Report 2000/05

Soil Degradation in Central and Eastern Europe

The Assessment of the Status of Human-Induced Soil Degradation

(Version 1.0)

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Food and Agriculture Organization of the United Nations

International Soil Reference and Information Centre

ISRIC

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ACKNOWLEDGEMENTS

The project GCP/RER/007/NET on Mapping of Soil and Terrain Vulnerability in Central and Eastern Europe (SOVEUR) was signed between the Food and Agriculture Organization of the United Nations (FAO) and the Government of the Netherlands, within the framework of the FAO/Netherlands Government Programme. In view of the specific nature of the services to be rendered, the Project activities were implemented under a Contractual Service Agreement with the International Soil Reference and Information Centre (ISRIC). National institutions in Belarus, Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Moldova, Poland, Romania, the Russian Federation, Slovak Republic and the Ukraine provided the primary degradation data, using a set of standardised criteria and guidelines provided by ISRIC. At ISRIC, Ms. J. Resink was responsible for GIS operations and printing of the maps and P. Tempel for the development of the data entry program.

1 INTRODUCTION

1.1 Background

In 1997 a project on Mapping of Soil and Terrain Vulnerability in Central and Eastern Europe (SOVEUR) was signed between the Food and Agriculture Organization of the United Nations (FAO) and the Government of The Netherlands, within the framework of the FAO/Netherlands Government Cooperative Programme (GCP/RER/007/NET). The project was implemented by FAO in cooperation with the International Soil Reference and Information Centre (ISRIC) under a Contractual Service Agreement which included Letters of Agreement with National Collaborators within the frame of their National Institutes representing their countries in the project (13 participatory countries). The project called for the development of an environmental information system for the region in close collaboration with soil survey institutes in Belarus, Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Moldova, Poland, Romania, the Russian Federation, Slovak Republic and the Ukraine. Using this system and auxiliary information on climate, land use and the type of soil pollution, the status of human-induced soil degradation and the areas considered vulnerable to defined pollution scenarios were identified and mapped (scale 1:2.5 million).

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

1.2 Degradation assessment

As a part of the SOVEUR project, the assessment of soil degradation in Central and Eastern Europe at a scale of 1:2.5 M aims to produce a geographical overview of the current status of soil degradation in this region, with emphasis on soil pollution.

The current report presents the results of this assessment.

At the scale of the current assessment it is difficult to provide quantitative criteria, in particular for soil pollution, considering the enormous variety in pollution types and impacts, but also in the criteria in so far as they exist. The criteria for the assessment of pollution applied here follow as much as possible the standards used previously for the other types of degradation, but separate classes and descriptions have been defined for the degree and the impact of pollution.

Like previous assessments of soil degradation at a global (GLASOD; Oldeman et al., 1991) and regional scale (ASSOD; van Lynden and Oldeman 1997), the Assessment of Soil Degradation in Central and Eastern Europe serves as a means to increase awareness on soil degradation status in general and on the status of pollution in particular. In view of the scale and the available data, this inventory is based on experts' estimates. As such it gives an overall impression of the status of soil degradation in the region. The information on the status of soil degradation may help to increase awareness of the problem and to facilitate the identification of specific areas considered at risk from soil pollution. For these areas more detailed studies will be required to determine the course of action.

2 CONCEPTS AND DEFINITIONS OF SOIL DEGRADATION

2.1 General

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

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

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

Some concepts and definitions used in this assessment are briefly discussed below. More details can be found in van Lynden (1997).

2.2 Types of soil degradation

The type of soil degradation refers to the nature of the degradation process (displacement of soil material by water and wind; in-situ deterioration by physical, chemical and biological processes). Types of soil degradation are represented by a code, the first capital letter indicating the major degradation type, the second lowercase letter referring to the subtype. A third lower case letter is sometimes used for further specification (see Appendix 1 and van Lynden, 1997). Most of the codes are the same as those used for the GLASOD map, but some extra ones have been added or definitions have slightly changed, in particular for pollution. In the context of the SOVEUR project, pollution has been treated as a separate main degradation type and the assessment criteria for pollution have been modified accordingly. In the Guidelines for the Assessment of Soil Degradation in Central and Eastern Europe (van Lynden, 1997) the different (sub)types of pollution are treated in more detail, together with a description of other types of degradation such as water- and wind erosion, other forms of chemical deterioration and physical deterioration and non-degraded land.

2.2.1 Pollution

Soil pollution may result from a wide range of human activities and can emanate either from local (point) sources or from diffuse sources. Pollution may affect the soil via different "pathways", namely through the air, over land or by water. The total “accumulated load” of a contaminant may thus emanate from various sources and different pathways. For the SOVEUR degradation assessment, five subtypes of soil pollution as identified in the Dobris report on Europe’s Environment (Stanners and Bourdeau, 1995) are distinguished.

2.2.2 Other types of degradation

Other types of degradation not only pose environmental threats by themselves, but may also trigger sudden delayed occurrences of pollution or chemical time bombs. They often do not occur in isolation, but may influence each other or have a cumulative effect. These other degradation types include various subtypes of water erosion, wind erosion, chemical deterioration (other than pollution) and physical deterioration. See Appendix 1 for more details.

2.3 Soil degradation extent

The extent of soil degradation here refers to the percentage of the area within a (map) polygon affected by a given type of degradation or by an association of several types. Often several types of degradation will overlap and in some cases even interact. The total percentage of degraded and non-degraded land in a polygon must always be 100%.

2.4 Degree and impact of degradation

Degree is defined in this context as the intensity of the soil degradation process, e.g. in the case of erosion: the amount of soil washed or blown away.
Impact refers to the effects of soil degradation on the various soil functions such as biomass production, filtering and buffering, physical basis for structures and roads, source of raw materials, biological habitat. Changes in soil and terrain properties (e.g. loss of topsoil, development of rills and gullies, exposure of hardpans in the case of erosion) may reflect the occurrence and intensity of soil degradation but not necessarily the seriousness of its impact. Removal of a 5-cm layer of soil may have a greater impact on productivity on a poor shallow soil than on a deep fertile soil. The impact is depending on the function/use of the soil: a heavily compacted soil is unsuitable for agriculture, but may be an appropriate basis for road construction.

2.5 Rate of soil degradation

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

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* reflects the dynamic situation of soil degradation, namely the change in degree over time.

2.6 Causative factors

Various types of human activities may lead to soil degradation. Although some degradation processes also occur naturally, this inventory focuses mainly on those degradation types that are the result of the human disturbance of either a natural or anthropogenic state of equilibrium. The different causative factors and their definitions are given by van Lynden (1997).

3 DATABASE IMPLEMENTATION

3.1 Base map

A 1:2.5 M scale physiographic map of Central and Eastern Europe, prepared according to the SOTER methodology (Batjes and van Engelen, 1997) has been drafted by ISRIC (for the western section) and IIASA (for the former Soviet Union) as a basis for developing the degradation database. Subsequent subdivisions based on soil units, and corrections were made by the collaborating countries in accordance with the guidelines. Although efforts were undertaken to harmonise the final map, a considerable variability in detail remains, also because smaller countries had a tendency to present a greater level of detail and smaller physiographic units.

3.2 Compilation of the regional soil degradation assessment database

Degradation data were collected for each polygon (unique delineated map unit) of the physiographic base map. The national data were compiled in a matrix table according to the standard methodology described in the Guidelines.

All data were stored in a dBaseIV database as well as in Excel sheet format. These data were then linked to a GIS through the polygon labels (Poly-Id's). The original database has various records for one polygon (see Table 13), each record representing a particular degradation type. For mapping of specific themes however, "one-to-one" tables have to be prepared (one record per polygon, see Table 14). For maps displaying the extent and degree or impact of a main type (e.g. water erosion, W), the extent for all subtypes (Wt,Wd,Wo) is totalled and converted to class values and a weighted average calculated for the degree or impact, as shown in the following example (only occurrence of water erosion shown):

POLY-ID	**Mha** (= 10^6 ha)	**Type**	**Extent**	**Degrarea**	**Extclass**	**Degree**	**Impact**
1234-AB	0,2578	Wt	30	0,0773	4	2	1
1234-AB	0,2578	Wd	15	0,0387	3	3	2

where the total extent of water erosion will be 45% (Extclass 4), the average degree will be (30*2+15*3)/45 = 2 (rounded), and the average impact (30*1+15*2)/45 = 1:

POLY-ID	**WatExtDeg**	**WatExtImp**
1234-AB	4.2	4.1

The calculation of areas affected by specific forms of degradation (**Degrarea** in the above example) is based on the extent percentages for the individual degradation types and the total area for that polygon (Mha in the above example) as derived from a Lambert equal area map projection in the GIS. These degraded area figures can be displayed in tabular or graphic format (see below). The attached tables and graphs were prepared with the Pivot Table feature in Excel, which enables quick summaries to be calculated for specific themes.

4 RESULTS

4.1 General

The database on the status of soil degradation contains a wealth of data from which a selection can be made for output in various formats: maps, tables, and graphs. In principle all relevant information can be stored and depicted in some way when desired, through the creation of separate thematic maps or as graphs and tables.

Maps on the extent and impact of soil degradation can be displayed in different ways. Thematic maps for a single degradation main type (maps 1-3) or subtype (map 4 and 5) where three degree classes are displayed in different colours (from green for low degree to red for high degree) and three extent classes by different shading of the colours.

The easiest overview of the extent of degradation (*"how much?"*) e.g. for degree and impact, is obtained from the pie and bar charts (Figures 1-13). The maps provide a good picture of the spatial distribution (*"where?"*). Tables 1-12 give more summarised information (*"what?"*).

Calculations of the absolute area coverage for the different degradation types produce a high predominance of the larger countries such as Ukraine and Russia. More useful therefore are the graphs showing the relative area expressed a percentage of the total land area per country for individual degradation types (Figures 3-7 and 9-13).

From the graphs, and to some extent from the maps, it appears that there are large differences between countries with respect to the extent and other attributes of degradation (Figures 2 and 8). This may reflect existing variations, e.g. for wind erosion and salinisation, which mainly occur in drier areas. But it could also partly be influenced by data availability and - in spite of standard, but qualitative, criteria provided in the Guidelines – by differences in perception by country. The maps, graphs and tables should therefore be interpreted with care.

4.2 Distribution of different degradation types

4.2.1 Type

The results of the assessment show that, besides about 385 Mha or 67% of the total area not being affected by degradation, *soil compaction (Pc)* is the most predominant degradation type: over 62 Million ha or 11% of the total area and 21.7% of all degradation (see Figure 1). Frequent use of heavy machinery – especially in the former communist era - could be the main culprit of this phenomenon. The degree of compaction is mostly light (40% of all compaction) to moderate (58%), but the inferred impact on productivity is more serious: more than 50% of all

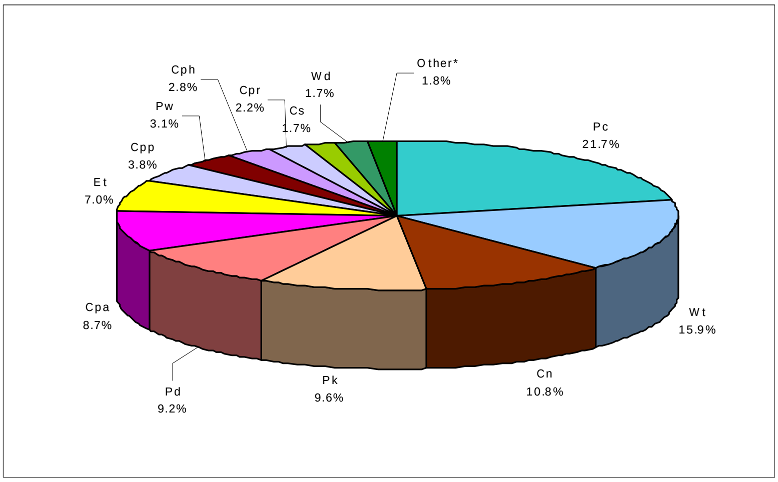

Figure 1. Relative distribution of different degradation types in Central and Eastern Europe

compaction is reported as having a strong or even extreme impact. Compaction often occurs in combination with crusting (Pk), which occurs on 27.5 Mha or close to 5% of the total area. The impact of crusting however is much lower than for compaction: almost all negligible to moderate. In relative terms, the Ukraine and Bulgaria suffer most from both compaction and crusting (between 20 and 40% of the land area, see Tables 6 and 12 and Figures 7 and 13). Map 1 shows the degree of *all* physical deterioration.

Water erosion is second in importance, covering 44 Mha or 7.5% of the total area. It occurs throughout the region (see Map 2), although some countries indicate an above average occurrence: Bulgaria (40% of the area affected), Moldova (35%) and Hungary (21%). Sheet erosion (Wt) is by far the most widespread subtype of water erosion, generally with both a light to moderate degree and impact on productivity, except for Russia where in general a strong degree and even extreme impact is indicated (see Tables 2 and 8 and Figures 3 and 9).

The other forms of degradation each cover less than 5% of the total area. *Wind erosion* occurs mainly in the drier SE part of the region (over 13 Mha in Russia and Ukraine, see map 3), but is locally important in Hungary and Romania/Bulgaria as well (Danube valley in particular). "Terrain deformation" (Ed) has a higher reported impact than "loss of topsoil" (Ed), but is much less widespread (see Tables 3 and 9 and Figures 4 and 10).

Data for *pollution* (Tables 4 and 10) are incomplete, partly due to a reported lack of existing data (e.g. for Russia). Some countries also report only local occurrence for certain pollution types, while other countries provided extensive spatial data. This rather disturbs the general picture, which should be taken into consideration when studying the results of the assessment for pollution.

Acidification (Cpa) is the most widespread type of pollution (map 4), with high total extent in Poland (10 Mha or 35% of the country area) and Ukraine (8 Mha or 14%). In relative terms it is also important in Hungary, Latvia and Lithuania. Degree and impact (on productivity) are mostly light to moderate (Figures 5a and 11a).

Pollution by heavy metals (Cph) is reported for Ukraine (4.7 Mha or 8% of the country area) and Lithuania (2.7 Mha or 42%) in particular, but reportedly the latter may be exaggerated by high natural background levels. Romania provided a detailed map of local occurrence of heavy metal pollution and some local incidence was also reported for a few other countries (Figures 5b and 11b).

Pollution by pesticides (Cpp) is second in occurrence with a total extent of 10 Mha (<2% of the total area). It is mainly reported in Ukraine (5.3 Mha or 9% of the country area) and Romania (4.5 Mha or 19%), with both light to moderate degree and impact (Figures 5c and 11c).

Considerable *contamination with radio-nuclides (Cpr)* is reported for Ukraine only, covering an extensive area of 6.4 Mha (11% of country area). The degree is light to moderate and the impact negligible to moderate (Table 4).

Of the *other chemical deterioration types* (Tables 5 and 11), *fertility decline (Cn)* is widely reported in Ukraine (25.2 Mha or 43% of the country area), mostly with light to moderate degree and impact. It is also relatively important in the three Baltic states (5-14 %), Moldova (31%) and Romania (14%). No occurrence at all was reported from other countries (Figures 6a and 12a). *Salinisation (Cs)* is identified to have some significance in Ukraine (2.5 Mha or 4.3% of the country area), Russia (1.6 Mha or 0.4%) and Hungary (0.7 Mha or 8%). See map 5. For Hungary the degree and impact are (negligible and) light to moderate, for Russia the degree is light to moderate but the impact strong, for Ukraine degree and impact are mostly moderate (Figures 5b and 12b).

4.2.2 Rate of degradation

The recent past *rate of degradation* was not analysed in detail, as this information was provided only for approximately 1/3 of the total degraded area. Although the provided data indicate that degradation is slowly to moderately increasing, especially in Moldova, Hungary, Romania and Russia, this is partly contradicted by some country reports presented during the workshop in Busteni. Declining economies were given as a cause for reduced fertiliser and pesticide consumption, with less pollution as a (positive) result. For the same reason damage caused by frequent use of heavy machinery (e.g. compaction) would be less than before (see Batjes, 2000).

4.2.3 Causative factors

Information on *causative factors* was also rather incomplete: for about 15% of the total degraded area no information on causative factors was provided. Agricultural and natural causes are the most frequently listed factors responsible for the various types of degradation. Agricultural mismanagement is causing more than half of all the water and wind erosion, while deforestation is also playing a significant role here. Also for various types of pollution, acidification (Cpa) and eutrophication (Cpn) in particular is contributed to agriculture. Industrial activities and urbanisation obviously play an important role in the occurrence of pollution (by heavy metals, Cph, and radio-nuclides, Cpr, in particular), but even natural causes are listed here, probably indicating relatively high background levels. Salinisation (Cs) and fertility decline (Cn) are caused by agriculture (about 50%) and natural causes. For physical deterioration this applies also to compaction (Pc), crusting (Pk) and aridification (Pa), with an additional minor role of overgrazing. The “industrial” component is more important for waterlogging (Pw) and obviously for urban/industrial land conversion (Pu)

5 DISCUSSION AND CONCLUSIONS

The compilation, harmonisation and correlation of degradation data from such a wide range of sources invariably causes some imperfections, even when based on standardised criteria. The data set is not yet 100% complete (some polygons have no data), nor have all required corrections as discussed during the concluding workshop in Busteni, been accomplished. In this context it must be realised that the participating countries also had to compile the primary data for the SOTER database and the vulnerability assessment within the short time frame of the SOVEUR project.

The current report, maps and database may incite comments that will enable further improvements to be made in the future.

For the interpretation of the data of this assessment, the following points should be taken into consideration:

- Although the Guidelines provide uniform standards and criteria for the assessment of degradation, most criteria are not quantitative and therefore leave room for subjectivity and differences in perception.
- The 1:2.5M scale of the assessment does not allow detailed conclusions, but helps to increase awareness on the degradation problem and facilitates the identification of specific problem areas that need further investigation.
- Varying data availability and quality may have led to local or regional under-representation of certain degradation types. This is true in particular for soil pollution (e.g. no information or only point data for Russia), and land use system conversion, which is probably taking place in all countries but has only been reported for some. The extent of degradation on the other hand may have been over-estimated in some cases (when compared with other countries).
- Although before, during, and after the workshop in Busteni efforts were undertaken to solve cross-border correlation problems, some problems remain, also in view of the previous points. Map 4 of the degree and extent of acidification is an example.
- Due to the fact that the degradation is displayed per map polygon, visual exaggeration may occur: a large polygon, displayed as being affected by degradation, may in reality only have a small part of the area (e.g. < 5% of the polygon) affected by degradation. The extent of acidification in Poland on Map 4 is another case in point. The entire country shows as being affected to some degree while in fact this is "only" 35% (still significant!) of the country area.
- Differences in base maps have been discussed above. These may concern differences in the level of detail and/or in the criteria used for the delineation of the units.
- Different interpretation of the criteria (e.g. risk vs. status of degradation). During the meeting in Busteni (October 1999) it became apparent that (erroneously) the risk rather than the **status** had been evaluated for some countries.
- Some records have incomplete or missing data: a total extent of < 100% per polygon, incomplete attributes for degradation types, such as missing degree, impact, cause or rate may still occur in this version 1.0 of the degradation database.
- Area calculations are based on the GIS data (ARCINFO PAT-file). Due to differences in projection, data gaps and some other inaccuracies, total areas shown may deviate somewhat from those in other data sources. The area figures should thus be seen as indicative rather than in an absolute sense.

- 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 (-change) data would be useful. A regional inventory of the distribution of land use types however would have been a project in itself (cf. Land Use and Cover Changes Project - LUCC) and was therefore not included in the current assessment. Where such data are available, this could be overlaid in a GIS and should certainly be taken into account in future inventories.
- Suggestions for fine-tuning the methodology, made during the Busteni workshop, will be carefully considered in future assessments of soil degradation and pollution.

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Appendix 1: Tables
(Impact of degradation)

Table 1: Impact and relative extent of different degradation types in Central and Eastern Europe

TYPE		Negligible	Light	Moderate	Strong	Extreme	Total	
Pc	Compaction	4.4%	13.6%	30.0%	26.8%	25.2%	*10.9%*	of SOVEUR area*
Wt	Water erosion (topsoil)	8.0%	20.6%	33.0%	2.7%	35.7%	*7.9%*	of SOVEUR area
Cn	Fertility decline	0.4%	25.6%	69.5%	4.5%	0.0%	*5.5%*	of SOVEUR area
Pk	Crusting	5.8%	30.4%	62.9%	1.0%	0.0%	*4.8%*	of SOVEUR area
Pd	Aridification	0.0%	0.4%	3.1%	25.4%	71.1%	*4.2%*	of SOVEUR area
Cpa	Acidification	5.1%	24.5%	69.1%	1.3%	0.0%	*4.3%*	of SOVEUR area
Et	Wind erosion (topsoil)	11.4%	11.6%	33.4%	6.9%	36.7%	*3.1%*	of SOVEUR area
Cpp	Pesticide pollution	7.7%	26.7%	64.0%	1.6%	0.0%	*1.9%*	of SOVEUR area
Pw	Waterlogging	17.0%	20.3%	41.4%	14.7%	6.7%	*1.5%*	of SOVEUR area
Cph	Heavy metal pollution	20.4%	24.0%	52.4%	3.2%	0.0%	*1.4%*	of SOVEUR area
Cpr	Radio-active contamination	47.1%	29.3%	23.4%	0.2%	0.0%	*1.1%*	of SOVEUR area
Cs	Salinisation	4.7%	13.8%	45.8%	27.0%	8.7%	*0.9%*	of SOVEUR area
Wd	Water erosion (terrain deformation)	1.0%	17.9%	22.1%	57.4%	1.6%	*0.9%*	of SOVEUR area
Other*							*0.9%*	of SOVEUR area
Non-degraded							*67.4%*	of SOVEUR area
Other:								
Wo	Water erosion (off-site effects)						*0.4%*	of SOVEUR area
Ed	Wind erosion (terrain deformation)						*0.3%*	of SOVEUR area
Pu	Land conversion						*0.1%*	of SOVEUR area
Ps	Subsidence						*0.1%*	of SOVEUR area
Cpn	Eutrophication						*(+)*	of SOVEUR area
Eo	Wind erosion (off-site effects)						*(+)*	of SOVEUR area
Non-degraded								
Sn	Stable (natural)						*44.4%*	of SOVEUR area
Sh	Stabilised						*22.5%*	of SOVEUR area
S-	Stable (not specified)						*0.5%*	of SOVEUR area
X	Non-used wastelands						*(+)*	of SOVEUR area

*** Total SOVEUR area:** 568.656 Mha

Table 2: Impact and relative extent of water erosion

Wt	IMPACT	(% of country area)				
COUNTRY	Negligible	Light	Moderate	Strong	Extreme	Total
Belarus	1.4%	2.7%	4.5%	0.0%	0.0%	8.5%
Bulgaria	26.6%	9.2%	3.4%	0.6%	0.0%	39.8%
Czech	0.0%	9.4%	5.7%	0.0%	0.0%	15.1%
Estonia	2.5%	0.7%	0.0%	0.0%	0.0%	3.2%
Hungary	0.4%	2.6%	16.4%	1.8%	0.0%	21.2%
Latvia	0.0%	6.3%	5.1%	0.0%	0.0%	11.4%
Lithuania	0.0%	3.0%	7.1%	0.3%	0.0%	10.4%
Moldova	0.8%	10.5%	16.5%	7.0%	0.0%	34.8%
Poland	0.0%	5.5%	1.2%	0.0%	0.0%	6.7%
Romania	0.8%	8.8%	8.4%	0.3%	0.0%	18.2%
Russia	0.0%	0.0%	0.0%	0.0%	4.2%	4.2%
Slovakia	0.0%	0.4%	0.7%	4.3%	0.0%	5.4%
Ukraine	0.0%	2.9%	12.1%	0.4%	0.0%	15.4%

Wd	IMPACT	(% of country area)				
COUNTRY	Negligible	Light	Moderate	Strong	Extreme	Total
Belarus	0.0%	0.2%	0.0%	0.0%	0.0%	0.2%
Moldova	0.3%	0.4%	0.2%	0.2%	0.0%	1.0%
Poland	0.0%	2.2%	0.3%	0.0%	0.0%	2.5%
Romania	0.2%	0.7%	0.8%	6.6%	0.3%	8.6%
Slovakia	0.0%	0.2%	2.4%	4.2%	0.0%	6.8%
Ukraine	0.0%	0.0%	0.8%	1.8%	0.0%	2.5%

Wo	IMPACT	(% of country area)			
COUNTRY	Negligible	Light	Moderate	Strong	Total
Lithuania	0.0%	0.4%	0.0%	0.0%	0.4%
Romania	0.4%	0.7%	2.8%	0.2%	4.0%
Ukraine	0.2%	0.0%	1.3%	0.9%	2.5%

Table 3: Impact and relative extent of wind erosion

Et	IMPACT	(% of country area)				
COUNTRY	Negligible	Light	Moderate	Strong	Extreme	Total
Belarus	1.7%	4.2%	0.0%	0.0%	0.0%	5.9%
Bulgaria	11.8%	2.3%	0.4%	0.0%	0.0%	14.6%
Czech	0.0%	0.6%	0.7%	1.8%	0.0%	3.1%
Hungary	1.8%	2.8%	5.0%	0.0%	0.0%	9.7%
Latvia	0.0%	0.0%	1.8%	0.0%	0.0%	1.8%
Lithuania	0.0%	2.3%	1.4%	0.1%	0.0%	3.8%
Poland	0.0%	0.5%	0.5%	0.0%	0.0%	1.0%
Romania	0.0%	0.0%	0.1%	0.8%	0.0%	0.9%
Russia	0.0%	0.0%	0.0%	0.1%	1.7%	1.8%
Slovakia	0.0%	0.0%	0.6%	0.0%	0.0%	0.6%
Ukraine	0.4%	0.6%	8.6%	0.9%	0.0%	10.5%

Ed	IMPACT	(% of country area)				
COUNTRY	Negligible	Light	Moderate	Strong	Extreme	Total
Latvia	0.0%	0.0%	0.2%	0.0%	0.0%	0.2%
Lithuania	0.0%	0.0%	0.3%	0.0%	0.0%	0.3%
Russia	0.0%	0.0%	0.0%	0.0%	0.3%	0.3%
Slovakia	0.0%	0.0%	0.2%	0.0%	0.0%	0.2%
Ukraine	0.0%	0.0%	0.2%	0.1%	0.0%	0.3%

Table 4: Impact and relative extent of pollution

Cpa	IMPACT	(% of country area)			
COUNTRY	Negligible	Light	Moderate	Strong	Total
Czech	0.0%	0.0%	0.0%	1.6%	1.6%
Estonia	0.4%	0.2%	0.0%	0.0%	0.6%
Hungary	0.0%	6.0%	11.6%	2.0%	19.6%
Latvia	17.6%	0.0%	0.0%	0.0%	17.6%
Lithuania	1.1%	24.4%	0.3%	0.0%	25.8%
Poland	0.0%	0.1%	34.8%	0.0%	34.9%
Romania	0.0%	3.3%	0.2%	0.0%	3.6%
Slovakia	0.8%	0.2%	0.1%	0.1%	1.2%
Ukraine	0.0%	5.2%	8.9%	0.0%	14.1%

Cph	IMPACT	(% of country area)			
COUNTRY	Negligible	Light	Moderate	Strong	Total
Belarus	0.0%	0.0%	0.0%	0.0%	0.0%
Bulgaria	0.0%	0.0%	0.0%	0.0%	0.1%
Czech	2.5%	0.0%	0.0%	0.0%	2.5%
Estonia	0.0%	2.5%	0.3%	0.0%	2.7%
Latvia	0.0%	0.0%	0.0%	0.0%	0.0%
Lithuania	19.5%	22.8%	0.0%	0.0%	42.2%
Moldova	0.1%	1.1%	0.7%	0.0%	1.8%
Poland	0.0%	0.0%	0.6%	0.0%	0.6%
Romania	0.0%	0.0%	0.0%	0.0%	0.0%
Slovakia	0.0%	0.0%	0.1%	0.0%	0.1%
Ukraine	0.3%	0.5%	6.8%	0.4%	8.0%

Cpp	IMPACT	(% of country area)			
COUNTRY	Negligible	Light	Moderate	Strong	Total
Bulgaria	0.0%	0.0%	0.0%	0.0%	0.0%
Czech	1.9%	0.0%	0.0%	0.0%	1.9%
Estonia	0.1%	0.0%	0.0%	0.0%	0.1%
Lithuania	0.0%	0.0%	0.0%	0.0%	0.0%
Poland	2.4%	0.0%	0.0%	0.0%	2.4%
Romania	0.0%	6.6%	12.7%	0.0%	19.3%
Slovakia	0.3%	0.0%	0.0%	0.0%	0.3%
Ukraine	0.0%	2.3%	6.7%	0.3%	9.2%

Cpr	IMPACT	(% of country area)			
COUNTRY	Negligible	Light	Moderate	Strong	Total
Bulgaria	0.0%	0.0%	0.0%	0.0%	0.0%
Estonia	0.0%	0.0%	0.0%	0.0%	0.0%
Ukraine	5.2%	3.2%	2.6%	0.0%	11.0%

Table 5: Impact and relative extent of other chemical deterioration

Cs	IMPACT	(% of country area)				
COUNTRY	Negligible	Light	Moderate	Strong	Extreme	Total
Belarus	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bulgaria	0.0%	0.0%	0.0%	0.4%	0.0%	0.4%
Estonia	0.0%	0.4%	0.4%	0.0%	0.0%	0.8%
Hungary	2.5%	1.5%	4.2%	0.0%	0.0%	8.2%
Moldova	0.0%	0.0%	0.0%	0.6%	0.0%	0.6%
Russia	0.0%	0.0%	0.0%	0.3%	0.1%	0.4%
Slovakia	0.0%	0.0%	0.2%	0.0%	0.0%	0.2%
Ukraine	0.0%	0.9%	3.2%	0.1%	0.0%	4.3%

Cn	IMPACT	(% of country area)			
COUNTRY	Negligible	Light	Moderate	Strong	Total
Estonia	0.1%	6.2%	0.4%	0.0%	6.7%
Latvia	0.0%	0.0%	5.5%	0.0%	5.5%
Lithuania	0.0%	4.1%	6.2%	3.8%	14.1%
Moldova	2.8%	5.1%	13.8%	9.6%	31.3%
Romania	0.0%	0.9%	12.7%	0.7%	14.3%
Ukraine	0.1%	12.1%	29.9%	1.2%	43.2%

Table 6: Impact and relative extent of physical deterioration

Pc	IMPACT	(% of country area)				
COUNTRY	Negligible	Light	Moderate	Strong	Extreme	Total
Bulgaria	23.6%	8.4%	3.2%	0.6%	0.0%	35.8%
Estonia	0.1%	13.6%	0.0%	0.0%	0.0%	13.7%
Hungary	0.0%	2.0%	5.0%	0.6%	0.0%	7.6%
Latvia	0.6%	6.9%	0.0%	0.0%	0.0%	7.5%
Lithuania	0.0%	2.2%	1.1%	0.1%	0.0%	3.4%
Moldova	0.4%	4.3%	3.5%	0.7%	0.0%	8.9%
Poland	0.0%	0.0%	0.6%	0.0%	0.0%	0.6%
Romania	0.3%	0.4%	5.0%	0.0%	0.0%	5.7%
Russia	0.0%	0.0%	0.0%	4.3%	4.1%	8.3%
Slovakia	0.6%	1.0%	2.1%	0.0%	0.0%	3.7%
Ukraine	0.0%	10.1%	27.8%	0.3%	0.0%	38.2%

Pk	IMPACT	(% of country area)				
COUNTRY	Negligible	Light	Moderate	Strong	Extreme	Total
Bulgaria	13.4%	6.8%	2.6%	0.6%	0.0%	23.5%
Czech	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hungary	0.0%	1.7%	5.0%	0.6%	0.0%	7.2%
Moldova	0.3%	0.9%	0.0%	0.0%	0.0%	1.2%
Poland	0.0%	0.0%	0.6%	0.0%	0.0%	0.6%
Romania	0.0%	2.3%	7.2%	0.0%	0.0%	9.5%
Ukraine	0.2%	11.8%	25.2%	0.3%	0.0%	37.5%

Pd	IMPACT	(% of country area)				
COUNTRY	Negligible	Light	Moderate	Strong	Extreme	Total
Hungary	0.0%	0.8%	3.1%	0.0%	0.0%	3.9%
Moldova	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Poland	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Romania	0.0%	0.0%	1.6%	0.0%	0.0%	1.6%
Russia	0.0%	0.0%	0.0%	1.6%	4.5%	6.1%
Ukraine	0.0%	0.0%	0.2%	0.0%	0.0%	0.2%

Pw	IMPACT	(% of country area)				
COUNTRY	Negligible	Light	Moderate	Strong	Extreme	Total
Estonia	0.0%	0.2%	1.7%	0.0%	0.0%	1.9%
Hungary	1.2%	2.7%	2.2%	0.4%	0.0%	6.5%
Russia	0.0%	0.0%	0.0%	0.0%	0.2%	0.2%
Ukraine	2.4%	2.6%	5.8%	2.1%	0.0%	12.9%

Ps	IMPACT	(% of country area)				
COUNTRY	Negligible	Light	Moderate	Strong	Extreme	Total
Lithuania	1.0%	0.0%	0.0%	0.0%	0.0%	1.0%
Romania	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%
Ukraine	0.0%	0.1%	0.1%	0.2%	0.0%	0.3%

Pu	IMPACT	(% of country area)				
COUNTRY	Negligible	Light	Moderate	Strong	Extreme	Total
Czech	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Estonia	0.1%	0.1%	2.2%	0.4%	0.0%	3.5%
Lithuania	0.0%	2.5%	1.4%	0.9%	0.0%	4.8%
Moldova	0.0%	0.0%	0.0%	0.0%	8.0%	8.0%
Slovakia	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%

APPENDIX 1: Tables
(Degree of degradation)

Table 7: Degree and relative extent of different degradation types in Central and Eastern Europe

TYPE		Light	Moderate	Strong	Extreme	Grand Total	
Pc	Compaction	40.4%	58.5%	1.2%	0.0%	*10.9%*	of SOVEUR area*
Wt	Water erosion (topsoil)	19.4%	38.8%	41.7%	0.0%	*8.0%*	of SOVEUR area
Cn	Fertility decline	26.3%	67.8%	5.9%	0.0%	*5.5%*	of SOVEUR area
Pk	Crusting	35.9%	62.4%	1.7%	0.0%	*4.8%*	of SOVEUR area
Pd	Aridification	15.8%	50.9%	33.3%	0.0%	*4.7%*	of SOVEUR area
Cpa	Acidification	18.4%	75.5%	6.1%	0.0%	*4.4%*	of SOVEUR area
Et	Wind erosion (topsoil)	28.3%	33.2%	37.6%	0.9%	*3.5%*	of SOVEUR area
Cpp	Pesticide pollution	39.5%	59.0%	1.5%	0.0%	*1.9%*	of SOVEUR area
Pw	Waterlogging	39.6%	43.6%	16.5%	0.3%	*1.5%*	of SOVEUR area
Cph	Heavy metal pollution	17.9%	78.7%	3.4%	0.0%	*1.4%*	of SOVEUR area
Cpr	Radio-active contamination	45.0%	54.1%	0.9%	0.0%	*1.1%*	of SOVEUR area
Cs	Salinisation	31.3%	55.2%	13.5%	0.0%	*0.9%*	of SOVEUR area
Wd	Water erosion (terrain deformation)	2.1%	33.6%	64.3%	0.0%	*0.9%*	of SOVEUR area
Other*						*0.9%*	of SOVEUR area
Non-degraded						*67.4%*	of SOVEUR area
Other:							
Wo	Water erosion (off-site effects)					*0.4%*	of SOVEUR area
Ed	Wind erosion (terrain deformation)					*0.3%*	of SOVEUR area
Pu	Land conversion					*0.1%*	of SOVEUR area
Ps	Subsidence					*0.1%*	of SOVEUR area
Cpn	Eutrophication					*(+)*	of SOVEUR area
Eo	Wind erosion (off-site effects)					*(+)*	of SOVEUR area
Non-degraded							
Sn	Stable (natural)					*44.4%*	of SOVEUR area
Sh	Stabilised					*22.5%*	of SOVEUR area
S-	Stable (not specified)					*0.5%*	of SOVEUR area
X	Non-used wastelands					*(+)*	of SOVEUR area

*** Total SOVEUR area:** 568.656 Mha

Table 8: Degree and relative extent of water erosion

Wt	DEGREE	(% of country area)			
COUNTRY	Light	Moderate	Strong	Extreme	Total
Belarus	1.8%	6.7%	0.0%	0.0%	8.5%
Bulgaria	21.0%	16.6%	2.1%	0.0%	39.8%
Czech	8.9%	5.7%	0.5%	0.0%	15.1%
Estonia	0.8%	2.4%	0.0%	0.0%	3.2%
Hungary	2.6%	8.5%	10.1%	0.0%	21.2%
Latvia	0.0%	11.3%	0.1%	0.0%	11.4%
Lithuania	3.0%	7.1%	0.3%	0.0%	10.4%
Moldova	0.3%	6.9%	27.6%	0.0%	34.8%
Poland	0.0%	6.4%	0.4%	0.0%	6.7%
Romania	11.0%	7.2%	0.0%	0.0%	18.2%
Russia	0.0%	0.0%	4.2%	0.0%	4.2%
Slovakia	0.5%	0.8%	4.1%	0.0%	5.4%
Ukraine	2.9%	12.1%	0.4%	0.0%	15.4%

Wd	DEGREE	(% of country area)			
COUNTRY	Light	Moderate	Strong	Extreme	Total
Belarus	0.1%	0.0%	0.0%	0.0%	0.2%
Moldova	0.3%	0.4%	0.3%	0.1%	1.0%
Poland	0.0%	2.2%	0.3%	0.0%	2.5%
Romania	0.2%	1.7%	6.7%	0.0%	8.6%
Slovakia	0.3%	2.4%	4.1%	0.0%	6.8%
Ukraine	0.0%	0.8%	1.8%	0.0%	2.5%

Wo	DEGREE	(% of country area)			
COUNTRY	Light	Moderate	Strong	Extreme	Total
Lithuania	0.0%	0.4%	0.0%	0.0%	0.4%
Romania	2.5%	1.5%	0.0%	0.0%	4.0%
Ukraine	0.2%	1.3%	0.9%	0.0%	2.5%

Table 9: Degree and relative extent of wind erosion

Et	DEGREE	(% of country area)			
COUNTRY	Light	Moderate	Strong	Extreme	Total
Belarus	5.9%	0.0%	0.0%	0.0%	5.9%
Bulgaria	8.2%	6.4%	0.0%	0.0%	14.6%
Czech	0.6%	1.7%	0.8%	0.0%	3.1%
Hungary	5.2%	1.4%	3.1%	0.0%	9.7%
Latvia	0.0%	1.8%	0.0%	0.0%	1.8%
Lithuania	2.3%	1.5%	0.0%	0.0%	3.8%
Poland	0.0%	1.0%	0.0%	0.0%	1.0%
Romania	0.1%	0.1%	0.7%	0.0%	0.9%
Russia	0.0%	0.1%	1.7%	0.0%	1.8%
Slovakia	0.3%	0.2%	0.0%	0.0%	0.6%
Ukraine	1.0%	8.6%	0.9%	0.0%	10.5%

Ed	DEGREE	(% of country area)			
COUNTRY	Light	Moderate	Strong	Extreme	Total
Latvia	0.0%	0.2%	0.0%	0.0%	0.2%
Lithuania	0.0%	0.0%	0.3%	0.0%	0.3%
Russia	0.0%	0.0%	0.0%	0.3%	0.3%
Slovakia	0.0%	0.2%	0.0%	0.0%	0.2%
Ukraine	0.0%	0.2%	0.1%	0.0%	0.3%

Table 10: Degree and relative extent of pollution

Cpa	DEGREE	(% of country area)			
COUNTRY	Light	Moderate	Strong	Extreme	Total
Czech	0.0%	0.4%	1.1%	0.0%	1.6%
Estonia	0.6%	0.0%	0.0%	0.0%	0.6%
Hungary	6.7%	8.9%	4.0%	0.0%	19.6%
Latvia	0.9%	16.7%	0.0%	0.0%	17.6%
Lithuania	1.1%	24.7%	0.0%	0.0%	25.8%
Poland	0.0%	31.3%	3.5%	0.0%	34.9%
Romania	0.2%	3.4%	0.0%	0.0%	3.6%
Slovakia	1.1%	0.0%	0.1%	0.0%	1.2%
Ukraine	5.2%	8.9%	0.0%	0.0%	14.1%

Cph	DEGREE	(% of country area)			
COUNTRY	Light	Moderate	Strong	Extreme	Total
Belarus	0.0%	0.0%	0.0%	0.0%	0.0%
Bulgaria	0.0%	0.0%	0.0%	0.0%	0.1%
Czech	2.4%	0.0%	0.0%	0.0%	2.5%
Estonia	0.1%	2.6%	0.0%	0.0%	2.7%
Latvia	0.0%	0.0%	0.0%	0.0%	0.0%
Lithuania	12.2%	30.1%	0.0%	0.0%	42.2%
Moldova	1.8%	0.1%	0.0%	0.0%	1.8%
Poland	0.3%	0.3%	0.0%	0.0%	0.6%
Romania	0.0%	0.0%	0.0%	0.0%	0.0%
Slovakia	0.0%	0.0%	0.1%	0.0%	0.1%
Ukraine	0.5%	7.1%	0.4%	0.0%	8.0%

Cpp	DEGREE	(% of country area)			
COUNTRY	Light	Moderate	Strong	Extreme	Total
Czech	1.8%	0.1%	0.0%	0.0%	1.9%
Estonia	0.1%	0.0%	0.0%	0.0%	0.1%
Poland	2.4%	0.0%	0.0%	0.0%	2.4%
Romania	8.2%	11.1%	0.0%	0.0%	19.3%
Slovakia	0.3%	0.0%	0.0%	0.0%	0.3%
Ukraine	2.3%	6.7%	0.3%	0.0%	9.2%

Cpr	DEGREE	(% of country area)		
COUNTRY	Light	Moderate	Strong	Total
Ukraine	4.9%	5.9%	0.1%	11.0%

Cpn	DEGREE	(% of country area)	
COUNTRY	Light	Moderate	Total
Czech	0.0%	1.1%	0.6%
Slovakia	1.1%	2.2%	3.2%

Table 11: Degree and relative extent of other chemical deterioration

Cn	DEGREE	(% of country area)			
COUNTRY	Light	Moderate	Strong	Extreme	Total
Estonia	6.3%	0.4%	0.0%	0.0%	6.7%
Latvia	0.0%	5.5%	0.0%	0.0%	5.5%
Lithuania	3.7%	6.6%	3.8%	0.0%	14.1%
Moldova	2.8%	5.7%	22.8%	0.0%	31.3%
Romania	2.0%	11.5%	0.8%	0.0%	14.3%
Ukraine	12.2%	29.9%	1.2%	0.0%	43.2%

Cs	DEGREE	(% of country area)			
COUNTRY	Light	Moderate	Strong	Extreme	Total
Bulgaria	0.0%	0.4%	0.0%	0.0%	0.4%
Estonia	0.1%	0.7%	0.0%	0.0%	0.8%
Hungary	1.3%	0.8%	6.2%	0.0%	8.2%
Moldova	0.0%	0.6%	0.0%	0.0%	0.6%
Russia	0.2%	0.2%	0.0%	0.0%	0.4%
Slovakia	0.1%	0.1%	0.1%	0.0%	0.2%
Ukraine	0.9%	3.2%	0.1%	0.0%	4.3%

Table 12: Degree and relative extent of physical deterioratation

Pc	DEGREE	(% of country area)			
COUNTRY	Light	Moderate	Strong	Extreme	Total
Bulgaria	16.9%	16.9%	2.0%	0.0%	35.8%
Estonia	7.0%	6.7%	0.0%	0.0%	13.7%
Hungary	3.0%	4.6%	0.0%	0.0%	7.6%
Latvia	0.4%	7.2%	0.0%	0.0%	7.5%
Lithuania	2.2%	1.1%	0.1%	0.0%	3.4%
Moldova	0.4%	4.8%	3.4%	0.2%	8.9%
Poland	0.0%	0.6%	0.0%	0.0%	0.6%
Romania	0.9%	4.7%	0.0%	0.0%	5.7%
Russia	4.2%	4.0%	0.1%	0.0%	8.3%
Slovakia	1.9%	1.8%	0.0%	0.0%	3.7%
Ukraine	10.1%	27.8%	0.3%	0.0%	38.2%

Pk	DEGREE	(% of country area)			
COUNTRY	Light	Moderate	Strong	Extreme	Total
Bulgaria	12.8%	8.8%	2.0%	0.0%	23.5%
Hungary	2.6%	4.6%	0.0%	0.0%	7.2%
Moldova	0.3%	0.9%	0.0%	0.0%	1.2%
Poland	0.0%	0.6%	0.0%	0.0%	0.6%
Romania	5.3%	3.8%	0.4%	0.0%	9.5%
Ukraine	12.0%	25.2%	0.3%	0.0%	37.5%

Pw	DEGREE	(% of country area)			
COUNTRY	Light	Moderate	Strong	Extreme	Total
Estonia	0.0%	1.9%	0.0%	0.0%	1.9%
Hungary	2.7%	2.1%	1.7%	0.0%	6.5%
Russia	0.0%	0.1%	0.1%	0.0%	0.2%
Ukraine	5.5%	5.6%	1.8%	0.0%	12.9%

Ps	DEGREE	(% of country area)			
COUNTRY	Light	Moderate	Strong	Extreme	Total
Lithuania	1.0%	0.0%	0.0%	0.0%	1.0%
Romania	0.0%	0.0%	0.1%	0.0%	0.1%
Ukraine	0.1%	0.1%	0.2%	0.0%	0.3%

Pu	DEGREE	(% of country area)			
COUNTRY	Light	Moderate	Strong	Extreme	Total
Czech	0.1%	0.0%	0.0%	0.0%	0.1%
Estonia	0.0%	1.8%	1.0%	0.0%	2.8%
Lithuania	2.5%	1.4%	0.9%	0.0%	4.8%
Moldova	0.0%	0.0%	0.0%	8.0%	8.0%
Slovakia	0.0%	0.1%	0.0%	0.0%	0.1%

Pd	DEGREE	(% of country area)			
COUNTRY	Light	Moderate	Strong	Extreme	Total
Hungary	0.8%	0.0%	3.1%	0.0%	3.9%
Romania	0.0%	1.5%	0.1%	0.0%	1.6%
Russia	0.4%	3.4%	2.2%	0.0%	6.1%
Ukraine	0.0%	0.2%	0.0%	0.0%	0.2%

Overview of the impact of degradation in Central and Eastern Europe

Figure 2a

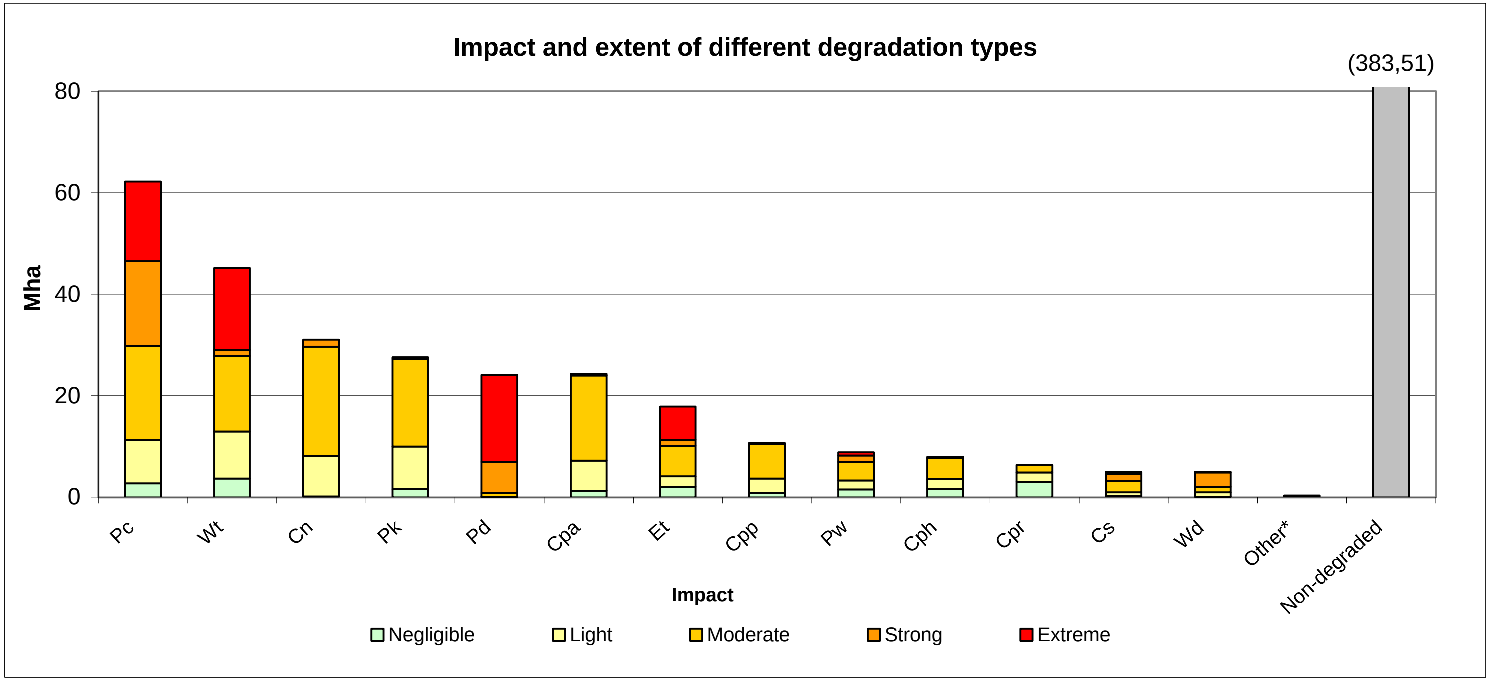


Figure 2b

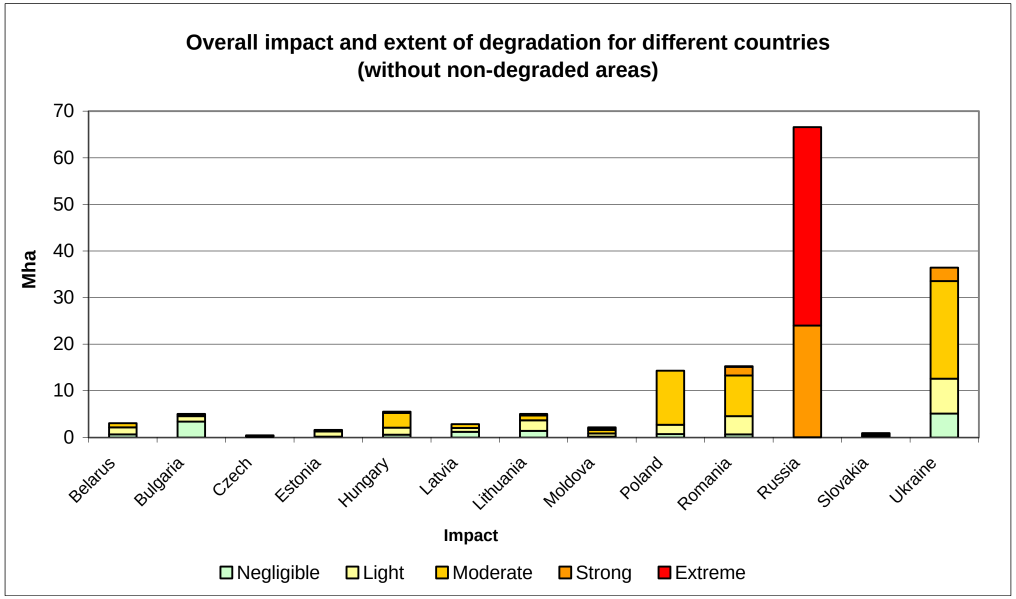
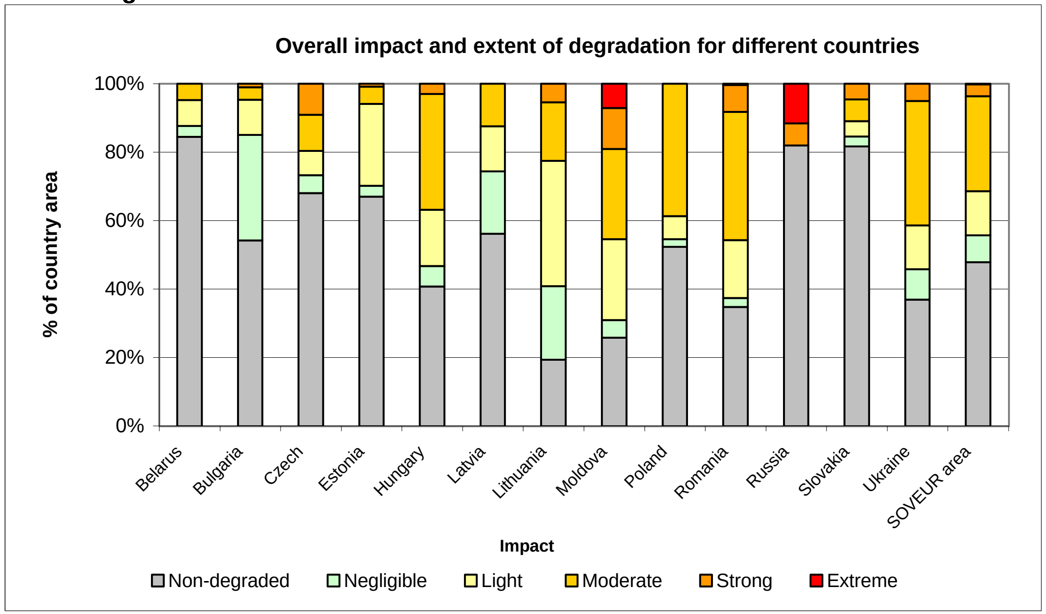


Figure 2c



Water erosion

Figure 3a

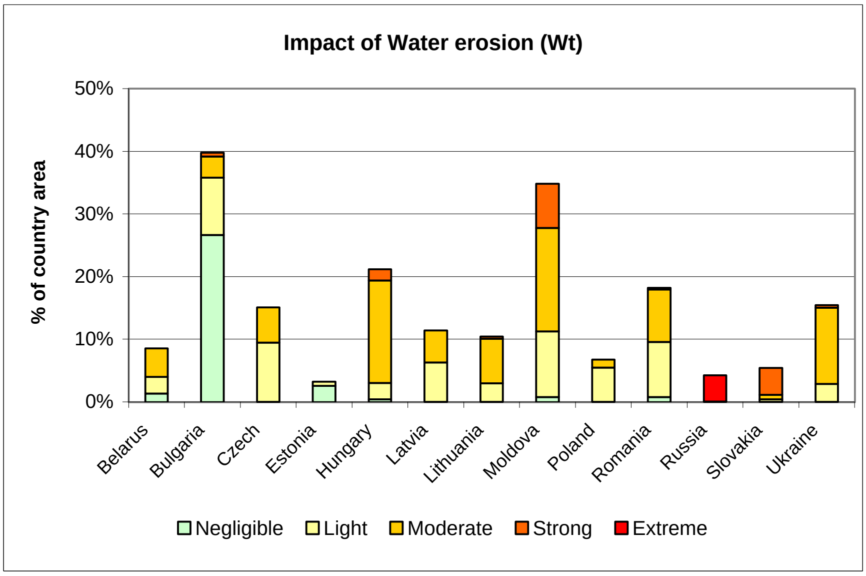


Figure 3b

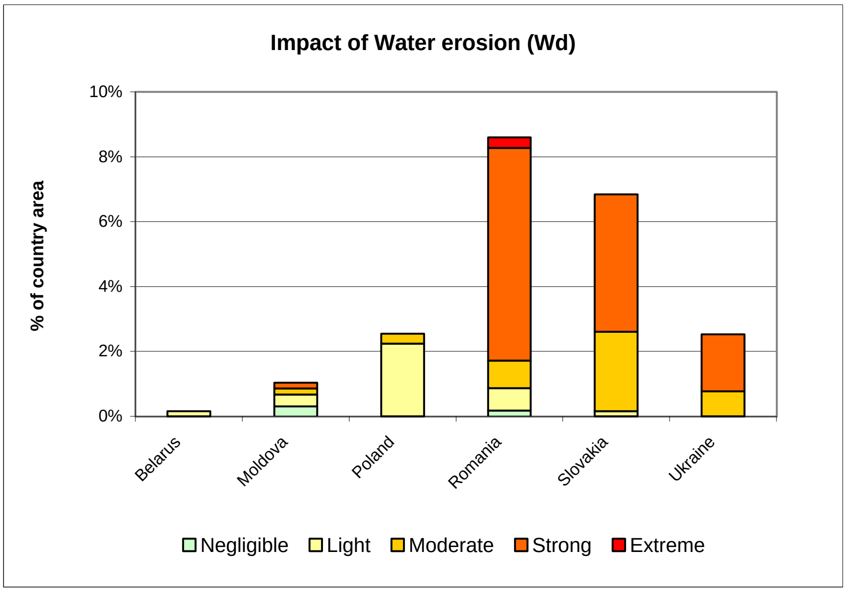
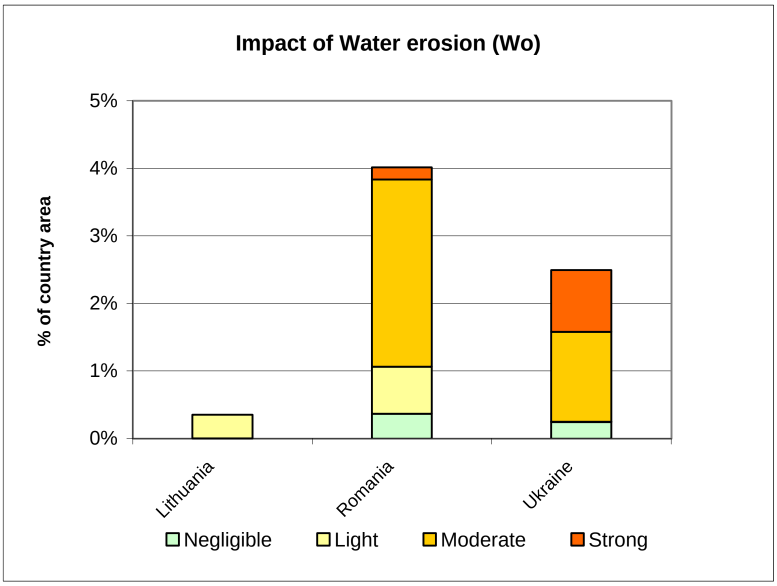


Figure 3c



<u>Wind erosion</u>

Figure 4a

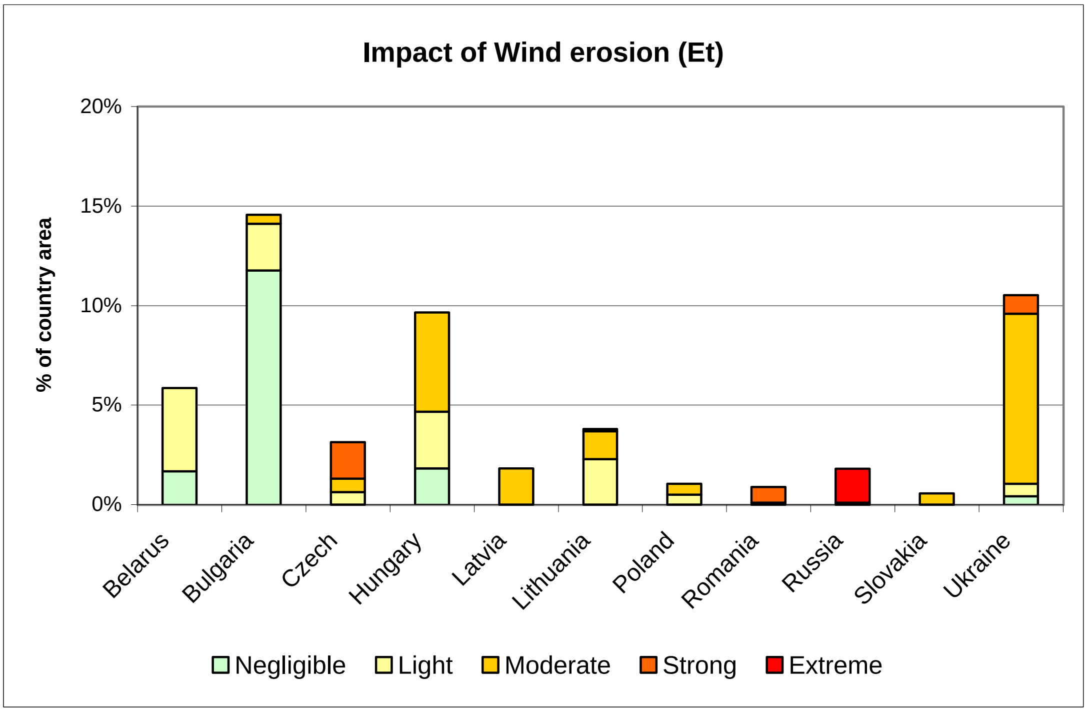
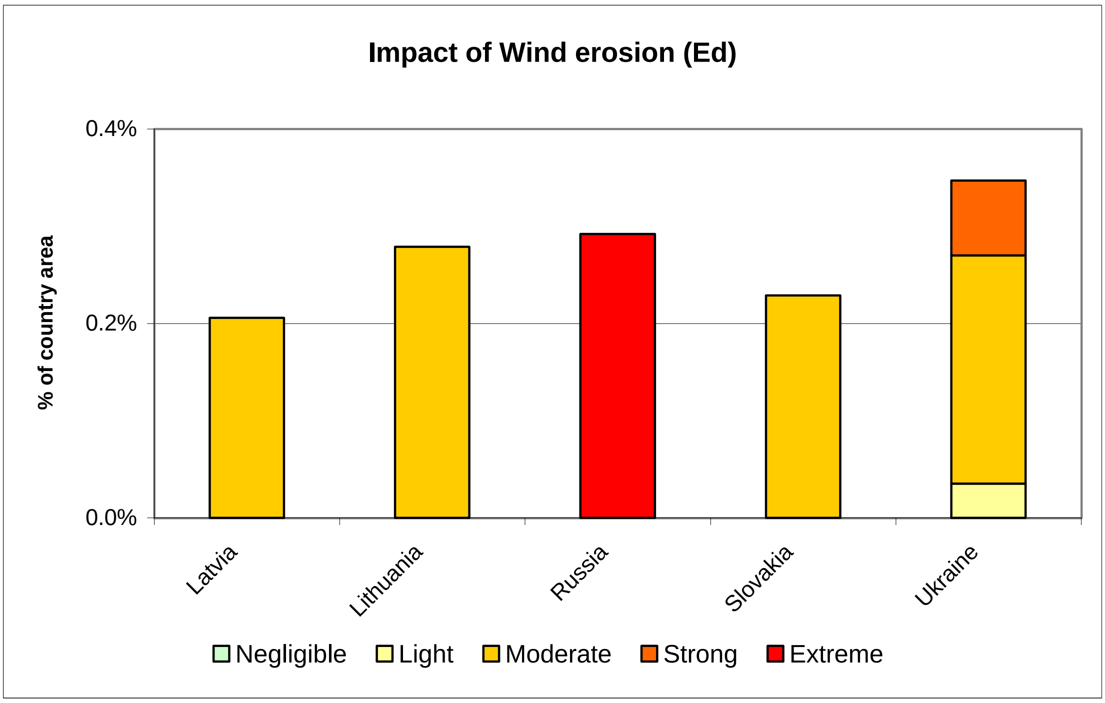


Figure 4b



Pollution

Figure 5a

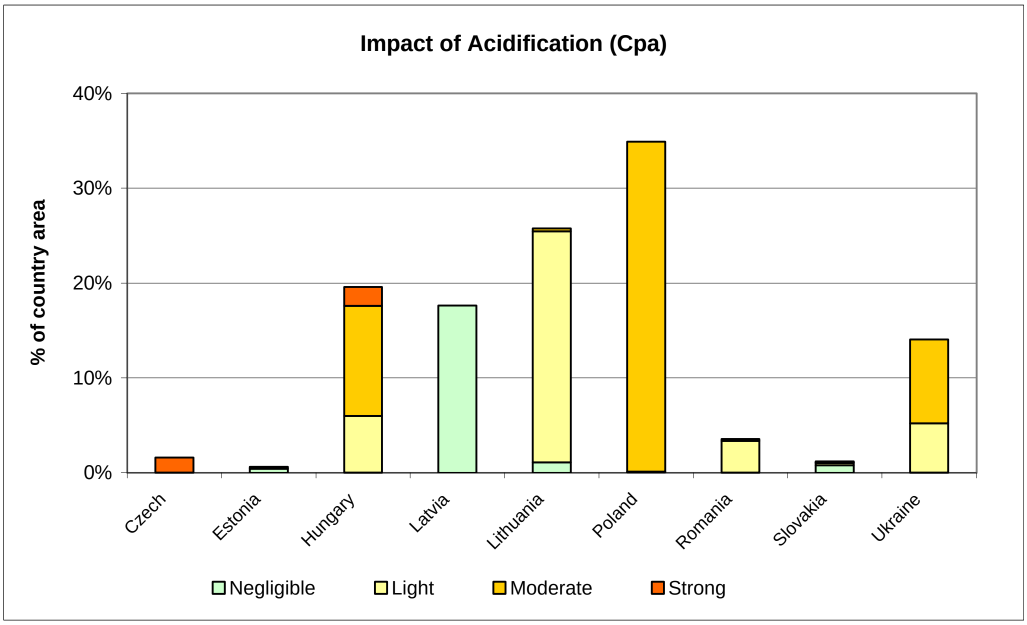


Figure 5b

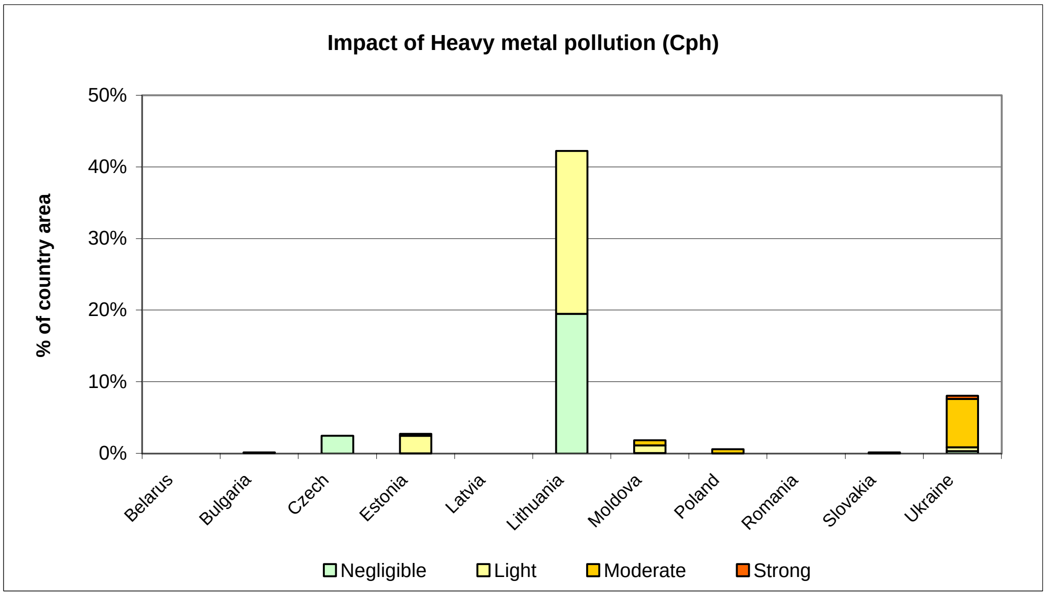


Figure 5c

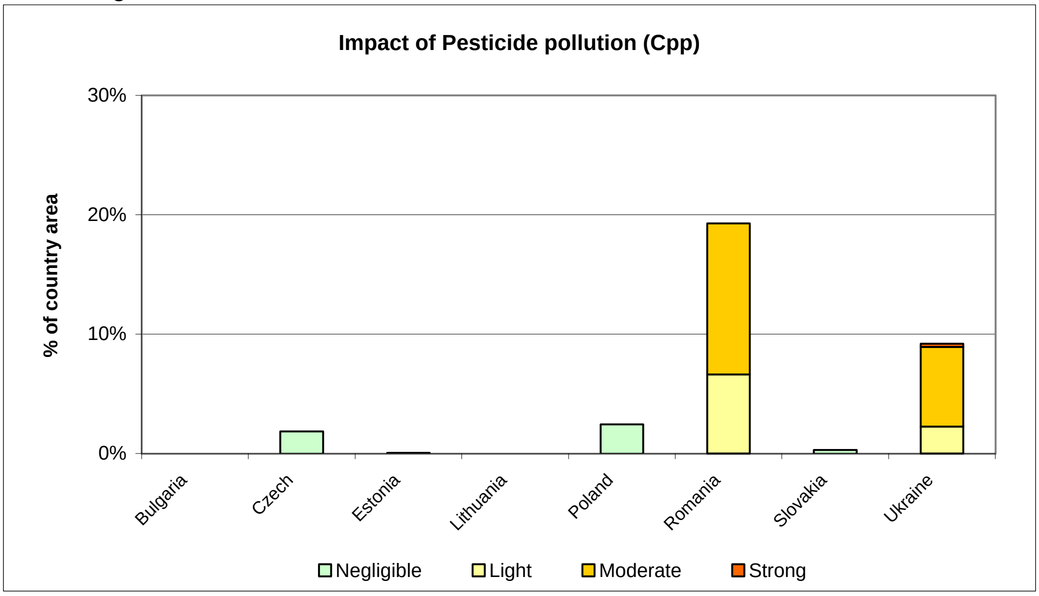


Figure 6a

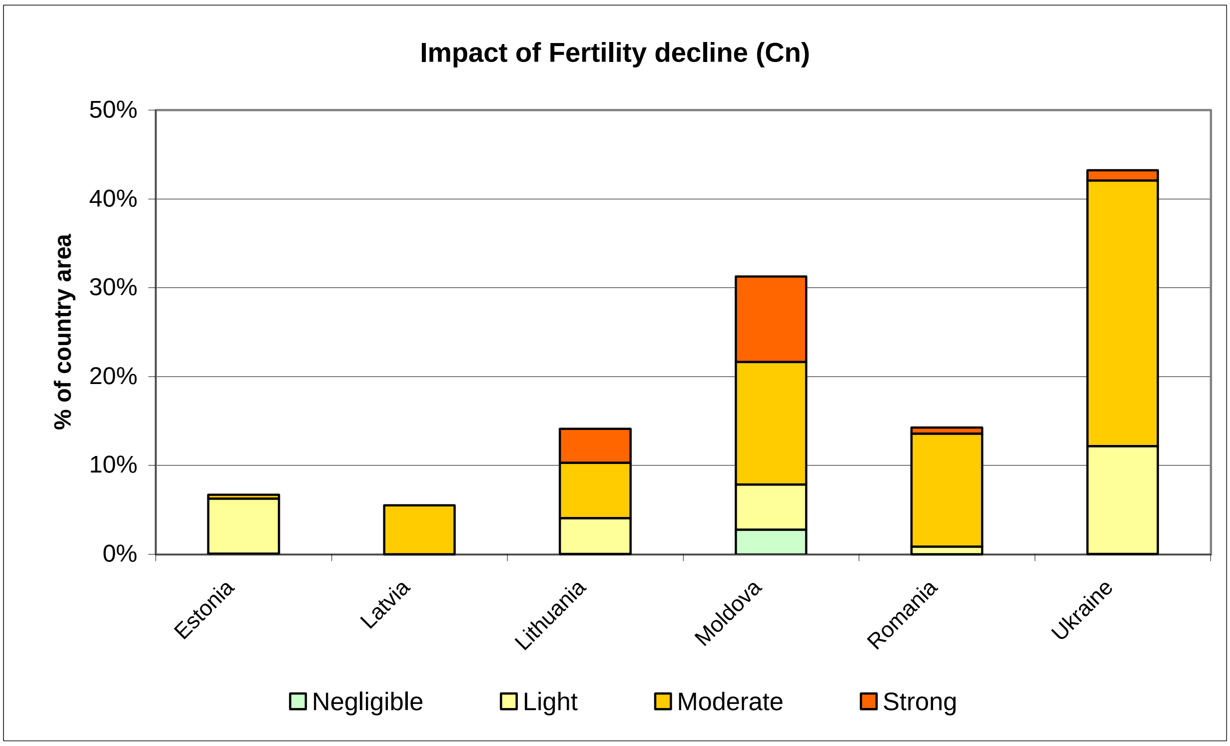


Figure 6b

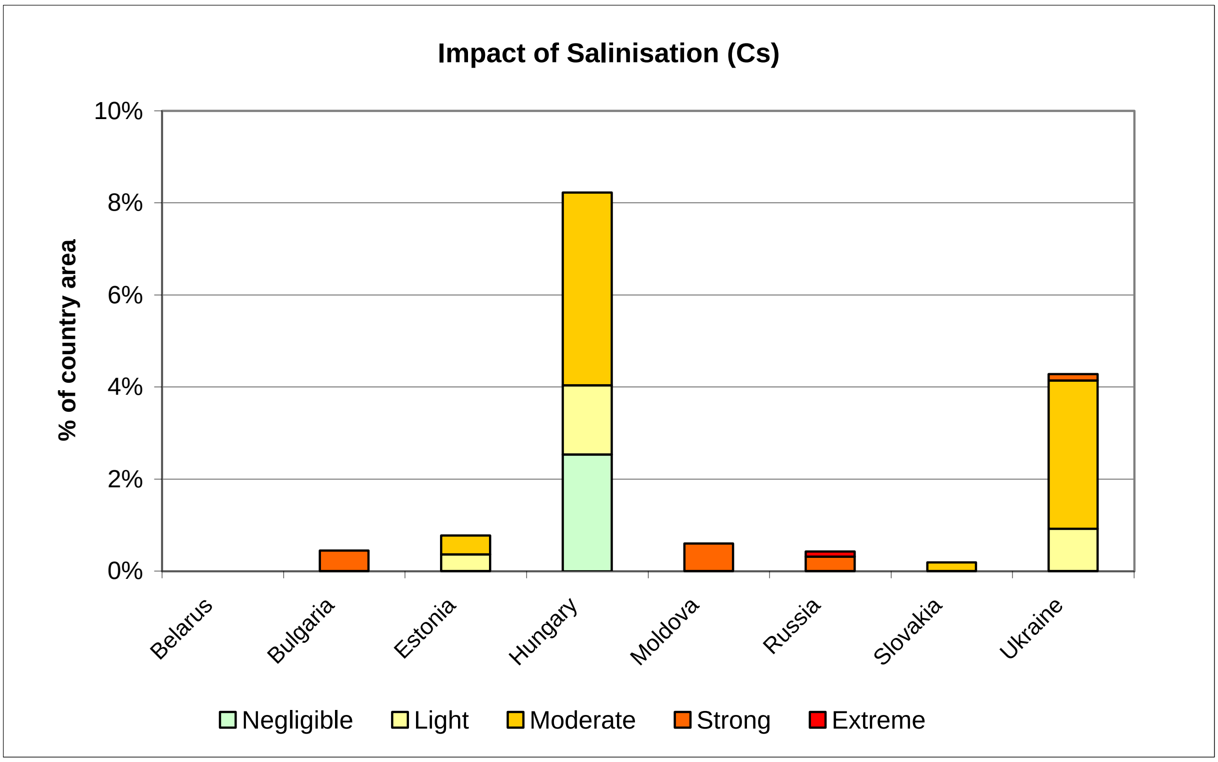


Figure 7a

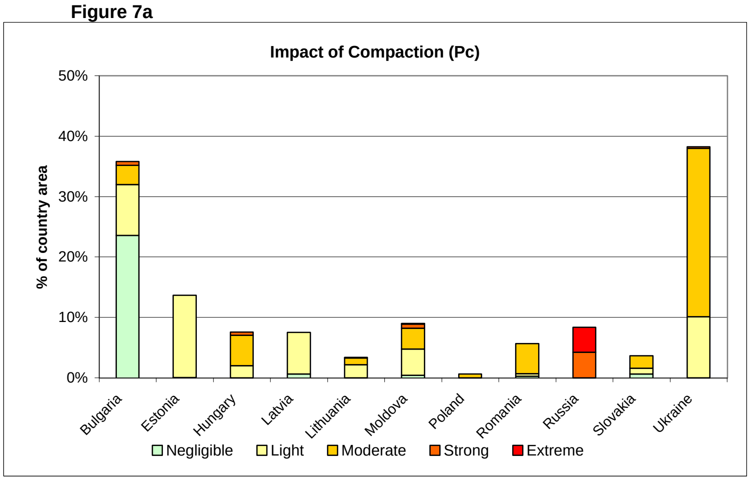


Figure 7b

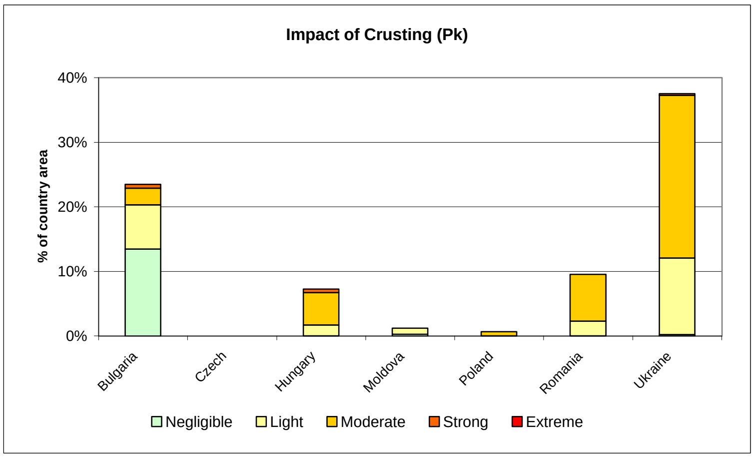


Figure 7c

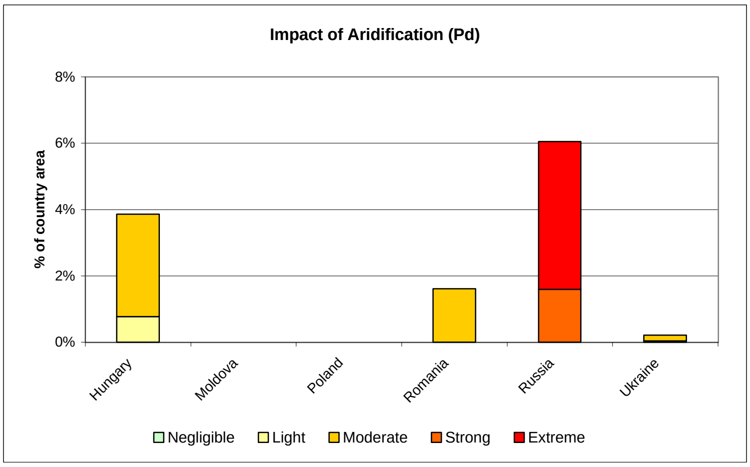


Figure 7d

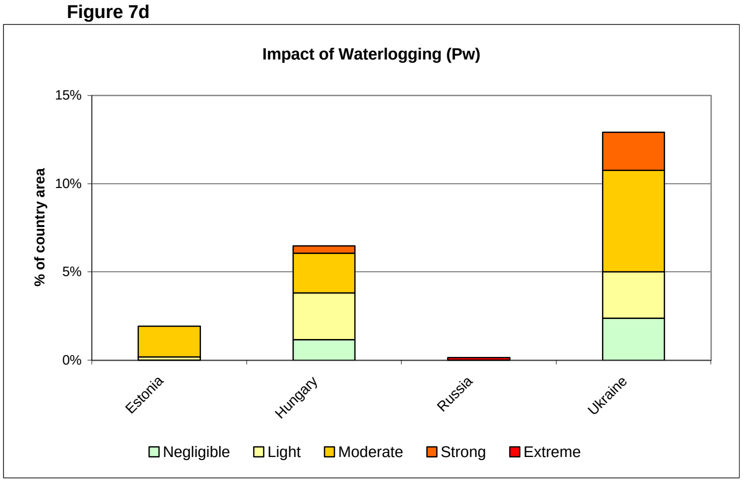


Figure 8a

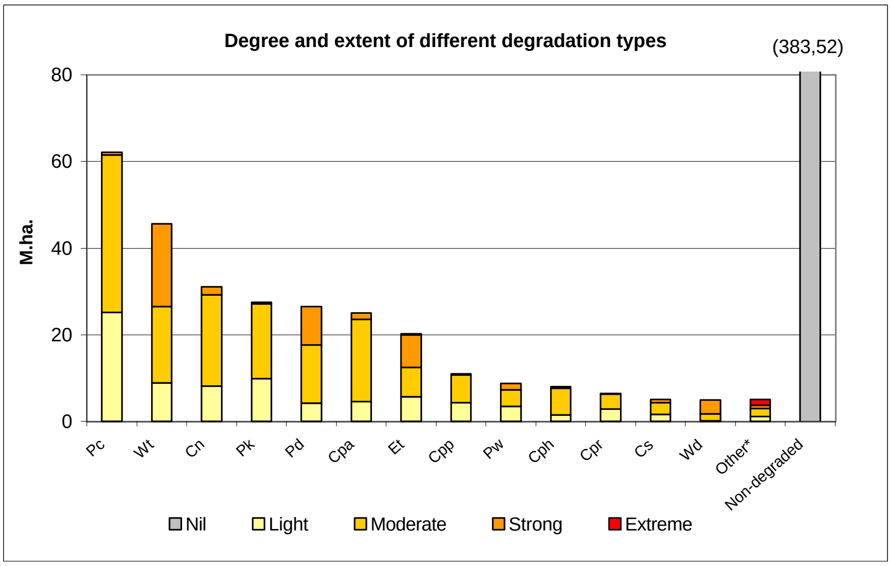


Figure 8b

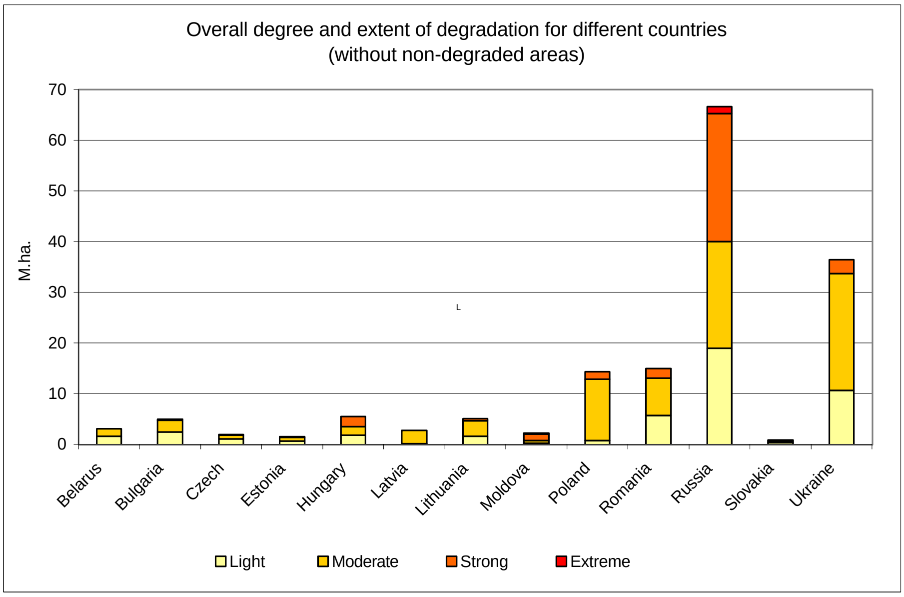
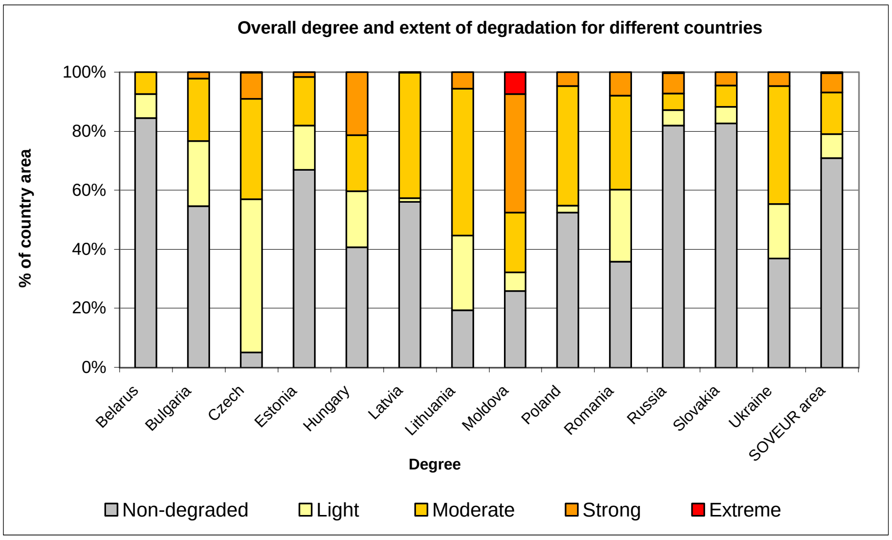


Figure 8c



Water erosion

Figure 9a

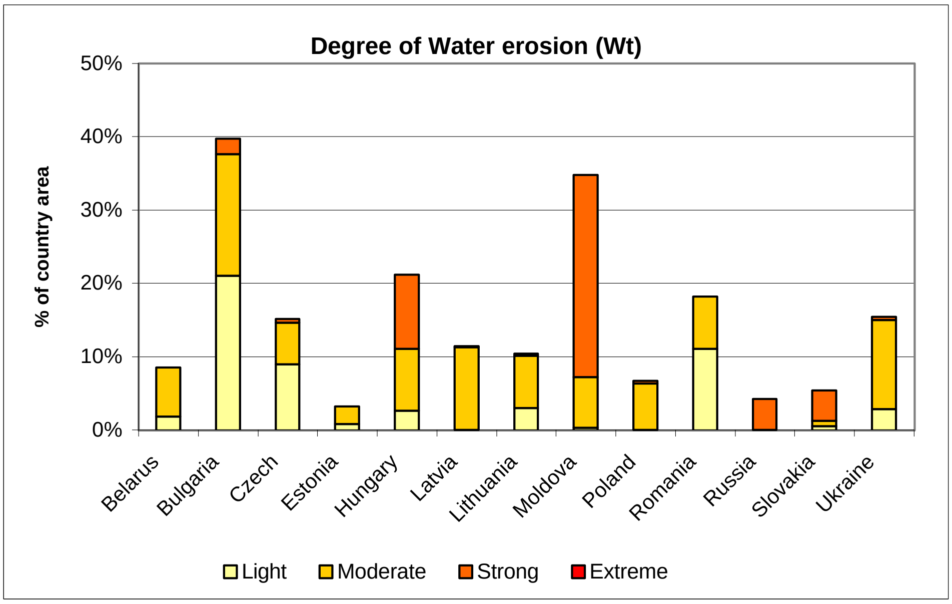


Figure 9b

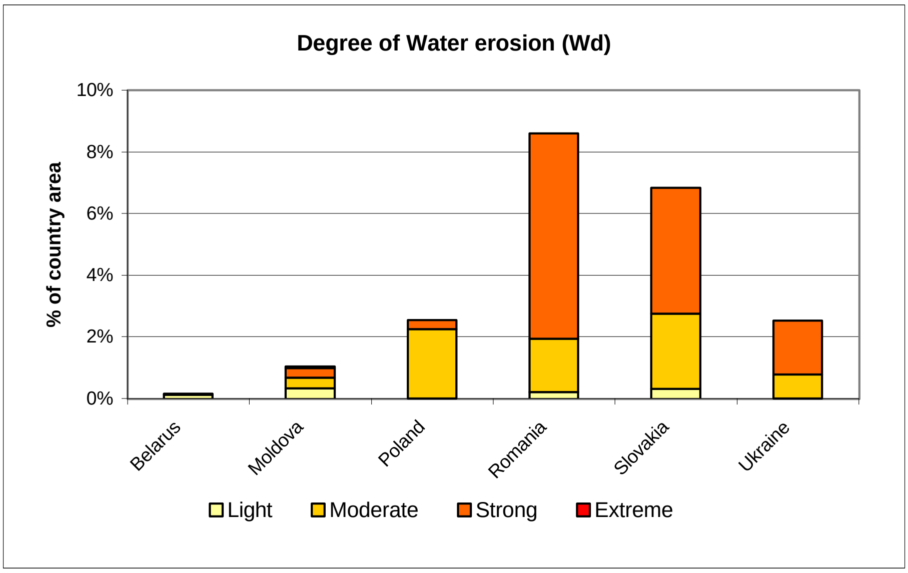


Figure 9c

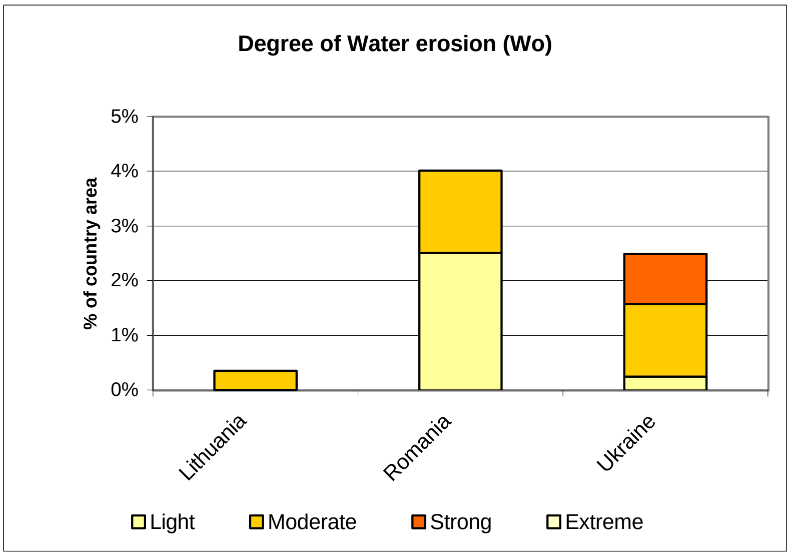


Figure 10a

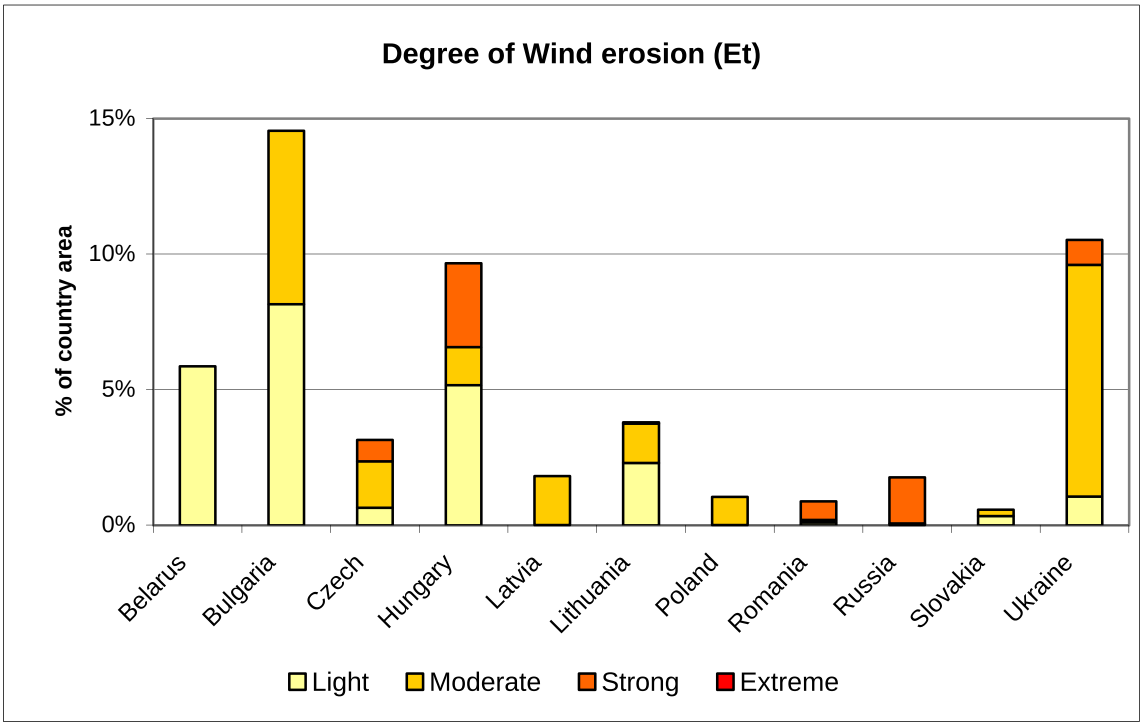
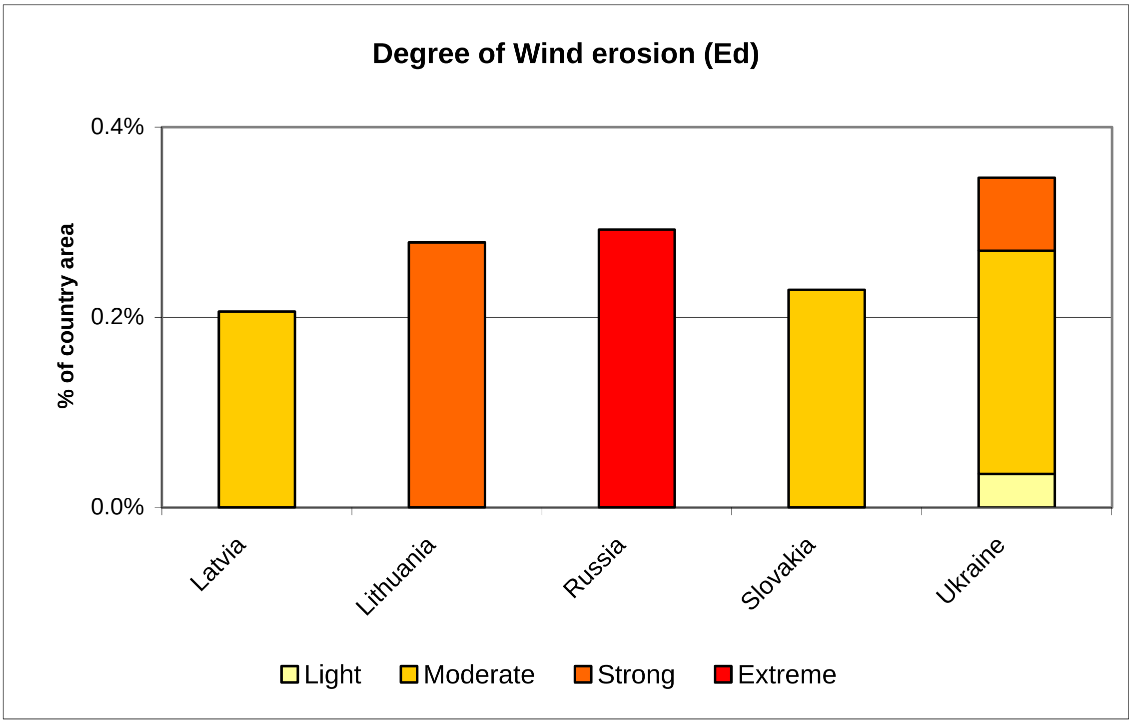


Figure 10b



Pollution

Figure 11a

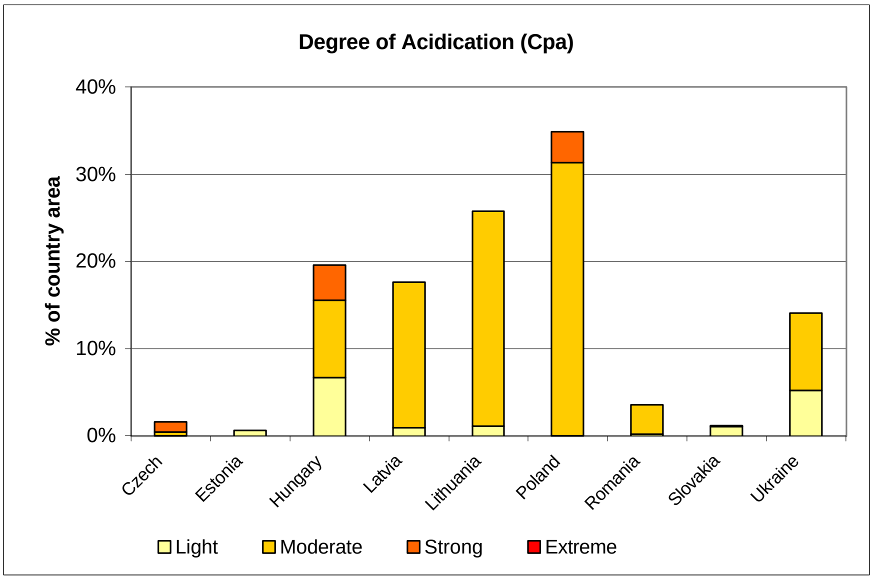


Figure 11b

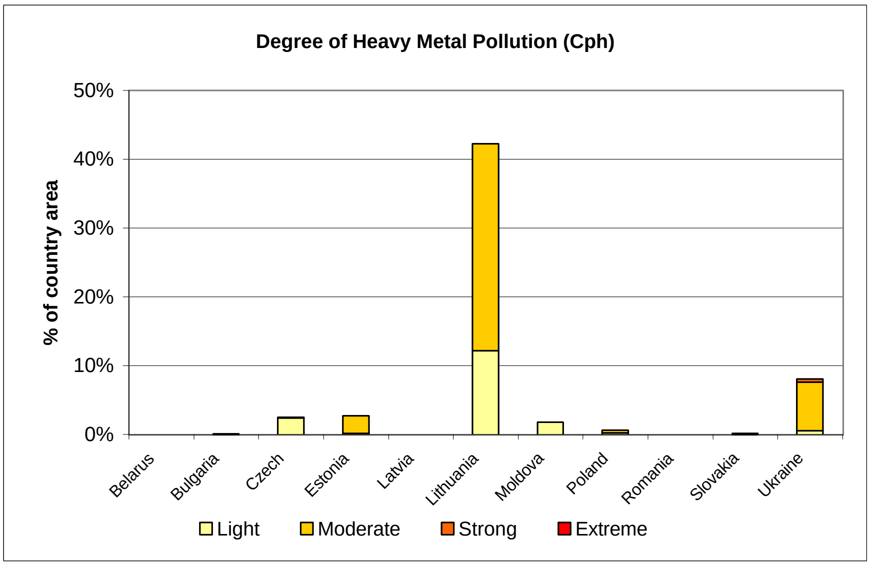


Figure 11c

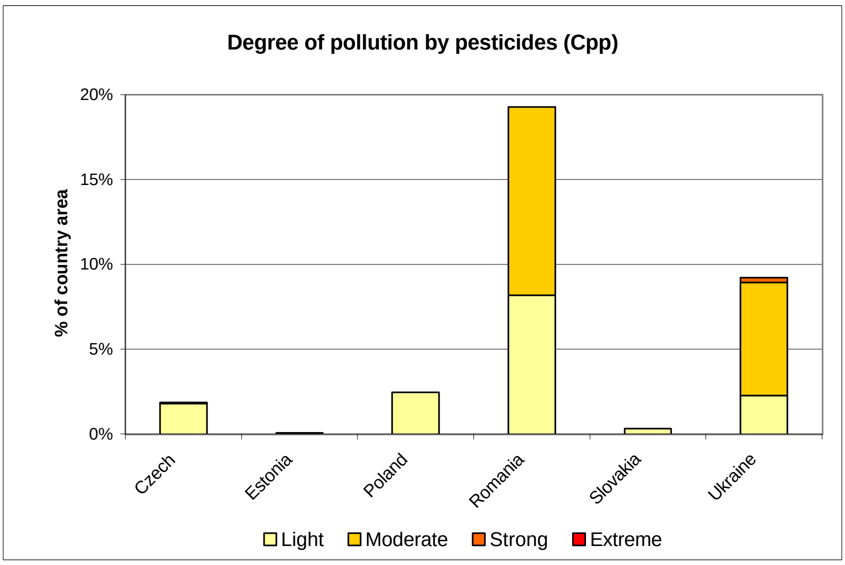


Figure 12a

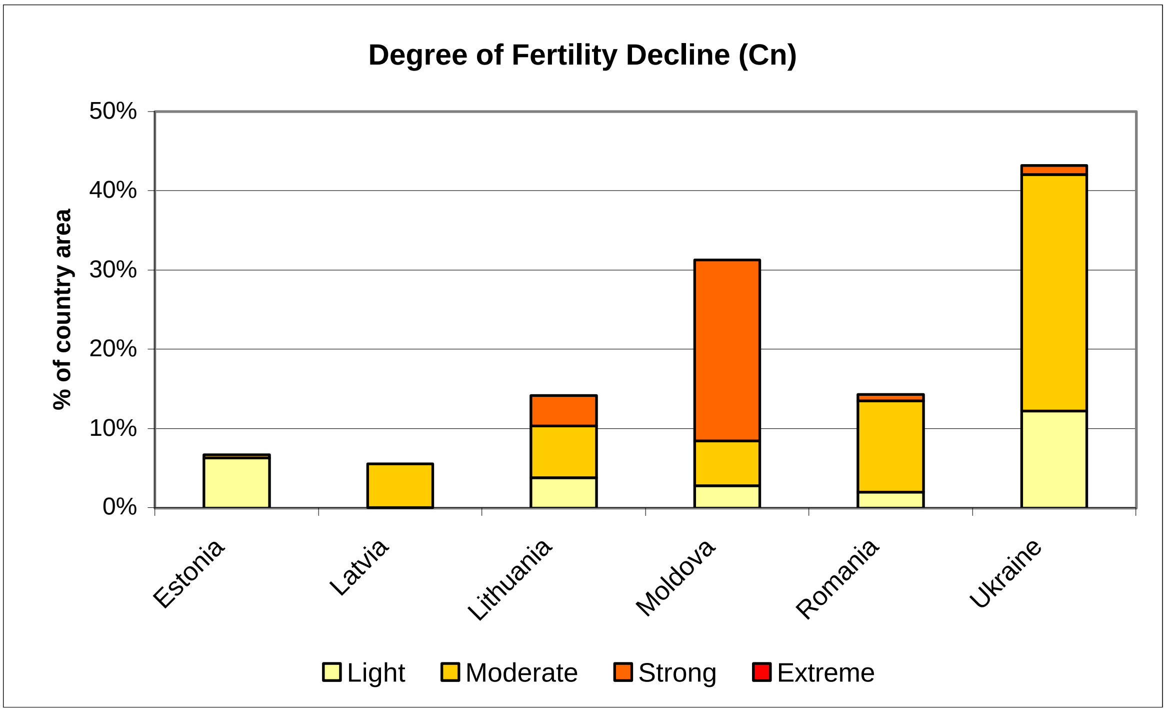


Figure 12b

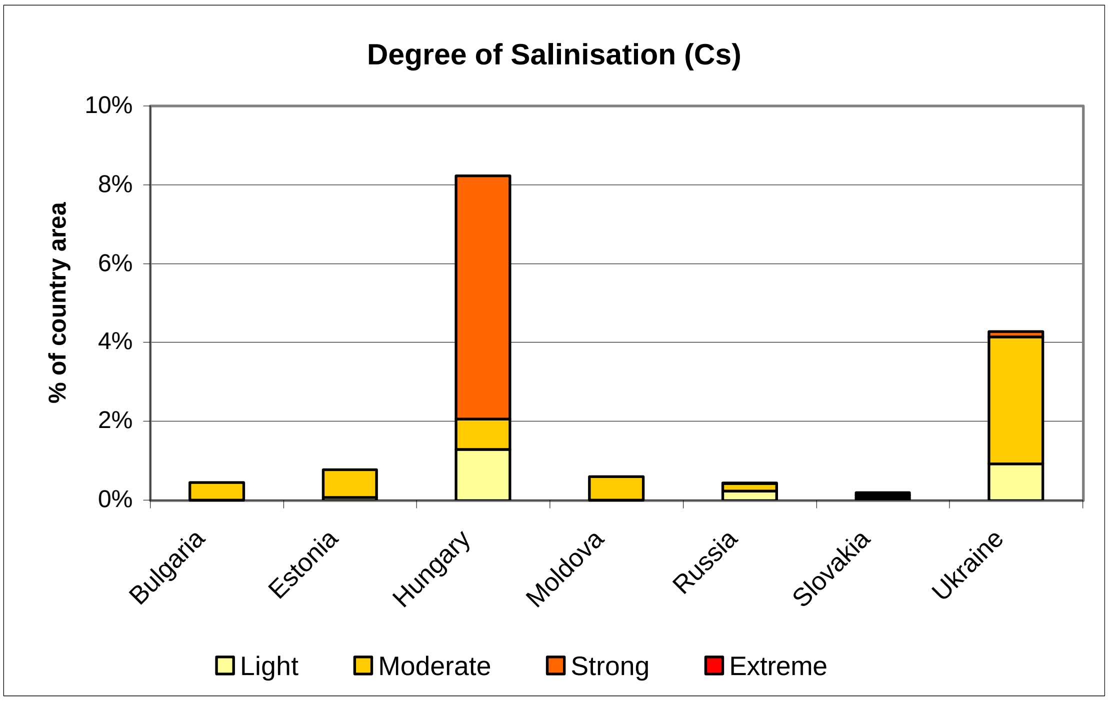


Figure 13a

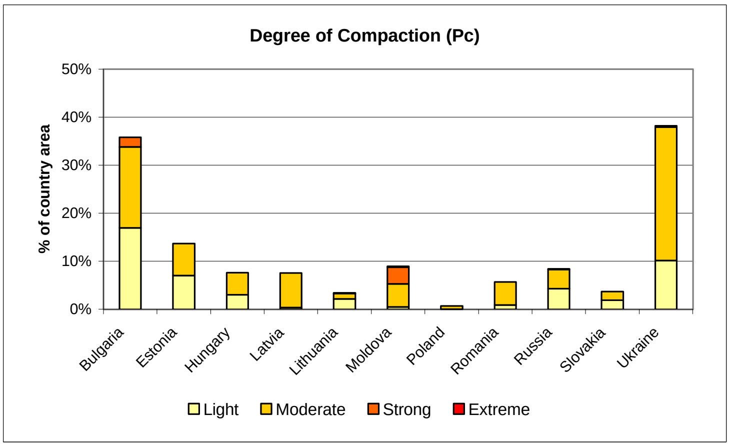


Figure 13b

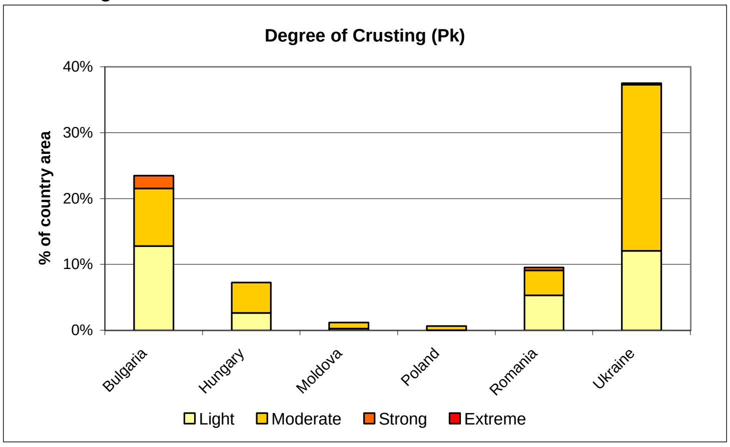


Figure 13c

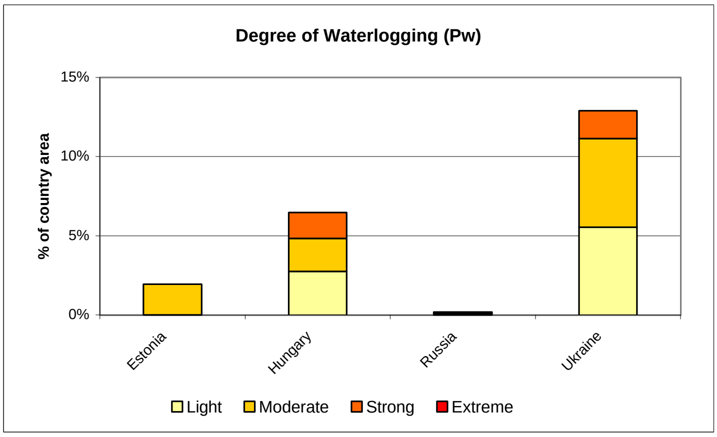


Figure 13d