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

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Wageningen, February 1997

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ACKNOWLEDGEMENTS

The Assessment of the Status of Human-Induced Soil Degradation in South and Southeast Asia was prepared under a financial agreement with the United Nations Environment Programme (UNEP) and has been made possible through the intense efforts of all collaborating national institutions (see Annex II for details). Major thanks are due to these institutions and the individuals involved for their cooperation. The support of the FAO Regional Office for Asia and the Pacific is greatly appreciated, in particular towards Mr. F.J. Dent for administrative and logistic support through the Asian Network on Problem Soils. The authors wish to express their gratitude for constructive critical comments from various persons, in particular from R. Gallacher and F. Nachtergaele (FAO), H. Hurni and H.P. Liniger (CDE), A. Ayoub (UNEP), T. van Mensvoort (WAU) and several ISRIC colleagues.

The administrative staff of ISRIC is greatly acknowledged for their assistance in coordinating secretarial and financial matters. Special appreciation goes to J. Resink of ISRIC for her important GIS support.

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FOREWORD

The soil is a natural resource, non-renewable in the short term or very difficult to renew and expensive either to reclaim or improve following erosion by the abrasive forces of water and wind or by chemical or physical deterioration of its properties. The intense and ever increasing pressure on land and water resources throughout the world leads to land degradation and pollution, which in turn may result in decreasing biological productivity and declining biodiversity. Although world cereal production almost doubled between 1966 and 1990, the growth in aggregate cereal output started to decrease after 1982, mainly as a result of a decline in the quality and performance of irrigation systems, an inefficient use of fertilizers, and a negative balance in nutrients in most non-irrigated drylands in developing countries. The mining of soil nutrients, often induced by poor socio-economic conditions, are pushing average yields into decline. In response farmers are trying to produce more food either by extending their traditional low-input practice into forest land or onto drier and more fragile lands, or by shortening fallow periods. As a result, the more vulnerable fertile topsoil is washed or blown away.

Recognizing the need to obtain a better overview of the geographical distribution and the seriousness of human-induced soil degradation worldwide, the United Nations Environment Programme (UNEP) commissioned the International Soil Reference and Information Centre (ISRIC) to coordinate a worldwide programme to produce, on the basis of incomplete existing knowledge, a scientifically credible global assessment of the status of human-induced soil degradation within the shortest possible time frame (ISSS, 1987). Thanks to a worldwide collaboration of over 200 soil scientists and environmental experts, a World Map of the Status of Human-induced Soil Degradation (GLASOD) was published in 1990 and complementing statistics on the global and continental extent of various types of soil degradation, their degree and causative factors were published in 1991. GLASOD aroused worldwide interest and the results have been cited in many policy papers and reviewed in several scientific journals.

Ever since GLASOD was published, requests were made for soil degradation assessments at regional and national scale. The World Resources Institute, which assembled many of the GLASOD results in its World Resources Report 1992-1993, indicated the critical need for further study to more accurately portray soil degradation problems at the national and local level. At FAO's 21st Regional Conference for Asia and the Pacific (New Delhi, 1992), it was recommended that FAO should find means to strengthen the collection and analysis of land degradation data in the Asia-Pacific region. The next year FAO's Asian Network on Problem Soils convened an expert consultation in Bangkok (October 1993) on the topic: Collection and Analysis of Land Degradation Data (Dent, 1994). This consultation recommended to prepare 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) and using as a working template a physiographic map and database to be constructed along the lines of the internationally endorsed SOTER (Soils and Terrain Digital Database) approach.

Late 1994 UNEP formulated a project under the title: Assessment of the Status of Human-induced Soil Degradation in South and Southeast Asia (ASSOD). Responsibility for coordination and implementation was entrusted to ISRIC in close collaboration with FAO's Regional Office for Asia and the Pacific and with national natural resource institutions.

The study presented here summarizes the findings as collected by the national institutes in the region and provides a more detailed view of the extent of human-induced soil degradation in the South and Southeast Asian region.

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1 Towards an assessment of the status of human-induced soil degradation in South and Southeast Asia

1.1 Background

The Assessment of Human-Induced 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, the Winand Staring Centre and ITC, based on contributions of a large number of experts worldwide (Oldeman, Hakkeling and Sombroek, 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.

The Expert Consultation of the Asia Network on Problem Soils convened at the invitation of FAO's Regional Office for Asia and the Pacific in Bangkok (October 1993) and discussed strategies for the collection and analysis of land degradation data (Dent, 1994). Participants were informed about the GLASOD approach and about the methodology for the development of an internationally accepted geo-referenced system capable of providing accurate, useful and timely information on soil and terrain resources - the SOTER concept (Soil and Terrain Digital Database, Van Engelen and Wen, 1993). The participants recommended that the GLASOD methodology be adopted as the common methodology in identifying soil degradation. ISRIC was requested to amend the general guidelines, based on suggestions for revision by Network member countries. The participants also recommended that a physiographic basemap be prepared by FAO and ISRIC utilising the SOTER methodology. Network nodal institutions would initiate action for the preparation of national soil degradation maps and databases, utilizing the revised guidelines. This information would be compiled by ISRIC/FAO into a regional South and Southeast Asian soil degradation map. Contacts would also be established with the WOCAT programme (World Overview of Conservation Approaches and Technologies, GDE, 1993). It was recognized that international funding support would facilitate the speedy completion of these activities.

These recommendations were acknowledged by FAO and UNEP. FAO assigned ISRIC to prepare a new physiographic map and database at 1:5 Million, while UNEP formulated a project document for the Assessment of the Status of Human-induced Soil Degradation in South and Southeast Asia (ASSOD) with ISRIC as the coordinating institution for this project. FAO's Regional Office for Asia and the Pacific would provide logistic support and organize a mid-term evaluation meeting. The national institutions represented in the Asia Network on Problem Soils (see Annex II) would function as the focal points for the ASSOD data collection and follow-up. For countries not participating in the Network, focal points still had to be identified, which succeeded in all cases except for Cambodia.

According to the ASSOD project document (UNEP, 1994), the immediate objective of the ASSOD study is to more accurately portray soil degradation problems at the national and regional level so that soils, as a major part of the life supporting system, will be used and managed in a sustainable manner. It is expected that the project will result in an enhanced knowledge on the status of soil and land resources and on the trend of soil degradation in South and Southeast Asia, as well as in strengthened national capacities in the field of soil degradation assessment. It is assumed that the participating countries provide the required information on which to accurately build the assessment. It is assumed that the participating countries provide the required information on which to accurately build the assessment.

1.2 Project Organization

Similar to GLASOD, the information to develop ASSOD is based on expert judgment and thus subjective. As stated by Thomas (1993), the approach is susceptible to much of the criticism that earlier UN assessments received, but he acknowledges that it is easy to criticize such an approach but difficult to suggest viable alternatives at the scale of investigation. Yadev and Scherr (1995) stated that the strength of the (informed opinion) approach lies in providing a sense of nature and relative importance across large areas.

As a first activity, ASSOD called for the preparation of Guidelines for Soil Degradation Assessment in South and Southeast Asia. These guidelines were prepared at ISRIC (van Lynden, 1995) and served 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 (Oldeman, 1988), incorporating comments received from various members of the Asian Network on Problem Soils and others.

Secondly, the a physiographic base map was compiled at ISRIC for FAO in a preparatory phase of the project. The draft physiographic base map was used as a template to identify major soil degradation types.

The third and most important step was the development of national soil degradation databases by the national nodal institutions. The ASSOD guidelines together with a set of physiographic country maps were distributed in February 1995. A set of (empty) matrix tables was attached to manually enter degradation data for each individual mapping unit. To enable computerized data input, a diskette containing a data-entry programme was also enclosed. Through letters of agreement the nodal institutions were requested to carefully check the physiographic map and database, make adjustments if deemed necessary and then identify for each map polygon the occurrence of human-induced soil degradation and its characteristics, using the ASSOD guidelines. In the various annexes of the guidelines, a detailed description was given of degradation parameters to be entered in the database. These national degradation data were compiled and stored in a computerized geo-referenced database by ISRIC and checked for errors. Although the computerized data entry programme contained several data error protection modules, it was inevitable in view of the large amount of data and the fact that the programme could not be used by all countries, that substantial corrections were still needed.

A mid-term evaluation of project progress was held during the Fourth Expert Consultation of the Asia Network on Problem Soils in Manila (October, 1995), during which some first results and emerging problems were discussed (see below) and where each country presented a report on the status of degradation (Dent, 1996).

By this time all country data had been received[1] and entered into the central database at ISRIC. It was clear, however, that no sufficiently reliable results could be expected by the end of the envisaged 15 month period, so UNEP was requested to extend the project period on a budget-neutral basis, which was granted. After the Manila meeting, thorough data integrity checking (e.g. tracing incorrect codes etc.) was done by ISRIC and countries were requested to provide the necessary correction before March 1996. When the corrected data arrived back at ISRIC, draft thematic maps were printed showing the four individual main degradation types with their extent and impact, which exposed other errors and inconsistencies. These maps had to be verified by the collaborators, in particular for cross-border correlation and/or other inconsistencies. That in fact entailed another error checking procedure, this time addressing the validity of the data themselves, e.g. is the occurrence of a certain degradation type and its given extent or degree plausible (like severe water erosion on a plain, or extensive degradation in nearly uninhabited areas)? The last phase consisted (to the extent possible) of correlation, elimination of inconsistencies and homogenization at the regional level by ISRIC. The final draft version of the ASSOD map was returned to the nodal institutions for comments and approval.

Some first results were displayed at the 9th ISCO conference in Germany in August 1996 to provoke comments, and also discussed during the national WOCAT workshop in Thailand, September 1996, where representatives from Thailand, Malaysia, Vietnam, the Philippines, Indonesia and FAO-RAP were attending, most of them from the institutes collaborating in the ASSOD project.

This report describes in detail the methodologies used to arrive at the first approximation of the Assessment of the Status of Human-induced Soil Degradation in South and Southeast Asia. ASSOD is more than just a revised and magnified GLASOD map for Asia and 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 in relation to the level of management, while some broad elements of conservation/rehabilitation are added as well. Unlike GLASOD, moreover, the end product of the project is not a single map, but a range of possible outputs generated by the database and GIS: various thematic maps, graphics, statistics, etc.

It must be realised that the short time frame of a eighteen months period and the scale of 1:5 M has necessitated some arbitrary decisions to be made by the national collaborators and by the ISRIC staff during compilation. This study will nevertheless provide a better insight in the extent and severity of human-induced soil degradation and its impact on agricultural productivity in the region.

[1] Except for Cambodia, where no contact could be established

2 Methodologies for the Preparation of a South and Southeast Asian Assessment of Soil Degradation

2.1 Preparation of the Physiographic Base Map

The base map for ASSOD was 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. This physiographic map provides the mapping units for the soil degradation assessment for South and Southeast Asia at the same scale (Van Lynden, 1994)

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 Africa (FAO, 1993-a) and Latin America (FAO, 1993-b) respectively.

Terrain units were delineated on a hand-drawn 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 Slope class.

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 slope class. 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 dominant slope and relief intensity. A further breakdown is made according to hypsometry and regional slope classes. 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[2].

[2] 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 Myanmar 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 metres 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)

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 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 to 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).

As this map was only a draft version, corrections could still be made by the collaborating nodal institutions where deemed necessary, before the degradation status of each unit was determined.

In view of the specific conditions in high mountain areas for which the used SOTER criteria were considered less applicable, Nepal provided an alternative physiographic map based on a 1:1M "Land Systems Inventory". The corresponding physiographic (SOTER) information for these polygons is however still lacking.

Most physiographic units (polygons) were bisected by country borders, but since the collaborating institutions only provided data within their national boundaries, it proved more practical to overlay country borders as additional polygon boundaries. A polygon initially covering an area in three different countries was now split up into three sub-polygons. The initial polygon ID was retained, with a country code suffix to distinguish the sub-units. This procedure explains why some map classes within a single physiographic unit change at country borders, although cross-border correlation has been carried out to the extent possible.

2.2 Guidelines for the Assessment of the Status of Human-induced Soil Degradation in South and Southeast Asia

2.2.1 Types of Soil Degradation

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, deteriorating 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 soil 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[3]

Cs *Definition:* salinisation/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 salinisation, caused by improper irrigation methods and/or evaporation of saline groundwater (Csi).

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

[3] 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.

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

Ce *Definition:* Eutrophication
Description: An excess of certain soil nutrients, impairing plant growth
Possible causes: Imbalanced application of organic and chemical fertilizer resulting in excess Nitrogen, Phosphorus; liming.

Pc *Definition:* compaction
Description: deterioration of soil structure by trampling by cattle 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; soil moisture; climate.

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 or 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 reduced organic matter content

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.

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.

W “Wasteland”: land without vegetation and with (near) absence of human influence on soil stability, e.g. deserts, high mountain zones. Natural soil degradation processes may occur!

2.2.2 Impact on Productivity

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 the 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, relative changes of the soil properties are better 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, while such data may exist for experimental plots and pilot study areas, precise and actual information is lacking for most of the region. Models that indicate exact relationships between decrease in 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 was not considered appropriate. The degree of soil degradation will thus be expressed in qualitative terms as **impact on productivity.**

A FAO/UNEP/UNDP intercountry project carried out a "Study of Land Degradation in South Asia: its severity, causes and effects upon the people" (Young, 1993). 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, the impacts of degradation are used 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.

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, etc., often in combination with one another. 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.

Soil degradation 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 changes should be seen in relation to the amount of inputs or level of management.

As a rather simplified approximation for assessing the degradation impacts on productivity, five classes indicate changes in productivity (ranging from “negligible” to “extreme”, taking the level of management into consideration (see table 1). This may include: introduction of fertilizers, biocides, improved varieties, mechanization, various soil conservation measures, and other important changes in the farming system. An estimation of the 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 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 rice per hectare was attained 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.

It must be emphasized that the *degree* of degradation reflects the intensity of the degradation process itself, whereas the *impact* considers the effect of that process. Consequently it is possible for instance that in an area with deep fertile soils, erosion is quite intense, but the impact is only light or even negligible. "Negligible" is thus not necessarily synonymous with "stable", which means no degradation!

Table 1: Impact of degradation: Management level and productivity

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

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 . . . . 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) Medium management level

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

C1-2. Small to large productivity increase . . . . Negligible[4]

C3 No productivity increase . . . . Negligible
(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 to unproductive . . . . Strong to Extreme
(equilibrium has been highly disturbed by external factors, unsustainable situation)

2.2.3 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 are indicated. If more than one type or subtype of degradation is present, overlaps may exist between the different (sub)types. Furthermore, each map unit which does not show a 100% extent for degradation must by definition have some stable and/or wasteland. Clearly, overlaps do not occur here.

2.2.4 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. From a purely physical point of view, the latter area would have a higher conservation priority than the former. At the same time, areas where the situation is improving (through soil conservation measures, for instance) might be identified. 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, plus one class for no changes.

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

4 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 (medium/high management)

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 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.

2.2.5 Causative Factors

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. 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, salinisation, 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 (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 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) and loss of productive function..

2.2.6 Rehabilitation or Protection Measures

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 consisted of and how much influence they have had upon the present situation. 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. More comprehensive conservation data are collected by the WOCAT project, which evaluates the results of soil and water conservation activities on a global scale. WOCAT primarily focuses on activities to combat soil erosion, this being by far the most prominent type of soil degradation worldwide.

Within the context of ASSOD, the following four broad categories are distinguished (after Bergsma, 1996):

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 salinisation problems.

Often a combination of these categories will exist.

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 was given. The extent here only concerns the percentage of the degraded part of the entire physiographic unit.

2.3 Compilation of the regional soil degradation assessment database

The main tool to generate the ASSOD maps was a computerized database, linked to a GIS, which enables flexible output generation, 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 or from thematic maps on specific issues.

Maps on the extent and impact of soil degradation can be displayed in different ways. The GLASOD map showed the four main degradation types in a single map, based on the severity (combined degree and extent) occurring for a given type, with the colour corresponding to the degradation type and the shading of that colour to its severity. Map 1 presents an overview of the dominant degradation types in that manner. Such a map does not differentiate between a light degree with a high extent or conversely an extreme degree with a rather low extent (both resulting in a severity class "high"). Nor are other types of degradation shown that also occur in the same polygon, but with a lower severity. Moreover, often only a part of the entire physiographic unit is affected by the given degradation type, but the colour on the map representing the degradation type covers the entire mapping unit, i.e. no subdivision of the units was made on the basis of degradation criteria. 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! This problem has been overcome by making thematic maps for a single degradation main type (map 2 and 3) or subtype (map 3 and 4) where five impact classes are displayed in different colours (from green for negligible impact to red for extreme impact) and five extent classes by different shading of the colours.

Because the original GLASOD map was compiled "manually", and only digitized afterwards, 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.

Table 2 Differences between GLASOD and ASSOD methodologies

	GLASOD	ASSOD
Coverage	Global	South and southeast Asia (17 countries)
Scale	1:10M (average)	1:5M
Base map	Units loosely defined (physiography, land use, etc.)	Physiography, according to standard SOTER methodology
Status assessment	Degree of degradation + extent classes (severity)	Impact on productivity (for three levels of management) + extent percentages
Rate of degradation	Limited data	More importance
Conservation	No conservation data	Some conservation data
Detail	Data not on country basis	Data available per country
Cartographic possibilities	Maximum 2 degradation types per map unit	More degradation types defined, no restrictions for number of types per map unit
End product	One map showing four main types with severity	Variety of thematic maps with degree and extent shown separately
Database/GIS	Digital information derived from conventional map	Data stored in database and GIS before map production
Source	Individual experts	National institutions

With the geo-referenced information in the ASSOD database, linked to a GIS, these problems can be alleviated. The database contains a wealth of data from which a selection can be made for output in various formats: maps, tables, graphs. In principle *all* relevant information can be stored and depicted in some way when desired (through the creation of separate thematic maps).

3 Results of the Assessment of Human-induced Soil Degradation in South and Southeast Asia

3.1 Comparison of ASSOD vs. GLASOD[5]

From the completed ASSOD database and maps, the first conspicuous difference with the GLASOD map section for South and Southeast Asia is the much higher amount of detail, which is only partly due to a larger scale (1:5M instead of 1:10M). As an example, India has only some 50 map units on the GLASOD map, whereas it counts more than 600 on the ASSOD map (see map 1)! This also underscores the major effort of the countries involved to realize this result within such a short time frame (for comparison, the GLASOD project had a duration of three years!).

A further important aspect of the ASSOD results is the greater differentiation of degradation types within the region.The GLASOD map showed a high predominance of water erosion in the region, whereas the picture emerging from ASSOD is more varied (see map 1, fig. 1, table 3).

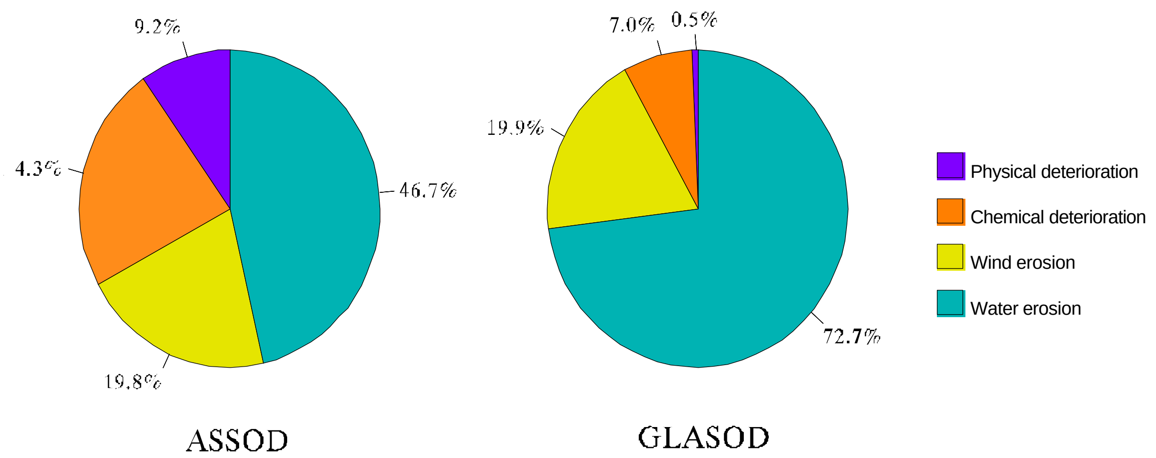

***Fig. 1. Distribution of main degradation types** in South and Southeast Asia (as % of total degraded area)*

Water erosion remains a dominant feature, but chemical deterioration and wind erosion are more prominent than in the GLASOD inventory. The total area without any human-induced degradation is smaller than on the GLASOD map. This certainly should not be perceived as an increase in degradation during the period since GLASOD was compiled, but rather as a result of the more detailed inventory, and of the somewhat fuzzy interpretation of the term "human-induced" (see 3.5: Discussion).

Although the extent of "non-degraded land" is lower than on the GLASOD map, the total extent of degradation with a negligible or light impact on the other hand is considerably higher.

5 See Oldeman, 1994 (in: RAPA, 1994)

Table 3 Comparison between ASSOD and GLASOD of Extent of Degradation subtypes in South and Southeast Asia (in M.ha)

Impact/ degree*	Negligible**	Light		Moderate		Strong + Extreme		Total	
	ASSOD	ASSOD	GLASOD	ASSOD	GLASOD	ASSOD	GLASOD	ASSOD	GLASOD
Wt	58.7	175.8	62.8	98.1	154.5	15.9	36.2	348.6	253.5
Wd	18.2	22.6	24.0	17.0	21.5	32.9	22.2	90.7	67.7
Wo**	5.3	3.2	-	1.4	-	1.9	-	11.7	-
Et	1.9	73.7	41.6	16.3	9.4	8.2	-	100.2	51.0
Ed	0.3	7.2	8.2	12.6	6.0	59.3	14.5	79.4	28.7
Eo	+	2.0	-	9.2	8.9	3.2	-	14.4	8.9
Cn	67.6	68.3	4.1	45.1	4.7	1.9	1.0	182.9	9.8
Cs	5.2	20.9	8.3	14.3	5.0	3.5	3.4	43.9	16.7
Ct	1.2	2.0	0.4	0.9	2.3	+	1.2	4.1	3.9
Cp	-	5.3	-	-	0.9	-	0.2	5.3	1.1
Ce**	0.2	0.3	-	+	-	-	-	0.5	-
Pa**	0.3	23.8	-	+	-	1.4	-	25.5	-
Pw	10.7	18.9	0.4	5.4	-	2.8	-	37.8	0.4
Pc/Pk***	6.5	2.9	+	1.5	-	+	-	10.9	0.5
Ps	0.9	0.4	0.7	-	-	+	0.2	1.3	0.9
Pu**	1.2	2.2	-	1.9	-	1.6	-	7.0	-
S****								998.9	1393.0

- No significant occurrence
+ Less than 0.1 M.ha but more than 0.01 M.ha
* NB: "impact" (ASSOD) and "degree" (GLASOD) are not fully equivalent (see 2.2.2)!
** Not defined in GLASOD
*** Pc and Pk separate in ASSOD
**** All "Stable" and "Non-used wasteland" together

3.2 Area calculations

It should be noted that in area calculations for the main types of degradation, it has been a standard assumption that (unless specifically stated otherwise) *subtypes of the same main type within one polygon overlap*, whereas *different main types are normally considered to have no overlap*. This is only a pragmatic assumption, by lack of detailed figures on overlap percentages, even though it may not always reflect reality. In all maps and area calculations that consider only main types, the subtype with the highest extent has been taken as reference. If this subtype has a light impact, it is possible that locally another subtype with higher impact occurs although it does not feature on the map. Figures on the overall occurrence of the main degradation types thus reflect the maximum extent - but not per se the maximum impact - of *one or more* subtypes. Therefore the sum of different subtypes does not necessarily correspond with the total for the main type. This also explains why the total area percentage of all main degradation types plus stable/ natural waste land is not 100% for some countries. Where the total is more than 100%, an overlap between two or more main degradation types can be assumed.

3.3 Extent and impact of soil degradation

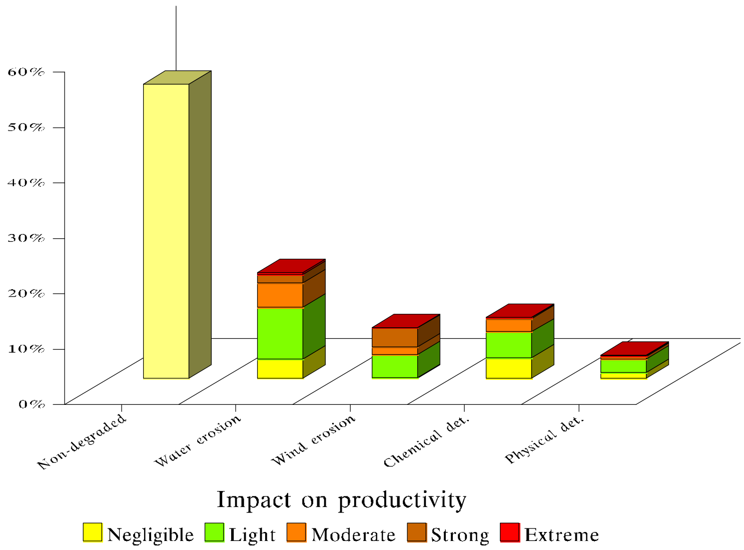

Fig. 2 Relative distribution of degradation main types and stable/wasteland *(as % of total land area)*

Map 1 illustrates the dominant occurrence of the main degradation types based on the highest severity (combined extent and impact) per polygon, while fig. 2 and fig. 3 show the relative distribution of the degradation main types and subtypes respectively The relative area of degraded land (as percentage of the total country area) varies highly per country and per degradation type (fig. 4-7). In some cases the explanation for this may be quite straightforward, such as the relative importance of wind erosion in China, India and Pakistan, or the low relative extent of water erosion in a largely lowland country as Bangladesh. In other cases however the differences may be more due to different perceptions of the extent and/or impact of degradation, particularly for chemical and physical deterioration, which rank rather high in some countries but are insignificant or nil in others. Due to widely varying area sizes of the countries involved, the absolute extent of degradation may show a completely different picture. Water erosion in China amounts to "only" 19% of the total land area (as opposed to, for instance, 48% for the Philippines), but this still corresponds to a staggering 180 M.ha, which is the highest absolute figure for extent of water erosion per country in the region.

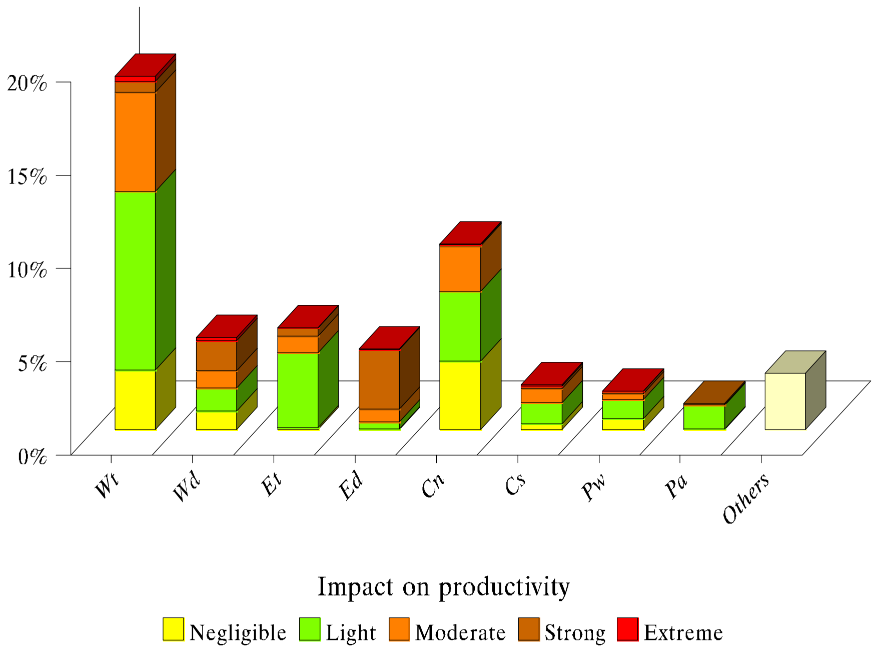

Fig. 3 Relative distribution of degradation subtypes
(as % of total land area)

3.3.1 Water erosion

Water erosion (map 2, fig. 4) covers 21% of the total land area in the region (or 46% of the total degraded area). It is predominant in large parts of China (>180 M.ha) except for the northern parts, on the Indian subcontinent (>90 M. ha) and in the sloping parts of Indochina (40 M.ha), the Philippines (10 M.ha) and Indonesia (22.5 M.ha). In relative terms (as percentage of the total country area) moderate to extreme water erosion is particularly important in India (10%), the Philippines (38%), Pakistan (12.5%), Thailand (15%) and Vietnam (10%). Although some other countries show high percentages for total water erosion (e.g. 56% for P.R. Korea, 38% for Malaysia or 32% for Sri Lanka), most of this has negligible or light impact. "Loss of topsoil" (Wt) is definitely the most common subtype of water erosion, but remarkably for a large part with negligible or light impact (see fig. 3, table 4). To some extent this might be also due to the less conspicuous character of sheet erosion as compared to "terrain deformation" (Wd, such as gullying, landslides) and off-site effects such as flooding and sedimentation (Wo).

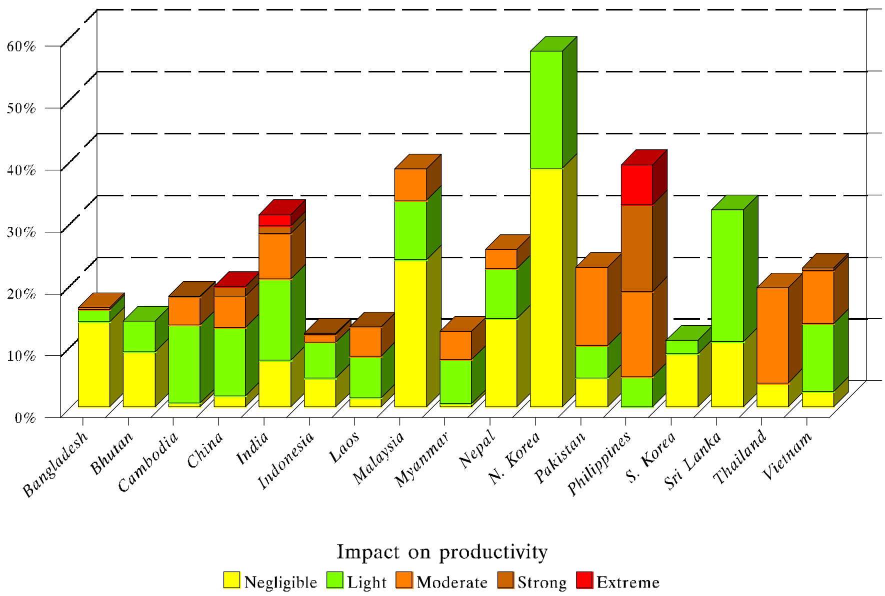

Fig 4 Relative distribution of water erosion (on-site effects)
(as % of total land area per country)

Table 4 **Distribution of subtypes of water erosion per country** *(in M.ha)*

	Total land area	Loss of topsoil (Wt)					Terrain deformaton (Wd)					Off-site effects (Wo)				
		Negligible	Light	Moderate	Strong	Extreme	Negligible	Light	Moderate	Strong	Extreme	Negligible	Light	Moderate	Strong	Extreme
Bangladesh	13.5	-	1.9	0.3	-	-	-	-	-	0.3	-	-	0.1	-	1.6	-
Bhutan	3.9	0.3	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-
Cambodia	18.0	0.1	2.3	0.8	+	-	-	-	-	-	-	-	-	-	-	-
China	925.9	15.8	105.9	44.9	3.8	0.2	0.5	7.9	5.9	24.0	-	0.2	0.2	0.2	-	-
India	318.6	19.1	41.2	22.2	3.3	2.9	6.5	2.0	4.5	4.8	3.1	-	0.3	-	0.3	-
Indonesia	190.5	6.3	5.5	0.3	+	-	2.7	5.5	2.1	0.2	-	-	-	-	-	-
Laos	23.0	0.3	1.6	1.1	+	-	-	-	+	-	-	0.4	-	-	-	-
Malaysia	33.5	8.0	3.2	1.7	-	-	-	-	-	-	-	-	-	-	-	-
Myanmar	66.6	0.4	1.3	0.4	-	-	-	3.4	2.6	-	-	+	0.4	-	-	-
Nepal	14.7	0.9	1.1	0.3	+	-	2.3	0.2	0.4	-	-	0.7	0.1	-	-	-
N. Korea	12.1	3.7	+	-	-	-	2.1	2.3	-	-	-	-	-	-	-	-
Pakistan	87.8	1.1	4.4	11.0	-	-	3.6	0.3	0.7	-	-	-	-	-	-	-
Philippines	29.2	0.4	1.4	4.0	3.7	1.9	-	-	0.6	0.4	-	-	1.5	1.2	-	-
Sri Lanka	6.5	0.7	1.4	-	-	-	0.5	1.0	-	-	-	1.6	0.4	-	-	-
S. Korea	9.6	0.8	0.2	-	-	-	+	-	-	-	-	2.3	0.2	-	-	-
Thailand	51.4	-	-	7.8	-	-	-	-	0.1	-	-	-	-	-	-	-
Vietnam	38.6	0.9	4.2	3.3	0.2	-	-	-	-	-	-	-	-	-	-	-
Total	1843.4	58.8	175.8	98.1	11.0	5.0	18.2	22.6	17.0	29.8	3.1	5.3	3.2	1.4	1.8	-

- No significant occurrence + Less than 0.1 M.ha but more than 0.01 M.ha

3.3.2 Wind erosion

As can be expected, wind erosion (9% of the total area, 20% of all degradation) is concentrated mainly in the most western and northern arid and semi-arid regions of Pakistan (>9 M.ha on-site and >2 M.ha off-site), India (20 M.ha on-site, 3.6 M.ha off-site) and China (>70 M.ha on-site, >8.5 M.ha off-site) (map 3, fig. 5, table 5). Although large parts of these regions may be considered deserts, some human-induced wind erosion was indicated by the national institutions.. In general, moderate to strong impact occurs relatively more frequently for wind erosion than for the other types of degradation (see fig. 2). This can be mainly attributed to the subtypes "terrain deformation" (Et) and the off-site effect "overblowing" (Eo), that show higher shares of moderate to extreme degradation than "loss of topsoil" (Et), which is the most common type of wind erosion. Again, as with water erosion, the latter type of wind erosion is less "spectacular" which may explain its higher share of light impact.

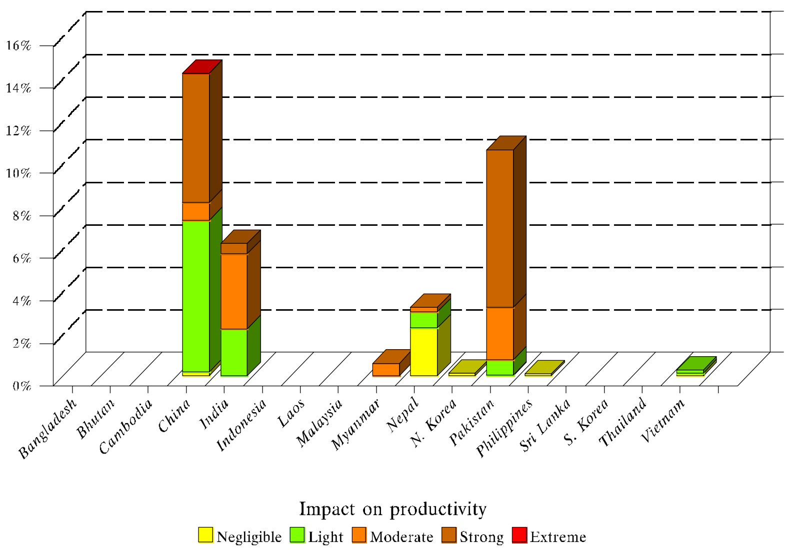

Fig. 5 Relative distribution of wind erosion (on-site effects)
(as % of total land area per country)

3.3.3 Chemical deterioration

The distribution of chemical deterioration (fig. 6) is quite varied, probably also partly due to different perceptions of this type of degradation. About 11% of the total (or 24% of the degraded) area is affected by some kind of chemical deterioration. High relative extents of chemical deterioration (>30% of total country area) can be observed in Bangladesh, Cambodia, Sri Lanka, Malaysia, Pakistan and Thailand, generally with negligible to light impact. The most common subtype of chemical deterioration is fertility decline (Cn), which accounts for more than 70% of all chemical deterioration and 10% of the total land area. It occurs in most countries, but is relatively most important in Bangladesh (7.5 M.ha), Thailand (25.5 M.ha), Sri Lanka (3 M.ha), Cambodia (8.5 M.ha), Myanmar (2.5 M.ha) and Pakistan (18.5 M.ha), see map 4 and table 6. Salinisation (Cs) is second in importance, although only some 17% of all chemical deterioration (2% of total land area) - obviously in drier areas (India 20 M.ha, Pakistan 9.3 M.ha, China 10 M.ha, see map 5) or along the coast (seawater intrusion: Bangladesh 2.4 M.ha; and some other minor occurrences).

Table 5 ***Distribution of subtypes of wind erosion per country*** *(in M. ha)*

	Total land area	Loss of topsoil (Et)					Terrain deformation (Ed)					Off-site effects (Eo)				
		Negligible	Light	Moderate	Strong	Extreme	Negligible	Light	Moderate	Strong	Extreme	Negligibl	Light	Moderate	Strong	Extreme
Bangladesh	13.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bhutan	3.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cambodia	18.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
China	925.9	1.7	65.9	2.5	+	+	+	7.2	5.5	57.9	-	+	2.0	6.5	0.2	-
India	318.6	-	7.0	11.3	1.4	-	-	-	4.2	0.8	0.5	-	-	0.6	3.0	+
Indonesia	190.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Laos	23.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Malaysia	33.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Myanmar	66.6	-	-	0.4	-	-	-	-	-	-	-	-	-	-	-	-
Nepal	14.7	0.2	0.2	-	-	+	0.1	-	-	-	-	-	-	-	-	-
N. Korea	12.1	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pakistan	87.8	+	0.6	2.2	6.5	-	-	-	2.9	-	-	-	-	2.2	-	-
Philippines	29.2	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Sri Lanka	6.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. Korea	9.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thailand	51.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vietnam	38.6	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-
TOTAL:	1843.4	1.9	73.7	16.3	8.0	0.1	0.3	7.2	12.6	58.8	0.5	+	2.0	9.2	3.2	+

- No significant occurrence + Less than 0.1 M.ha but more than 0.01 M.ha

Table 6 Distribution of the dominant subtypes of chemical deterioration *per country (in M ha)*

	Total land area	Fertility decline (Cn)					Salinisation (Cs)					Dystrification (Ct)				
		Negligible	Light	Moderate	Strong	Extreme	Negligible	Light	Moderate	Strong	Extreme	Negligible	Light	Moderate	Strong	Extreme
Bangladesh	13.5	1.0	6.2	0.2	-	-	-	2.2	0.2	-	-	-	-	-	-	+
Bhutan	3.9	0.3	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Cambodia	18.0	+	8.1	0.3	-	-	-	-	-	-	-	-	-	-	-	-
China	925.9	32.4	31.7	4.8	-	-	0.5	6.8	2.6	-	-	-	+	-	-	-
India	318.6	14.5	1.9	10.3	0.9	0.6	3.4	4.8	10.2	1.5	-	-	-	-	+	-
Indonesia	190.5	-	-	-	-	-	+	+	-	-	-	0.2	0.4	-	-	-
Laos	23.0	1.5	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Malaysia	33.5	7.6	2.2	1.7	+	-	-	-	-	-	-	0.8	-	-	+	-
Myanmar	66.6	0.3	2.2	-	-	-	-	-	-	-	-	-	-	-	-	-
Nepal	14.7	0.2	+	-	-	-	-	-	-	-	-	-	-	-	-	-
N. Korea	12.1	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Pakistan	87.8	4.8	11.0	2.6	-	-	1.2	6.8	0.3	1.0	-	-	-	-	-	-
Philippines	29.2	1.6	+	-	-	-	-	-	-	-	-	+	-	-	-	-
Sri Lanka	6.5	3.0	0.1	-	-	-	+	-	-	-	-	-	-	-	-	-
S. Korea	9.6	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thailand	51.4	-	1.1	24.5	-	-	-	-	1.0	-	1.0	0.1	1.6	-	-	-
Vietnam	38.6	0.2	3.6	0.8	0.4	-	+	0.3	+	-	-	-	-	0.9	-	-
TOTAL:	1843.4	67.6	68.3	45.1	1.3	0.6	5.2	20.9	14.3	2.5	1.0	1.2	2.0	0.9	+	+

\- No significant occurrence   + Less than 0.1 M.ha but more than 0.01 M.ha

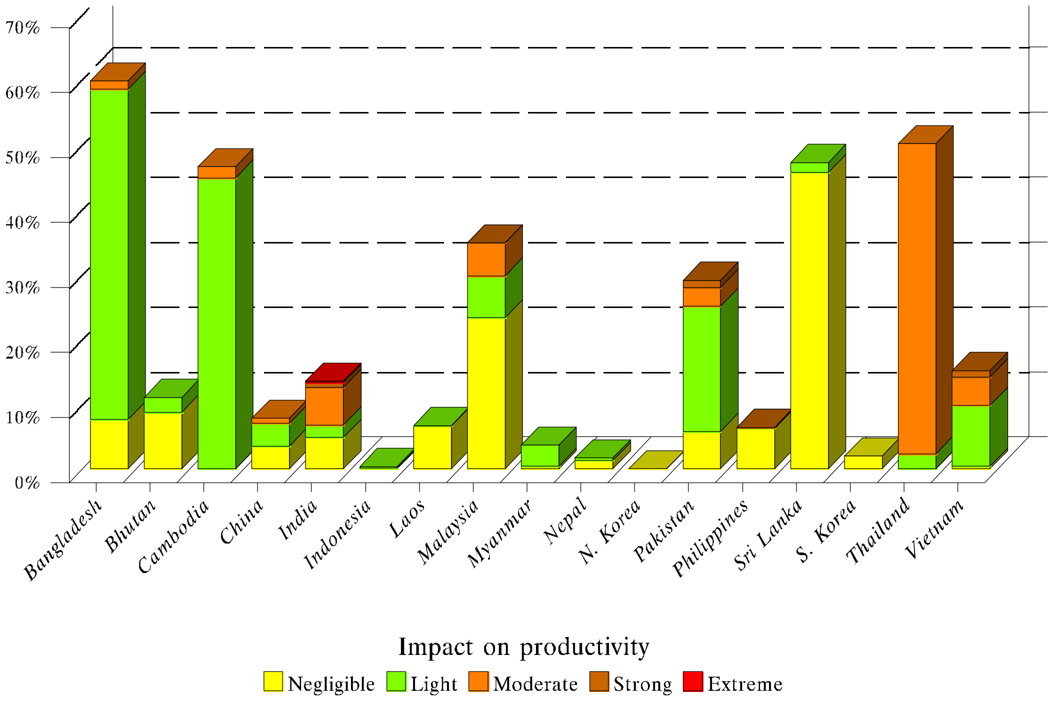

Fig. 6. Relative distribution of chemical deterioration
(as % of total land area per country)

3.3.4 Physical deterioration

Occurrence of physical deterioration (affecting about 4% of the total area or 9% of the total degraded area) is even more disperse and infrequent than chemical deterioration (fig. 7), with waterlogging (Pw) and aridification (Pa) as the main subtypes, in particular in Bangladesh (Pw 0.85 M.ha, Pa 1.2 M.ha), China (Pa 23.5 M.ha, Pw 3.8 M.ha), India (Pw 18 M.ha, Pa 0.1 M.ha) and Pakistan (Pw 14.2 M.ha); see table 7. Compaction or crusting/sealing has been allotted relatively little importance, except for Thailand (7.3 M.ha) and the Philippines (2 M.ha). Its occurrence has nevertheless been mentioned in some other country reports. Waterlogging and compaction as a result of paddy cultivation has not be considered as degradation, at least not under current land use! Loss of productive function (Pu) as a result of urbanisation, industrialisation and infrastructure has been indicated by a few countries only (China: 1.9 M.ha, Thailand: 3 M.ha, Philippines 1.4 M.ha), but can be assumed to be of more importance in general. In most cases its impact on productivity should be extreme by definition, since land that is being built upon is automatically completely lost for agricultural production.

Table 7 ***Distribution of the dominant subtypes of physical deterioration per country*** *(in M ha)*

	Total land area	Aridification (Pa)					Compaction and crusting (Pc/Pk)					Waterlogging (Pw)				
		Negligible	Light	Moderate	Strong	Extreme	Negligible	Light	Moderate	Strong	Extreme	Negligible	Light	Moderate	Strong	Extreme
Bangladesh	13.5	-	-	-	1.2	-	-	-	-	-	-	-	0.4	0.5	+	-
Bhutan	3.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cambodia	18.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
China	925.9	-	23.7	-	-	-	-	0.5	-	-	-	3.8	-	-	-	-
India	318.6	0.1	-	-	+	-	-	0.6	-	-	-	3.0	10.8	2.3	1.8	-
Indonesia	190.5	0.1	+	+	0.1	-	-	-	-	-	-	-	-	-	-	-
Laos	23.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Malaysia	33.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Myanmar	66.6	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-
Nepal	14.7	-	-	-	-	-	-	-	-	-	-	0.1	+	-	-	-
N. Korea	12.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pakistan	87.8	-	-	-	-	-	0.4	+	-	-	-	3.1	7.6	2.6	1.0	-
Philippines	29.2	-	-	-	-	-	-	1.8	0.2	+	-	-	+	-	-	+
Sri Lanka	6.5	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-
S. Korea	9.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thailand	51.4	-	-	-	-	-	6.1	-	1.3	-	-	0.6	-	-	-	-
Vietnam	38.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL:	1843.4	0.3	23.8	+	1.4	-	6.4	2.9	1.5	+	-	10.7	18.9	5.4	2.7	+

- No significant occurrence + Less than 0.1 M.ha but more than 0.01 M.ha

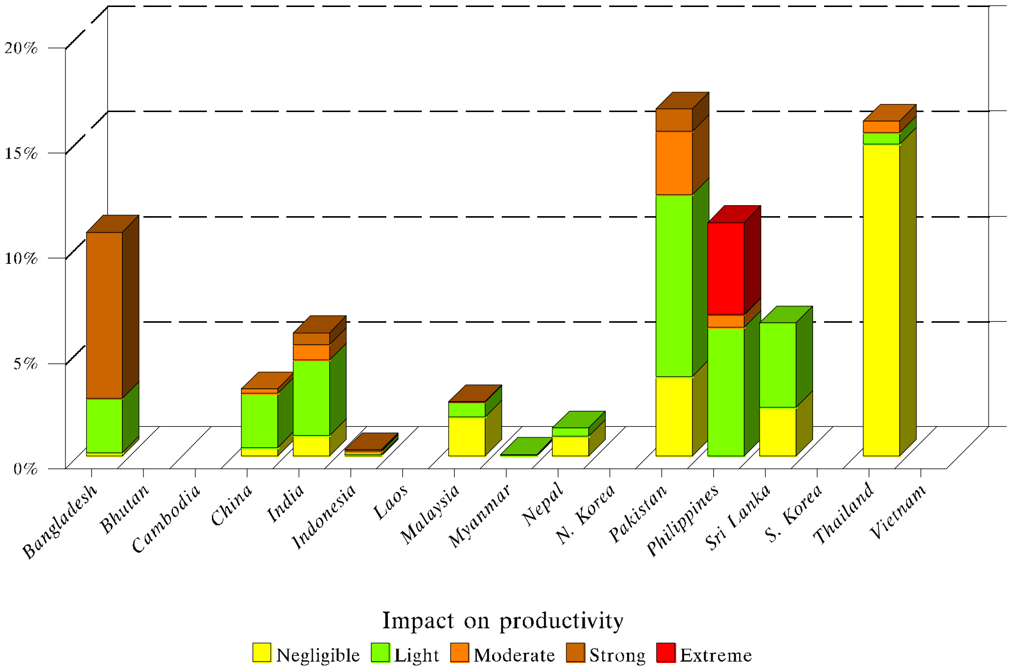

Fig. 7 Relative distribution of physical deterioration
(as % of total land area per country)

3.4 Degradation and causative factors

For each type of degradation one or more causative factors have been indicated. Water erosion is chiefly caused by agricultural activities and deforestation. Agricultural and forest land are also the most widespread land use types in the more humid parts of the region, where more water erosion is bound to occur (total area arable land for ASSOD region: 380 M.ha, against 437 M.ha permanent pasture outside China, FAOSTAT, 1996). Only a relative small percentage of agricultural activities have a strong or extreme impact. In contrast, the effects of overgrazing appear to be more serious. (see fig. 8), most often connected with wind erosion, for which deforestation and overexploitation are other important causes. Agricultural activities can also lead to wind erosion, but this is less conspicuous from the data. Chemical degradation is almost exclusively a result of improper management of cultivated arable land. Similarly, physical deterioration is mainly a result of agricultural activities.

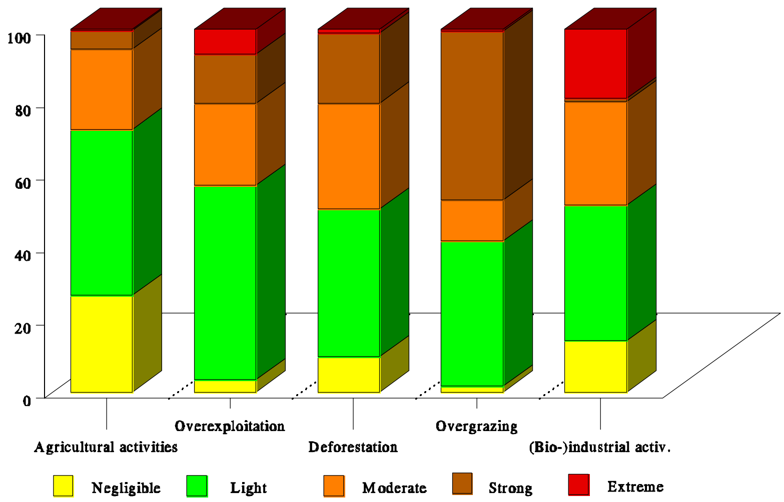

Fig. 8 Causative factors and impact of degradation
(as % of total area for each causative facor)

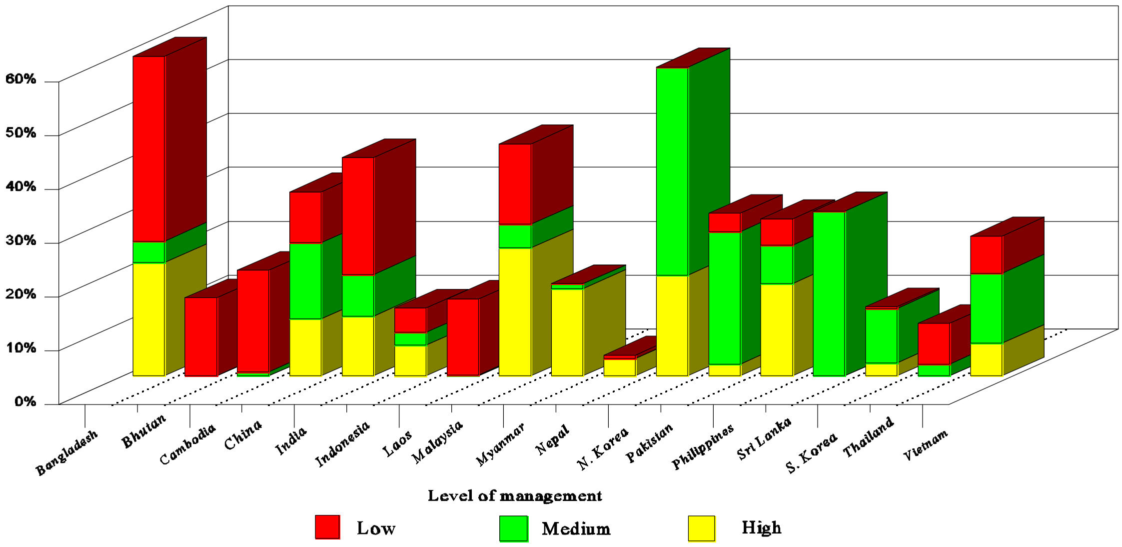

Fig. 9 Relative distribution of management levels
(as % of total land area per country)

3.5 Management level and degradation

3.5.1 Management level

A new element in ASSOD is the link between impact on productivity and management level. The relative extent of three levels of management per country (fig. 9) presents a rather varied picture, which at the same time illustrates that information on management levels may not be fully adequate for the entire region. It should also be noted in this respect that information on management levels was only given for degraded areas (and was sometimes incomplete). Since the impact on productivity was given for three possible levels of management, the distribution of the impact of degradation can be shown for these three levels (fig. 10). This reveals hardly any difference between the importance of the various *impact* categories from one management

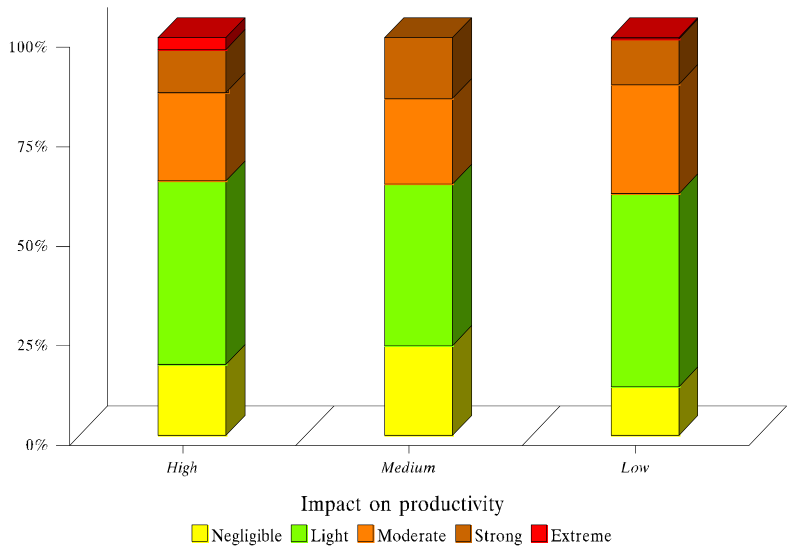

Fig. 10 Management level and impact of degradation
(as% of total area per management level)

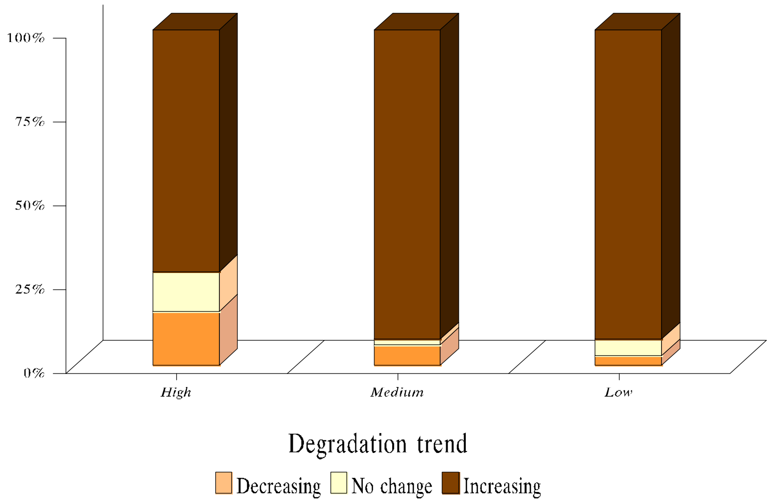

Fig. 11 ***Management level and degradation trend***
(as % of total area per management level)

level to another. With regard to the *rate* of degradation however, medium and low management show a higher share of increasing degradation than the high management level (Fig. 11). This could be attributed to the fact that many remediation or conservation measures automatically imply higher inputs in labour and materials, or conversely, that high management systems have better means available to tackle degradation problems. The provided data on conservation and rehabilitation were unfortunately too scanty and fragmented to support this hypothesis or to enable a regional evaluation.

3.5.2 Conservation and rehabilitation measures

Information on conservation measures was provided for 58% of the records with any type of degradation or "stable under human influence". Out of these records, only 25% shows a decreasing trend in degradation! Where the conservation category (see 2.2.6) was indicated, the average extent of conservation measures was around 20% of the degraded area. Remarkably, the average was much higher for records without indication of the type of conservation measures. Vegetative conservation measures are the most widespread (113 M.ha), with land management practices (90 M.ha) being second in importance. Structural measures (27.7 M.ha) and other practices (37.7 M.ha) are less widespread. Further refinement of the above figures according the WOCAT approach would mean a very useful complement to the present assessment.

4 Discussion

Although the ASSOD guidelines asked for some information on overlap between degradation types, this should have been more emphasized. Lack of precise information on overlap (sub)types creates considerable problems in area calculations. Where the sum of the affected area for all (sub)types of degradation is greater than the total degraded area within a polygon, some overlap must be assumed, but it is not known how big and between which types. The standard assumptions mentioned earlier imply that the total area of degraded and non-degraded land will not always equal the total land area, but may be higher or lower, depending on the ratio between assumed and real overlap.

Causative factors give an indication under what type of land use degradation is taking place, but a more narrow linkage between degradation and land use data would be quite useful. An regional inventory of the distribution of land use types however would have been a project in itself and was therefore not included in the current assessment. Where such data are available, this should certainly be taken into consideration in future inventories.

Several countries alluded to the difficulties in distinguishing human-induced from natural degradation, especially for water erosion in steep mountain areas, wind erosion and salinisation. This may partly explain for instance the relatively large extent of water erosion in remote areas of the Himalayas or wind erosion in the Takla Makan, Gobi and Thar deserts where these processes occur both naturally and due to human activities. Similarly, the effects of different degradation types may sometimes overlap. Part of fertility decline may actually be a consequence of soil erosion, a distinction which is sometimes difficult to make.

Some physiographic units were considered too large to be appropriate mapping units for the degradation assessment. Nepal thus used a more detailed map based on "Land system units", which combine physiographic (non-SOTER) criteria with other information. Although this has implications for the basic mapping units, the overall degradation criteria have been applied and ensure compatibility with surrounding units. Other units covering rather distinct landscape features or two different catchment areas, such as the Indo-Gangetic plain vs. the Indus plain, appeared as one polygon, since the SOTER criteria (hypsometry or slope class) could not differentiate the watershed boundary from the plains on either side. In such cases subdivisions of the polygon have been made. This has also been done for some other large polygons on the basis of non-physiographic criteria, such as distinct climatic patterns, land use, etc.

As indicated in some country reports, (see RAPA, 1996), lack of available data may have led to local or regional under-representation of certain degradation types, e.g. pollution (Cp) which has only been indicated for China (5.3 M.ha). This may also be true for dystrification (Ct) which is of some importance only in Thailand (1.7 M.ha), Vietnam (0.9 M.ha), Malaysia (0.8 M.ha) and Indonesia (0.6 M.ha) and for eutrophication (Ce) which occurs only sparsely.

Some countries indicated difficulties in calculating or estimating the "impact on productivity", due to lack of data. For this reason, Indonesia for instance calculated the *degree* - along the GLASOD criteria - rather than the impact. The same applies somewhat to data on management level.

During the mid-term project meeting in Manila it became apparent that sometimes the risk rather than the **status** had been evaluated. It was pointed out that these are two entirely different things (Sanders, 1994) and that ASSOD is evaluating the current status only.

The compilation and correlation of so manifold data from such a wide range of sources invariably gives problems. The data set is not yet 100% complete (some polygons have no data), nor have all required corrections been realised. The current report, maps and database will incite comments that will enable further improvements to be made in the future.

Certain figures for areas affected by some kind of degradation differ considerably with existing data, such as those in the country reports presented in Manila (RAPA 1996). Differences in the assessment methods may justify these differences to some extent, but it illustrates that the development of objective and quantitative criteria (and moreover, data!) is a major task that would greatly benefit the regional assessment of soil degradation.

5 Conclusions

The Assessment of Human-induced Soil Degradation in South and Southeast Asia (ASSOD) is the result of the collaborative effort of 16 national institutions on natural resources together with ISRIC, FAO and UNEP. It presents the most recent knowledge on soil degradation in the region and a higher amount of detail than the Global Assessment of Soil Human-induced Degradation from 1990.

The expected outputs of the project are briefly re-iterated herewith.

(I) Revised sub-regional Guidelines for General Assessment of the Status of Human-Induced Soil Degradation

(ii) South and Southeast Asia Sub-regional Map on the Status of Human-Induced Soil Degradation at a scale of 1:5M and digitized version of the map as a digital geographical database. Additional maps will be reproduced and made available to governments at cost if extra funds are not available to enable the production and distribution of more maps.

(iii) Report on the Assessment of the Status of Human-induced Soil Degradation in South and Southeast Asia

(iv) 25 natural resource scientists from the participating countries familiarized with the Soil and Terrain Digital Database Concept and database compilation.

All these outputs have been realized herewith. With regard to output (ii) it should be noted that rather than preparing a map and digitizing it afterwards, the approach was taken to develop a geo-referenced degradation database first and produce one or more maps as output of the database (as attached to this report). This way additional maps can be produced with relatively little effort and at low cost. Experts from the collaborating national institutions have been familiarized with the general principles of SOTER and a project proposal has been formulated for more detailed SOTER training and database development at the regional and national level.

Water erosion is (like in GLASOD) the most widespread degradation type with generally light to moderate impacts on productivity. Various subtypes of chemical degradation also occur in most countries, also mostly with light to moderate impacts.

Although the distribution of degradation types is also more diverse than on the GLASOD map, certain degradation types like water erosion and nutrient decline are definitely more well-known in most countries than others such as pollution, eutrophication, loss of productive function, etc. The latter types of degradation also show a more disperse distribution pattern than the former ones, i.e. some countries indicate a certain distribution but where other countries do not report any occurrence, this could perhaps be partly attributed to lack of data or unfamiliarity with those types of degradation. In particular loss of productive function due to urbanization, industrialization and infrastructure development seems a rather underrated form of degradation (extent nil in most countries).

Whereas in GLASOD the number of degradation (sub)types per map unit was restricted to two, ASSOD allows for a potentially unlimited number of degradation types per unit.

This heightens the need for proper data on the amount of overlap of different types within a unit, which is important for area calculations. However, since such precise data were generally lacking some standard assumptions on overlap of degradation had to be made. Especially when "simplified" figures are presented, like the extent of main types only, the total extent of the various impact classes, etc., this may result in only general approximations. It is **not** possible to aggregate the extent of different degradation types within a unit to achieve the total extent of degradation within that unit!

The present assessment defines degradation in the context of "impacts on productivity", which in practice generally refers to *agricultural* productivity. It should be realized that (agricultural) productivity is only one of the various soil functions. Therefore it would be useful to define soil and land degradation in relation to different soil functions or land uses, but this was not feasible in the present assessment.

Since the *effect of degradation* (impact on productivity) is taken in ASSOD as a standard for the intensity of degradation rather than the intensity of the process ("degree" in GLASOD), some units show occurrence of degradation but with a "negligible" impact. This means that although for instance erosion is occurring, its effect on productivity is trivial which may be thanks to a deep and fertile topsoil. However, other effects of this degradation that are not related to productivity may be more serious.

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ANNEX III: *Abbreviations*

ASSOD . . . . Assessment of the Status of Human-induced Soil Degradation in South and Southeast Asia
CDE . . . . Centre for Development and Environment, Univ. of Berne
FAO . . . . Food and Agriculture Organization of the United Nations
GIS . . . . Geographic Information System
GLASOD . . Global Assessment of the Current Status of Human-induced Soil Degradation
ISCO . . . . Internation Soil Conservation Organization
ISRIC . . . . International Soil Reference and Information Centre
ITC . . . . International Institute for Aerospace Survey and Earth Sciences
RAPA . . . . Regional Office for Asia and the Pacific of FAO
SOTER . . . . Global and National Soil and Terrain digital database
UNEP . . . . United Nations Environment Programme
WAU . . . . Wageningen Agricultural University
WOCAT . . . . World Overview of Conservation Approaches and Technologies

ANNEX IV: *Available materials*

In this report various maps, graphs and tables are presented that are derived from the ASSOD database. Besides the overview map showing the dominant degradation types for the entire region (at small scale), examples of thematic maps are given for specific regions in which these degradation types are the most significant (with the exception of water erosion which occurs in many parts of the region).

Detailed information for each polygon can be derived from the ASSOD database which is available on request as a dBaseIV, Excel, or ASCII (“ delimited) file. These data can most easily be examined by linking the database to a GIS. A more user-friendly database “viewer” will be produced in the near future and will be available from ISRIC at low cost. It is the intention to also make the database and viewer accesible in the near future through Internet.

Copies of this report and the maps for the entire region at A1 (59.4x84.1 cm) format can be ordered from ISRIC (see address below) at USD 25,- + USD 15,- airmail charges:

- Overview of dominant degradation types (map 1 in this report)
- A map with four thematic windows on: water erosion (eastern China, Korea), wind erosion (northern China), fertility decline (Indochina) and salinization (India, Pakistan), similar to map 2 in this report.
- Report on the Assessment of Human-Induced Soil Degradation in South and Southeast Asia

On request, specific maps can be prepared by ISRIC for certain themes and/or regions. These maps will be slightly more expensive, depending on the requested theme and scale. Tables and graphs can be produced as well.

For further information please contact

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