambridge University Press

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

Dent, F.J. (ed.), 1993. The collection and analysis of land degradation data. Report of the Expert Consultation of the Asian Network on Problem Soils, Bangkok, 25 to 29 October 1993. RAPA Publication: 1994/3

Engelen, V.W.P. van, Wen Tin-tiang (ed.), 1992. The SOTER Manual (Procedures for small scale digital map and database compilation of soil and terrain conditions, 5th edition). FAO/ISRIC/ISSS/UNEP.

Eschweiler, J.A, 1993. A draft physiographic map of Africa. FAO, Rome

GDE, 1993. World Overview of Conservation Approaches and Technologies (WOCAT). Workshop Proceedings of the 2nd International WOCAT Workshop, Berne and Riederalp 11-15 October 1993. Group for Development and Environment, Institute of Geography, University of Berne.

Lynden, G.W.J. van, 1994. Draft Physiographic Map of Asia (excluding the former Soviet Union). FAO, Rome

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.

Oldeman, L.R. (ed.), 1988. Guidelines for General Assessment of the Status of Human-Induced Soil Degradation. ISRIC Working Paper and Preprint No 88/4.

Sanders, D.W, 1994. A Global Perspective on Soil Degradation and its Socio-Economic Impacts: The Problems of Assessment. Keynote paper presented at the 8th ISCO Conference, New Delhi, 4-8 December 1994

Wen, T.T, 1993. A draft physiographic map for Central and South America. FAO, Rome

Young, A, 1993. Land Degradation in South Asia: its severity, causes and effects upon the people. World Soil Resources Reports N° 78. FAO/UNDP/UNEP

ANNEX XII

GLOSSARY

ASSOD . . . . Soil Degradation Assessment for South and Southeast Asia
FAO . . . . Food and Agriculture Organization of the United Nations
GDE . . . . . . Group for Development and Environment, Geographical Institute, University of Berne
GIS . . . . Geographic Information System
GLASOD . . . . Global Assessment of human-induced Soil Degradation
ISRIC . . . . International Soil Reference and Information Centre
ITC . . . . International Institute for Aerospace Survey and Earth Sciences
SALT . . . . Sloping Agricultural Land Technology
SOTER . . . . World Soils and Terrain Digital Database
SWC . . . . Soil and Water Conservation
WOCAT . . . . World Overview of Conservation Approaches and Technologies
UNEP . . . . United Nations Environmental Programme